TEACHING INTERVENTIONS TO INCREASE MATHEMATICS ACHIEVEMENT IN ELEMENTARY STUDENTS WITH MODERATE TO SEVERE LEARNING DISABILITIES

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Abstract

Educating all students by today’s standards for tomorrow’s living is essential for students to be a part of the community of high quality learners. By 2014, No Child Left Behind legislation mandates that all students in grades three through eight make adequate yearly progress of 100% proficiency in reading and math (Browder & Cooper-Duffy, 2003). Mathematical research needs to be evaluated to determine how to achieve proficiency for special education students. The literature review focused on mathematical interventions that may promote an increase in achievement for students with learning disabilities. Strategies reviewed were peer tutoring, explicit instruction, self-monitoring, and technology.
Chapter I: Introduction

The responsibility of educators is to provide a quality mathematical education so that all students can develop proficiency in mathematics in becoming productive citizens. The Elementary and Secondary Education Act of 1965 was passed to address educational standards and accountability and to provide equal access to education for all children in the United States. When Congress amended and reauthorized the act as No Child Left Behind in 2001, Adequate Yearly Progress (AYP) was a new requirement. Research or evidence based instruction became the new educational vocabulary words and was referred to several times in the NCLB Act.

Statement of Problem

A question that arose from NCLB was the types of instructional strategies that would support students with special needs to show AYP. In a peer reviewed article by Browder and Cooper-Duffy (2003), research-based practices that focused on accountability relevant for students with severe disabilities were reviewed considering how to measure AYP on states’ alternate assessments. Students with severe disabilities individual needs are limited in scope and practice to what is most functional and age appropriate for the individual. Common characteristics assessed were identified as community, home, leisure, and vocational skills with prioritizing what is functional and preferred by the student. The problem, however, is the uncleanness in prioritizing what functions meet the criteria for AYP in academic content standards. If educating all students by today’s Common Core State Standards for future self-reliance and independence is the goal, then what teaching strategies will increase mathematic achievement in elementary students with moderate to severe learning disabilities?
The review of literature will examine the theoretical framework of social constructivism and how the two main principles support research-based instruction. Next the review will scrutinize research pertaining to explicit instruction, peer or class wide peer tutoring, progress monitoring, self-monitoring, and technology as effective strategies to increase mathematical achievement in students with learning disabilities. Lastly, the review consummates with recommendations and areas for further research.

To meet the educational challenges for students with mathematical learning disabilities, research is necessary to find the most successful strategies that will propel the students forward to achieve and be a part of the international community of quality learners. When searching for peer reviewed articles in One Search, some key words used for the query of the sub categories were “peer tutoring,” “progress monitoring,” “explicit instruction,” “learning disability,” “math instruction,” and technology. Also reviewing the reference lists from reviews that were found provided abstracts supporting the sub areas.

**Research Questions**

What teaching interventions have been successful to increase mathematics achievement for elementary students with learning disabilities?

What content areas should teachers focus on that will further the special education population of students to achieve adequately?

**Definition of Terms**
The following terms are the significant ones the reader will experience throughout the paper. The given definitions are referenced from peer reviewed articles, government, and organizational web sites used to compile this paper.

**Math Difficulties.** Refers to students who are currently identified as having a math disability, as well as those students at risk for math disabilities (Doabler & Fien, 2013).

**Students with Disabilities.** A child’s educational performance must be adversely affected due to a disability (National Dissemination Center for Children with Disabilities).

**Explicit Instruction.** Often referred to as direct or meaningful instruction is a systematic approach that facilitates important instructional interactions between teachers and students around critical math content (Doabler & Fien, 2013).

**Research-Based Instruction.** Research that involves the application of rigorous, systematic and objective procedures to obtain reliable and valid knowledge relevant to education activities and programs (NCLB, 2001).

**Class-wide Peer Tutoring.** Refers to instructional strategies given to an entire classroom in which students are taught by peers who are trained and supervised by the classroom teacher (Maheady & Gard, 2010).

**Peer Tutoring.** Where two children work together and one child is the tutor and serves as the teacher and one is the tutee and serves as the learner (Beirne-Smith, 1991).
Chapter II: Literature Review

Research-based instruction is an intricate part of NCLB. “The NCLB Act defines the term 'scientifically based research' as research that involves the application of rigorous, systematic and objective procedures to obtain reliable and valid knowledge relevant to education activities and programs” (http://www.tats.ucf.edu/docs/ScBR.pdf). The most effective teachers will adhere to the rigors of research-based instruction because the instruction will help the novice to learn and achieve progress. Research-based instruction can be found in any academic classroom where teachers promote success and scaffold instruction for students to progress to the next level. This review looks at four types of instructional strategies researchers have investigated to increase mathematical achievement. The strategies are peer tutoring, explicit instruction, self-monitoring, and technology.

The theoretical framework of Leo Vygotsky’s social constructivism emphasizes how teachers and peers play an important role in learning (McLeod, 2013). The two main principles of the theoretical framework of Leo Vygotsky’s social constructivism supports peer tutoring, explicit instruction, self-monitoring, and technology strategies. More Knowledgeable Other (MKO) refers to someone or something, i.e. electronic support that has a better understanding than the learner on a particular task or concept. MKO supports the principle of the Zone of Proximal Development (ZPD). ZPD is the difference between what a student can achieve independently and what the student can achieve with guidance by a peer, explicit instruction, self-monitoring, or technology (McLeod, 2013).

The effectiveness of peer tutoring

One instructional strategy researchers have investigated is the effectiveness of peer tutoring. Class-wide Peer Tutoring (CWPT) is one such example and is where students are taught
by peers who have been trained and are supervised by the classroom teacher (Maheady & Gard, 2010). CWPT consists of four components which are (a) teams that change weekly, (b) highly structured tutoring protocol, (c) daily feedback through point earning, postings, and rewards, and (d) direct practice. CWPT is done only when the content has been taught previously through direct instruction and requires a 30-minute block per day anywhere from three to five days per week.

In the practitioner narrative section from the research, CWPT was used in a mathematical remedial classroom on a purposeful sampling of students. One of the researchers noted that the students complied well to the rules and appeared very excited to play the game. Also noted were the immediate and noticeable improvements in math multiplication and division fluency. The researcher commented how the points earned continued to grow, demonstrating the students were doing more work in the same amount of time and reducing the gap between themselves and their normally achieving peers. In the peer reviewed article, one of the researchers observed that the students were more confident, tried more challenging math applications, increased pro-social comments to each other, were supportive and helpful to others struggling, and proud of their improvements (Maheady & Gard, 2010).

Researchers have also investigated peer tutoring in an experimental setting (Beirne-Smith, 1991). Peer tutoring can be a self-regulating strategy for general and special education classrooms where two children work together. One child is the tutor and serves as the teacher and one is the tutee and serves as the learner.

In the experiment to test the effects of peer tutoring students identified with math learning disabilities were paired with their cross aged tutors to contrast two procedures, counting on and rote memorization for basic single digit addition problems. Researchers
used students from four adjacent school districts, two rural and two urban, in a purposive sampling. Tutors were either trained to present Method A, involving a three task counting on procedure with explicit interrelationship among facts, or Method B, a two task procedure using rote memory without the explicit interrelationship. Method C was the control group that received no treatment. Tutors and tutees all were pre-tested (phase one) and post-tested (phase three) on sixty single digit addition facts. During the second phase a strict treatment plan with observations from the experimenter was followed for Method A and B.

The results indicated that peer tutoring does have a significant effect on performance scores for both methods. Pretest scores for the tutees Method A: 23.8 correct, Method B: 23.1 correct, Method C: 22.9 correct and posttest scores Method A: 40.8 correct, Method B: 37.9 correct, and Method C: 25.9 correct. No significant difference was indicated in the comparison of Method A and B as to one method being better than the other (Beirne-Smith, 1991).

A meta-analysis of 15 coded studies, which included peer tutoring or peer assisted mathematics performance as one of the categories, supported the findings on the effectiveness of peer tutoring (Baker, Gersten, & Lee, 2002). The 15 studies were controlled experimental and quasi-experimental studies that met standards of scientific rigor in which students were randomly assigned to either treatment or comparison groups. The six studies addressing peer tutoring or peer assistance had a moderately strong effect size of 0.66 according to Cohen’s interpretation and led to positive effects on student achievement from peer assisted learning interventions.

The effectiveness of explicit instruction
Teaching students with mathematics difficulties is challenging, but research indicates that incorporating explicit instruction as a framework may increase proficiency and skills (Doabler & Fien, 2013). Guidelines for explicit instruction include teacher modeling, guided practice, and academic feedback. Teacher modeling includes clear and consistent wording, unambiguous explanations and demonstrations, and think-alouds. Guided practice consists of select and sequential examples, pre-teach skills, verbal prompts, math models, and reviews. Academic feedback is ongoing, timely, corrective and positive. Teachers can improve daily math instruction by following the guidelines and making explicit instruction more clear-cut and methodical.

The Common Core State Standards for mathematics emphasize the application of problem solving skills for real life scenarios that are addressed in collaborative, group efforts. Wilson and Sindelar (1991) organized a quantitative, peer reviewed experimental investigation to test the strategy of direct instruction of word problems for identified students with learning disabilities that met the criteria for the study. The students were selectively placed in one of three groups consisting of strategy plus sequence, strategy only, and sequence only. All three treatment groups had similarities that included the amount of time students were in instruction, the use of detailed, scripted lesson plans, same number and identical sets of word problems, and accessibility to trainers during seat work time to answer questions or reinforce work and behavior. Analysis of Covariance (ANCOVA) was used on pretest, posttest, and follow-up tests.

The results indicated that strategy plus sequence group had a pretest mean score of 10.95, the strategy only group 16.67 and the sequence only group 13.85. The posttest adjusted mean scores were strategy plus sequence 16.42, strategy only 15.83, and the sequence only 13.99. The follow up test adjusted mean score was strategy plus sequence 17.48, the strategy only 15.00 and
the sequence only 12.94. The results indicated that the groups using direct instruction with strategy plus sequence and strategy only scored significantly higher than the sequence only group. The data supported the superiority of the direct instructional strategy for teaching students with learning disabilities to solve addition and subtraction word problems.

In the peer reviewed article Fuchs, Fuchs, Powell, Seethaler, Cirino, and Fletcher (2008) focused on seven principles of effective intervention. Story problems and number calculations can be an obstacle for students with learning disabilities and provide major challenges for increasing mathematical competency. Number calculations refer to problems which can be solved either by automatic retrieval or counting. Story problems involve linguistic processing and the ability to set a problem up where in number calculations the problem is already set. Story problems involve the process of figuring out what is missing, identifying the mathematical operation, and accurate solving.

There are seven principles examined in the review of research in cognitive strategy instruction for mathematics. The first is the principal of instructional explicitness where the teacher directly shares and provides guided practice necessary for information to be learned. The next principle for effective intervention is instructional design to minimize the learning challenge. The principle anticipates and eliminates misinterpretations by careful sequencing and providing direct instruction to close the gap between functional levels of performance and benchmark levels. The third principle is a strong conceptual basis which provided a scaffold for the fourth principle of drill and practice. An example of strong conceptual basis is the use of manipulatives, number lines, touch math strips, role playing, etc. Drill and practice supports fluency of math facts and improves accuracy. The fifth principle is cumulative review which supported revisiting math foundation skills and continued support of using the skills acquired.
The sixth principle is motivators to help students regulate their attention and behavior to work hard. Students with learning disabilities often lack the ability to attend to the areas mentioned because of the degree of difficulty challenging students daily and the frustration of repeated failure. Motivators can be visual graphing to show gains as students achieve growth. The seventh and deemed the most essential by the authors is that of ongoing progress monitoring. Progress monitoring is an effective protocol that generates valid data to show growth or failure to respond so that instruction can be tailored to individual student needs. Curriculum based measurement is a form of progress monitoring providing regular intervals of assessment towards an end of the year predetermined aim point or goal. Progress monitoring enhances the teacher’s ability to plan instruction for stronger outcomes.

The peer reviewed quantitative study by Fuchs, Powell, Seethaler, Cirino, Fletcher, Hamlett, and Zumeta (2009) that complimented the seven principles of effective interventions assessed the effectiveness of tutoring third grade students with mathematical difficulties with explicit instruction. The randomized control study of 133 third grade students across 18 large, urban schools in Houston and Nashville focused on number calculations and word problem deficits. Number calculations were referred to as Math Flash and word problem was referred to a Pirate Math because of the tutoring protocol and the materials each used. Math Flash used 200 number combinations with addition and subtraction facts from zero to nine. Pirate Math was a story problem intervention with posters and materials in a pirate theme. The measures used to establish the criterion for eligibility was the Wide Range Achievement Test-3 (WRAT) for number calculations, a 5 item version of a test originally developed by Riley, Greeno, and Heller (1983) referred to in Fuchs, Powell, Seethaler, Cirino, Fletcher, Hamlett, and Zumeta (2009), reading subtest of the WRAT, and Wechsler Abbreviated Scale of Intelligence. Of the 924
screened, the random placement of students resulted in 42 placed in Pirate Math, 44 in number calculations tutoring, and 47 in the no treatment control group. The sampling included 45% female and 55% male students of African-American, Hispanic, and White descent along with consideration for socioeconomic, ELL, and disability status. Seventeen percent were students with learning disabilities. The tutors, who were employees of the research, were trained in instructions, implementing procedures, practice with corrective feedback, and met during implementation of the experiment to address concerns or questions. Every session was taped and reviewed as checklists were completed. Upon completion of the tutoring, all students completed posttests which used the pretest measures and the Iowa Test of Basic Skills. Math Flash and Pirate Math students improved on number calculations more than the students in the control group. The effect size for Math Flash to the control group was large, 0.85 and the effect size for Pirate Math to the control group was somewhat smaller but still considered moderately large at 0.72. Explicit instruction through tutoring favored improvement on mathematical skills and applied to students with mathematical difficulties.

Referring to a meta-analysis of 15 coded studies, three of which included explicit teacher led instruction, the studies emphasized conceptual understanding over procedural accuracy and were taught with more explicit instruction than is typical (Baker, Gersten, & Lee, 2002). The 15 studies were controlled experimental and quasi-experimental studies that met standards of scientific rigor in which students were randomly assigned to either treatment or comparison groups. The moderately strong effect size of 0.58 according to Cohen’s interpretation led to positive effects on student achievement from explicit instruction.

A meta-analysis by Kroesbergen and Van Luit (2003) reviewed 58 studies of mathematic
interventions for elementary students with special needs. The defined research questions included whether an outcome was dependent on the treatment components such as direct instruction, self-instruction, computer assisted instruction, or peer tutoring. Of the 61 empirical studies, 21 had single subject designs and 40 had group designs. Studies with an intervention showed a higher effect size than the studies without an intervention. The interventions with older students had more effect than with younger students. The effect of students with learning disabilities showed a higher weighted effect size of 1.36 than the effect of low performing 0.74, mild mental retardation 0.80, and mixed groups 0.73. An interesting result was most studies used direct instruction as the intervention but self-instruction had a higher effect size. The weighted effect size for the methods was 0.91 direct instruction, 1.45 self-instruction, 0.34 mediated/assisted instruction, 0.51 computer method, 1.05 teacher method, and 0.87 for peer tutoring. When choosing an intervention to promote growth, direct instruction and self-instruction seemed to be adequate for students with special needs.

The peer reviewed, quantitative study of Ketterlin-Geller, Chard, and Fien (2008) examined the effects of two supplemental interventions for mathematics for low performing fifth grade students. The study was conducted over one school year and evaluated the effects of two approaches: Knowing Math a small group mathematics intervention program and Extended Core, an intervention designed by classroom teachers and the project’s research team. Extended Core allows extra time and support with specific content being taught from the district’s curriculum. When applicable, teachers used systematic and explicit instruction when using Extended Core interventions. There was also a control group that received no additional support outside of mathematics instruction in the general education classroom.

Data analysis indicated a moderate effect size for students who had received either
intervention as compared to those in the control group. While both interventions showed promise of benefiting students at risk, the analysis indicated that one intervention benefitted students with learning disabilities over the other intervention that benefitted students at risk. Students receiving the Know Math intervention benefitted from relearning concepts that eluded them while students receiving Extended Core benefitted from extended time and practice on daily topics.

The Common Core State Standards include understanding and fluency of the four mathematical operations. Woodard (2006) states, “The information-processing theory supports the view that automaticity in math facts is fundamental to success in many areas of higher mathematics” (p. 269). A peer reviewed experimental quantitative study by Woodward (2006) looked at a two pronged approach for math fluency which used strategies for teaching facts and timed practice drills. The controlled study of 58 fourth grade students were randomly assigned to 30 students in the intervention group and 28 students in the comparison group. The intervention group included eight students with LD and the comparison group included seven students with LD. Both groups received the same amount of instruction time and the teachers had extensive experience with the methods used. The results which used Cohen’s $d$ analyses indicated small effect sizes and favored the integrated approach overall on automaticity of math multiplication facts. Students in the integrated group had a mean score of 73% correct and the timed practice only group had a mean score of 69% for the common multiplication facts. The mean score for the integrated group was 37% and for the timed practice only group was 40% for the hard multiplication facts. The mean scores for the extended facts test was 74% integrated and 59% timed practice only. The mean scores for the computations test was 33% for integrated and 60% for timed practice only. The mean scores for the approximations test was 67% integrated and 37% timed practice only. The results indicated the integrated and timed practices were effective
in learning automaticity of multiplication facts, but the integrated group performed better on posttest and maintenance test measures assessing application, extended, and approximation tasks.

NCLB made clear the expectations that students with special needs have access to, participate in, and demonstrate academic progress in the general education curriculum. The ability to fluently recall basic facts for computation is a goal The National Council of Teachers of Mathematics listed for instruction. The peer reviewed article by Burns (2005) discussed the use of incremental rehearsal (IR) to increase fluency. IR is a gradual increasing ratio of known to unknown basic facts until the ratio is 90% known to 10% unknown. As more known facts are added to meet the 90/10 ratio, eventually one is removed and the one unknown fact now becomes part of the 90% and a new unknown fact is added to the deck of facts. The qualitative study examined three-third grade children with mathematical learning disabilities in computations within the same district in central Michigan but in different elementary schools. The students were a Caucasian male, an African American male, and a Caucasian female. Socio-economic data were not available. Student progress was monitored on single digit multiplication with weekly curriculum-based measurement (CBM) fluency assessments. Student researchers were trained and a strict protocol was adhered to during a 15 week period. Fidelity of implementation was assessed through observations during the study. The data suggested improvement from the baseline points for each student and continuous increases in performance during the study. IR could be a useful strategy for increasing multiplication computations, however, there were some limitations noted in the study. The control during the study was limited to the classroom but could have been affected by external influences such as practice at home. Second, the naturalistic setting did not allow for control of consistency. Although intervention and assessment did not vary much between students, the treatment schedule varied,
i.e. Monday one week, Tuesday another week. Lastly, the number of baseline data points was within four of five. Being able to extend the baseline would have strengthened the multiple-baseline design. IR appears to be easy to implement but would be intensive and require a one-on-one arrangement.

The effectiveness of self-monitoring

Common Core State Standards for Mathematics for elementary students are focused on a new type of instruction commonly referred to as standards-based curricula. This curricula takes a dramatic departure from past practices and is focused on application rather than skill development. While there is agreement among researchers in the field of special education who advocate for real world problem solving, students with learning disabilities in mathematics are challenged with problem solving.

A peer reviewed article by Sayeski and Paulsen (2010), investigated strategies to complement reformed math and the needs of students with mathematical disabilities. The reform curricula emphasis is solving real life problems and encouraged group work, the use of calculators and manipulatives, and invented algorithms. Students with mathematical disabilities lack fundamental essential knowledge to engage in problem solving with their peers. Strategy instruction along with daily timed trials may result in better outcomes for students with LD. Strategy instruction may include derived fact, doubling, counting backward, split and add, distributed multiplication, and doubling and halving. Regardless of the method used, teachers of students with math LD should be mindful to select the algorithm that can be done most efficiently and effectively by the individual student. Emphasis should not be on one size fits all. Problem solving places greater responsibility on the students and students with LD tend to be poor self-regulators. However, strategy instruction and self-regulation such as using self-
monitoring checklists may improve mastery of solving word problems. Pedagogical support such as direct instruction, modifying grouping formats, and progress monitoring may increase the student’s ability to learn and be actively involved. Students with LD can be successful in standards-based instruction when special education teachers take advantage of well-designed curricula and make the necessary adaptations to allow students to embrace real world problem solving.

Self-monitoring is a strategy that engages students in helping to plan, perform, and monitor a skill. A peer reviewed article by Zrebiec Uberti, Mastropieri, and Scruggs (2004) presented a teacher-researcher qualitative study that focused on an inclusive third grade classroom and six students in need of intensive intervention in mathematics. The sampling consisted of four male and two female students; five were eight years old and one was nine years old. Four of the six were identified as students with learning disabilities. Additionally ethnicity, socioeconomic status, and English as a Secondary Language were also reported. After completion of a pretest the students worked on daily practice sheets with specific color coding strategies and self-instruction checklists. A reward system was established to encourage participation. The results of the intervention were encouraging. The mean total score from the pretest to the posttest rose from 31% correct to 90% correct. Individual performance improved daily and reliance on the self-instruction checklist dissipated over the course of the study. The students were also motivated by using dry erase markers, checklists, stickers, and rewards for gains acquired. While the intervention showed credibility, it did lack elements of a more formal study. There was not a control group of students with disabilities to compare to the intervention group.
Cover, Copy, and Compare (CCC) is a self-regulated, simple intervention used to improve mathematical accuracy and fluency. A qualitative study by Grafman and Cates (2009) examined CCC and a modified procedure called Copy, Cover, and Compare (MCCC). The study examined how students performed using one and then the other when completing subtraction problems. CCC required students to look at a problem with the solution on the left side of the paper, cover the problem with an index card, then write the problem and solution on the right side of the paper. Once completed, the student checks the work by uncovering the problem and solution and comparing the response to the problem. If any were incorrect, the student were instructed to complete an error-correction procedure. The procedure required the student to copy the problem and the correct answer one time. The modified version is basically the same except a step has been added at the beginning where the student was instructed to first copy the problem before covering it up. Forty-seven second grade students between the ages of seven and eight that lived in a middle class Midwestern suburban district participated in the study. Ethnicity was reported but the number of students identified with disabilities was not known. A pretest and posttest was administered and each worksheet used in the research was marked with either “Cover” or “Copy” at the top. The study took three days and consisted of a pretest on day one, interventions on day two, and posttest on day three with all situations timed for two minutes. The students were actively engaged in both self-managed strategies and surveyed at the end of the study to determine what strategy was preferred. The tests were scored for error rate and fluency. The results of pretest to posttest for fluency were 1.11 which is a large effect size according to Cohen’s $d$. The results for error rate was 0.14 which is small suggesting that accuracy level was maintained. The data also suggested that students had a higher level of fluency when using CCC as opposed to MCCC.
The effectiveness of technology

The effective integration of technology as a purposeful tool within mathematics empowers students to acquire and construct new knowledge. A peer reviewed report by Allsopp, Farmer, and McHatton (2010) examined technological innovations considered for effective mathematic instruction for students with learning disabilities and how the tools better satisfy the needs of the students considering learning barriers and strengths. The use of technology has been categorized in two ways for students with LD. One is the technology that circumvents or bypasses a disability barrier such as calculators. The second is the technology that enhances instructional strategies and helps educators make sound instructional decisions such as interactive white boards (IWB). The categories can be further separated into applications between low tech and high tech. Low tech applications include materials that do not require large amounts of money or computers, special equipment, or broadband. High tech applications are ones that include computers and software. The importance here is to realize technology does not have to be expensive or require extensive training. Emerging technologies such as social websites, i.e. Facebook, and free communication software, i.e. blogs, may help in collaboration among peers and teachers. The research needed the use of these innovations for students with LD. Technology must be closely assimilated with research-based practices that promote learning. Research is lacking for students with LD that encompass the scope and depth of reformed math curricula. A framework, one that complements effective instructional practices, needs to be developed on how to integrate technology into mathematics.

Directly related to special education and technology is the Assistive Technology Act of 2004 (AT Act). This act provides assistive technology devices or services to any child or adult with a disability. The AT Act ensures that all students have access to technology that supports
the activities of life such as learning, leisure, recreation, and work. The use of technology may provide essential supports for students with disabilities. A meta-analysis study by Li and Ma (2010) examined the impact of computer technology (CT) defined as computer software for mathematics in K-12 classrooms including special education students. The study reviewed 46 primary studies involving 36,793 students. Mathematical achievement was defined as performance scores on standardized or teacher made tests. The four types of CT were tutorial, communication media, exploratory environments, and tools. The coding was based on gender, racial, and socioeconomic composition, student type, i.e. general and special needs including students with disabilities, and grade level. The studies were either controlled where students were randomly assigned to experimental or control conditions or were statistically controlled for quasi-experiments. The effects ranged from 0.13 to 0.43 which is considered small to moderately small on Cohen’s $d$ interpretation. All gender, racial, and socioeconomic groups benefitted from technology. Students with special needs had a statistically significant effect of 1.31 which is considered a very large effect according to Cohen’s $d$. Elementary students had a larger effect than the secondary students. The effect was 0.22 and was considered a small advantage when using technology to promote achievement. The implications discussed by the authors were that shorter technological interventions of six months or fewer were more effective in promoting mathematics gains than longer interventions of between six to twelve months. The moderate effect of mathematical achievement on elementary students over secondary students was not surprising due to the visual, hands-on approach which is more commonly used at the elementary level than the secondary level. Finally, the meta-analysis suggested that students with special needs in mathematics could benefit from the use of technology. The limitations to this study
indicated more comprehensive analyses need to be researched on the use of CT with students with disabilities.

Access to technology can provide meaningful learning opportunities for developing problem solving and higher-order thinking skills needed to function in the world beyond the classroom. A peer reviewed article by Hasselbring and Zydney (2005) examined evidence that indicated students with disabilities and students at risk of school failure were not improving significantly in mathematical achievement as determined by the criteria outlined in the No Child Left Behind Act. Math difficulty referred to students in the study as being at risk or disadvantaged, with dyscalculia, and with learning disabilities. Concurrently, the authors sought to understand how technology-based innovations could provide effective approaches to help students with disabilities make gains to lessen achievement with their peers.

The three types of mathematical knowledge required for development are declarative, procedural, and conceptual. Declarative knowledge was defined as factual knowledge such as $3+3=6$. Procedural knowledge was defined as the rules, algorithms, or procedures to solve math problems such as the order of operations. Conceptual knowledge was defined as the full understanding of interrelating the pieces of information together.

The review investigated software that may promote increased mathematical achievement in student with math difficulties. The review was guided by the National Curriculum & Training Institute Mathematics Matrix which included building computational fluency and converting symbols, notations, and text. The Matrix also included building conceptual understanding, making calculations and creating mathematical representations, organizing ideas, and building problem solving and reasoning.
Computational fluency was the ability to recall basic math facts rapidly, effortlessly, and accurately. Students with math difficulties are less proficient than their peers and typical drill and practice software that asked students to recall facts from memory may not be the best strategy. Software that practiced the strategy of procedural counting may be more effective. One example of software with the strategy-based procedural counting was Fluency and Automaticity through Systematic Teaching (FASTT).

Scaffolding has been defined as a “process that enables a child or novice to solve a problem, carry out a task or achieve a goal which would be beyond his unassisted efforts” (Wood, Bruner, and Ross, 1976) as referred to in Hasselbring and Zydney (2005). Vygotsky’s constructivist’s theory emphasized scaffolding within the zone of proximal development (ZPD). Scaffolding is modeled for the desired task and then gradually removed during the learning process as the responsibility shifts to the student. ZPD is the difference between what a student can achieve independently and what the student can achieve with guidance by a peer, explicit instruction, self-monitoring, or technology (McLeod, 2013). There can be several ranges of ZPD within a classroom which include students with math difficulties. The degree of ZPD ranges can make it difficult for a teacher to provide scaffolding that meets the varied needs of all students. A computer tool that could be used by students with math difficulties is software that converted text, symbols, and math notations, however, this may not be sufficient as there may be more areas of need to address.

Building conceptual knowledge and understanding was defined as being able to make the connection between declarative and procedural knowledge to the real world. Anchored instruction used video technology as an approach that created real-world scenarios of math problems for students without prior knowledge and made connections to understand.
The use of graphing or scientific calculators may simplify making calculations and creating mathematical representations when solving mathematical expressions. Calculators can promote achievement, problem solving skills, and increase understanding of mathematical ideas. Handheld computers offer flexibility and many options in a convenient size with a wide variety of software applications such as database, spreadsheet, and more.

The review described organizing ideas was supported by the building and classifying of a problem. A graphic organizer is a visual representation and can be an effective tool along with software that has been designed to help students organize and discover the component parts of a math problem.

The building of problem solving and reasoning skills was the last idea reviewed. There are many types of computer tutorial programs and anchored instruction programs depending on the mathematical idea addressed. Whatever program was being used, the challenge for students with math difficulties was knowing and executing strategies. Students could be successful with computer software if they have the declarative, procedural, and conceptual knowledge necessary to apply the facts.

Research on the effectiveness of using iPads in the classroom to increase mathematical learning for students with disabilities is new and very limited. However, a qualitative study examined the effect of the use of basic math skill application on an iPad to increase basic math fluency by O’Malley, Jenkins, Wesley, Donehower, Rabuck, and Lewis (2013). The sampling of ten seventh and eighth grade students with moderate to severe cognitive disabilities was conducted in an urban Eastern school district. The students were between 12 to 15 years old and the group contained three females and seven males with a primary eligibility of autism or multiple disabilities. Before the study began, surveys of access and use of technology were
completed by teachers and parents of the students participating in the research. Basic math achievement and fluency was assessed before the intervention of using an iPad application was administered. Fidelity of intervention was measured by teachers’ completion of a five item checklist to ensure all students followed the same protocol. Social validity was assessed by teachers’ completion of a seven question survey using a Likert-type scale. Technology integration was evaluated by surveys, observation, and interviews to identify advantages and barriers for using iPads for teaching and learning. The four week, single case research methodology used an ABAB design of pencil and paper assessment during baseline phases and an iPad application called Math Racer during the intervention. The dependent variable was the rate of basic math fluency gains and the independent variable was the timed math probe. Before the start of the intervention all parents gave consent for the four week, class-wide intervention and student demographic data were collected.

The results indicate the iPad was an effective tool for students with moderate to severe disabilities. Comparison of baseline and intervention showed an average of a 12 point gain in the number of correct problems per minute when using the iPad application Math Racer. Three advantages that were discussed were teachers rated their perceptions of the iPad intervention as highly acceptable and effective for classroom instruction; teachers reported the intervention allowed students to master or make progress toward learning goals not yet mastered; and finally, teachers expressed that the experience enhanced teaching skills and improved students’ interest.

Some disadvantages were a high level of technical support was needed throughout the intervention by teachers and there was a vast range in teachers’ abilities to access and use the technologies. Students had a variety of technology available at home but the students had limited use. Technology was primarily used for entertainment not learning because the students
required moderate to high assistance. Finally, logistics were a barrier in that it took more time
and effort than originally thought to oversee, use, store, and maintain the iPads. It was not known
if the iPad intervention had a long-term effect.
Chapter III: Results and Analysis Relative to the Problem

The expectation for adequate yearly progress and the need to achieve AYP through scientifically based research was mandated by the No Child Left Behind Act of 2001 and applies to all students. Research-based instructional programs should be able to withstand the test of standard scientific testing, gather information about significant questions, use objective methods that involve reliable and valid observations and measurements, meet rigorous standards of peer review, and can be replicated and generalized. Research-based instructional strategies begin lessons with short reviews, present new material in small steps with student practice, ask many questions and checks for responses, provide models, guide practice for students, check for understanding, obtain a high success rate, provide scaffolds for difficult tasks, require and monitors independent practice, and engage students in weekly and monthly review (Rosenshine, 2012). This chapter discusses results and analysis of what strategies may increase mathematical achievement for elementary students with moderate to severe learning disabilities.

Peer Tutoring

Peer tutoring, whether implemented class-wide or offered to specific students in a one-on-one structure, may have a significant effect on student performance for increasing mathematical achievement. The literature regarding the use of peer tutoring established noticeable improvements on math multiplication and division fluency and single digit addition facts for students with a mathematical learning disability (Maheady and Gard, 2010; Beirne-Smith, 1991). The six meta-analysis studies that included a small percentage of students with a learning disability, supported improvement on the effects of computation skills with two of the studies including a measure of general math achievement (Baker, Gersten, and Lee, 2002). A commonality in the studies was students worked in pairs as opposed to small groups. The sample
sizes were small which limited the ability to generalize the results to larger settings. Frequency and duration was another commonality. Two studies took place over a four week instructional period (Maheady and Gard, 2010; Beirne-Smith, 1991). Two studies required a 90 minute block of math instruction, 60 minutes in the classroom and 30 minutes of the intervention (Maheady and Gard, 2010; Baker, Gersten, & Lee, 2002). More current studies are needed to support the data but peer tutoring is a cost effective strategy proven to increase mathematical achievement.

**Explicit Instruction**

Explicit instruction is systematic, direct, engaging, success oriented, and has been shown to promote achievement for all students. Guidelines for explicit instruction include teacher modeling, guided practice, and academic feedback (Doabler & Fien, 2013).

Research supported explicit instruction as a method for increasing math skills when problem solving for real life scenarios, word problems, number calculations, and automaticity of basic math facts by rote memorization or incremental rehearsal (Wilson and Sindelar, 1991; Fuchs, Seethaler, Cirino, Fletcher, Fuch, Hamlett, and Zumeta, 2009; Kroesbergen and Van Luit, 2003; Ketterlin-Geller, Chard, and Fien, 2008; Woodward, 2006; Burns, 2005).

Wilson and Sindelar’s (1991) tested the use of direct instruction for teaching students with LD strategies for solving word problems. The study indicated the groups using direct instruction with strategy plus sequence and strategy only scored significantly higher than the sequence only group. The data supported the superiority of direct instruction for teaching students with learning disabilities to solve addition and subtraction word problems.

Kroesbergen and Van Luit (2003) included both single and group designs in the review of 58 studies of mathematical interventions for elementary students with special needs. The results were favorable for direct instruction and self-instruction as interventions, however, both the
single and group designs were not analyzed separately which may have affected the reported effect size.

The study by Ketterlin-Geller, Chard, and Fien (2008) focused on the effects of two interventions, Knowing Math and Extended Core. While the approaches retaught basic mathematical concepts and allow extended time for learning, the study used a small sample size. Minor modifications to the initial random assignments of groups were made by teachers and district administration that may have affected the possible misalignment of students’ need and influenced the outcomes.

Woodard’s (2006) study examined the explicit instruction strategies for teaching multiplication facts along with the use of timed practice drills to develop automaticity of facts. The results suggested that both were effective but when integrated together were even more effective on performances on posttests and maintenance tests. The limited time frame did warrant the need for a longitudinal study. Also students were moved on to new fact mastery based on performance of 70% of the class. The strategy may not have helped students with low achievement the additional practice the students could have benefitted from. Burns (2005) research examined incremental rehearsal (IR) as a strategy to increase mathematical fluency. IR could be a useful strategy for increasing multiplication computations but could have been affected by external influences such as practice at home. The naturalistic setting did not allow for control of consistency, i.e. Monday one week, Tuesday another week for treatment. The baseline data points were narrow but extending the baseline would have strengthened the multiple-baseline design. IR also involved intensive direct instruction and a one-on-one arrangement.

All researchers mentioned above expressed the need for more research analyzing explicit instruction.
Self-Monitoring

Self-monitoring is a strategy that engages students in helping to plan, perform, and monitor a skill. Sayeski and Paulsen (2010) investigated strategies to help students with LD when trying to solve real-world problems. Strategy instruction included effective and efficient methods but needed to be tailored to the students’ individual needs.

Zrebiec Uberti, Mastropieri, and Scruggs (2004) research focused on self-instruction checklists that supported daily practice worksheets. The study lacked the elements of a formal study, but had data that indicated improvement of the student’s score after the intervention. The small number of six students in the intervention group also lacked a control group for comparison. Future research would strengthen the reliability of the study’s findings.

Grafman and Cates (2009) used cover, copy, and compare as a math fluency strategy. A modified procedure called copy, cover and compare was also used on the same group of students in the study. The students were actively engaged in both self-managed strategies and the results were favorable for error rate and fluency, but the sampling was small. It was a quick strategy allowing students to track progress. Some limitations with the study were students would need to be monitored to make sure they all are following directions; the same amount of time was used to complete both strategies even though MCCC had one more step; the study needed a treatment integrity check; and the timing of two minutes for the intervention along with the length of one week to complete the strategy could be increased to investigate of a possible change in the outcomes.

Technology

The effective integration of technology as a purposeful tool could empower students to acquire and construct new knowledge. Allsopp, Farmer, and McHatton (2010) examined the use
of technology for effective math instruction for students with LD. Research is needed regarding the use of the innovations reviewed in the study. A framework, one that complements effective instructional practices, needs to be developed to integrate technology into mathematics.

The research of Li and Ma (2010) examined the impact of computer technology in K-12 classrooms including special education students. The large sampling involving 36,793 students benefitted from technology, but students with special needs had a statistically significant effect of 1.31 which is rated as a very large effect according to Cohen’s $d$. Shorter technological interventions of six months or fewer were more effective in promoting math gains than longer interventions. The limitations of this study indicated more comprehensive analyses need to be researched on the use of CT for students with disabilities.

Hasselbring and Zydney (2005) examined how computer technology could provide effective approaches to help students with disabilities make gains. Students could be successful with computer software if they have the declarative, procedural, and conceptual knowledge necessary to apply the facts.

Research on the effectiveness of using iPads in the classroom to increase mathematical learning for students with disabilities is new and very limited. O’Malley, Jenkins, Wesley, Donehower, Rabuck, and Lewis (2013) researched the effect of the use of basic math skill applications to increase fluency. The small sampling was conducted on a group of 7th and 8th graders with moderate to severe cognitive disabilities for four weeks. The use of an iPad application for increasing fluency showed an average 12 point gain when doing a comparison of the baseline and the intervention. Teachers discussed the advantages of using the iPads. The iPad intervention was highly acceptable and effective for classroom instruction. The intervention allowed students to master or make progress towards learning goals. The teachers expressed the
experience enhanced teaching skills and improved students’ interest. Disadvantages were a high level of technical support was needed. Teachers had a vast range in abilities to access and use the technologies. Finally, logistics were a barrier because more time and effort was needed to oversee, use, store and maintain the iPad.

A commonality throughout each study reviewed was the need for more current research that focuses on the students with learning disabilities. The majority of what was available to review was dated and included students with and without learning disabilities. Research can be time consuming and expensive which can affect the availability of the studies needed to address the special education population.
Chapter 4: Recommendations and Conclusion

The movement to higher standards and accountability under No Child Left Behind, and the alignment of special education with educational reform requires that special education students be able to access, participate in, and demonstrate academic progress in the general education curriculum. Research recommends how students with learning disabilities can increase mathematical achievement. The research also suggests areas for further research to enhance the current strategies that may be used. This chapter discusses these recommendations and areas for further research.

**Recommendation**

Peer tutoring can be an effective strategy for increasing mathematical achievement for students with learning disabilities. The studies support that while increasing correct computational responses in math, students were more confident, prosocial, supportive, and helpful to others struggling. Peer tutoring, after the initial training of tutors and tutees, can be time efficient, cost efficient, and implemented with relative ease. The opinion of the writer of this research paper is collaboration between general education and special education teachers would be the starting point. The challenges teachers face in both settings could be addressed by trying to implement one of the studies reviewed in this paper. Peer tutoring is used within classrooms but not effectively. The tutoring that is happening is one of trying to help another student stay on task or get through the objective of a lesson. Real peer tutoring needs structure, planning, and desired outcomes to be a valid teaching tool to enhance achievement.

Explicit instruction can be an effective strategy of instruction for students with mathematical learning disabilities. The methodology often used by teachers when planning and presenting a lesson often includes explicit instruction, especially if following Dr. Madeline
Hunter’s lesson plan format, which includes modeling, checking for understanding, and guided and independent practice. Reviewed in the research paper were a diverse number of teaching strategies that used explicit instruction. Ongoing progress monitoring of math skills is essential for explicit instruction to be successful.

Self-monitoring can provide students with guidelines for completion of mathematical operations. Self-monitoring is an intervention that is easy to prepare quickly and provides students with a strategy when a teacher may not be available to assist. More formal studies are needed to strengthen the credibility of the strategy.

Technological advances bring exciting innovations into the classroom that may address mathematical difficulties. Research is needed for students with learning disabilities that encompass the scope and depth of the reformed math curricula. A framework needs to be developed on how to integrate technology into mathematics that compliments effective instructional practices. Technical support must be readily available for teachers to access to successfully use technology in the classroom. New technology requires time to oversee and maintain in order for the strategy to be useful.

**Areas for Further Research**

Peer tutoring, explicit instruction, self-monitoring, and technology, can be effective strategies, but additional research would strengthen reliability. Studies that compared peer tutored groups to teacher instructed groups would provide meaningful insight. More randomized control trials for between-group experiments would strengthen class wide peer tutoring external validity to the extent which the findings could be generalized to other students, teachers, and settings. Studies that focused on all four math operations would be helpful. Longitudinal studies are needed to determine how well students maintain automaticity of math facts. Additional
research on a larger scale such as building wide or district wide would be helpful as many of the studies reviewed were a small sampling. Students would benefit from further studies that were not exclusive to the development of basic skills and the increase of acquired and retained factual knowledge but could be applied to higher order academic outcomes. New research needs to take into account the changes that are happening due to math reform as compared to the traditional methods used for mathematic instruction for student with disabilities. Technology must be closely assimilated with research-based practices that promote learning.

**Conclusion**

Research indicates that students with mathematical learning disabilities can learn and achieve. Ideally instruction should be small group with a highly qualified instructor who understands the learning abilities of students with mathematical LD. Instruction should be intense and time limited. The dilemma is the current move toward inclusion in general education for students with LD with instructors not highly qualified to teach students with LD (Montague, 2008). The pressure to complete required core curriculum may impact the effectiveness of implementing teaching strategies that may increase achievement. Continued research is necessary as strategies are reviewed to provide growth for students with LD. Educators will be expected to provide a quality mathematical education as students with learning disabilities strive to make adequate yearly progress.
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