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Rethinking Undergraduate Mathematics Education: The importance of classroom climate and self-efficacy on mathematics achievement

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Abstract

Given the growing societal demand for a more mathematically proficient work force, mathematics proficiency is viewed as a necessary component for success in today's world. To ensure proficiency, undergraduate institutions may need to *rethink* their instructional approaches to teaching mathematics. Understanding the influence of classroom climate and self-efficacy on mathematics achievement may lead to instructional practices that increase the percentage of students choosing to pursue mathematics related majors. This literature review synthesizes research that has empirically examined the influence of classroom climate and self-efficacy on mathematics achievement. This review also offers recommendations for future research and policy in the area of undergraduate mathematics.

Keywords: mathematics education, mathematics self-efficacy, mathematics achievement, classroom climate, learner-centered environments, teacher-centered environments, literature review

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Rethinking Undergraduate Mathematics Education: The importance of classroom climate and self-efficacy on mathematics achievement

For nearly fifty years leaders in American industry, military, education, and politics have focused considerable attention on STEM (science, technology, engineering, and mathematics) education. It has been argued that growing the number of college graduates proficient in STEM fields is essential to America's economic well being and national security. The federal government has legislated billions of dollars to fund STEM research and education (Lips & McNeil, 2009). Recently, the American Recovery and Reinvestment Act of 2009 signed into law by Barack Obama included an additional $2.5 billion to fund the National Science Foundation including STEM programs. In spite of increased spending the number of undergraduate students completing STEM degrees is not increasing sufficiently to meet workforce demands.

Viewed separately, proficiency in mathematics is a necessary component for success in today's technological workforce (MDHE, 2007; Shinn et. al, 2003). Higher education institutions are an avenue for preparing this workforce. To ensure proficiency, undergraduate institutions need to *rethink* their instructional approaches to teaching mathematics. The challenge to undergraduate mathematics educators is to teach students with diverse backgrounds and interests. According to NCES (2007), the total number of bachelor's degrees conferred continues to increase from year to year. The number of women and minorities pursuing college degrees is also increasing (Hussar & Bailey, 2008). Despite the fact that the demographics of undergraduate mathematics classes have dramatically changed over the years, undergraduate mathematics education has remained pedagogically stagnant. As a result, student achievement in those mathematics classrooms has declined (Fletcher & Tienda, 2010; Nelson, 1996; Treisman, 1992).

Teachers often teach in the manner in which they were taught (Ball, 1988; Clark, DiCarlo, & Gilchrist, 2003). For those who have had traditional schooling experiences, this may lead them to believe that their role is to give information to students utilizing didactic teacher-centered approaches. Compounding this, Walczyk, Ramsey, and Zha (2007) reported mathematics faculty perceive obstacles to instructional innovation including the weight given to teaching effectiveness in personnel decisions, challenges in assessing teaching effectiveness and lack of formal professional development. With little or no incentive to improve instruction and little or no professional development in innovative teaching practices, the learner-centered directions in undergraduate mathematics education called for by the National Research Council (NRC) in 1999 will likely not be pursued. The concern is that the infrequent use of learner-centered instruction has negative effects on undergraduate learning and motivation (Walczyk, Ramsey, & Zha, 2007).

This literature review synthesizes research that has empirically examined the influence of classroom climate (teacher-centered and learner-centered) and self-efficacy on mathematics achievement. Improving classroom climate and self-efficacy in undergraduate mathematics is increasingly important as the percentage of students earning mathematics degrees is not increasing at the same rate as college enrollments. In a September 2008 report, the National Center for Education Statistics (NCES) reported, "total enrollment in degree granting institutions increased 23 percent from 1992 to 2006" (Hussar & Bailey, 2008, p. 8). Between 2006 and 2017, the NCES has projected the following enrollment trends:

1. Thirteen percent increase in total college enrollments from 17.8 million to 20.1 million.
2. Ten percent increase for students between the ages of 18 and 24 and 8% for students over 35 years of age.
3. Thirteen percent increase for both males and females.
4. Twelve percent increase in undergraduate enrollments and 18% increase in graduate enrollments.
5. Five percent increase for students who are White, 26% for Black students, 39% for Hispanic students, 26% for Asian or Pacific Islander students, 30% for American Indian or Alaska native, and 1% for nonresident aliens.

Although college attendance rates are climbing, the number of mathematics majors is not increasing. This poses a challenge for the traditional ways of approaching or thinking about undergraduate mathematics education. Though the percentages of minorities, women, and older students deciding to pursue college degrees is increasing, groups such as these typically have reported lower self-efficacy and achievement in their previous mathematics courses (Betz, 2001; O'Brien & Martinez-Pons, 1999; Stevens, Olivarez, Lan, & Tallent-Runnels, 2004). As a result, educational institutions are going to be faced with the challenge of educating an increasingly diverse set of learners.

Research shows that only 2.6 out of 30 students in the class or approximately 9.0% percent will complete a degree in mathematics or choose to major in a mathematics related field NCES, 2008). Given society's need to maximize the usage of human capital in an increasingly technological world, a strong background in mathematics is critical for many career and job opportunities (Meece, Wigfield, & Eccles, 1990). Mathematics proficiency is necessary, particularly for those students in post-secondary education who will someday take the middle and higher-level jobs in the current and future economy (Augustine, 2007).

Despite the growing need for graduates prepared to enter mathematics related fields, trends show those needs will be largely unmet. Research shows that the lack of self-efficacy (Bandura, 1997) relating to mathematics is a significant contributor to why students are not successful in mathematics (Hackett & Betz, 1989; Hall & Ponton, 2005; Lent, Brown, & Larkin; 1986; O'Brien, Martinez-Pons, & Kopala, 1999; Pajares & Miller, 1994). Self-efficacy is defined as a person's perception of his or her capabilities at performing a given task (Bandura, 1997). In order to build self-efficacy on the way to increasing mathematics achievement, the classroom climate in undergraduate mathematics may need to address and support the development of students' mathematics self-efficacy.

Many students entering undergraduate education lack confidence or a sense of efficacy in their academic abilities because of unpleasant mathematical experiences, such as poor mathematics grades in high school. Due to an increasing number of individuals seeking to earn higher education degrees, the traditional classroom climate utilizing the teacher-centered perspective may no longer be sufficient for ensuring academic success in an undergraduate mathematics course for a majority of students with diverse mathematical skills and career goals. Consequently, if greater numbers of students are to be successful in undergraduate mathematics courses, it may be imperative to examine the influence classroom climate can have on mathematics self-efficacy and ultimately mathematics achievement.

Given that K-16 studies have shown that mathematics self-efficacy influences mathematics achievement, a review of the empirical studies may illuminate what could be done to ensure that more students choose to major in mathematics-related career fields, and thus add to today's workforce in technical fields (Cooper & Robinson, 1991; Hackett & Betz, 1989; Hall & Ponton, 2005; Lent, Lopez, & Bieschke, 1991; O'Brien & Martinez-Pons, 1999; Pajares & Graham, 1999; Pajares & Miller, 1994; Schunk & Hansen, 1985; Randhawa, Beamer, & Lundberg, 1993). Research has verified that self-efficacy beliefs greatly influence decisions that college students make concerning choice of college majors and career decisions (Hackett, 1985; Hackett & Betz, 1989; Lent & Hackett, 1987; Lent, Lopez, & Bieschke, 1991). As a result of low perceptions of mathematical ability, students tend to choose career fields that do not require success in mathematics. According to NCES (2007), approximately 91% of bachelor's degrees awarded in 2005-2006 were primarily from non-mathematics degree fields. These statistics clearly indicate that the majority of students are choosing not to pursue mathematics-based fields. Yet, the demands of society are requiring greater numbers of competent graduates in mathematics.

Theoretical Framework

This section provides a proposed conceptual framework, concerning the relationships between (a) classroom climate and mathematics self-efficacy, (b) mathematics self-efficacy and mathematics achievement, and (c) classroom climate and mathematics achievement. Based on our review of the literature we believe learner-centered classroom climates promote mathematics self-efficacy, which in turn improves mathematics achievement.

Classroom Climate

Research suggests that classroom climate can influence achievement directly through the environment established by the teacher in a classroom (Brown, 1960; Eggen & Kauchak, 2007; O'Reilly, 1975; Pierce, 2001). Classroom climate is defined as the learning environment that the instructor creates by teaching in a teacher-centered or learner-centered manner. Teacher-centered (TC) refers to an instructional preference or teaching style focusing most on teaching and assessing behavioral objectives through course content and delivery. The needs of the student are placed second to instructing and assessing the curriculum. The teacher-centered instructional preference is the dominant approach across all levels of education in North America (Conti, 1990). This is especially the case for mathematics teachers, whose subject matter expertise and skill in organizing and structuring content is what makes them most useful (Boldt, 2002).

On the other hand, learner-centered (LC) climate refers to an instructional preference or teaching style that focuses most on the needs and well being of the student, not to mention the process of learning (Knowles, Holton, & Swanson, 2005). A learner-centered environment provides students with: (a) support and guidance, (b) positive feedback and encouragement, (c) empathy, and (d) mutual trust and respect (Pratt, 2002). When teachers create a classroom climate based on mutual trust and respect, which is also free of ridicule and criticism, students tend to feel more secure (Pratt, 2002). This sense of safety is believed to have a positive influence on mathematics self-efficacy and, consequently, mathematics achievement (Adelman & Taylor, 2005; Harradine, 1999; Pianta, Stuhlman, & Hamre, 2002; Pierce, 2001; Stipek, Feiler, Daniels, & Milburn, 1995).

Learner-centered teachers at all levels have faith that learners can grow and, therefore, can learn. A primary role of the learner-centered educator is to establish a learner-teacher relationship that fosters growth in confidence and self-efficacy. It is believed that educators who embrace the learner-centered perspective of teaching: (a) seek to empower the learner, (b) divulge a sense of personal regard for the welfare of their learners, and (c) view subject-matter content as simply a means for learner self-efficacy (Pratt, 2002). In facilitating self-efficacy, learner-centered teachers attempt to find a balance between caring and challenging by believing in their students and helping them achieve their goals. From this point of view, teaching is effective if achievement is the means and self-efficacy is the end.

Mathematics Self-Efficacy

The link between self-efficacy and achievement is well documented in the literature (Cooper & Robinson, 1991; Hackett, 1985; Hackett & Betz, 1989; Hall & Ponton, 2005; Lent, Lopez, & Bieschke, 1991; O'Brien, Martinez-Pons, & Kopala, 1999; Pajares & Graham, 1999; Pajares & Miller, 1994; Randhawa, Beamer, & Lundberg, 1993; Schunk & Hansen, 1985; Siegle & McCoach, 2007). An individual's level of self-efficacy affects his or her behavior in many ways in that it influences the choices that a person will make and the courses of action he or she will choose to pursue (Pajares, 1996). Bandura (1986, 1997) claimed that a person's self-efficacy is a major determinant of whether there will be persistence in a given task, how much effort will be expended toward the task, and whether a person will even attempt it (Pajares, 1996). People tend to avoid tasks for which they feel less competent and confident, but do engage in those tasks in which perceived competence and confidence is high. Research suggests that the higher the self-efficacy, the greater the effort and persistence expended toward a given task (Schunk, 1991).

There are four key factors that contribute to the development of a student's self-efficacy: (a) prior behaviors and performances, (b) verbal persuasion, (c) vicarious learning, and (d) emotional arousal (Bandura, 1986, 1997; Ormrod, 1998; Schunk, 1989). Students are more likely to feel confident in their mathematics ability, and thus have higher academic achievement, if they have experienced success in a previous mathematics class, if they have received positive feedback and encouragement for their mathematics accomplishments, or if they have witnessed others of a similar age and ability successfully solving a difficult mathematics problem.

In academic venues, self-efficacy research has primarily focused on two main areas: (a) exploring the relationships among self-efficacy beliefs, related psychological constructs, and motivation and achievement (Cooper & Robinson, 1991; Hackett & Betz, 1989; Hall & Ponton, 2005) and (b) examining the link between self-efficacy beliefs and college major and career choices (Betz & Hackett, 1983; Hackett, 1985; Lent, Lopez, & Bieschke, 1991; Pajares, 1996). As previously mentioned, the results from past K-16 studies have shown that mathematics self-efficacy is positively correlated with mathematics ability/performance. In other words, students who report higher levels of mathematics self-efficacy also report higher levels of mathematics performance. Research has also indicated that self-efficacy is a mediating factor for academic outcomes, cognitive engagement, and academic performance (Patrick & Hicks, 1997). The mediating effects of mathematics self-efficacy on mathematics performance have been of great interest to many researchers (Hackett, 1985; O'Brien, Martinez-Pons, & Kopala, 1999; Pajares & Miller, 1994; Randhawa, Beamer, & Lundberg, 1993; Stevens, Olivarez, Lan, & Tallent-Runnels, 2004).

Review of the Research Literature

An exploration of the empirical literature was undertaken to better understand the relationships among (a) classroom climate and mathematics self-efficacy, (b) classroom climate and mathematics achievement, and (c) mathematics self-efficacy and mathematics achievement. The developmental nature of self-efficacy and the lack of empirical research for all grade levels required studies to be reviewed from the K-16 literature base. Given the limited amount of research on the above relationships carried out in mathematics classrooms, these studies were taken primarily, but not entirely, from studies conducted in mathematics.

The search of literature on classroom climate was limited to studies published after 1936, when it was discovered that the environment and its interaction with an individual's personal characteristics were powerful determinants of human behavior. Few studies of collegiate teachers' classroom teaching practice actually exist (Speer, Smith, & Horvath, 2010). Given the lack of relevant research conducted using undergraduate and/or mathematics students, classroom climate studies focused primarily on non-mathematics K-12 literature. The relationship between mathematics self-efficacy and achievement has been well established in the K-16 literature base. Empirical research in self-efficacy was limited to studies published after 1977 the year Bandura's Social Learning Theory was published.

Initially, the search discovered 71 articles on classroom climate, mathematics self-efficacy, and mathematics achievement. In order to narrow the number to only those that addressed the research purpose and questions, each article was reviewed thoroughly to determine if it did or did not meet the necessary criteria for inclusion. Although several articles were examined for this literature review, only 5 of the classroom climate studies and 12 of the self-efficacy studies met the criteria for inclusion. The classroom climate studies were restricted to those demonstrating a link between (a) a learner-centered classroom climate and self-efficacy and (b) a learner-centered classroom climate and achievement. The self-efficacy studies were limited to those primarily, but not entirely, in higher education examining the relationship between mathematics self-efficacy and mathematics achievement.

Studies of Classroom Climate

For more than 20 years, the influence of classroom climate on student learning has been of interest to researchers. According to Fraser (1989), "the strongest tradition in past classroom environment research has involved investigation of associations between students' cognitive and affective learning outcomes and their perceptions of psychosocial characteristics of their classrooms" (p. 315). Research has shown that student perceptions account for a considerable amount of variance in learning outcomes and, as a result, one could assume that student outcomes might be improved by creating a classroom environment conducive to student learning (Fraser, 1989).

Haertel, G., Walberg, and Haertel, E. (1981) conducted a meta-analysis involving 734 correlations from 12 studies (823 classes in eight subject areas, 17,805 K-12 students in four nations). The purpose of the study was to estimate the sign and size of the correlations between student perceptions of the social psychological climates of their classrooms and student learning outcomes. Findings indicate that better achievement on a variety of learning outcomes was positively associated with classrooms consisting of cohesiveness, satisfaction, task difficulty, formality, goal direction, democracy, and the material environment. Negative associations were found to exist in those classrooms consisting of friction, cliqueness, apathy, and disorganization.

In 1981, Walberg incorporated classroom environment as one factor in a multi-factor model of educational productivity. The model claims that student learning is codetermined by the following factors: (a) student age, ability, and motivation, (b) quality and quantity of instruction, and (c) the psychosocial environment of the home, the classroom, the peer group, and the mass media (Walberg, 1981). Research not only confirmed the importance of all of the factors in the model, but also concluded that even when all other factors in the model were held constant; classroom environment was a strong predictor of student achievement and attitudes (Fraser, 1989; Walberg, Fraser, & Welch, 1986). For the purpose of this review, only classroom environment (climate) will be utilized as a factor in determining self-efficacy and achievement levels.

Classroom Climate and Self-Efficacy

This review of the literature revealed a lack of empirical research directly related to whether classroom climate builds self-efficacy in an undergraduate mathematics class. However, related K-12 research links learner-centered environments to increased self-efficacy in other classroom contexts (Pianta, Stuhlman, & Hamre, 2002). Results of such studies indicate that the climate in a classroom affects a student's confidence in his or her abilities (Adelman & Taylor, 2005; Harradine, 1999; Stipek, Feiler, Daniels, & Milburn, 1995).

Stipek, Feiler, Daniels, and Milburn's (1995) study compared children in learner-centered preschools and kindergartens with children in *didactic* (teacher-centered) preschools and kindergartens in terms of motivational variables, such as perceptions of abilities and expectations for success. Their study consisted of a total of 227 children (105 males, 122 females), from 32 classrooms (age 4-6). To differentiate classroom types, observers, using a 47-item observation measure, rated each classroom based on classroom instruction and social climate. The didactic group consisted of 123 students (60 males, 63 females) and the learner-centered group consisted of 104 students (45 males, 59 females). Findings indicated that, compared to students in teacher-centered classrooms, students in learner-centered classroom climates tend to (a) rate their abilities significantly higher, (b) have higher expectations for success, (c) select higher levels of task difficulty, (d) have less dependency on the teacher, and (e) display more pride in their accomplishments.

In a similar study conducted by Harradine (1999), possible relationships between classroom climate, self-efficacy, and interest were examined with 107 third and fourth-grade students from four classrooms and two schools throughout the duration of one Social Studies unit. The two classes in School I were taught in the traditional manner, with the teacher positioned at the front of the room and the students sitting in clusters of four desks. Classroom activities were teacher-driven, with students seated at their desks, and the textbook primarily drove instructional content. The students in School II did not have assigned seats and each classroom consisted of numerous work centers where the students could work. Each student was afforded quite a bit of autonomy in deciding what they would do, when they would do it, and where they wanted to do it.

Students were administered a 10-item self-efficacy scale, a 12-item general interest scale, and a 7-item unit-specific interest scale constructed by the researcher. In addition, a modified version of the Origin Climate Questionnaire was administered to each student to gauge perceptions on classroom climate. The classroom teachers administered each of the scales, one per day, in the same week. The results of the study concluded that classroom climate was responsible for fostering the students' interests and self-efficacy was directly related to student interest in the classroom topics and activities.

Classroom Climate and Achievement

Various characteristics of the classroom environment, such as satisfaction and "democraticness" (one aspect of a learner-centered environment), were found to be directly linked to academic achievement (O'Reilly, 1975). In order to evaluate various aspects comprising classroom climate on mathematics achievement, O'Reilly (1975) surveyed 1,100 ninth and tenth-graders in 48 mathematics classrooms from 12 secondary schools in eastern

Ontario. In two sittings, students were administered the Stanford Achievement Test-Mathematics and the Learning Environment Inventory (LEI). The results indicated that a positive significant relationship existed between classroom satisfaction and mathematics achievement, $r = .45$, $p < .05$, and between democraticness and mathematics achievement, $r = .47$, $p < .05$. The results of this study suggested that the higher the satisfaction perceived by the student concerning the class, the greater the mathematics achievement and the more democratic the learning environment, the greater the mathematics achievement.

Teacher characteristics related to establishing a learner-centered environment, such as praising and encouraging students, can affect the classroom climate and, subsequently, academic achievement (Brown, 1960; Pratt, 2002). Brown (1960) conducted a study to gauge a teacher's classroom climate, based on verbal behavior, and compared it to student achievement. The study consisted of 15 third-grade classrooms (N = 318; 175 males, 143 females). To measure the classroom climate of the teachers, observers classified the verbal behavior toward the students into seven categories, such as learner-supportive statements and teacher-supportive statements, and then placed each teacher on a continuum that extended from learner-centered to teacher-centered. To gauge student achievement, students were administered various forms of the Elementary Battery of the Stanford Achievement Test. The findings indicated a higher relationship between a learner-centered classroom climate and the arithmetic subtest of the Elementary Battery of the Stanford Achievement Test.

A more recent study examined the influence of other teacher behaviors on her classroom's climate, and thus her students' achievement. Pierce (2001) conducted a case study involving a middle school teacher with 24 years of teaching experience (21 at-risk students). The teacher was selected for the study based on recommendations from teachers, administrators, parents, and former students. Observations were conducted over a period of 12 weeks in the form of audiotapes and field notes paying close attention to verbal/nonverbal teaching behaviors, teacher personality characteristics, and student learning. Findings showed that the teacher created a classroom atmosphere that promoted a non-threatening environment for taking risks and participating freely in the learning process, provided students with a sense of safety and support, and showed enthusiasm and respect for her students. As a result, she increased her students' level of academic achievement.

Mathematics Self-Efficacy and Achievement

In contrast to the body of work on classroom climate, the self-efficacy and achievement literature is more rich and complex. Bandura's Social Cognitive Theory has greatly influenced researchers in many disciplines, particularly in the field of mathematics. In academic venues, self-efficacy research has focused on exploring the relationships between self-efficacy beliefs, related psychological constructs, and motivation and achievement (Pajares, 1996). It is held that self-efficacy fosters engagement with learning activities, which promote educational competencies, which influence academic achievement (Zimmerman, 1995). In addition, research has shown that self-efficacy is a mediating factor for academic outcomes, cognitive engagement, and academic performance (Bikkar, Beamer, & Lundberg, 1993; Patrick & Hicks, 1997).

The effects of mathematics self-efficacy on mathematics performance have been of great interest to many researchers. Although there might be a reciprocal relationship between self-efficacy and achievement (Pajares, 1997), a range of K-16 studies have shown that mathematics self-efficacy is positively correlated with mathematics ability/performance (Betz, 1978; Cooper & Robinson, 1991; Goldman & Hewitt, 1976; Hackett, 1985). Results from these studies indicated that students who tend to report higher levels of mathematics self-efficacy also tend to have higher levels of mathematics performance (Hackett & Betz, 1989; Pajares and Miller, 1994; Schunk and Cox, 1986; Schunk & Hanson, 1985).

Modeling (vicarious experience) and persistence increase mathematics self-efficacy and thus have a direct effect on skill acquisition and performance (Bandura, 1997; Schunk & Gunn, 1986; Zimmerman & Ringle, 1981). In 1985, Schunk and Hansen conducted a study to explore the influence of modeling on self-efficacy and mathematics achievement. The study involved 72 elementary students (36 boys, 36 girls, mean age = 10.1) selected from eight classes in two schools (Schunk & Hansen, 1985). Students were administered a pre-test on which each student rated his or her self-efficacy for solving subtraction problems correctly. Immediately following the self-efficacy assessment, each student took a subtraction skill test composed of 25 problems.

Following the pre-test students were randomly assigned by sex and school to one of the six experimental conditions including one control group. All children in the five model conditions received two 45-minute treatment sessions on consecutive school days. Students viewed two videotapes that presented various subtraction operations in 15-minute blocks. The day after students viewed the second videotape, children participated in a subtraction- training program consisting of 40-minute sessions on five consecutive days. Students assessed their subtraction self-efficacy, skill, and persistence the day following the last training session, and it was concluded that modeling led to higher self-efficacy for learning and subtraction skills.

Several years later, McCoach and Siegle (2007) conducted a study to assess whether training teachers in ways to enhance self-efficacy could influence mathematics self-efficacy and achievement. This study consisted of 872 fifth-grade mathematics students from 10 school districts, 15 schools, and 40 classrooms. Each of the 15 schools was randomly assigned to either the treatment (n = 7 schools, 21 classrooms, 430 students) or the control (n = 8 schools, 19 classrooms, 442 students) group. After the teachers assigned to the treatment group received staff development training in self-efficacy strategies to use in their classrooms, all of the fifth-grade mathematics teachers taught a 4-week unit on measurement. Prior to and following instruction, all of the students completed the Student Mathematics Survey and the Math Achievement Test. The results of the hierarchical linear modeling (HLM) analysis indicated that mathematics self-efficacy was a statistically significant predictor of mathematics achievement and the relationship for post-test mathematics achievement and self-efficacy was stronger for the treatment students than for the control students.

In a study consisting of middle school students, Pajares and Graham (1999) chose 273 sixth-graders (150 boys, 123 girls) from one suburban, public middle school in the south to investigate the impact of various motivation variables on task-specific mathematics performance. Attitude and outcome measures were administered in October and again in April, including a mathematics self-efficacy scale and a mathematics performance examination. The results of the multiple regression analyses concluded that mathematics self-efficacy was the only variable to predict mathematics performance at the beginning and the end of the school year.

During the same year, O’Brien and Martinez-Pons (1999) published a study designed to assess relationships among mathematics self-efficacy, performance, ethnicity, gender, and career interests in mathematics/science. Four-hundred and fifteen (221 boys, 194 girls) 11th grade high school students were surveyed using the Mathematics Self-Efficacy Scale (MSES), adapted for high school students, and their achievement scores were obtained through pre-Scholastic Test (PSAT) scores. The results of path analyses techniques showed statistically significant correlations between mathematics self-efficacy and academic performance, indicating that as mathematics self-efficacy increases, so does mathematics performance.

In a somewhat similar study, Stevens, Olivarez, Lan, and Tallent-Runnels (2004) conducted a study to determine if self-efficacy could predict mathematics achievement across ethnicity. High school algebra students (317 ninth-graders, 100 tenth-graders, mean age = 14.7, 53% Hispanic, 30% Caucasian, 4.6% African American) participated in the study. Each student was required to take a mathematics self-efficacy instrument created by Pajares and Graham (1999) to evaluate the confidence levels of eighth-grade students at the end of the school year. In addition, mathematics performance was assessed by having each student complete 20 problems similar to those found on the self-efficacy instrument. The findings suggested that on the average the Hispanic students have a lower mathematics self-efficacy and mathematics performance than did the Caucasian students and a statistically significant relationship existed among mathematics self-efficacy and mathematics performance for the entire sample. The findings showed a statistically significant relationship among mathematics self-efficacy and mathematics performance for the entire sample, $r = .47$, $p < .01$, Caucasian sample, $r = .46$, $p < .01$, and the Hispanic sample, $r = .41$, $p < .01$.

Studies evaluating the relationship between self-efficacy and academic achievement have also been conducted utilizing various groups of undergraduate student populations. In 1985, employing the use of undergraduate volunteers (N = 262; 109 males, 153 females) enrolled in an introductory psychology course, Hackett (1985), utilizing data that were collected as part of a larger project on mathematics self-efficacy, developed a causal model examining the role of mathematics self-efficacy as a mediating variable in the choice of mathematics-related majors (Betz & Hackett, 1983).

Each participant was administered the MSES and participant ACT mathematics scores were obtained from college records. To investigate the relationship between ACT mathematics scores and mathematics self-efficacy, path analysis techniques were applied and found a significant positive relationship between ACT mathematics scores and mathematics self-efficacy, $r = .66$, $p < .001$. These results suggest that as mathematics self-efficacy increases, so does mathematics achievement. In addition, findings showed that there existed a relationship between gender and mathematics self-efficacy, $r = -.25$, $p < .01$, and gender and mathematics achievement, $r = -.19$, $p < 05$. Men tended to have higher mathematics self-efficacy and achievement than women.

In 1989, Hackett and Betz, extending on the previous study (Betz & Hackett, 1983), extended their research to further explore the relationship between mathematics self-efficacy and mathematics performance in undergraduate college students. Pearson product-moment correlations were conducted to examine the relationships between mathematics self-efficacy and mathematics performance. The results of the Pearson product-moment correlation indicated that there was a significant positive relationship between mathematics self-efficacy and mathematics performance, $r = .44$, $p < .001$. In other words, the higher the mathematics self-efficacy, the higher the mathematics performance.

In 1991, two other research teams, Cooper and Robinson and Lent, Lopez, and Bieschke published findings addressing the relationship between mathematics self-efficacy and achievement. Building on previous research conducted on mathematics self-efficacy, Cooper and Robinson's (1991) study aimed to examine the relationships between Hackett's (1985) recommended variables of mathematics and career self-efficacy, perceived external support, mathematics background, math anxiety, and mathematics performance.

This study targeted engineering and applied science students at a public mid-western university. Participants included 229 male and 61 female undergraduates, who selected mathematics-based college majors, attending the first, third, and fifth summer orientation session. During the first two days of the orientation session, each participant was administered various survey instruments, including the Mathematics Self-Efficacy (MSE) scale constructed by the investigators. The American College Testing Program mathematics academic test (ACT-9) scores were obtained from student transcripts. Pearson product-moment correlations were computed between mathematics and mathematics ability. The results indicated that significant correlations existed between scores on the MSE and ACT-9. A significant positive relationship was found to exist between mathematics self-efficacy and mathematics performance, $r = .22$, $p < .001$, suggesting that as mathematics self-efficacy increased, mathematics performance increased.

Building on prior research on career and academic self-efficacy, Lent, Lopez, and Bieschke's (1991) study investigated mathematical self-efficacy beliefs and the relationship of those beliefs to outcome expectations, academic interests, and science-based career choices. At a large mid-western university, participants (53 men, 85 women; 94% white, and 80% freshmen/sophomores) enrolled in an introductory psychology course received experimental credit for agreeing to take part in this study. Each participant completed various measures, to include a mathematics self-efficacy scale designed specifically for this study. In addition, researchers obtained participant ACT scores from university records. Predicting for mathematics self-efficacy, the results of the regression analysis indicated that after controlling for gender, only the mathematics ACT scores and perceived performance variables explained unique variation.

A couple of years later, Randhawa, Beamer, and Lundberg (1993) proposed a structural model to test the mediational role of mathematics self-efficacy between mathematics attitudes and mathematics achievement. A sample of 225 (117 male, 108 female, age 17-19) high school students, from nine Algebra 30 (an academic Grade 12 course) classes in three high schools, was chosen to participate in the study. Each participant was administered 3-rating scales including the MSES) and a mathematics achievement test. Results indicated that not only did mathematics self-efficacy act as a mediator variable between mathematics attitudes and mathematics achievement, it was also statistically correlated with mathematics achievement, $r = .44$, $p < .05$.

The following year, Pajares and Miller (1994) decided to use path analysis to test Bandura's hypotheses regarding the mediational role of self-efficacy in the area of mathematics. The authors were interested in examining whether mathematics problem- solving self-efficacy had a greater effect on problem-solving performance, than did math anxiety, gender, math self-concept, prior experience with math, and perceived usefulness of mathematics. In addition, Pajares and Miller tested whether self-efficacy had a mediating effect on gender and prior math experience on problem-solving performance.

Students at a large public university in the South, (121 men, 229 women), a majority of whom were enrolled in courses in the College of Education (137 education majors, 213 other majors), volunteered to participate in this study. In the individual classes, in one sitting, students were asked to complete four survey instruments, including a modified version of the Mathematics Confidence Scale (MCS), and were required to complete the Mathematics Problems Performance Scale (MPPS) to assess their mathematics performance.

The correlation of the variables in the path analysis results indicated significant relationships between mathematics self-efficacy and mathematics performance. Path coefficients from mathematics self-efficacy, $\beta = .545$, $t = 10.87$, $p < .0001$, were found to be significant to mathematics performance. In comparison to the other variables in the study, mathematics self-efficacy had the stronger direct effects on mathematics performance. In addition, self-efficacy was found to mediate the effect of gender and prior mathematics experience on mathematics performance.

Several years later, Hall and Ponton (2005) aimed to determine whether there were self-efficacy differences between undergraduates enrolled in a calculus course and those enrolled in a developmental mathematics (Intermediate Algebra) course. Hall and Ponton hypothesized that self-efficacy beliefs may impede success for those students enrolled in developmental mathematics courses. Freshman students, enrolled in either Intermediate Algebra (N = 105; 42 men, 63 women) or Calculus I (N = 80; 42 men, 38 women), were solicited from a medium-sized southeast rural university. Each participant was required to complete the MSES.

The results of an independent t-test indicated that there was a statistically significant difference between the self-efficacy beliefs of the Intermediate Algebra and Calculus I students, $t(185) = 8.902$, $p < .001$. The Calculus I students (mean MSES = 7.08) showed a higher self-efficacy than the Intermediate Algebra students (mean MSES = 5.33). The Pearson product-moment correlation results for all participants, $r = .580$, $p < .001$, and the Calculus I students, $r = .454$, $p = .598$, indicated that there was a relationship between MSES scores and ACT scores, whereas there was no relationship found with the Intermediate Algebra students, $r = .052$, $p = .598$.

Discussion

Summary of the Literature

The studies reviewed provide evidence of relationships among (a) classroom climate and mathematics self-efficacy, (b) classroom climate and mathematics achievement, and (c) mathematics self-efficacy and mathematics achievement. The research here shows that it is reasonable to link classroom climate to learner and teacher-centered climates (Harradine, 1999; Stipek, Feiler, Daniels, & Milburn, 1995). Empirical studies indicate that learner-centered classroom climates increase learner self-efficacy and influence academic achievement indirectly and directly. In addition, the results of studies also suggest that self-efficacy affects mathematics achievement (Hackett & Betz, 1989; Harradine, 1999; Pajares & Graham, 1999). Results of several studies suggest that as self-efficacy increases mathematics achievement also increases (Hackett, 1985; Hackett & Betz, 1989; Lent, Lopez, & Bieschke, 1991; Siegle & McCoach, 2007; Stevens, Olivarez, Lan, & Tallent-Runnels, 2004). Research therefore indicates that self-efficacy influences academic achievement directly.

Implications for Practice

Mathematics proficiency is a must for today's technological workforce (MDHE, 2007; Shinn et. al, 2003) and colleges and universities are one avenue for preparing individuals for that workforce. Given that most higher education institutions require the successful completion of at least one mathematics course and that many college students lack confidence in their mathematics abilities (Ashcraft, 2002; Lent, Lopez, & Bieschke, 1991; Stipek, 1998), undergraduate mathematics classroom instruction may need to be augmented with a classroom climate that engenders the success of all students thereby increasing the number of students choosing to pursue degrees that prepare them for mathematics-related careers.

This review of the literature suggests that one means to increase the number of students who successfully complete undergraduate mathematics courses and, in turn, the percent of students who decide to major in mathematics or pursue mathematics related careers is to utilize learner-centered approaches designed to empower the learner and develop learner self-efficacy.

Undergraduate mathematics instructors can be instrumental in ensuring this by creating a classroom climate which fosters mutual respect and trust, affords sufficient support and guidance, provides positive feedback and encouragement, and bestows frequent opportunities for student success. Learner-centered approaches would include, but are not limited to, encouraging students to ask questions, eliciting classroom discussion among students, instructor willingness to provide additional assistance, and empowering students through positive communications about their ability to achieve success.

Surprisingly little research exists on undergraduate mathematics education. The impact of instructional methods and classroom environment on students' learning has not been well documented. Consequently if greater numbers of students are to be successful in undergraduate mathematics courses, it follows that more research in this arena needs to be undertaken.

Recommendations for Future Research

Given the dearth of literature, several recommendations are suggested for future research examining the dynamics of undergraduate mathematics courses. Based on our review of the literature, we would argue that quantitative methods dominate the majority of published research studies conducted in mathematics education. We question whether all research questions dealing with undergraduate mathematics education can or should be answered using quantitative methods.

Given that the classroom is a learning environment abundant with psycho-socio elements, it logically follows that survey instruments cannot adequately measure the contextual inputs that influence individual and group performance in an undergraduate mathematics classroom. For instance, the dynamics involved in teacher-student interactions cannot be completely captured or measured using the responses to a Likert scale (*Always Agree – Always Disagree*). As a result, researchers should broaden their data collection methods to include classroom observations, interviews, and/or focus groups to gather data that may lead to deeper understanding of the complex interactions between environment and learners.

In the event that a researcher chooses to examine the climate of a mathematics classroom using a survey instrument, he/she must be cautious in his/her selection. Although validated classroom climate or environment scales are already in existence (e.g., *College and University Classroom Environment Inventory* (Fraser et al., 1986), *Learning Environment Inventory* (Fraser, 1994), *Principles of Adult Learning Scale* (Conti, 1978)), for the most part, several of the survey items appear to either not apply or to be inappropriate for measuring the climate of a mathematics classroom. Given the importance of classroom climate on the academic success of mathematics students, one might consider either modifying a pre-existing instrument or developing an instrument that is designed to specially measure the climate of mathematics classrooms.

Last, but not least, very little research examining the dynamics of mathematics classrooms appears to acknowledge the nested structure that exists within a classroom. For instance, mathematics self-efficacy and academic achievement more often than not occur at the individual level, while classroom climate typically takes place at the classroom level. In this particular case, the unit of analysis poses a methodological dilemma. In the past, researchers have chosen to address this issue by aggregating individual level variables to the group level (e.g., district, school, classroom) or assigning group level variables to the individual level (e.g., student). This statistical strategy often poses many challenges, such as: (a) aggregation bias, (b) heterogeneity of regression among groups, and (c) misestimated standard errors (Raudenbush &

Bryk, 2002). As a result, future research in mathematics might consider analyze quantitative data using a multi-level analysis technique, such as Hierarchical Linear Modeling (HLM).

HLM results are more precise and credible than those of a single-level analysis, such as Pearson's correlations, Analysis of Variance (ANOVA), and regression. HLM has the distinct advantage of allowing for the analysis to be conducted simultaneously at multiple levels by using procedures that let the researcher examine relationships among variables within a nested structure, such as students within a classroom, thereby preventing the bias toward the rejection of the null hypothesis and thus the inflation of Type-I errors (Frank, 1999; Raudenbush & Bryk, 2002). As a result, estimations can be made for between-classroom variables (e.g., classroom climate) and within-student variables (e.g., mathematics self-efficacy and achievement). In addition, HLM also has the unique ability to account for the violation of the interdependence of observations assumption. Given that students within a class represent a cluster and, therefore, share similar educational experiences, their responses to survey items or answers on achievement examinations would not necessarily be independent of one another.

Recommendations for Policy

It is important to accept certain "givens"; the diversity of students choosing to attend college is increasing (Hussar & Bailey, 2008); most students entering college have low self-efficacy in mathematics; and most students entering college will be required to successfully complete at least one mathematics course, such as college algebra, to graduate college. Therefore, it would seem that providing classroom climates conducive to enhancing student success in mathematics is imperative.

Colleges and universities can be instrumental in the academic success of students enrolled in undergraduate mathematics courses. All newly hired mathematics instructors could be required to either have a K-12 teaching certification and/or to have successfully completed teacher preparation coursework (e.g., educational psychology, human growth and development, development, diversity). Another avenue would be to require instructors to attend professional development workshops focused on methods and strategies aimed at developing favorable classroom climates that enhance student self-efficacy. Professional development could be provided in the form of paid workshops instructed by national experts, seminars taught within the university's School of Education, or departmental meetings addressing topics dealing with how to enhance student learning.

In sum, current trends suggest that a much smaller percentage of undergraduate students are completing degrees in mathematics than is needed to meet increasing demands for mathematics proficiency in the workforce. Although insufficient supply to meet demands in the workforce tends to ensure more competitive salaries and benefits for those who meet the need, relatively few undergraduate students are choosing to pursue mathematics education. One explanation for this may be the structure of undergraduate mathematics education.

The review of the literature presented in this paper documents the relationships between mathematics self-efficacy and mathematics achievement and classroom climate and self-efficacy. Combined, the studies imply that climate influences self efficacy and therefore achievement. In particular, learner-centered climates in which instructors seek to empower learners, show empathy and are committed to learner success have been shown to foster growth in learner confidence and self-efficacy. Rethinking how undergraduate mathematics courses are taught to incorporate strategies and approaches that support development of learner self-efficacy could lead to increased enrollment in mathematics courses and subsequently, help meet the need for a more mathematics proficient workforce.

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