

Mathematics Self-Efficacy of College Freshman

By J. Michael Hall and Michael K. Ponton

Students lack the ability to identify factors that limit their success [in mathematics].

ABSTRACT: The purpose of this study is to determine differences in mathematics self-efficacy between students enrolled in a developmental mathematics course and those enrolled in a calculus course. Data from a sample of 185 freshmen students at a single 4-year institution using the Mathematics Self-Efficacy Scale are analyzed. Results indicate that calculus students possess not only better mathematical skills but also a more powerful sense of self-belief in their ability to succeed in a college mathematics course. The results of this study suggest that future teaching methodologies should be designed specifically for students enrolled in developmental courses that not only develop mathematics capability but also a self-awareness of increased capability. Efficacy-enhancing instructional strategies should be tested for effectiveness, thereby improving the teaching and learning process for all learners.

Students' ability to learn and succeed in mathematics has been a concern of educators for many years, especially since mathematics seems to be a determinate of not only choice of a college major but also serves as a determinant in the acquisition of a college degree. Trusty and Niles (2003) assert that high school students earning high school credit in rigorous math courses have a much greater likelihood of success in acquiring a bachelor's degree than students not completing such a course. Related research has been conducted in an attempt to establish a relationship between success in mathematics courses and success in college. For example, several studies (Campbell & Hackett, 1986; Hackett, Betz, O'Halloran, & Romac, 1990) have determined that previous mathematics performance and perceived ability are both key elements for success in mathematics. Furthermore, research (Dorner & Hutton, 2002; Moreno & Muller, 1999; Hagedorn, Siadet, Fogel, Nora, & Pascarella, 1999) indicates that, although many courses aide students in the completion of a college degree, mathematics is the subject most essential to students' choices in determining college majors and ultimately to success in attaining a college degree.

The number of students enrolling in colleges and universities, and consequently in developmental courses such as developmental mathematics, has continued to increase over the past 30 years to a level where 3 out of 10 first-time freshman students are enrolled in such a course (Breneman & Haarlow, 1998; Smittle, 2003). With the number of students requiring developmental courses growing yearly, many colleges and universities are continuing to invest money in these courses by creating additional courses, hiring new faculty, and sometimes creating new departments for developmental studies. As a result of colleges spending valuable resources on developmental coursework, many in the faculty and surrounding community want assurance that the funding for developmental courses is not wasteful. In addition, Arendale (2003) notes that both legislatures and boards of higher education desire to make institutions more accountable for remediation of students. Therefore, creating quality instruction in developmental courses has become a priority at many institutions.

At its core, developmental education should attempt to expand the academic skills of students. Hence, relationships between the students enrolled in developmental courses and cognitive factors such as self-efficacy need to be established. Research (Breneman & Haarlow, 1998; Higbee & Thomas, 1999; Stanley & Murphy, 1997; Wheland, Konet, & Butler, 2003) indicates that, for developmental mathematics students, academic self-concepts, attitudes toward success in mathematics, confidence in ability to learn mathematics, mathematics anxiety, self-efficacy, and locus of control are all variables that affect student goals, performances, and attainments in mathematics. Higbee and Thomas opine that for educators to be effective, they must have an understanding of how students cognitively process information.

Wheland, Konet, and Butler (2003) suggest that many students attribute poor performances in mathematics not to themselves, but to factors out of their control. Such factors include instructors, time and day of class, and instructional style. At the same time, students lack the ability to identify factors that

J. Michael Hall
Assistant Professor
Department of Mathematics and Statistics
Arkansas State University-Jonesboro
P.O. Box 70
State University AR 72467
mhall@csm.astate.edu

Michael K. Ponton
Professor of Education
School of Education
Regent University
1000 Regent University Drive
Virginia Beach, VA 23464

limit their success. Furthermore, Higbee and Thomas (1999) assert that correlations between mathematics anxiety, test anxiety, and lack of confidence in one's ability to complete mathematical tasks do exist and may possibly indicate that student achievement is not only related to external factors, such as the faculty member and their instructional style, but also to student attitudes toward mathematics. Furthermore, because of the mandatory enrollment associated with developmental classes, previous research (Bassarear, 1986; Higbee & Thomas, 1999) indicates that there is a stigma associated with being labeled as a remedial math student. The embarrassment of enrollment in remedial mathematics is especially damaging to females and minorities (Green, 1990) and their perception of mathematics (Glennon & Callahan, 1968). Research by Betz and Hackett (1983) suggests that educators need to gain a complete understanding of how these individuals are affected academically by such stigmas because many career decisions are based on the perception of ability to excel in a given field.

It is hypothesized in this study that personal beliefs in capability may be one of the inhibitors to success for students enrolled in courses such as developmental mathematics. Personal belief in capability to organize and execute actions to produce outcomes is defined as self-efficacy (Bandura, 1997). Perceptions of self-efficacy are derived from four sources of information: (a) personal accomplishments, (b) verbal persuasion, (c) vicarious learning experiences, and (d) physiological and affective reactions (Bandura, 1986). To be more specific, each of these sources of self-efficacy serves as a primary determinant of how individuals make choices, expend effort to achieve goals, and persevere through the completion of these goals (Bandura, 1997; Schunk, 1996). Thus, individuals with low levels of self-efficacy feel as if they do not possess the requisite skills necessary to perform given tasks.

Human behavior is motivated by anticipatory thought processes in which the capability of forethought is used to cognize desirable future states and select courses of action that are ideated as paths to these states. This process is mediated by capability perceptions perhaps without the presence of actual capability (Bandura, 1997; Zimmerman, 1990). Hence, although students may lack all the necessary skills to perform tasks, motivation with self-efficacy can serve as a mechanism through which students overcome finite ability and successfully achieve the desired goals (Bandura, 1997; Zimmerman, 1990; Zimmerman, Bandura, Martinez-Pons, 1992). Conversely, students who do not feel efficacious in per-

forming tasks and lack motivation to do so have no incentive to exert effort (Schunk & Pajares, 2002). Therefore, self-efficacy is a mediating factor for academic outcomes, cognitive engagement, and performance (Patrick & Hicks, 1997).

Purpose

Self-efficacy has been shown to be a mediating factor in human achievement across numerous domains, thereby necessitating research that focuses attention on the difficulties of accomplishing tasks. One such area of difficulty for numerous individuals is the ability to complete a college-level mathematics course. Being able to establish a relationship between perceived ability to successfully accomplish mathematical tasks and class enrollment (i.e., developmental vs. calculus) could serve college and university programming efforts. It would allow for the creation of programs and instructional methods aimed at creating self-sufficient learners capable of making choices concerning their ability to complete tasks and accomplish goals. Unfortunately, there is a lack of research comparing the self-efficacy of developmental students to nondevelopmental students. Therefore, the purpose of this research was to examine the differences in the mathematics self-efficacy of freshman students enrolled in Developmental Mathematics (Intermediate Algebra) and Calculus I.

Study Description

The subjects in this study were random cluster samples of intact classes enrolled in one of two freshman-level mathematics courses (Intermediate Algebra, $N = 375$, and Calculus I, $N = 400$) at a medium-sized, rural, state, research university in the Southeast for the Fall 2001 semester. Placement of the students into each of the classes is based on American College Test (ACT) math sub scores. The ACT is comprised of four sections (i.e., reading comprehension, mathematics, verbal, and science reasoning) each having a range of scores from 0-36. Similar to other U.S. colleges and universities, the University of Mississippi uses the ACT as a method to evaluate student ability in courses such as mathematics. Calculus I is designed for engineering, physical science, and mathematics majors with ACT math sub scores above 25, whereas Intermediate Algebra is taken by students in nonmathematics majors with ACT math sub scores of 16 or less. At the University of Mississippi Intermediate Algebra is the course designation for developmental mathematics. The sections of each class chosen to participate in the study were

randomly selected clusters from the total number of sections offered.

Students enrolled in the class sections chosen for participation were approached during the first month of the fall semester and asked to participate in the study. Since student participation was completely voluntary, it was explained that failure to participate in the study would have no effect on their grade or standing in the class.

Sample

The sample consisted of 185 freshman students from four sections of Calculus I and four sections of Intermediate Algebra. Of the total 185 participants, 80 were enrolled in Calculus I and 105 were enrolled in Intermediate Algebra (see Table 1). Eighty-five of the students were male, and one hundred were female. It should be noted that questionnaires completed by nonfreshman students enrolled in either of the courses were not included in this sample. Within the courses, a total of 43 males and 37 females were enrolled in Calculus I, whereas a total of 42 males and 63 females were enrolled in Intermediate Algebra.

Table 1
Descriptive Data of the Sample

Class	Gender	<i>n</i>	%
Calculus I	All	80	43.2
	Male	42	52.5
	Female	38	47.5
Intermediate Algebra	All	105	56.8
	Male	42	40.0
	Female	63	60.0

Note. $N = 185$

Instrumentation

Consisting of two subscales and a total of 34 items, the Mathematics Self-Efficacy Scale (MSES) was originally developed in 1983 by Betz and Hackett and contained 75 items. Revised in 1993 for the interest of parsimony, the current version of the MSES contains a Mathematics Tasks subscale and a Mathematics Courses subscale. The purpose of the Mathematics Tasks subscale is to measure student confidence in the ability to perform everyday mathematics tasks; the purpose of the Mathematics Courses subscale is to assess student confidence in their ability to earn a B or better in a college course that requires mathematical skills.

Betz and Hackett (1993) note that the content validity for the MSES has been demonstrated through research that validates each area measured by the instrument. They note that there were positive correlations between the MSES and other mathematics scales such as math anxiety ($r = .56$), confidence in doing

mathematics ($r = .66$), perceived usefulness of mathematics ($r = .47$), and effectance motivation in math ($r = .46$), thus enhancing the concurrent validity of the instrument.

Results

An independent t -test was conducted to determine if there was a significant difference between the mathematics self-efficacy of students enrolled in Intermediate Algebra and Calculus I as measured by the MSES. A two-sample Kolmogorov-Smirnov Test was conducted to validate the assumption of normality. The results indicated ($p = .580$) that the data were indeed normal, thereby allowing for the use of the two-sample t -test. The mean MSES score for the students in Intermediate Algebra was 5.33 ($SD = 1.4464$); the mean MSES score for the students in Calculus I was 7.08 ($SD = 1.1411$). The results of the t -test ($t = 8.902$, $p < .001$) suggested that the means are not equal (see Table 2). Thus, a significant difference between the level of mathematics self-efficacy between freshman students enrolled in Calculus I and Intermediate Algebra was demonstrated: Calculus I students exhibited a higher mathematics self-efficacy than the Intermediate Algebra students.

Table 2
 t -Tests of MSES Score by Class Enrollment

Class	Mean MSES	SD	n	t	p
Calculus I	7.08	1.1411	80	8.902	<.001
Intermediate Algebra	5.33	1.4464	105		

Note. $N = 185$

In addition, a Pearson product-moment correlation was also performed to determine if MSES scores correlated with individual ACT test scores. The results for all participants ($r = .580$, $p < .001$) and for the students enrolled in Calculus I ($r = .454$, $p < .001$) showed moderate correlations, whereas the results for students enrolled in Intermediate Algebra ($r = .052$, $p = .598$) indicated no significant correlation.

Since mathematics self-efficacy has been shown to be a mediating factor influencing choices of academic major by females (Betz & Hackett, 1983; O'Brian, Martinez-Pons, & Kopola, 1999), additional t -tests were performed (see Table 3) on data within each course concerning gender differences. In Intermediate Algebra, results of an independent t -test indicated that there was no significant difference in the MSES score based on the gender of the students ($t = .254$, $p = .800$). In Calculus I, the results of an independent t -test indicated that there was no significant difference in MSES score based on gender of the students ($t = .337$, $p = .737$).

Table 3
 t -Tests of MSES Score by Gender

Variable	Mean MSES	SD	n	t	p
Calculus I					
Male	7.111	1.0452	43	.254	.800
Female	7.046	1.2571	37		
Intermediate Algebra					
Male	5.392	1.3011	42	.337	.737
Female	5.294	1.5448	63		

Due to two independent variables on the dependent variable MSES, a two-way analysis of variance was performed to determine the main effects and interactions (see Table 4). The results indicate no gender main effect ($F = .167$, $p = .683$) and no significant interaction between gender and course enrollment on mean MSES score ($F = .007$, $p = .936$). Consistent with the t -test, the two-way ANOVA shows ($F = 75.753$, $p < .001$) that the mean MSES score of Calculus I students is unequal to the mean MSES score of Intermediate Algebra students, thereby suggesting a greater self-efficacy for the Calculus students.

Discussion

With 40% of all freshmen in 4-year colleges and universities requiring developmental education of some kind (Smittle, 2003), faculty at these institutions are charged with the task of not only being able to recognize deficiencies in students but also adjusting instructional methods in a way that enables each student the same opportunity to succeed in a college classroom. If students have not achieved success in high school mathematics, additional

Table 4
Two-Way Analysis of Variance of MSES Score by Class and Gender

Source	SS	df	MS	F	p
Class	133.977	1	133.977	75.753	<.001
Gender	.295	1	.295	.167	.683
Class*Gender	.0115	1	.0115	.007	.936
Error	320.117	181	1.769		
Total	459.194	184			

pressure is placed on developmental mathematics instructors. This pressure is heightened by the identified link between success in mathematics and college success (Trusty & Niles, 2003). Also, self-efficacy is one area specifically shown to aid individuals in the determination of how much effort they should expend in order to complete a task. Bandura (1997) suggests that individuals attribute their

self-efficacy to past experiences and how those experiences relate to them personally. Self-reflection of exposure to, or lack of exposure to, mathematics classes is therefore the primary source of mathematics self-efficacy. In essence, it is difficult for students to objectively evaluate themselves on topics for which they have little knowledge.

Therefore, exposure to mathematics with positive outcomes increases mathematics self-efficacy, whereas exposure to mathematics with negative outcomes decreases self-efficacy, provided the positive outcomes are attributed to increase in personal capability and/or effort by the student.

Implications for Practice

Most educators would agree that a given amount of mathematical knowledge is necessary for all college graduates. Although not all students need to learn calculus, all students do need a comfortable level of mathematical ability that does not limit life-altering choices, such as the choice of a major. Thus, the role of educators should be to do whatever is necessary to aid students in increasing their perception of actual ability. In classes such as Intermediate Algebra, raising the mathematics self-efficacy of all students to a level where students' choices are not limited should, therefore, be a primary concern of educators.

Research conducted by Trusty and Niles (2003) indicates that high school students completing rigorous mathematics courses have much higher levels of success in college than students who do not earn credit in such a course. Developmental education is a method to offer students who have not had the opportunity to be successful in mathematics

such an opportunity, especially important in a content area recognized as a gatekeeper to college retention and success. By fusing the concepts of developmental education and rigor of mathematics, teachers of developmental mathematics courses could hold the key for college success. For this reason, it is suggested that teachers of developmental mathematics courses create

a learning environment conducive to fostering self-efficacy in developmental students while keeping the rigor of the course comparable to other college courses. This may be accomplished by several means. For example, giving students chances for success in small increments can serve to improve their mas-

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tery experiences. Additionally, creating an environment that exhibits the magnificence of mathematics and its implications to other fields can allow students to see practical applications that may be of interest to them. Lastly, encouraging students to ask questions regarding mathematical operations and applications and then serving as a guide through discussion can augment student understanding that mathematics holds the key to many fields of study and ultimately to choice of major.

Past experiences, often times failures, in mathematics usually dictate student opinions concerning their perception of personal ability in mathematics as well as their optimism about career choices for which mathematics is the basis of the curriculum. Therefore, without confidence in mathematical ability, students' choices of majors, and ultimately their futures, may be limited to nonmathematical areas. Though some students would naturally choose to major in such an area, the point is to broaden students' choices rather than limitations. Hence, institutions of higher learning and educators themselves should implement modes of instruction that develop and enhance self-efficacy in groups of students with lagging self-concepts of mathematical ability. Doing so would allow students to more adequately gauge their actual ability, thereby helping students to make better choices concerning their future.

Because self-efficacy has been shown to be a mediating influence on motivation and performance (Bandura, 1997; Ponton, Horine-Edmister, Ukeiley, & Seiner, 2001), enhancing mathematics self-efficacy should be an important part of any effort to aid in the academic growth of students enrolled in lower-level mathematics classes. Too often educators attempt to teach students with low mathematics self-efficacy in the same manner by which students that have higher levels of mathematics self-efficacy are taught. By altering instructional methodologies educators can assist students to create more meaningful mastery experiences in mathematics. Ponton et al. propose that faculty consider two suggestions when attempting to design mastery experiences for students: (a) What exactly do we want the students to master? and (b) How are we going to let them know? It should be the role of a faculty member to clearly define for the students the importance of the explicit/implicit material, create mastery experiences to enhance knowledge and skill, develop modes of assessment that accurately assess desired attainments, and highlight to students actual increases in capability (Ponton,

et al.). Pointing out increases in capabilities may be even more important for students in developmental courses because, in order to increase choices that influence life trajectories, changes in actual capability must be accompanied by adjustments to self-efficacy.

Future Research

With the results of this research indicating differences in levels of mathematics self-efficacy for students enrolled in Intermediate Algebra versus students enrolled in Calculus, prospects for future research concerning the mathematics self-efficacy and students enrolled in developmental mathematics courses are promising. First, specific instructional strategies need to be evaluated longitudinally to determine their influence on enhancing self-efficacy beliefs. Second, Cassazza (1999) has shown that the fastest growing segment of higher education is the number of nontraditional-aged learners, and research regarding self-efficacy should be conducted

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with this population. Lastly, many students entering college are simply not prepared in high school to be successful in college mathematics classrooms. Factors contributing to this unpreparedness may include, but are not limited to, the physical size and location of the high school, mathematics courses offered at the high school, and the highest mathematics class completed in high school. Therefore, additional research should include the development of instructional methodologies that focus on increasing the mathematics self-efficacy and ability of each subgroup identified as having substandard levels of each.

Contrary to previously established research (Betz & Hackett, 1983; Hackett, Betz, O'Halloran, & Romac, 1990; Lent, Lopez, Brown, & Gore, 1996; O'Brian, Martinez-Pons, & Kopala, 1999) suggesting that females possess lower levels of mathematics self-efficacy than males, the findings of this study suggest that there is little difference in the mathematics self-efficacy between males and females. Various factors that might contribute to differences in the findings include the possibility that the females participating in the study do indeed possess higher levels of mathematics self-efficacy than their male counterparts. It is also possible that the participating females inaccurately assessed their level

of mathematical ability, thereby necessitating additional research to determine not only the sources of information each gender group uses to determine self-efficacy but also to further establish the relationships between gender and mathematical ability.

Conclusion

Unsuccessful attempts have been made to enhance mathematics self-efficacy through training (Rushing, 1996). Students in Rushing's treatment group were given specialized materials such as teacher-created vocabulary lists, individualized study guides, and journaling materials aimed at improving their understanding of the mathematical material and their self-efficacy. Though such attempts may seem futile, it must be noted that learning mathematics has been a lifelong struggle for many students. Thus, development and classroom implementation of new tools for learning subjects that have continually plagued students is quite difficult and challenging for faculty and students.

There are no easy solutions to the complex problems that confront students with low levels of mathematics self-efficacy. However, continual attempts should be made at enhancing the learning experience for students who have been shown to have low levels of self-efficacy thereby enabling individuals to master the important concepts of mathematics while enabling them to become lifelong, self-regulated learners. To maximize their impact on students' lives, developmental courses must not only develop actual skills but also a positive self-image of capability.

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