Winter 12-15-2012

A study of the impact of instructional approach on community college students' problem solving and metacognitive abilities in the developmental mathematics course, Introductory Algebra

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A study of the impact of instructional approach on community college students' problem solving and metacognitive abilities in the developmental mathematics course, *Introductory Algebra*

A Dissertation

Submitted to the Graduate Faculty of the
University of New Orleans
in partial fulfillment of the
requirements for the degree of

Doctor of Philosophy
in
Curriculum and Instruction

by
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December, 2012

Acknowledgement

It was with the encouragement and support of my husband, my dissertation committee, and my four colleagues that I was able to conduct this study. I thank all of them for making this possible.

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Abstract

The purpose of this quasi-experimental study was to examine the cognitive, metacognitive, affective and instructional constructs that influence students' problem solving development in a community college *Introductory Algebra* course. The study addressed the lack of success that developmental mathematics students in a community college have in the *Introductory Algebra* course and in subsequent curriculum mathematics courses. Research suggests that the prevalent procedural-oriented instructional methodology used in most mathematics classrooms may be contributing to the lack of student success. The community college students (N = 140) in this study were enrolled in an *Introductory Algebra* course. The study investigated the relationships among the constructs self-regulation, students' problem solving development, and instructional methods used in the *Introductory Algebra* course. A correlational design established the quantitative relationships among the constructs. The aim of this study was to heighten the awareness of both the cognitive and non-cognitive aspects of adult student learning, as well as, the importance of attending to the students' conceptual understanding of mathematics.

Key words: Adult education, mathematics, developmental education, community college, conceptual approach, algebra

Chapter I

Statement of the Problem

Students' success rate in developmental education is a hot topic in the current community college literature due in large part to the substantial investments that the Gates and Lumina Foundations and the federal government are making in community college initiatives. As a direct or indirect result of various initiatives, several states are in the process of redesigning the developmental mathematics curriculum in the hope of improving the success rate of students who take developmental mathematics courses. Research on K-12 reforms and the latest data from the community college *Achieving the Dream* initiative suggest that a focus on data-based decision making may not be enough to improve student achievement; schools should focus on classroom instruction and strategies for overcoming students' learning difficulties (Rutschow et al., 2011). This study investigates the impact of instructional approaches on students' problem solving ability and on students' metacognitive abilities.

Mathematics education researchers, who investigate the K-12 mathematical curricula that stress students' understanding of mathematics and strategic competence for solving word problems, later found that students' mathematical achievement is generally higher and student motivation to learn stronger when understanding, reflection, and teacher-assisted discovery of strategies are emphasized (Boaler, 1998; Hollar & Norwood, 1999; Huntley et al., 2000; McCaffrey et al., 2003; Pressley, 1990; Renninger, Hidi & Krapp, 1992; Reys, Reys, Lapan, Holiday, & Wasman, 2003; Riordan & Noyce, 2001; Thompson & Senk, 2001). Overall, in the United States, mathematics teachers spend a small percentage of the instructional time engaging students in problem solving and reasoning activities. Frequently, the types of problems that are posed to students involve simple steps in procedures and algorithms and do not lead to a deeper understanding of mathematics (Lemke et al., 2004). Rasmussen and his colleagues (2003) found support in their research for instruction that expects students to discuss solutions to problems before the students attempt a solution and to explain their reasoning once they have found a solution. Within classrooms that utilize this type of instructional methodology, the nature of classroom learning changes dramatically (Ramussen, Yackel, & King, 2003).

The theoretical framework

The theoretical framework for this study is influenced by Bandura's social-cognitive theory, Vygotsky's cognitive-constructivism and the evolving information processing theories. Bandura's social-cognitive theory, with other influences, provides a basis for this study's theoretical framework. Within social cognitive theory, individuals are agents who are proactively engaged in their own development and who can make things happen by their actions. Bandura posits that "what people think, believe, and feel affects how they behave" (Bandura, 1986, p. 25) and that factors such as economic conditions, socioeconomic status, and educational and familial structures indirectly influence people's goals, self-efficacy beliefs, personal standards, emotional states, and other self-regulatory influences. At the core of social cognitive theory are self-efficacy beliefs, "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura, 1986, p. 391). Bandura (1997) contends that, "people's level of motivation, affective states, and actions are based more on what they believe than on what is objectively true" (p. 2). For this reason, how people behave can often be predicted better by the beliefs they hold about their capabilities than by what they are actually capable of accomplishing; self-efficacy perceptions help determine what individuals do with the knowledge and skills they have.

The second theory that influences this study is cognitive-constructivism. As a leading theorist, Vygotsksy argues that knowledge is actively constructed by the learner rather than passively absorbed, and is based on mental representations derived from past learning experiences. Each learner interprets experiences and information in the light of his or her existing knowledge, stage of cognitive development, cultural background, personal history, and so forth. Learners use these factors to organize their experience and to select and transform new information.

Thirdly, the study was influenced by information processing theory, a theory that has its roots in the "human as a processor of information." The study uses the theory in an evolved form that views the brain as a system through which learners select and organize relevant knowledge, and connect the organized information to familiar knowledge structures already in the brain (Mayer, 1992).

Purpose of the study

The purpose of this quasi-experimental study is to examine the cognitive, metacognitive, affective and instructional constructs that influence students' problem solving development in a community college *Introductory Algebra* course. Although there are no nationwide studies of classroom instruction in developmental mathematics classrooms, smaller observational studies report that the main focus of instruction is on procedural skill building. The instructional methods most frequently reported by developmental mathematics instructors are review, lecture, and independent seatwork employing problems that are devoid of application to the real world (Grubb, 2010; Grubb & Worthen, 1999; Goldrick-Rab, 2007; Hammerman & Goldberg, 2003). As an alternative to these traditional instructional methods, the *Community College Research Center* at Columbia University highlights five categories of effective instructional approaches for adult learners in developmental mathematics. All five of these instructional approaches focus on problem solving: student collaboration, metacognition, problem representation, application, and understanding student thinking (Hodara, 2011).

Reform-based mathematics instruction strives to develop problem solvers who can self-regulate their actions while solving problems. Becoming a self-regulated problem solver involves an understanding of mathematics, and to understand mathematics, students need much more than procedural fluency (Hiebert & Grouws, 2007; Kilpatrick, Swafford, & Findell, 2001). To accomplish a high level of understanding and competence in problem solving, adult students in developmental mathematics courses must be exposed to ample problem-solving opportunities and be required to reflect on their problem solving. This recursive exercise develops a metacognitive skill that promotes self-regulated learning (Cifarelli, Goodson-Espy, & Chae, 2010).

This quasi-experimental study examined two different instructional approaches to teaching algebraic problem solving and compared their ability to enhance self-regulated learning in mathematics. One instructional approach involved procedure-oriented skill instruction (traditional approach) and the other emphasized problem-oriented conceptual instruction. Both of the instructional approaches incorporated direct instruction of metacognitive knowledge into the curricula throughout the semester. The metacognitive knowledge instruction included strategies that students were to use to help them acquire information and to effectively use the strategies. In an effort to determine if there are instructional methods that improve developmental mathematics students' ability to self-regulate their problem solving processes, this study asks the questions, "Do the instructional approaches (problem-oriented conceptual vs. procedure-oriented) in an *Introductory Algebra* course impact the students' problem solving abilities? Do the instructional approaches impact the students' development as self-regulated problem solvers?" It is hypothesized that in the course sections of *Introductory Algebra* in which students receive instruction from a problem-oriented conceptual approach, there will be more students who develop as self-regulated problem solvers than in the course sections of *Introductory Algebra* in which students receive instruction from a procedure-oriented approach.

Rationale for the study

Higbee, Arendale, and Lundell (2005) highlight the important contributions that developmental education makes to the goal of post-secondary education for all. Developmental education makes a college education possible for approximately two million students per year who could not gain access to college without the opportunity to remediate. In an effort to increase student success rates, community college systems across the U. S. are taking a hard look at the student learning outcomes for developmental mathematics courses and at the instructional practices used in those courses (Achieving the Dream, 2010).

A thorough review of the developmental education research literature finds many studies and state agency reports that focus on two areas: first, the success and failure rates of students in developmental education courses, and secondly, the comparison of student course outcomes in online courses versus seated courses (Attewell, Lavin, Domina, & Levey, 2006; Bahr, 2007, 2008, 2010; Bailey, 2009; Perin & Charron, 2006; Provasnik & Planty, 2008). Lacking in the literature, however, are studies that look at the specific instructional methods used in developmental mathematics classrooms. In particular, the body of literature concerning developmental mathematics lacks studies conducted by researcher-practitioners who study adult learners within the context of the classroom. This study focuses not only on the outcome for students enrolled in developmental education courses, but on the instructional methods used in the classroom and thereby enhances the existing literature on developmental education in community colleges. In addition, this study hopes to encourage other researcher-practitioners to examine the impact that the choice of instructional method has on the students in their classes. And finally, it is intended to heighten the awareness of community college instructors, staff, and administrators to the cognitive, metacognitive, and affective needs of students who place into developmental education and ultimately will lead to improvements in practice.

Definition of Key Terms

Throughout this study, the terms attributions, calibration, conceptual knowledge, developmental education, instructional approaches, mathematics anxiety, mathematics beliefs, metacognition, persistence, self-efficacy, skilled problem solver, and self-regulation are used. The following definitions enable the reader to understand the meanings of these words as they relate to this study.

Attributions - Attribution theory (Weiner, 1986) describes the causes that individuals acknowledge for their successes and failures. The types of attributes most often given as the cause of students' successes or failures can be grouped into four categories: 1) effort, 2) ability, 3) task difficulty, and 4) luck. The attributes that students connect to successes and failures result in how they assess their efficacy beliefs and result in the feelings that the students have about themselves as learners (Boekaerts, Otten, & Voeten, 2003; Covington, 1992; Fennema & Sherman, 1976; Kloosterman, 1988; Schunk, 1991). Students who blame their academic difficulties on factors that are out of their control are likely to experience anxiety, put forth lower effort, and may have difficulty in learning new material; whereas, students who attribute their academic difficulties to controllable factors are likely to experience less anxiety and may put forth greater effort.

Calibration **-** Learners make confidence judgments about whether or not they know the information or concepts needed to perform a task. Calibration refers to the degree of consistency between learners' judgments of their competence to perform a task and their actual performance on the task (Chen, 2003; Garavalia & Gredler, 2002; Pintrich, Wolters, & Baxter, 2000; Winne & Jamieson-Noel, 2002). Knowing what one knows is an important metacognitive skill linked to academic achievement.

Developmental education – Based upon the scores from a placement test in reading, English and mathematics, it is determined if students entering community college have the skills deemed necessary for success in college-level courses. If students are found to be lacking in prerequisite skills, they are assigned to courses that will prepare them for college-level curriculum course material. These pre-college courses are often called remedial or developmental education courses.

Mathematics anxiety – Mathematics anxiety is defined as "feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (Richardson & Suinn, 1972). Behavioral studies, mainly in adults, show the negative effect of math anxiety on performance of basic numerical operations (Maloney, Risko, Ansari, & Fugelsang, 2010). For individuals who pursue higher education, the research shows a connection between mathematics anxiety, aversion to mathematics (Walsh, 2008) and how well students can learn mathematics concepts. Studies show that approximately 60% of the adult population in the U.S. has some degree of mathematics anxiety (Tobias, 1993). It is believed that methods that emphasize the primacy of correct answers over concept development, speed over understanding, and rote repetition over critical thinking contribute to the problem that individual experience with mathematics anxiety (Ma, 2003).

Mathematical Beliefs - Op 'T Eynde, De Corte, and Verschaffel (2002) define mathematical beliefs as those ideas which students and instructors have about how mathematics is learned, about how it should be taught, and about how mathematics fits into their lives. An important aspect of the students' mathematical beliefs is the view that students have of themselves within a mathematical context or within a community of mathematical learners. Skemp (1971, 1976) defines two types of understandings about mathematics that both students and instructors hold: ***relational understanding and instrumental understanding***. Skemp defines relational understanding of mathematics as having the ability to use mathematical knowledge and to solve problems through the use of alternative methods, not just by reproducing an algorithm. He defines an instrumental understanding of mathematics as a rule-driven system with procedures that must be memorized and then plugged into problems so that the right answer can be found. Yackel (1984) in her ***Mathematical Beliefs System Survey*** uses the terms relational and instrumental beliefs. Yackel's survey will be used in this study to measure the mathematical belief systems of the students and the instructors.

Instructional Approaches **–** The two types of instructional approaches that are investigated in this study are: 1) conceptual - an approach to the teaching and learning of mathematics that emphasizes understanding and 2) procedural - an approach to teaching and learning mathematics that emphasizes the direct teaching of formula and routines. Instructors who hold relational beliefs about teaching and learning mathematics are predisposed to the conceptual approach and provide learning opportunities that emphasize understanding. In this type of learning environment, students can explore a variety of problem solving strategies, and are encouraged to use prior knowledge when faced with solving novel problems. Instructors who hold instrumental beliefs about teaching and learning mathematics are predisposed to a procedural approach that uses direct instruction, teaching-by-telling, and using memorization of rules, formulas, and procedures to solve problems.

Metacognition involves three interrelated but conceptually different components: 1) metacognitive knowledge which are strategies that can be used to acquire procedural knowledge; 2) metacognitive judgments which are judgments about when and why to apply the strategies, and 3) the self-regulation or control of use (Bembenbutty, 2008; Pintrich, 2002; Schunk & Zimmerman, 2008). Metacognitive techniques allow students to keep track of what they have done, plan what to do next, and to make connections between their problem solving work and their knowledge of procedures.

*Persistence***,** in this study, is defined as completing the online homework sets to a mastery level by the completion dates. Students are expected to seek help if they have difficulty with the problems in the homework sets.

Self-efficacy – Self-efficacy is defined as the student's self-evaluation of competence when undertaking a specific academic task and is considered to be a major determinant of intention to learn (Bandura, 1977, 1982, 1986). Research has found that the higher a student's sense of efficacy, the greater the student's effort, persistence, resilience, and ability to cope with negative emotions will be (Bandura, 1986).

Skilled problem solver **–** Garofola & Lester (1985) state that successful problem solvers employ both an understanding of the mathematics concepts involved in the problem and metacognition, the ability to monitor and regulate problem-solving behavior. The researcher created a rubric that describes the characteristics of a skilled problem solver: a) attaches meaning to the quantitative information, b) makes inferences to acquire needed information, c) recognizes the type of problem beyond the surface information, d) arrives at a correct representation of the problem, e) understands the problem and organizes the information before attempting to solve, and f) demonstrates the use of the problem structure as a means of arriving at a solution.

Self-regulation is an aspect of metacognition that deals with control of metacognitive strategies (Schoenfeld, 1987, 1992). The types of self-regulating behavior seen in problem solving are: a) taking time to understand the problem before beginning to solve the problem, b) creating a solution plan before beginning to solve the problem, c) monitoring the success of the problem solving process, and d) monitoring resources, especially time (Schoenfeld, 1987). Zimmerman (1995) and Schunk (1995) add the following behaviors: e) attributing causation to results, and f) evaluating strategies in order to adapt them in future problem solving methods.

Contemporary research tells us that self-regulation of learning is not a single personal trait that individual students either possess or lack. Developing self-regulatory skills in complex subject-matter domains often involves "behavior modification," unlearning inappropriate control behaviors. Such change requires sustained attention to both cognitive and metacognitive processes (Schoenfeld, 1987).

Research Questions

The areas of interest that this study of community college developmental mathematics students investigates are the effect of instructional methods that influence students' problem solving skills and self-regulation of learning. The questions that guide the investigation are:

1) What relationship, if any, exists between students' metacognitive ability (comprised of beliefs, mathematics anxiety, attributions, self-efficacy for self-regulation, self-efficacy for word problems, and persistence) and the development of the students' ability to solve word problems development as measured by a problem solver rubric?

2) What is the effect of instructional methods (concept-based or skill-based) on students' development as self-regulated learners as measured by a self-regulated learner rubric?

3) What is the impact of instructional methods (concept-based or skill-based) on students' ability to solve word problems as measured by the problem solver rubric?

In keeping with the recommendations from the Community College Research Center for rigorous studies, a variety of quantitative statistical procedures were used in this study to determine the impact of instructional strategies on student problem solving and on the students' development as self-regulated problem solvers. Pearson product-moment correlations for the various combinations of variables were used in conjunction with a correlation matrix of all variables to exclude from a factor analysis any variables with correlations that are either too high or too low.

Once the appropriate variables were identified, regression analysis of the variables was conducted by entering the variables in an order that aligned with research. Bonferroni correction for the between-group mean differences for means controlled for Type I errors. MANOVA statistical procedures were used to determine the effects of instruction and level of self-regulation on the students' problem solving ability and the effects of instruction and level of problem solving level on the students' level of self-regulation.

CHAPTER II

Review of Literature

Cognitive theories

The theories of learning that influence this study, social constructivism, socio-cognitive theory, and cognitive information processing theory arise from Piaget's theory of constructivism in which the learner is a seeker of his or her own understanding. Social constructivism (von Glasersfeld, 1978) assumes two principles: (1) knowledge is not passively received but actively built up by the learner; and (2) cognition is adaptive and is a function of the experiential world. Socio-cognitive theory advocates that learning is enhanced when guided mastery is progressively reduced as competency expands and is replaced by a focus on motivation (Bandura, 1986). For Vygotsky (1978), the learning goal is to proceed from assisted learner to self-regulated learner.

Cognitive information-processing theory deals with the building cognitive structures, the processing of information, and the connection of experienced events. This theory explains the impact that affective constructs have on memory (Nilsson, 2000). The overarching premise of information processing theory is that humans are processors of information with the brain as the information-processing system, a view of cognition rooted in Posner's (1978) work on the cognitive analysis of intellectual tasks. This study uses the constructivist view of informational processing which holds that mental processing involves an active search for understanding and the integration of incoming experiences with existing knowledge (Mayer, 1992).

Community College students

Unlike universities with admissions requirements that sort applicants into accepted or denied admission, community colleges often have an open door policy and sort students after they have been accepted based on cut-off scores from a placement test (Bailey, Jeong, & Cho, 2010). The sorting is in the form of college-ready or not and selectively places students into developmental education courses or college curriculum courses. The unfortunate aspect of open admission is that community colleges admit some students who are not prepared academically for college curriculum and who do not understand or embrace the commitment required of a successful college student (Wedege, 1999). For the academically underprepared student, community college developmental education programs offer remediation in content skills and the self-regulatory skills necessary to succeed academically at the college level (Grubb, 2010; Levin & Calcagno, 2008; McCabe, 2000).

Currently, of the six million students enrolled in U.S. community colleges, half must take a developmental education mathematics courses before they can take curriculum mathematics courses. According to the 2008 National Education Longitudinal Study, approximately 30% of the students who are recommended to the *Introductory Algebra* course never enroll and of those who do enroll, 30% do not successfully complete the course. The ultimate goal for developmental education is to prepare students for college level curriculum courses, but approximately 28% of the students who successfully complete a course, do not attempt to take college-level math courses (Bailey, Jeong, & Cho, 2010). This lack of enrollment is unfortunate because the findings from recent, large scale tests of the efficacy of remediation in post-secondary education indicate that students who successfully remediate in developmental courses and transfer to a four-year university experience academic outcomes that are comparable to those of students who enter the university as college-prepared (Adelman, 2006; Attewell, Lavin, Domina, & Levey, 2006**;** Bahr, 2007, 2008, 2010; Bailey et al., 2010; Boylan & Saxon, 1999; Fike & Fike, 2008; Perin & Charron, 2006; Provasnik & Planty, 2008).

Conceptual Teaching and Learning

Students who receive instruction in mathematics using a procedural approach are often more successful on tests that assess discrete skills than on tests of problem solving and conceptual understanding. Students who learn mathematics using a conceptual problem solving approach have performance measures on skills-oriented tests that are statistically similar to the performance of students in skills-oriented courses, but they score higher on assessments of conceptual understanding and problem solving than students who learn mathematics from a skills-oriented approach (Lemke et al., 2004).

In the last twenty years, there has been a gradual shift in mathematics teaching and learning from a primary emphasis on procedures to a focus on what students can do with procedures. Rittle-Johnson and Koedinger (2005) advocate the integration of the contextual, conceptual and procedural knowledge within the domain. Several studies support the cognitive theory that students who develop an understanding of the connections between the different representations of concepts can then link these representations to the procedures that are necessary to solve problems (Brenner et al., 1997; Friel, Curcio & Bright 2001; Jitendra et al., 1998; Nathan & Kim 2007; Rittle-Johnson, Siegler, & Alibali, 2001; Swafford & Langrall, 2000; Witzel, Mercer, & Miller, 2003). The National Council for Teachers of Mathematics (NCTM) Standards for Mathematical Content advocates a balanced combination of procedure and understanding. NCTM's position is that students who lack understanding of a topic may rely on procedures too heavily and that this lack of understanding prevents a student from engaging in the mathematical practices.

Cognitive theory explains the importance of helping students make the connection between the problem and its different representations before students begin to plan and execute the procedural steps to solve a problem (Brenner et al., 1997; Chappell, 2006). This is juxtaposed with the sequence of events in the procedurally oriented classroom where the different representations of problems are often addressed by a unit on symbol manipulation, followed by separate units on patterns and tables, and graphing. When problem solving is presented with the emphasis on symbol manipulation, students miss the opportunity to make important connections, and they miss a critical phase of problem solving which is important in college level algebra and more advanced mathematics courses (Hodara, 2011, Brenner et al., 1997; Zawaiza & Gerber, 1993).

Mathematics Instruction

In the U.S., algebra instruction tends to focus on elementary topics of symbol manipulation, simplifying expressions, solving equations, and memorizing sequences of steps leaving students without a coherent mathematical picture (Ginsburg, Manly, & Schmitt, 2006). Algebra is a language for expressing mathematics, but it is also a set of effective problem solving methods that enable students to find solutions to large classes of problems (Schoenfeld, 2007). Three critical skills that Schifter (2001) finds are often absent in the preparation programs of mathematical teachers include: 1) focusing on student thinking through an awareness of the mathematics within what students are saying and doing, 2) having an appreciation of the mathematical validity of students' non-standard ideas, and 3) maintaining a focus on the conceptual issues on which students are working.

Schoenfeld (1991, 1994; 1998) in descriptions of his own teaching uses the teaching methods that advocate the building of a mathematical community by encouraging individual, small group and collective work. Schoenfeld encourages students to solve difficult problems while using Polya-like heuristics in problem solving and to rely on their own understanding and mathematical sense rather than see the instructor as the mathematical authority. The heuristics developed by Polya are: (a) understand the problem before starting to compute an answer, (b) look for the structure of the problem based on similar problems, (c) devise a plan for solving the problem that includes using prior knowledge to do so, (d) carry out the problem solving plan, and (e) check the solution for reasonableness. To this list of heuristics, Montague's (1992) adds visualizing the problem events by drawing a schematic representation.

In her book, *Teaching Problems and the Problems of Teaching*, Lampert (2001) highlights the complexity of mathematics instruction during which teachers must coordinate multiple goals: a) ensuring that students learn the content, b) helping students connect the present content to previously learned content, c) creating activities that help students become effective learners, and d) placing students into cooperative learning situations so that students learn to interact productively with other. There is far more to the task of mathematics teaching than just the task of solving mathematics problems; teachers guide students in their explorations and investigations, assess their progress, provide feedback and advice, and adapt instruction to the needs of the students as the students transition between stages of development (Vygotsky, 1978, 1997).

Metacognition

The connection between metacognition and math learning is supported by a number of theories (Boekaerts, 1999; Flavell, 1979; Hodara, 2011; Pintrich, 2000; Schoenfeld, 2002). Information processing theory explains the type of deep processing of word problems thought to promote the metacognitive development of the students and to aide in memory and retrieval (Nilsson, 2000). Garofalo and Lester (1985) state that mathematical problem solving can be improved if students incorporate metacognition into their problem-solving process. In the math classroom, instruction that uses a cognitive–metacognitive framework emphasizes not only problem solutions, but encourages students to assess a problem's difficulty, choose an appropriate strategy, engage in self-monitoring during the problem-solving process, and evaluate the final solution for its accuracy and reasonableness.

Self-Regulation

Instructors should not assume that students will automatically evolve into self-regulated learners (Brown & Palincsar, 1989). In fact, students need support to develop the behaviors of self-regulated problem solvers and should be taught explicit strategies (Schunk, 1989). Self-regulatory processes, such as goal setting, strategy use, and self-evaluation can be learned from instruction and modeling (Boekaerts, 1999; Hodara, 2011; Ridley, 1991). With this in mind, instructors can help students establish specific academic goals, teach students to self-evaluate their work, and ask students to estimate their competence on new tasks. These are the types of competencies that, although absent in many students, prepare students to learn on their own and are essential qualities for lifelong learning (Bandura, 1982; 1986; Schunk, 1984; Thoresen & Mahoney, 1974; Winne & Butler, 1995; Zimmerman, 1983; Zimmerman, Bonner, & Kovach, 1996; Zimmerman & Paulsen, 1995).

Self-regulated learners know what to do and why to do it, recognizing the importance of not only monitoring their course goals at the macro-level, but of monitoring their problem solving behavior at the micro-level (Muir & Besswick, 2005; Ridley, 1991; Wilson, 1998; Yeap & Menon, 1996). Self-regulated learners have the ability to recognize faulty problem solving strategies and to make changes in their learning strategies. Research shows that the characteristics of self-regulated learners depend on several underlying beliefs, including perceived efficacy (Pajares, 1999; Pajares & Miller, 1994; Usher & Pajares, 2006, 2008).

Self-efficacy

Pajares and his colleagues (2006, 2008) examined the role of self-beliefs in mathematics achievement and found that self-efficacy is a predictor of mathematics performance and that a strong relationship exists between self-efficacy beliefs measured in a manner specific to the academic task at hand and the use of self-regulatory skills to solve mathematics problems. In addition to knowing self-regulatory strategies, students must believe that they can apply them effectively; this is called "self-efficacy for self-regulated learning" (Usher & Pajares, 2008, p. 444).

Mathematics Beliefs

Students come to community college with beliefs about what mathematics is, what mathematics classrooms are like, and their role in doing mathematics (Cifarelli, Goodson-Espy, & Chae, 2010). Schoenfeld (2007) points out that if students believe that mathematics consists of working problems that involve rather meaningless operations on symbols, they will produce responses to mathematics problems are meaningless. He and other researchers believe that students pick up the following beliefs about the nature of mathematics from their experiences in the mathematics classroom (Lampert, 1990**;** Schoenfeld, 1992):

- Mathematics problems have one and only one right answer.
- There is only one correct way to solve any mathematics problem—usually the rule the teacher has most recently demonstrated to the class.
- Ordinary students cannot expect to understand mathematics; they expect simply to memorize it and apply what they have learned mechanically and without understanding.
- Mathematics is a solitary activity, done by individuals in isolation.

- Students who understand the mathematics they study will be able to solve any assigned problem in five minutes or less.
- The mathematics learned in school has little or nothing to do with the real world (Schoenfeld, 1992, p. 359)

Instruction for self-regulation

The purpose of cognitive strategy instruction is to teach students how to think and behave like proficient problem solvers who can understand, analyze, represent, execute, and evaluate problems. Cognitive strategy instruction combines cognitive processes and metacognitive or self-regulation strategies (Schoenfeld, 1985). Paris and Winograd (1990) describe the following principles that teachers can use to design activities that promote students' self-regulated learning. These principles informed the metacognitive instruction that the students in this study received.

1. Self-appraisal of personal learning styles and evaluating what you know and don't know leads to a deeper understanding of learning.
2. Self-management of thinking, effort, and affect begins with the setting of appropriate attainable goals.
3. Self-regulation can be taught in diverse ways: explicit instruction, metacognitive discussions, modeling, participation in practices with experts, and by assessing evidence of personal growth.
4. Each person's level of self-regulation plays a role in the creation of the learner's self-identity and future goals. Being part of a reflective community helps students examine their self-regulation habits.
5. Self-regulated students display motivated actions that are goal-directed and are appropriately applied to specific situations.

Mathematics anxiety

Researchers exploring student difficulties with mathematics courses (Hembree, 1990) have identified affective and motivational factors as prominent predictors of difficulty (Hall, Davis, Bolen, & Chia, 1999; Linnebrink & Pintrich, 2002). Algebra, considered a gateway course, is generally assumed to be difficult, approached with a great deal of anxiety by students and teachers alike, and is often taught as if it were completely irrelevant to real life or to any prior mathematics learning. There are discrepant views as to the cause of math anxiety, but what researchers know is that mathematics anxiety peaks at 9th to10th grade, during the years when formal algebra is introduced to students (Hembree, 1990). Mathematics anxiety is associated with an inability to handle frustration, excessive school absences, poor self-concept, internalized negative parental and teacher attitudes toward mathematics, and an emphasis on learning mathematics through drill without conceptual understanding (Harper & Daane, 1998; Jackson & Leffingwell, 1999; Norwood, 1995).

Mathematics anxiety can develop into pervasive math avoidance or a math phobia (Tobias, 1978). When mathematics anxiety rises to this level, it often becomes a critical factor in a student's educational and vocational decision-making process and may ultimately influence a student's attainment of his or her educational and career goals. Mathematics anxiety can impede both learning (Betz, 1978; Felson & Trudeau, 1991; Fiore, 1999) and performance in mathematics (Hembree, 1990; Ho et al., 2000; Richardson & Suinn, 1972; Wigfield & Meece, 1988). Mathematics' anxiety has a negative effect on decision making sometimes prompting students with math anxiety to drop out of math courses (Bessant, 1992), develop negative attitudes toward math activities, avoid majors and careers that require quantitative skills (Ashcraft & Krause, 2007; Turner et al., 2002) and, in case of elementary teachers, dislike teaching mathematics (Hembree, 1990; Ho et al., 2000; Ma, 1999). Jackson and Leffingwell (1999) indicated that only 7% of Americans report having positive experiences with mathematics from kindergarten through college. Similarly, Burns (1998) contends that two thirds of adults in the United States ‘‘fear and loathe” math.

Tobias (1978, 1993) reports from her interviews of 600 college-age and older students that many students with mathematics anxiety lack the knowledge of how to be mathematics students and do not feel comfortable in a community of mathematics learners. The symptoms of math anxiety can be diverse, including nausea and stomachache, a ‘blank’ mind, extreme nervousness, inability to concentrate, and negative self-talk (Kitchens, 1995). Thus, mathematics-anxiety represents a bona fide anxiety reaction with immediate cognitive implications that can also affect a student’s future educational goals and aspirations.

Chapter III

Methodology

Participants

During the fall of 2011, approximately 140 students (96 Female, 44 male) and four instructors who each taught two sections of *Introductory Algebra* at a small community college in the southeastern region of the U.S. took part in a study of instructional approaches for teaching mathematics. For this quasi-experimental study, students self-selected into the course sections of *Introductory Algebra* and were unaware of which of the instructional approaches would be used in any given section when they registered for the course. The course section rosters; therefore, determined the sample. Since course scheduling can influence the types of students that register for a course, treatment and control sections were offered at similar times to reduce the likelihood that any outcomes were partly determined by student characteristics related to the time of day that the course sections are offered (Hodara, 2011).

To determine that the groups were comparable, the researcher gathered *ACCUPLACER* college placement test information and the students' grades in prior mathematics courses taken at the community college from the college database. Additionally, in the first few days of the semester all of the students took a pre-test of algebra word problems. The researcher analyzed these data to determine if there were any pre-treatment ability differences between students in the various sections of *Introductory Algebra.* The analysis of student demographics, age, gender, graduation type, ethnicity academic goals, and a prior developmental mathematics course revealed that there were no observable differences in groups. Each instructor involved in the study was a full-time faculty member with several years of teaching experience. All of the instructors held either a master's degree or were in the process of attaining a master's degree.

Homogeneity of groups

An analysis of variance (ANOVA) of the pre-test of problem-solving test determined the initial homogeneity of the groups. This analysis compared the means from the pre-test of each of the eight groups in order to test the null hypothesis that the eight groups were equal at the start of the semester. The researcher graded the problems on the pre-test for all of the students involved in the study to ensure consistency in scoring (Schurter, 2002).

Measures and Instruments

Variable 1: Self-regulated learner (includes mathematics beliefs, math anxiety, persistence, self-efficacy, and attributions)

Mathematical Beliefs

Yackel (1984) designed the *Beliefs Survey*, a five-point Likert value scale, to determine the expressed beliefs of college students about mathematics, and to measure how likely they were to favor rule following (instrumental understanding) versus reasoning (relational understanding). Yackel (1984) based the design of the *Beliefs Survey* on the research of Skemp (1976). The survey asked questions to probe the students' beliefs about mathematics and asked students to characterize their problem-solving behaviors. Questions stated as positive relational statements were coded with *Strongly Agree* (*SA*; 5.0) reflecting a strongly relational view. Overall survey scores were labeled as follows: (1.0–2.0) *instrumental*, (2.1–3.0) *somewhat instrumental*, (3.1–4.0) *somewhat relational*, and (4.1–5.0) *relational*. An example of a question is: "I usually try to understand the reasoning behind all of the rules I use in mathematics."

Quillen (2004) developed and conducted a reliability analysis of the items in the beliefs survey for the data collected in a doctoral study to determine the strength of the alpha where she found a Cronbach alpha of .89. In that psychometric analysis of the *Beliefs Survey*, Quillen found that the inter-item correlation for four of the survey items, 13, 15, 16, and 19 was found to be low and did not fit well into the scale psychometrically. Quillen deleted these four items from the *Beliefs Survey* and used a 16-item survey for her study. The Alpha for the revised 16-item document was 0.89 indicating strong reliability of the *Beliefs Survey*. This study used the 16-item survey.

Mathematics Anxiety

A revised version of the *Mathematics Anxiety Scale* measured mathematics anxiety. The *Mathematics Anxiety Scale* (MAS), adapted by Betz (1978) from the anxiety scale of the Fennema- Sherman *Mathematics Attitudes Scales (*Fennema & Sherman, *1976),* is purported to be an instrument more appropriate to college students. The MAS consisted of 10 items—five positively worded and five negatively worded. Scoring of the negative items was reversed so that a high score indicates low anxiety. Betz reported a split-half reliability coefficient of .92. *The Mathematics Anxiety* scale assessed "feelings of anxiety, dread, nervousness, and associated bodily symptoms related to doing mathematics" (Fennema & Sherman, 1976, p. 4). Item responses were obtained on a 5-point Likert scale; responses range from 1 (strongly disagree) to 5 (strongly agree).

Alpha coefficients ranging from .86 to .92 have typically been reported on the original MAS (Hackett & Betz, 1989; Pajares & Kranzler, 1995; Pajares & Urdan, 1996). Items include: ‘‘It wouldn’t bother me at all to take more math courses.’’ and ‘‘I get really uptight during math tests.’’ Correlations of about .70 have been reported between the MAS and the 98-item

Mathematics Anxiety Rating Scale (Cooper & Robinson, 1991). Dew, Galassi, and Galassi (1983) reported Cronbach's alpha of .72 and 2-week test-retest reliability of .87. Hackett and Betz (1989) report the scales to be highly reliable, with KR 20 and Cronbach's alpha values ranging from .86 to .90. Frary and Ling (1983) subjected the items to factor analysis and found that they loaded highly (.89) on the factor they defined as math anxiety (Pajares & Miller, 1994).

Persistence and effort

The completion of homework assignments by the pre-assigned deadline determined the students' persistence and effort. The students accessed the homework online through either MathLab by Pearson Higher Education (skill-based) or Cognitive Tutor by Carnegie Learning (problem-solving based). Students were given two weeks to complete the problem sets, due on the day of the test. Homework had to be completed to mastery (Cognitive Tutor) or 80% accuracy (MyMathLab) by the due date to be considered complete.

Self-efficacy for Self-regulated learning

The *Self-efficacy for Self-regulated Learning Scale* from the *Children's Multi-dimensional Self-Efficacy Scales* (Bandura, 1989) included 11 items that measured students' perceived capability to use a variety of self-regulated learning strategies. Previous research on students' use of learning strategies revealed a common self-regulation factor (Zimmerman & Martinez-Pons, 1986) that provided a basis for aggregating items in a single scale. Since self-efficacy is a multidimensional construct (Bandura, 1997), this scale measured the ability to structure environments conducive to learning, to plan and organize academic activities, to use cognitive strategies to enhance understanding and memory of the material being taught, to obtain information and get teacher and peers to help as needed, to motivate oneself to do schoolwork, to complete assignments within deadline, and to pursue academic activities when there are other interesting things to do. Two examples of items are, “How well can you get instructors to help you when you don’t understand something?” and “How well can you study when there are other interesting things to do?”

The internal structure and empirical dimensions were found to correspond with previous factor and component analyses of MSPSE scores from middle school students (Bandura et al., 1996, 1999) and high school students (Miller et al., 1999). Bandura et al. (1996, 1999) found that second-order factors from MSPSE correlated well with theoretically associated outcomes (Choi, Fuqua, & Griffin, 2001). Pajares and Graham (1999) found, in their investigation of mathematics performance for middle school students, that self- efficacy for self-regulated learning correlated positively with a number of theoretically linked variables (e.g., mathematics performance and mathematics self-concept) and negatively with mathematics anxiety.

Self-Efficacy for solving word problems

On each unit test throughout the semester, the students’ self -efficacy for solving word problems was measured by asking students to assess the degree of confidence that they had in their assessment of their ability, 10 (*very confident*) to 0 (*not confident at all*). This method is consistent with Bandura's (1986) conceptualization of self-efficacy measurement that suggests incorporating both magnitude and strength information in the self-efficacy measure. Bandura also recommends that the test with which self-efficacy is correlated and the self-efficacy measure should be administered closely in time (Lee & Bobko, 1994). In this study, they were administered simultaneously.

Attributions

The *Attribution Scale* from the *Online Motivation Questionnaire* (Boekaerts, 1999) determined the students’ attributions of success or lack of success following each test. Upon completion of the test, the student chose between two statements: “I am confident that I did well on the task because…” or “I believe that I did not do well on the task because…” Based on the student’s response, the student responded to a corresponding list of behaviors that the student believed brought about the success or lack of success. Examples of attributions: “Because I did the homework assigned for this test” or “Because I did not use positive self talk and was too nervous to think.” The internal consistency of the various scales is satisfactory with Cronbach’s alphas ranging from .78 to .61.

Variable 2 Student development as a problem solver

The word problems on each of the six tests given throughout the semester and the word problems on the final exam were scored with a problem solving rubric that charts the development of the students’ problem solving skills across three levels: beginner, intermediate and skilled problem solver. Students were awarded point in the following area according to the demonstrated skill level: The rubric measures: a) the student’s ability to attach meaning to the numbers in the problem; b) the student’s ability to make inferences to acquire needed information for the problem solution; c) the student’s ability to demonstrates the use of the problem structure as a means of arriving at a solution; d) the student’s ability to connect the problem structure to the correct representation of the problem; and e) the student’s ability to understand the problem and to organize the information before attempting to solve the problem. The problem-solving rubric designed by the researcher was based on the work of Schoenfeld (2002), and Zimmerman (2006).

Procedures

Research packets were given to the four instructors who participated in the study. The packet included a cover letter (see Appendix G), inviting the prospective instructors to participate in the study. An Informed Consent for Prospective Participants in an Investigative Project was given to all instructors. All instructor participants returned the signed informed consent to the researcher.

Data about the students' gender, ethnicity, age, previous mathematics courses, type of transcript, and ***ACCUPLACER*** scores from both the arithmetic and algebra subtests were entered into the ***SPSS*** data file. After *the Self-efficacy for Self-regulated Learning Questionnaire*, *Mathematical Beliefs Survey, Math Anxiety Scale* and a pre-test of problem solving skills were completed, those scores were also entered into the ***SPSS*** data file. Students were asked in writing if they would agree to participate in an interview if selected.

The scores on each of the surveys or questionnaires for each of the 140 respondents to the survey items were averaged and entered as a summed score under the new variable "the survey name" Average. The scores were averaged in order to obtain a summed score for each participant on each of the surveys. This was necessary in order to be able to examine the various relationships that were included in the study. This procedure was also used for the scores from the pre-test.

Instructors

Four full-time instructors participated in this study, each of whom taught two sections of *Introductory Algebra.* Each instructor taught one section using the intervention strategy of a conceptual approach to problem solving and each instructor taught one control section using a skill-based approach to problem solving instruction. In May 2011 and again in August 2011, the researcher trained the four instructors in how to teach problem solving from both instructional approaches.

Prior to the study, the instructors stated that they typically spent 90% of classroom time on skills based problems and about 10% on word problems. The word problems that represented

10% of the instruction often did not require reasoning and higher order thinking skills. This ratio of skills to application agrees with the findings of mathematics education researchers who state that instructors teach the way they were taught and often let textbooks guide the curriculum. In the community college arena, this is compounded by the fact that instructors often lack a wide variety of pedagogical skills. In a pre-project interview, the four instructors described themselves as instructors who relied primarily on traditional methods of instruction, such as lecture, problems worked by the instructor at the board:

> “I typically use the older method of demonstration.” (Instructor 1)
>
> “I am very much skills-based. My role is to get information to the students.” (Instructor 2)
>
> “I do demonstrations; I provide information. (Instructor 3)
>
> “I'm still a traditional type teacher. I do an example for each objective, ask for feedback, give a few practice problems for them to try and then go over those on the board.” (Instructor 4)

Fidelity to instruction

To ensure the fidelity of the instructional approaches used by instructors in the respective sections of *Introductory Algebra,* the researcher utilized techniques from the literature on fidelity of implementation. This literature focuses on the following areas: training, appropriate instructional materials, investigating teacher beliefs, and frequent observation of instruction (Moncher & Pinz, 1991, Mowbray, Holter, Teague, & Bybee, 2003).

The instructors received two courses of study: one for the conceptually oriented course section and one for the skills-based course section. Each course of study included daily lesson plans, instructional notes, example problems, worksheets, homework problems, metacognitive lessons and assessments. The four instructors involved in the study received training in how to achieve the course objectives and how to facilitate the intended student learning outcomes from both a skill-based approach and from a conceptual problem-based approach to instruction. One training session took place in May of 2011; a follow-up training took place in August of 2011. On-going training throughout the semester was delivered to the instructors by the researcher as needed following instructional observations.

As a part of the initial training, each instructor was given a handbook that outlined the philosophies of the instructional approaches (see Appendix J), the instructional sequences, student learning outcomes, use of the instructional materials, guidelines for teaching metacognitive strategies, and information on the types of questioning that were specific to each approach. The researcher provided the instructors with daily lesson plans that outlined the use of a researcher-created workbook for the conceptually-oriented course sections and that assigned problems from the previously used textbook for the skills-based course sections.

The researcher prepared all of the assessments that were administered in the course sections that were participating in the study. Instructors graded their own test using common scoring guides, and the researcher randomly selected tests from each of the sections for review in an effort to validate fidelity in the use of the scoring rubrics. Students in the conceptually-oriented course sections were assigned homework problems from an on-line homework system, *Cognitive Tutor*, that was aligned with the particular instructional approach. Students in the skills-based course sections were assigned homework problems from the previously used on-line homework system, *MyMathLab*, that focused on basic skills rather than problem solving.

In addition to the measures outlined above, the researcher conducted frequent unannounced visits to the classes to observe the instructional activities, as well as, the behaviors and comments of the students. During the observations, a checklist of behaviors inherent to each instructional approach was completed by the instructor and reviewed with the instructor following the observation. If necessary, additional training was provided to an instructor who was having difficulty with either of the instructional approaches.

Ethical Considerations: Research with Human Subjects

Before undertaking the study, the researcher obtained approval from my university's Institutional Review Boards (IRB) for the research design. The IRB required that a study proposal include a discussion of potential psychological risks that human subjects may face as a result of participation.

Validity

During the semester in all eight sections of *Introductory Algebra*, the students' knowledge for solving word problems was assessed through six unit tests and a final exam; each test was scored using the same problem-solving rubric. Each test given during the semester provided an opportunity to assess the students' self-efficacy for solving word problems. After finishing the whole test, students completed the *Attribution Scales* from the *Online Motivation Questionnaire*, a scale that measured the strategies that the student believes impacted his or her success or failure on the test. Building on the suggestions for conducting rigorous research studies put forth by the CCRC, the researcher developed tests and a final exam to assess knowledge and skills addressed in both treatment classrooms. The four instructors graded the final exams and the researcher checked the grading of the word problems to ensure that the students in all of the course sections were assessed fairly (Hodara, 2011).

The Introductory Algebra course

The *Introductory Algebra* classes met for approximately 250 minutes per week, some sections met five days a week; some sections met three days a week. The course learning outcomes, mandated by the state, included the traditional Algebra I topics, but the intervention and control groups were taught using different instructional approaches. The conceptual problem solving instruction classes employed a conversational style, encouraging students to work together to solve problems and to ask questions. Using a minimal amount of direct instruction, the instructor using the conceptual instructional approach encouraged students to work with peers to solve problems while the instructor monitored the students' progress and provided assistance as needed. The students in the conceptually oriented classes used printed materials and an online homework system from Carnegie Learning called *Cognitive Tutor*.

The procedural skill-based classes employed predominately lecture and teacher examples on the board. After the lecture and teacher demonstration of examples, students practiced similar problems. The students in the procedurally oriented classes used the text from Pearson, *Beginning and Intermediate Algebra* by Martin-Gay and the accompanying online homework system, *MyMathLab*.

Design and Analysis

A correlational design was used in this study, as described by Andy Fields (1996) in *Discovering Statistics with SPSS*. Correlational design is used to determine if relationship(s) exist among variables, and if so, to what extent. The correlation coefficient is a measure of the strength of the linear relationship between two variables. This study investigated the relationships among aspects of self-regulated learning (beliefs, self-efficacy, attribution, math anxiety and persistence) and problem solving skill. The study also investigated the relationship between a self-regulated learner and instructional methods, as well as the relationship between problem solving skills and instructional methods.

1) To determine the prevalence of:

a) mathematics beliefs (relational or instrumental) as measured by the ***Mathematical Beliefs*** (Yackel, 1984); b) levels of math anxiety as measured by the ***Mathematics***

Anxiety Survey; c) type of attribution as measured by the ***Motivation Scale***; d) level of self-efficacy for problem solving self-reported by the students; (e) level of self-efficacy for self-regulated learning as measured by the ***Self-Efficacy for Self-regulated Learning Scale***; f) level of problem solver as measured by the problem solver rubric; h) persistence as measured by timely completion of six homework sets

A frequency distribution was constructed to determine the mean, standard deviation, the skewness (lack of symmetry in the normal curve), and kurtosis. A histogram of frequencies that graphically demonstrated how spread out the data points were.

2. To determine the respective relationships and the strength of the relationships between each of the variables and the student's regulated learner score as defined by the self-regulated learner rubric.

Pearson product-moment correlations for belief and self-regulation, persistence and self-regulation, self-efficacy for problem solving, self-efficacy for self-regulation, attribution, and math anxiety were determined.

3) To determine the factors that should to be considered as part of the self-regulated learner construct, the researcher constructed a correlation matrix of all variables as part of the factor analysis and excluded from the factor analysis any variables with correlations below .3. To avoid multi-collinearity, the researcher examined the correlation matrix for variables with a high correlation ($r > .8$) and tested variables that may be causing the high correlations using direct oblim for the determinant of the R-matrix. This procedure assisted the researcher in determining which item may be too highly correlated with other items. Once the researcher determined which variables were appropriate for the construct, a hierarchical regression analysis was performed adding the remaining

variables in the following order: a) self-efficacy for self-regulation, b) self-efficacy for problem solving, c) persistence, d) mathematical beliefs, e) goals, f) level of problem solver, g) math anxiety

4) To explore the data for any between-group (between classes) differences between means, the researcher used the Bonferroni correction to control for possible inflation of Type I error rates.

5) To determine the effects of:

a) age, b) gender, c) whether the student has previously taken *Essential Math* course prior to taking the Introductory Algebra course, and d) the score on ACCUPLACER, a regression analysis on level of problem solver for each of the variables was performed.

6) To determine the effects of:

a) age, b) gender, c) whether the student had y taken *Essential Math* course prior to taking the Introductory Algebra course, and d) the score on ACCUPLACER, an ANCOVA on level of self-regulated learner for each of the variables was performed.

8) To determine the effects of instruction and level of self-regulation on problem solving ability a MANOVA was performed.

10) To determine the effects of instruction and level of problem solving level on level of self-regulation a MANOVA was performed.

CHAPTER IV

Results

This purpose of this study was three-fold: 1) to determine the relationship, if any, between students' metacognitive abilities and problem solving abilities, 2) to determine the effect of instructional methodology on problem solving ability and on self regulated learning, and 3) to determine the effect of self-regulation on problem solving ability. Before students received any instruction, the researcher analyzed the students' algebra scores from the *Accuplacer* college placement test and from a pre-test of problem solving skills. Both the pre-test and the algebra placement test scores revealed no serious violations of normality, linearity or homogeneity of variance. An independent t-test on type of instruction (conceptual or skill-based) revealed no significant differences between the pre-test scores for the two instruction groups, $t(132) = .541$, $p = .59$. The two instructional groups were comparable in respect to student demographics, such as, gender, age, type of diploma, college goals, and ethnicity.

To answer the first question, "What relationship, if any, exists between students' metacognitive ability and the students' ability to solve word problems?" a problem solver score and a self-regulated learner score were determined. For the problem solver score, the researcher created a rubric used in the scoring of 19 word problems. The rubric measured the students' ability to understand variable expressions (Variable Meaning) and to use variable expressions when creating equations to represent word problem events (Creating Equations). These two measures combined with a third measure of students' ability to estimate their problem solving ability (Calibration) were averaged to create the Problem Solving score. Preliminary testing of the three scores revealed no serious violations of normality, linearity or homogeneity of variance assumptions.

Table 1 Descriptive statistics for the component scores of the problem solver score

		Concept	Skills
Calibration			
	Mean	**5.30**	**4.52**
	SD	**1.82**	**1.66**
	n	**64**	**76**
Variable Meaning			
	Mean	**7.23**	**6.52**
	SD	**1.78**	**2.17**
	n	**64**	**76**
Create Equations			
	Mean	**6.05**	**5.30**
	SD	**2.95**	**2.20**
	n	**64**	**76**

The second score used to answer the first research question, students' ability to self-regulate, was measured by a researcher-created self-regulated learner rubric. This rubric assessed the students' beliefs about learning mathematics, persistence as measured by the students' homework grade, attributions about students' level of success per test, mathematics anxiety, self-regulation efficacy, and word problem efficacy. Preliminary testing of the scores revealed no serious violations of normality, linearity and homogeneity of variance assumptions.

An exploratory factor analysis (EFA) was conducted on the six items with oblique rotation (direct oblimim). The Kaiser-Mayer-Olkin measure verified the sampling adequacy for the analysis, KMO = .616. Bartlett's test of sphericity χ^2 (6)= 64.88, p< .001, indicated that the correlation between items were sufficiently large for EFA. An initial analysis was run to obtain eigenvalues for each component in the data. One component had an eigenvalue over Kaiser's criterion of 1 and in combination explained 30.6% of the variance. The scree plot showed an inflexion that justified retaining the one component. Correlations for all items, except attribution and anxiety, were > .3. The attribution and anxiety items were removed from the EFA and factor loadings for the remaining items were determined from the EFA.

Table 2 Factor loading for the EFA on the components of the Self-Regulated Learner Score

	Factor 1
Beliefs	.431
Word Problem Efficacy	.409
Persistence	.515
Self-Regulation Inventory	.778

Standardized scores were determined for each of the four items, Beliefs, Word Problem Efficacy, Persistence, and the self-reported self-efficacy for self-regulation, and then averaged to create a Self-Regulated Learner score.

Table 3 Descriptive Statistics for the theoretical components of the Self-Regulated Learner Score

		Concept	Skills
Beliefs			
	Mean	2.73	2.51
	SD	.42	.46
	n	64	76
Persistence			
	Mean	6.97	5.25
	SD	2.70	2.97
	n	64	76
WP Efficacy			
	Mean	6.16	5.52
	SD	1.72	1.74
	n	64	76
Self-Regulation	Mean	5.51	5.01
Inventory	SD	1.02	1.09
	n	64	76

Once the two scores, problem-solver and self-regulated learner were created, they were correlated to determine the answer the first research question, "What relationship, if any, exists between students' metacognitive ability and the students' ability to solve word problems?" It was found that there was a significant relationship between the problem solver score and the self regulated learner score, r = .63, p = .000.

Table 4 Descriptive statistics for the problem solver and self-regulated learner scores

	Concept	Skills
Problem Solver		
Concept	**.25**	**-.20**
Skills	**.94**	**1.01**
n	**64**	**76**
Regulated Learner		
Concept	**.26**	**-.22**
Skills	**.60**	**.67**
n	**64**	**76**

Results from the regression analysis on Problem Solving Ability for age, gender, ethnicity, prior math course, graduation type, and college goals is shown below. Table 5 shows the results from the regression analysis for those variables shown to be significant: age and prior developmental math course.

Table 5 Results from Regression analysis on problem solving ability for demographics

Model		B	SE B	β	R^2	ΔR^2	p
Step 1	**Age**	.69	.30	.19	.04	.04	.025
Step 2	**Age**						
	Prior DE Math	-1.24	.27	-.36	.16	.13	.000

T-test of independent variable on type of instruction for Variable Meaning, t(1, 138) = 2.37, p = .02, Creating Equations, t(1, 138) = 2.08, p = .04, Calibration, t(1, 138) = 2.74, p .007, and for Problem Solver Score, t(1, 138) = 2.74, p< .007, showed significant difference between instruction groups.

Table 6 Results from the Regression analysis on the components of the Self-Regulated Learner Score

	B	SE B	β	R^2	ΔR^2	p
Step 1						
Persistence	**.457**	**.04**	**.68**	**.46**	**.46**	**.000**
Step 2						
Persistence	**.300**	**.03**	**.44**	**.75**	**.29**	**.000**
Self-Regulated	**.395**	**.03**	**.59**			
Step 3						
Persistence	**.311**	**.02**	**.46**	**.88**	**.14**	**.000**
Self-Regulated	**.288**	**.02**	**.43**			
WP Efficacy	**.270**	**.02**	**.40**			
Step 4						
Persistence	**.250**	**.00**	**.37**	**1.00**	**.12**	**.000**
Self-Regulated	**.250**	**.00**	**.37**			
WP Efficacy	**.250**	**.00**	**.37**			
Beliefs	**.250**	**.00**	**.37**			

A point-biseral correlation determined significant correlations between the Regulated Learner Score and Persistence, r = .676, p = .000; Word Problem Efficacy, r = .617, p = .000; Self-regulation Inventory, r = .761 p = .000; Attribution, r = .179, p = .000; and Anxiety, r = -.399; p = .000.

An Analysis of Covariance (ANCOVA) was performed on level of self-regulation for gender (male or female), ethnicity (black or white), graduation type (GED, high-school graduate, or currently in high school), college goals (Associate Degree or college transfer), age group (under 26, over 25), and took prior Developmental math course (Yes or No). Only the interactions between age code and instruction, F(1, 136) = 6.72, p = .01, and took prior Developmental math course and instruction, F(1, 137) = 5.92, p = .02, were found to be significant.

To answer the second research question, "What is the impact of instructional methods (concept based or skill-based) on students' ability to solve word problems as measured by the problem solver rubric?" a Multivariate Analysis of Variance (MANOVA) was conducted to determine the effect of instruction on the students' level of problem-solving ability. Prior to conducting the MANOVA, preliminary testing revealed no violations of normality, linearity and homogeneity of variance assumptions. The results of the MANOVA indicate that the effect of level of problem solving (Wilks' Lambda = .936, $F(3,136) = 3.10$, $p = .03$) on type of instruction was significant . Analysis of the pre-test and the algebra scores as covariates did not reveal any difference in significance for the Problem Solver Score.

To answer the third and last research question, "What is the effect of instructional methods (concept-based or skill-based) on students' development as self-regulated learners as measured by a self-regulated learner rubric?" a Multivariate Analysis of Variance (MANOVA) was conducted to determine the effect of instruction on the students' level of problem-solving ability and on students' level of self-regulated learner. Prior to conducting the MANOVA, preliminary testing revealed no violations of normality, linearity and homogeneity of variance assumptions. The results of the MANOVA indicate that the effect of level of self-regulated learner (Wilks' Lambda = .872, $F(4,135) = 4.96$, $p = .001$) on type of instruction was significant.

CHAPTER V

Discussion

The statistical results of this study demonstrated a significant positive relationship between the problem solver score and self-regulated learner score. The type of instruction used (conceptual or skill-based) affected problem-solving score and self-regulated learner score. The MANOVA resulted in stronger problem solver scores for the students who were in classes that used the conceptual type of instruction. The students in the conceptual class demonstrated a stronger ability than the students in the skills class for using the correct variable expressions and for creating the correct algebraic representations of the word problems. This is important for algebra students because typically students read word problems and do not know where to begin or how to utilize the language of algebra to solve problems. The students in the conceptual class also had stronger perceptions of themselves as self-regulated learners and were more persistent in completing homework in a timely manner.

The educational implications of this study point to a balanced approach to teaching student how to solve algebraic word problems; an approach that incorporates a deep understanding of the structure of the word problems, a logical plan for moving from the words of the problem to algebraic representations of the problem events and the procedural skills to accurately solve the problem. This view of teaching aligns closely with the NCTM's support of the common core standards, standards that stress a conceptual approach to the teaching of mathematics. The common core standards for mathematics describe mathematically proficient students as those who can explain to the meaning of a problem, correspondences between equations, verbal descriptions, and tables, and who can draw diagrams of important features of the problem. All of these strategies were taught to the students in the conceptually oriented sections of this research student. This makes the results of the study valuable to both K-12 and higher education.

A second educational implication of the study was that the instructional approach in the conceptually orientated course sections facilitated the building of community. This is important because students who struggle with mathematics often do not feel that they belong to a community of mathematical learners. Mathematical collaboration and communication is a practice that constitutes mathematical thinking and knowing. Classrooms must be communities in which mathematical sense-making is created through the students' communication and collaboration with their peers (Schoenfeld, 1992). The mission of community college is to help students reach their goals in order to successfully enter the world of work. The group approach to problem solving used in this study encouraged students to justify their conclusions to their peers, and to respond to the arguments of others. This outcome is again shared in the K-12 common core standards. Ultimately, it is hoped that students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace.

This study was based on Bandura's social-cognitive theory, a theory with a basic tenet that learners must be proactively engaged in their own development and that learners can make things happen by their actions and on social-constructivism which believes that knowledge is actively constructed by the learner, rather than passively absorbed. Inherent in the design of this study was large amount of time spent in the conceptually oriented classes group working and discussing word problems. The students in those classes were encouraged to think through the problem events, thereby creating neural pathways for mathematical knowledge later received. The students in the conceptual classes had a stronger belief that they could work word problems and they believed that they could have good study habits.

Becoming a self-regulated problem solver involves an understanding of mathematics, and to understand mathematics, students need much more than procedural fluency (Hiebert & Grouws, 2007; Kilpatrick, Swafford, & Findell, 2001). To accomplish a high level of understanding and competence in problem solving, adult students in developmental mathematics courses must be exposed to ample problem-solving opportunities and have opportunities to reflect on the structure of word problems, a metacognitive skill that promotes self-regulated learning (Cifarelli, Goodson-Espy, & Chae, 2010). All too often instructors avoid or downplay word problems, and students simply do not get enough practice doing them.

Limitations

The study was conducted at only one site and for only one semester. More time and a larger sample would be needed to determine if the effects shown in this study hold true for other samples of the populations. The study also only investigated the impact on algebra word problem. It would be important to study the effects of instructional approaches for other topics in developmental mathematics.

The pedagogical skills and the conceptual material used in the project by the instructors were new to them at the beginning of the semester. The instructors described themselves at the beginning of the project as traditional skill-based instructors. Even though the instructors embraced many of the conceptual approach strategies as the semester unfolded, the outcomes of the project may have been different if the instructors had been exposed to the instructional strategies and to the course materials for a year prior to the study. Although the instructors tried to keep the fidelity to instructional method pure within each course section, they admitted that as the semester progressed, they began to use some of the conceptually oriented methods in their skills classes because they could see that the conceptual methods were effective.

The same instructors taught both the skills based and conceptual course sections. In some ways, this lent strength to the project since the results would not be based on instructor differences. If, however, an instructor was more comfortable with one instructional approach over another instructional approach, it could affect the results of the project. The researcher did not compare test grades or final course grades between the instructional groups as a basis for comparison because the test grades included problems other than algebraic word problems and the final course grades were difficult to interpret due to the students who withdrew from the class before the final exam.

A surprising result in the study was that contrary to the existing literature, math anxiety did not play a significant role in problem solving ability or self-regulated learning. This result may be due to the instrument that was used to measure anxiety or it may be that the metacognitive direct instruction that students received throughout the semester about mathematics anxiety helped the students regardless of course sections and instruction type.

Follow up studies

There are very few research studies that investigate the instructional methods used to teach developmental mathematics. Using rigorous methods, studies that focus on instructional methods in seated classrooms for a broad range of mathematics topics, and on several population sub-types. As recommended by the *Community College Research Center* at Columbia University, studies that highlight effective instructional approaches for adult learners in developmental mathematics: student collaboration, metacognition, problem representation, application, and understanding student thinking (Hodara, 2011) and which incorporate problems that facilitate higher order thinking skills.

Interesting follow-up studies might include: a) a study on the best instructional approaches for each of the topics taught within the developmental mathematics curriculum, b) a study of which metacognitive lessons have the most impact on student success, c) a study of the best professional development to help mathematics instructors acquire the skills to teach from a conceptual approach, d) a longitudinal study that follows students taught with different instructional methods from developmental mathematics courses to curriculum mathematics courses and e) a larger study that focuses on different age groups of students

Conclusion

The results of this study indicate that an instructional approach to teaching algebraic problem solving that focuses on a conceptual approach rather than a focus on solving equations is an approach that bears investigation. Effective instructors need a variety of instructional tools and this conceptual approach that focuses on problem solving is often ignored in mathematics classrooms. Since this approach aligns with the instructional goals set forth in the K-12 common core standards for mathematics, community college instructors, especially those in developmental mathematics need to become familiar with the approach.

This study was about changing mindsets. It was about changing the students' perceptions of mathematics instruction and the instructors' perceptions of themselves, their students, and the curriculum that they teach. Given that nation-wide, community colleges are looking for ways to improve the success rate of students in developmental mathematics courses, a study of how the curriculum is being delivered to students can provide important information for improving the students' rate of success.

Collaborative problem solving was an important component to the instruction in the conceptually oriented course sections. Since one of the primary goals of community colleges is to help students become educated for the workforce, it is important that community college instructors help students to build capacity for skills that are important to employers; ability to solve problems and the ability to work collaboratively with others. Developmental mathematics classes, as communities of mathematics learners, can create learning opportunities for students who lack these skills.

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Appendix A

On-line Motivation Questionnaire (Boekaerts, 1997)

If you believe that you did well on the test, place a check next to the behavior that you did that helped you to do well.

I am confident that I did well on the task ………	
1. Because I am good at math word problems	______________
2. Because I put forth my best effort	______________
3. Because I did the homework assigned for this test	______________
4. Because I studied the concepts for this test	______________
5. Because I was lucky	______________
6. Because I used positive self talk when I got nervous	______________
7. Because it was an easy test	______________
8. Because I used good test taking strategies	______________
9. Because I knew a lot about the solving math word problems	______________
10. Because I attended class when the class worked on word problems	______________
11. Because I took good notes for solving word problems	______________
12. Because I worked with my instructor or tutor when I did not understand how to work the problems in class and on the homework	______________

On-line Motivation Questionnaire (Boekaerts, 1997)

If you believe that you did not do well on the test, place a check next to the behaviors that you think kept you from doing well.

I believe that I did not do well on the task because:	
1. Because I am not good at solving word problems	_______________
2. Because I did not give the test my best effort	_______________
3. Because I did not do all of the homework assigned for this test	_______________
4. Because I did not spend enough time studying for this test	_______________
5. Because I was not lucky	_______________
6. Because I did not use positive self talk and was too nervous to think	_______________
7. Because it was a difficult test	_______________
8. Because I didn't use good test taking strategies	_______________
9. Because I hardly knew anything about solving word problems	_______________
10. Because I did not attend class when the class worked on these	_______________
problems	_______________
11. Because I did not take good notes for the concepts on the test	_______________
12. Because I did not worked with my instructor or tutor when I did not understand how to work the problems in class and on the homework	

Appendix B

Problem Solver Rubric

Beginning Problem Solver	Intermediate Problem Solver	Skilled Problem Solver
Manipulates numbers without any recognition of their meaning in the problem	Recognizes that there should be meaning attached to the numbers in the problem, but does so incorrectly	Attaches meaning to the numbers in the problem
Does not use the given numerical information correctly	Ignores inferences	Makes inferences to acquire needed information for the problem solution
Tries to solve the problem using the surface features of the problem as a model	Recognizes the type of problem beyond the surface information, but does not arrive at a correct representation of the problem	Recognizes the type of problem beyond the surface information and arrives at a correct representation of the problem
No evidence of strategy use	Does not adapt or switch strategies if one is not working	Willing to use a variety and combination of strategies in order to solve the problem
Moved to solution before understanding the problem	Understood the problem but did not read for details	Understands the problem and organizes the information before attempting to solve the problem
Does not demonstrate recognition of the problem structure	Demonstrates recognition of the problem structure but does not use the problem structure to move to a solution	Demonstrates the use of the problem structure as a means of arriving at a solution
Poor calibration	Good callibration	Excellent callibration

Appendix C

*Self-efficacy for Self-regulated Learning: (*Zimmerman, Bandura, & Martinez-Pons, 1992)

<u>How well can you:</u>

1. Finish mathematics homework assignments by deadlines?

1 2 3 4 5 6 7
Not very well Very well

2. Study mathematics when there are other interesting things to do?

1 2 3 4 5 6 7
Not very well Very well

3. Concentrate on mathematics?

1 2 3 4 5 6 7
Not very well Very well

4. Take notes during mathematics class instruction?

1 2 3 4 5 6 7
Not very well Very well

5. Plan your mathematics schoolwork?

1 2 3 4 5 6 7
Not very well Very well

6. Organize your mathematics schoolwork?

1 2 3 4 5 6 7
Not very well Very well

7. Remember information presented in mathematics class and in the textbook?

1 2 3 4 5 6 7
Not very well Very well

8. Arrange a place to study mathematics without distractions?

1 2 3 4 5 6 7
Not very well Very well

9. Motivate yourself to do mathematics schoolwork?

1 2 3 4 5 6 7
Not very well Very well

10. Participate in class discussion during mathematics classes?

1 2 3 4 5 6 7
Not very well Very well

Appendix D

Mathematical Beliefs Survey - Revised (Yackel,1984)

All individual responses on this survey will be kept strictly confidential. Your responses will be used to study the relationships between beliefs held by students about mathematics, mathematics content knowledge, and certain other variables such as previous mathematics experiences. For each item, circle the response that indicates how you feel about the item as indicated below.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
SD	D	U	A	SA

1. Doing mathematics consists mainly of using rules.

SD D U A SA

2. Learning mathematics mainly involves memorizing procedures and formulas.

SD D U A SA

3. Mathematics involves relating many different ideas.

SD D U A SA

4. Getting the right answer is the most important part of math.

SD D U A SA

5. In mathematics it is impossible to do a problem unless you've first been taught how to do one like it.

SD D U A SA

6. One reason learning mathematics is so much work is that you need to learn a different method for each new class of problems.

SD D U A SA

7. Getting good grades in mathematics is more of a motivation than is the satisfaction of learning the mathematics content.

SD D U A SA

8. When I learn something new in mathematics I often continue exploring and developing it on my own.

SD D U A SA

9. I usually try to understand the reasoning behind all of the rules I use in mathematics

SD D U A SA

.

10. Being able to successfully use a rule or formula in math is more important to me than understanding why it works.

SD D U A SA

11. A common difficulty with taking quizzes and exams in math is that if you forget relevant formulas and rules you are lost.

SD D U A SA

12. It is difficult to talk about mathematical ideas because all you can really do is explain how to do specific problems.

SD D U A SA

13. Most math problems are best solved by deciding on the type of problem, then using a previously learned solution for the type problem.

SD D U A SA

14. Mathematics is a rigid, uncreative subject.

SD D U A SA

15. In mathematics there is always a rule to follow.

SD D U A SA

16. The most important part of mathematics is computation.

SD D U A SA

Appendix E

Math Anxiety Scale (Betz, 1978)

SA or A = strongly agree or agree; U = undecided; D or SD = disagree or strongly disagree.

1.) It wouldn't bother me at all to take more math courses.

SD D U A SA

2. I have usually been at ease during math tests.

SD D U A SA

3. I have usually been at ease during math courses.

SD D U A SA

4. I usually don't worry about my ability to solve math problems.

SD D U A SA

5. I almost never get uptight while taking math tests.

SD D U A SA

6. I get really uptight during math tests.

SD D U A SA

7. I get a sinking feeling when I think of trying hard math problems.

SD D U A SA

8. My mind goes blank and I am unable to think clearly when working mathematics.

SD D U A SA

9. Mathematics makes me feel uncomfortable and nervous.

SD D U A SA

10. Mathematics makes me feel uneasy and confused.

SD D U A SA

Appendix F

COVER LETTER FOR Instructor Participants

Dear Colleague:

You have been selected to participate in a research study of the instructional methods used in the *Introductory Algebra* course. This study compares a skills-oriented approach to teaching algebra problem solving with a conceptually oriented approach. By conducting this study, I hope to discover the most effective ways in which developmental students learn mathematics. You will be teaching two sections of the *Introductory Algebra* course this semester, Fall 2011, and the students in your respective course sections will be part of the research study. Your participation in this study represents an opportunity for you to investigate the most effective instructional approaches for the students that you teach and to help other instructors understand the impact of instructional approaches on student learning.

Mitchell Community College has given me permission to conduct the study. Additionally, the Human Subjects Institutional Review Board for UNO has reviewed procedures regarding the protection of the rights and welfare of the human subjects involved in this research. This study will pose no risk to you, and I am the only person who will have access to the information that you provide through the surveys and interviews. When the final report is written only whole group statistics will be used; no individual information will be used in the report.

Without your assistance, this study during the FALL 2011 would not be possible. I sincerely appreciate your willingness to share your expertise in an effort to further the understanding of mathematics instruction for developmental mathematics students. Results of the study will be available upon completion of the study and can be obtained by contacting me at

704-878-3325. If you are interested in learning more about this opportunity before signing the attached consent form, please do not hesitate to contact me, Sandra Landry, at 704-878-3325; my major professor, Dr. Germaine-McCarthy, University of New Orleans, 2000 Lakeshore Drive, New Orleans, Louisiana, 504- 280-6533; or Dr. Ann O'Hanlon (504-280-3990) at the University of New Orleans for answers to questions about this research, and your rights as a human subject.

Sincerely,

Sandra Landry
Director of Developmental Education

Appendix G

Dear Student:

My name is Sandra Landry, and I am the Director of Developmental Education at the college. I am currently finishing my doctoral coursework in Curriculum and Instruction from The University of New Orleans. As part of this process, I am conducting a research project. The purpose of my study is to compare the instructional approaches used to teach algebraic problem solving. By conducting this study, I hope to discover the most effective ways in which developmental students learn mathematics.

Mitchell Community College has given me permission to conduct the study. Additionally, the Human Subjects Institutional Review Board for UNO has reviewed procedures regarding the protection of the rights and welfare of the human subjects involved in this research. I ask for your consent to be interviewed in this study during this FALL 2011 semester. Your consent to be interviewed is entirely voluntary and will not affect any part of your coursework or your grade in this course. If you agree to be interviewed then information from the interview will be used as data for the study, but at no point will you be identified in the research paper. This study will pose no risk to you, and I am the only person who will have access to the information that you provide through the interviews.

Please complete the consent to be interviewed form. If you are interested in learning more about this opportunity before signing the attached consent form, please do not hesitate to contact me, Sandra Landry, at 704-878-3325; my major professor, Dr. Germaine-McCarthy, University of New Orleans, 2000 Lakeshore Drive, New Orleans, Louisiana, 504- 280-6533; or Dr. Ann O'Hanlon (504-280-3990) at the University of New Orleans for answers to questions about this research, and your rights as a human subject.

Sincerely,

Sandra Landry
Director of Developmental Education

Appendix H

Self-regulated Learner Rubric

Levels	Characteristics	Will be measured using
Self-regulated	• High efficacy for solving word problems • Homework on time • Skilled problem solver • Sets, monitor, adapts challenging goals	• *Online Motivation Scale* • MyMath Lab • Problem solver rubric • Attributions, *Efficacy for Self-regulated Learning*
Intermediate Self-regulated	• Moderate efficacy for solving word problems • Often has homework on time • Intermediate problem solver • Sets high goals, monitors, makes changes	• *Online Motivation Scale* • *MyMath Lab* • Problem solver rubric • Attributions, *Efficacy for Self-regulated Learning*
Beginning Self-regulated	• Expresses some efficacy for word problems • Sometimes turns homework in on time • Beginning to intermediate problem solver • Moderate goals but no changes based on feedback	• *Online Motivation Scale* • *MyMath Lab* • Problem solver rubric • Attributions, *Efficacy for Self-regulated Learning*
Not Self-regulated	• No self-efficacy for solving word problems • Consistently turns homework in late • Beginning problem solver • Sets low goals, no monitoring or changing behavior	• *Online Motivation Scale* • *MyMath Lab* • Problem solver rubric • Attributions, *Efficacy for Self-regulated Learning*

APPENDIX I

Table 7 Frequencies for demographics

	Concept		Skill	
	N	%	N	%
Gender				
Male	22	50.0%	22	50.0%
Female	42	43.8%	54	56.2%
Ethnicity				
White	36	41.9%	50	58.1%
Black	23	54.8%	19	45.2%
Age				
Under 26	42	45.7%	50	54.3%
Over 25	22	45.8%	26	54.2%
Grad Type				
In HS	4	40.0%	6	60.0%
HS Grad	46	45.5%	55	54.5%
GED	14	48.3%	15	51.7%
Goals				
Undecided	2	25.0%	6	75.0%
Associates	35	55.6%	28	44.4%
Four-year	27	39.1%	42	60.9%
Prior DE Math				
Yes	36	45.6%	43	54.4%
No	28	51.4%	33	49.6%

Table 8 Descriptive statistics for preliminary testing of pre-test and algebra placement test scores

	Mean	SD	N
Pre-test			
Concept	2.75	2.15	59
Skills	2.57	2.06	67
Algebra Test			
Concept	35.87	8.84	61
Skills	37.49	12.75	69

APPENDIX J

TRAINING MANUAL

Classroom Observation Checklist

Conceptual Instructional Behaviors

	Concepts introduced through questions or students' reasoning.	
	Rules are the pedagogical endpoint, not the starting point.	
	Instructor listens to students’ math ideas.	
	Instructor discourages thoughtless application of procedures.	
	Objective is to elicit students’ thinking about math.	
	Instructors’ questions provide an understanding of students’ thinking.	
	Student talk is more important than teacher talk.	
	Instructor insists that students be intellectually engaged in challenging tasks and activities.	
	Students discuss problems and mathematical processes with other students.	

Skills-based Instructional Behaviors

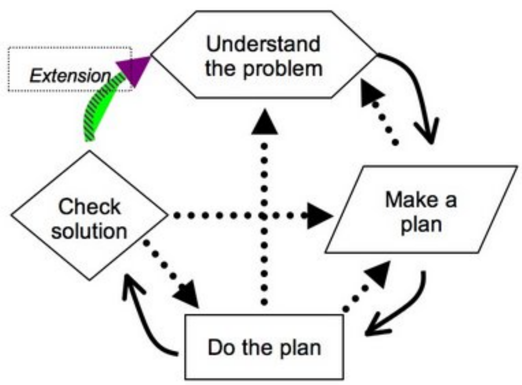
	Students work problems from the text.	
	Students engage in individual or parallel problem solving activities.	
	The lesson is introduced through lecture.	
	Instructor begins with rules and set procedures.	
	Teacher listens for correct answers.	
	Instructor wants students to replicate the worked examples.	
	Objective is to correctly apply an already taught procedure.	
	Instructors call on students who will probably have the correct answer.	
	Instructor is the math authority and dispenser of knowledge.	
	Students work problems from the text.	

A CONCEPTUALLY-ORIENTED APPROACH

Conceptual knowledge refers to the hierarchical network of mathematics knowledge and its corresponding relationships. An example is the relationship among a verbal problem, a graph, and an equation, or between the geometric concept of area and multiplication through arrays. Approaches such as multiple representations, mathematics discourse, collaborative learning and contextual teaching and learning are instructional approaches that can help students achieve conceptual understanding of mathematics.

The conceptual problem solving instruction classes will employ a conversational style, encouraging students to work together to solve problems and to ask questions. Using a minimal amount of direct instruction, the instructor will encourage students to work with peers to solve problems while the instructor monitors the student's progress and provides assistance as needed. A mathematics curriculum that develops a deep understanding of concepts and skills must be driven by teaching through problem solving, that is, new concepts and skills should be introduced in the context of solving problems. Examples should be used that extend understanding and promote thinking and reasoning.

Emphasis on the Problem Solving Process



Students in a conceptually oriented classroom are encouraged to examine problem structure and develop schemas. Schemas make effective reasoning and problem solving possible because they facilitate pattern recognition. For example: examining the similarities among distance, investment and coin problems. Conceptual teaching is intended to help students understand the mathematical procedures used to obtain correct answers. Both procedural and conceptual knowledge are considered necessary aspects of mathematical understanding.

Classroom discourse and examples of probing questions:

1. What did you do first? Why?
2. What do you plan to do next?

3. Does this problem remind you of another problem we've seen?
4. Can you state the problem in your own words?

The teacher in a conceptually oriented classroom needs to develop a deep knowledge of mathematics concepts and principles in order to understand the reasons behind students' errors. A teacher needs to have one eye on the underlying mathematical concepts while the other eye is focused on the current understandings of the students. Paul Cobb (2006) states that there are two parts to a mathematical explanation: 1) the calculation explanation that involves explaining the process that was used to arrive at the answer, and 2) a conceptual explanation that involves explaining why that process was selected. In this way students have to be able to not only perform a mathematical procedure, but to justify why they have used that particular procedure for a given problem.

SKILLS-BASED INSTRUCTION

The procedural skill-based classes will employ predominately lecture and teacher examples on the board. After the lecture and teacher demonstration of examples, students will practice similar problems. Direct instruction is the predominate mode of instruction. It may take several lessons before students are ready for guided and/or independent practice. The instructor identifies and teaches the main concepts and skills that satisfy the learning objectives. The instructor relies on clear explanations, frequent use of examples and/or diagrams, and invites students to repeat the demonstrated procedures. The instructor checks for understanding by observing and interpreting student reactions and the use of formative evaluations. Based upon the instructors interpretation of the students' readiness, he or she will adjust instruction and reteach if necessary. The instructor assigns independent practice to solidify skills and knowledge when students have demonstrated understanding.

Conceptual Characteristics	Skills-based Characteristics
Students are intellectually engaged in challenging tasks.	Students are engaged in routine textbook problems.
Students work collaboratively with their peers to investigate a mathematical concept and/or solve a mathematical problem, discuss problems and mathematical processes, and engage in decision making with their peers	Students engage in parallel or independent problem practice, and sometimes exchange answers or procedures.
Students explain and justify their thinking and provide feedback on the ideas of other students	Students sometimes provide feedback on the correctness of a peer's answer.
Student talk is more important than teacher talk.	Teacher talk is more important than student talk.
Concepts are introduced through questions or students' reasoning	Concepts are introduced through instructor directed instruction and teacher worked examples
Rules are the pedagogical endpoint	Rules are the pedagogical starting point
Instructor listens to students' math ideas	Instructor gives the students mathematical information
Instructor discourages thoughtless application of procedures.	Instructor encourages the memorization of procedures with little emphasis the mathematical reason for using the procedure.
The main objective is to elicit students' thinking about math.	The main objective is to impart mathematical information to students.
Instructors' questions provide an understanding of students' thinking.	Instructors' questions seek correct answers and procedures.
Instructor asks questions that help students understand new mathematical concepts and skills	Instructor asks questions to determine if the students worked and got the correct answer.
Instructor identifies and addresses misconceptions.	Instructor is unaware of students' misconceptions
Instructor observes students during group problem solving to ensure that they understand the task at hand, for individual responsibility in each of the students working in a group	Instructor observes students to make sure that all are on task
Instructor promotes pair or small-group discussion in which students share their ideas, strategies, and solutions with others	Instructor allows for limited whole-group discussion
Instructor encourages students to consider the appropriateness, effectiveness, and accuracy of different strategies.	Instructor encourages students to remember rules and demonstrated procedures.

VITA

The researcher was born in New Orleans, Louisiana. She obtained her Bachelor's degree in Secondary Education from Loyola University in 1974. She joined the University of New Orleans curriculum and instruction graduate program to pursue a PhD in curriculum and instruction in 2002.