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Shaping The Self Efficacy Beliefs Of First Year Engineering Students: What Is The Role We Play?

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Abstract

Numerous studies have linked undergraduate students' interests, performance, and retention in science and engineering fields to self-efficacy. The research also suggests that female science and engineering students have poorer self-efficacy beliefs, those beliefs about their capabilities to perform the tasks necessary to achieve a desired outcome, than do their male counterparts. This study is aimed at identifying factors related to students' self-efficacy beliefs during their first engineering course. Results are presented from a mid-semester survey administered to freshman engineering students (n = 1387) enrolled in ENGR 106, *Engineering Problem-Solving and Computer Tools*, at Purdue University. The survey incorporated qualitative measures of student self-efficacy beliefs. Open-ended survey questions prompted students to list those factors affecting their confidence in their ability to succeed in the course. Gender trends emerged in student responses to factors that affect confidence in success. These trends are discussed in light of the four categories Bandura[1] has identified as sources of self-efficacy beliefs: mastery experiences, vicarious experiences, social persuasions, and physiological states. The results presented here provide a useful look into how the classroom and curricular practices being employed during students' first year in engineering affect confidence, and ultimately, retention and success.

Introduction

Currently, the fields of science and engineering are faced with two major challenges in producing the necessary workforce for the future: recruiting students to the fields and then retaining those who do enroll through the completion of their degrees. Significant steps are now being taken to increase interest in these fields and boost enrollments of students into related programs. Science and engineering programs must also modify the learning environment to retain more students than they currently do if the demands for the workforce of the future are to be met. National trends show that the retention rate of women in these fields varies from 30 to 46 percent, depending on the size and type of institution studied, while, for their male counterparts, rates vary from 39 to 61 percent.[2] These data indicate that retention is poor on the whole, but also that the problem is more significant among women.

The occurrence of poor retention in science and engineering fields has already become the focus of numerous studies. Results of these studies have linked the efficacy beliefs of undergraduate students in science, technology, engineering, and mathematics (STEM) programs

to their persistence,[3-10] achievement,[3, 4, 11, 12] and interest[3, 11-14] in these fields. For example, Lent et al.[3] found that students' confidence for which they could complete each of ten engineering majors with an overall grade point average of B or better predicted their interests in technical activities (e.g., "solving complicated technical problems," "reading articles or books about engineering issues") and their expectations for positive outcomes resulting from earning a bachelor of science degree in engineering (e.g., "earn an attractive salary," "get respect from other people," "do work that I would find satisfying").

Such studies support Albert Bandura's social cognitive theory which represents humans as self-regulating individuals rather than individuals who function solely on reactions to internal or external events.[15] He introduced the concept of self-efficacy beliefs, an individual's beliefs that he or she has the abilities necessary to complete specific criterial tasks (e.g. complete an engineering major with a grade point average of B or better), as a major contributor to human behavior. Specifically, individuals' beliefs and behaviors are explained as "reciprocal interactions among personal, behavioral, and environmental factors."[16]

Beyond connecting students' self-efficacy beliefs to interest, performance, and retention, studies have shown women to be particularly influenced by efficacy beliefs. Research suggests that many women who leave STEM programs have less confidence in their abilities than those who stay in the programs ("stayers"), despite earning similar grades.[9, 17-20] Moreover, female stayers possess lower self-efficacy perceptions than their male colleagues.[21-25] Brainard and Carlin[18] noted at least 25% of undergraduate women persisting in engineering and science programs most frequently cited "lack of self-confidence" as a barrier that challenged their persistence; by senior year, the percentage of women citing lack of confidence as a barrier nearly doubled to 44%. In a cross-institutional study (17 institutions), Besterfield-Sacre et al.[22] noted that at the end of their freshman year, female engineering students maintained lower confidence in their basic engineering knowledge and skills, problem-solving abilities, and overall engineering abilities than male engineering students.

While the literature is rich in studies assessing students' self-efficacy beliefs in the fields of science and engineering, there is little to draw from when trying to determine what can be done to promote positive self-efficacy beliefs, and therefore interest, performance, and retention, among students. Answering this question entails establishing how students arrive at these beliefs.

Bandura has defined four sources from which efficacy beliefs are developed: mastery experiences, vicarious experiences, social persuasions, and physiological states.[1] Self-efficacy beliefs are shaped by mastery experiences through one's interpretation of his or her performance with a particular task. Actions leading to outcomes perceived as positive by the individual will raise self-efficacy while perceived negative outcomes will lower self-efficacy. Theory and research predict mastery experiences as the single most influential source of student self-efficacy beliefs.[26, 27] Vicarious experiences are slightly less influential; however, when individuals are unsure of their abilities in a certain area or have no experience in the area, their beliefs will be influenced by how they perceive the outcomes experienced by others who have performed similar tasks. The result of vicarious experiences on individuals' self-efficacy beliefs depend largely on the extent to which the individuals see similarities between themselves and those

whom they observe. The verbal judgments of others, called social persuasions by Bandura, can also influence self-efficacy beliefs. In traditionally male-dominated fields, vicarious experiences and social influences may play a more dominant role in the formation of women's self-efficacy beliefs.[28-30] Finally, physiological states associated with an action, whether they be anxiety, stress, fatigue, or any other emotion, can also be somewhat influential on individuals' self-efficacy beliefs.

To date, studies aimed at identifying the determinants of students' efficacy beliefs have been primarily quantitative in nature. Researchers have hypothesized sources of college student self-efficacy beliefs (based on studies of institutional climate and student development), developed quantitative measures for these sources, and identified sources of significant increments in self-efficacy variation.[1, 3, 13, 21, 22, 28, 31, 32] Fewer qualitative studies of self-efficacy belief formation have been conducted. Zeldin and Pajares used a case study methodology to investigate how the self-efficacy beliefs of women graduates succeeding in mathematics-related careers were developed and maintained.[29] Lent et al. employed a thought-listing cognitive assessment technique to identify the factors affecting the mathematical self-efficacy beliefs of undergraduate students in an introductory psychology course.[33] These studies had conflicting results, likely due to the different characteristics of the subjects employed and to different criterial tasks on which the efficacy judgments were based.[22, 34] Qualitative studies of the influences contributing to the gender gap in computer science and the influences leading undergraduates to switch from STEM majors into non-science majors help elucidate factors contributing to students' general self-confidence, "... a general, trait-like self-belief of capability that fails to specify the object of that belief."[35] However, the heuristics with which students form specific efficacy beliefs from these sources were not investigated.

As argued by self-efficacy theorists, a discovery-oriented, qualitative approach is required to better understand the sources and cognitive processing of student self-efficacy beliefs.[36-38] This study is designed to answer the question: Which aspects of students' first course in the field of engineering are most influential on their self-efficacy beliefs? Within the study, factors affecting students' self-efficacy beliefs associated with their first semester in engineering have been identified using an exploratory approach. Responding to an open ended question concerning their ability to succeed in their first college engineering course, students have discussed factors they find particularly influential on their confidence in this ability. Those factors emerging as significantly affecting students' beliefs are described in detail and categorized using Bandura's framework for sources of self efficacy beliefs.

Research Design

Theoretical Framework

This study was conducted with a phenomenographical focus. Phenomenography, developed in large part by Marton and his co-workers[39], is a study of, "…the limited number of qualitatively different ways in which we experience, conceptualize, understand, perceive, apprehend, etc., various phenomena in and aspects of the world around us" (p. 4424). These different ways of conceptualizing or understanding are then categorized by description and

logically related to each other to form a sort of outcome space for the ways in which the phenomenon under investigation is perceived.

This study was designed to identify those factors affecting students' self-efficacy beliefs. Often confused with phenomenology, the study of the single essence of an experience shared by all, phenomenography looks at the various ways in which different people perceive the same experience. It is established within the literature that men and women have different self-efficacy beliefs and that these beliefs further vary even among members of the same gender. Therefore, it is apparent that there is not a single essence associated with the experience of students' first year in engineering. Rather, how students perceive the experience will vary, falling into several categories of perception, lending this study to a phenomenographical focus.

Participants

The participants for this study were 1387 freshmen engineering students enrolled ENGR 106, *Engineering Problem Solving and Computer Tools*, at a large Midwestern university. Required of all first year engineering students for admittance into any of the engineering professional schools, the 2.00 credit hour course covers engineering problem solving, computer logic and the use of computer software (UNIX, Excel, MATLAB), teaming, and statistics and economics in an engineering context. Of the students surveyed, 81.9% (n = 1136) were men and 18.9% (n = 251) were women. Ethnically, the group was 66.7% (n = 925) Caucasian American, 11.4% (n = 158) International, 6.1% (n = 85) Asian American, 2.7% (n = 37) Hispanic/Latin American, 2.6% (n = 36) African American, 0.7% (n = 10) Puerto Rican, 0.1% (n = 2) Native American Indian, and 3.0% (n = 41) another unlisted ethnicity. The remaining 6.7% (n = 93) of the students provided no ethnicity data.

Procedure

An engineering efficacy survey was administered to all students enrolled in ENGR 106. The survey was presented to students as a required on-line, WebCT[40] homework assignment two weeks following their first exam. By administering the survey at this particular point in the semester, students had some experience with the ENRG 106 environment, assignments, and exams on which to base their confidence, but were not far enough into the semester that their course grade could be determined.

Instrument

The survey administered to ENGR 106 students probed students' perceptions of the learning environment and their efficacy beliefs.[41] This paper focuses on a subset of the survey questions aimed at assessing students' confidence in their abilities to succeed in ENGR 106 in addition to identifying those factors that they attributed to influencing their confidence. Students' self-efficacy beliefs concerning ENGR 106 were first assessed using a Likert-scale like item patterned after the cognitive thought-listing technique employed by Lent.[33] Students were asked to think about ENGR 106 and rank the extent to which they agreed with the statement: "I am confident I can succeed in ENGR 106." Following this item, students were told to reflect on all of the factors they considered when ranking their confidence and to briefly describe them.

They were encouraged to report everything that came to mind. After listing all of the factors they considered, students were asked to rank the factors from most to least influential.

Analysis

Due to the large number of students enrolled in ENGR 106, smaller sample populations were selected for analysis using stratified random sampling. The population of men and women were each stratified by ethnicity (Table 1) and randomly sampled based on a 95% confidence level and a confidence interval of 5. Sample sizes of 284 men and 152 women were analyzed. Within these samples, blank student surveys and those exhibiting ambiguity in the factors discussed were rejected and replaced; this lead to the rejection and replacement of 61 surveys submitted by men and 11 submitted by women.

	Men		Women	
	# in Sample	% of Sample	# in Sample	% of Sample
Caucasian	191	67.3 %	102	67.1 %
International	34	12.0 %	12	7.9 %
Asian American	17	6.0 %	10	6.6 %
African American	6	2.1 %	9	5.9 %
Hispanic/Latin American	8	2.8 %	4	2.6 %
Puerto Rican	2	0.7 %	0	0.0 %
Native American Indian	0	0.0 %	1	0.7 %
Other/No Response	26	9.3 %	14	9.2 %
Total	284	99.5 %	152	100.0 %

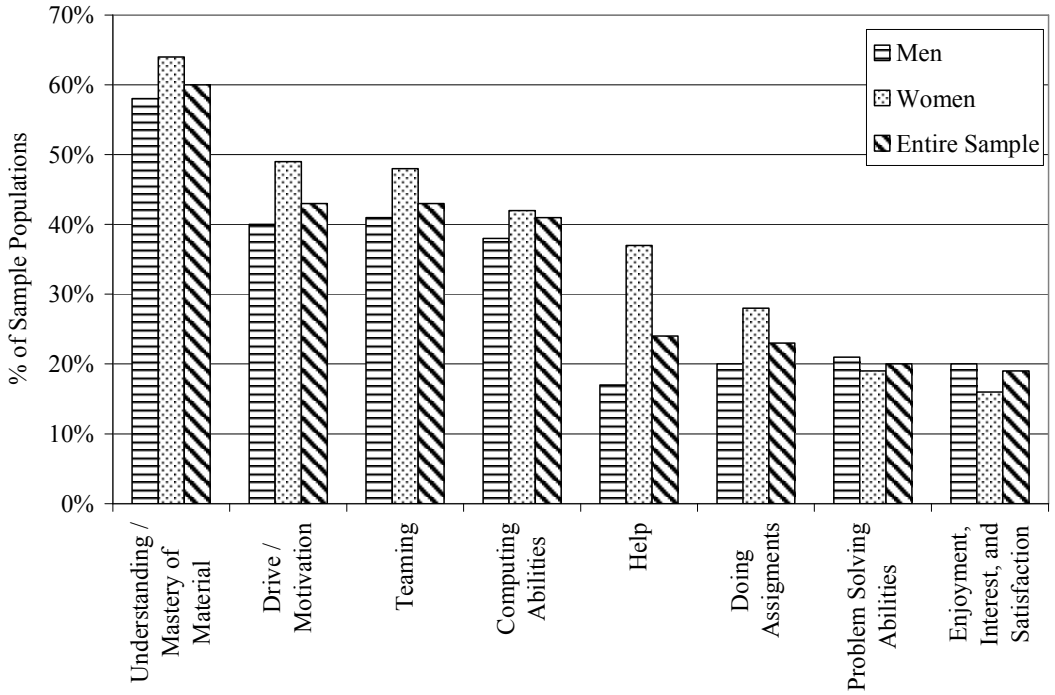
Table 1: Demographic description of sample population.

Analysis was performed using the qualitative data management program, ATLAS.ti, version 5.0.[42] Each sample was entered into ATLAS.ti and analyzed separately. Responses were coded based on the factors students listed as influencing their confidence in their success in the course. Once a list of factors cited by students as affecting their confidence was generated, those factors affecting a significant portion of the class (~20%) were identified. Each of these was then further coded to include more detail as well as whether students indicated it as a positive or negative influence. Specifically, data analysis looked at factors listed as highly influential by both men and women and variations in factors reported by men and women.

Results

Analysis of student responses to the factors affecting confidence in success in ENGR 106 revealed eight prominent factors. These factors were understanding or mastery of the material; drive or motivation toward success; teaming issues; computer abilities; the availability of help and ability to access it; issues surrounding doing assignments; student problem solving abilities; and enjoyment, interest, and satisfaction associated with the course and its material. The percentage of sampled men and women, as well as the percentage of the entire sample population, mentioning each of these factors is summarized in Figure 1.

Figure 1: Factors indicated by students as influencing efficacy beliefs.



Each of the factors is also further defined and discussed in light of Bandura's four identified categories for sources of self-efficacy beliefs: mastery experiences, vicarious experiences, social persuasions, and physiological states.

Understanding. The factor listed most frequently by students as influencing their confidence in success in ENGR 106 was their ability to learn or understand the material presented in the course. Further, the concepts of learning and understanding appear to affect men and women to nearly the same degree. Few students indicated being affected specifically by understanding or lacking an understanding of homework assignments ("I am understanding the work more than I did before so my confidence level is higher."), lab tasks ("Some of the labs feel very rushed and are finished when I don't really understand how."), projects, engineering economics ("I don't understand Engineering Economics as well as I should."), lecture ("I understand what we talk about in lecture."), or reading material; the large majority of students that indicated an item falling within this category listed a general understanding or ability to learn the material without any more specifics ("My ability to understand new concepts quickly and fully."). While most students cited a boost in their self-efficacy beliefs because they did understand or were capable of learning the course material, it would be reasonable to expect that their self-efficacy beliefs would be negatively affected should they encounter material that they did not understand. Within Bandura's categories of sources for self-efficacy beliefs, understanding can be categorized as a mastery experience; students become more highly efficacious when they are able to understand and learn material, but experience diminished beliefs when they feel they are not learning or grasping course material.

Drive and Motivation. A strong desire to succeed in ENGR 106 or engineering in general was also expressed by a large number of students. This factor seemed to be slightly more influential among women than men. Students expressing this sentiment made statements such as, “If I want to be an engineer I am going to be an engineer, I am not going to give up my goals,” and, "If I don't get the grade I want, I will work harder." These students all expressed an internal locus of control mentality: with enough persistence, determination, and hard work, they could achieve success. Less than 5% of the sample population associated negative self-efficacy beliefs with a lack of drive and motivation; this factor appears to almost always positively affect students. Drive and motivation may be characterized as outcome expectations, beliefs that certain behaviors or wants, such as hard work or the desire to become and engineer, will lead to desired outcomes, success in ENGR 106 for example.[8] According to Bandura, such beliefs bias the ways in which individuals process sources of efficacy information.[26] For example, people who regard ability as an acquirable skill evaluate mastery experiences more by personal improvement than by comparison against the achievement of others. People who view ability as an inherent aptitude are “prone to measure their ability by social comparison and to belittle their own accomplishments when others surpass them.”

Teaming. The concept of teamwork is stressed as highly important in ENGR 106 in order to prepare students for this aspect of engineering. Nearly half of the sampled students indicated teaming as influential on their belief that they would be successful in the course[a]. A slightly higher percentage of the women sampled cited teaming as affecting their self-efficacy beliefs; however, the variation between genders was not significant. Of the students who mentioned this factor as affecting their beliefs, two different aspects of teaming emerged in the students’ responses. Many students, both male and female, described heightened confidence in their success based on the discovery that they possessed the ability to work well in a team; this is what most students referred to as teaming skills. Examples of students statements to this effect include, “I think this class has honed my teaming skills and I think I can do well in the real world team work,” and “Using my teaming skill and being able to work together as a team after all this class is partly to teach us how to work in a team.” The other large majority of students, both men and women, discussing teaming were more highly efficacious due to the support, help, and motivation they received from their team members. These students looked at their team as a small support group that raised confidence through interactions. They made comments such as, “My team members help and encourage me,” and “Working with a team was really a great experience. Having someone to rely on was nice, and I grew confident in their skills as well as mine by the end.” In both cases, most students cited teaming as increasing self-efficacy beliefs. A few students indicated that they were not confident they would succeed due to the poor quality of their team, though, these students were the minority. It can be inferred, however, that students whose confidence is raised due to a successful teaming experience would likely be negatively affected by a poor teaming experience. Student mastery of teaming skills is an efficacy belief source falling into the category of mastery experiences, while, students discussing the support of their team members are likely using social persuasions in part as sources of self-efficacy beliefs. Likely, these social persuasions lead to mastery experiences with the material that further increase beliefs.

[a] Team-based work accounts for 30% of the ENGR 106 course grade.

Computing Abilities. Computing abilities affected about the same fraction of men and women, however, variations were seen in how they were affected. Responses given by students who expressed computing as influential included abilities using one or all of the programs or computing environments taught in ENGR 106 (Excel, MatLab, and Unix), programming abilities, and the ability to use a computer in general. The break down of student comments concerning computing abilities is summarized in Table 2.

	Student Comments			
	Male		Female	
	Positive	Negative	Positive	Negative
Abilities Using Software	7%	0%	4%	3%
Excel Abilities	23%	2%	22%	4%
General Computer Skills	14%	3%	8%	4%
Matlab Abilities	20%	5%	17%	12%
Programming Abilities	11%	1%	4%	4%
Unix Abilities	13%	1%	13%	4%

Table 2: Computing factors affecting students' efficacy beliefs.

The largest portion of both men and women indicated that they had experienced an increase in self-efficacy due to their ability to use the Excel and MatLab programs; however, the percentage of men indicating this was higher than that of women. Further, a significantly larger portion of women than men indicated MatLab as a negative influence on their confidence in success. A slightly smaller portion of men and women indicated positive beliefs associated with being able to work in the Unix environment. While an appreciable number of the men surveyed discussed their abilities to use a computer and their programming abilities as positively influencing their confidence, only a very small number of women expressed these sentiments. Overall, very few men discussed computing as negatively affecting their self-efficacy beliefs, while nearly one-third of the responses given by women described feelings that they may not be able to succeed due to a lack in computing abilities. This source of self-efficacy beliefs arises from the mastery experience of using a computer and its applications. Students who feel that they have mastered these abilities experience more positive self-efficacy beliefs than those who do not feel this way.

Help. The largest gender variation discovered in this study emerged from students' discussions of getting help in ENGR 106. This factor was found to be significantly more influential among women than men. While many more women than men discussed getting help as a factor influencing their confidence, among those students who did mention it, results were quite similar. Two aspects of getting help in the course were mentioned: the numerous resources available for help and the students' ability to recognize when and how to seek help. Nearly all of the students sampled who discussed getting help in ENGR 106 cited it as increasing their confidence in their success. Over half of these students claimed that they were confident they would succeed due to the fact that there were many different avenues they could use to attain help. The majority of the remaining student responses focused on an ability to recognize when help was needed, how to get help, and how to use help effectively to benefit their success. A very small portion of students sampled (<15) discussed doubts in their success because they did not know how or where to get help for the course. These sources of self-efficacy beliefs are likely two-fold. Students who seek help may have their beliefs shaped by social persuasions

experienced through interactions with those from whom they are receiving help. Additionally, students may associate mastery experiences with receiving help when the help leads to mastery of the material.

Doing Assignments. A significant fraction of both the men and women sampled discussed their ability to complete assignments as influential on their confidence in success in ENGR 106. This factor was found to affect women slightly more than it did men. While the vast majority of men indicated being positively affected by the fact that they were able to complete assignments, only about a quarter of the women sampled expressed these same sentiments; many more described experiences of being affected negatively or having their confidence vary from assignment to assignment depending upon the degree to which they were able to complete it. The source of these students' self-efficacy beliefs can be categorized as a mastery experience. Students' confidence in success is increased when they are able to master an assignment but is lowered when an assignment cannot be completed.

Problem Solving Ability. Students' problem solving abilities appeared to influence nearly equal portions of men and women. Variation was seen, however, in how problem solving abilities affected each population. All but two of the 54 responses given by men concerning their problem solving abilities indicated confidence being raised due to what the men perceived to be their successful problem solving abilities. Conversely, women were not as confident that their problem solving abilities would lead them to success; only three-quarters of the women sampled were affected positively by their problem solving abilities while the rest saw them as detrimental to their success. Again, students' efficacy beliefs are being shaped by whether or not they feel they have mastered the ability to use problem solving techniques effectively.

Enjoyment, Interest, and Satisfaction. Similar portions of men and women sampled discussed their enjoyment, interest, and satisfaction in ENGR 106 as being influential on their self-efficacy beliefs. The majority of students, both male and female, discussing these factors were influenced positively; enjoying the course material or being interested in it or satisfied by it increased their confidence in their success in the course. Less than a quarter of the men and women sampled indicated that they felt less confident in their abilities because they were not enjoying the course, were uninterested in it, or were not satisfied by it. Influence on self-efficacy beliefs in this manner could be categorized as a physiological state of enjoyment and satisfaction leading to heightened efficacy beliefs. Interestingly, about half of the students discussing these feelings also mentioned having mastered the aspects of the class that they found satisfying or that they enjoyed, indicating that it was specifically the material they had mastered that they enjoyed and not necessarily the course in general. For these students, mastery experiences are also likely playing a role in the shaping of efficacy beliefs.

Conclusions

This work supports the theory that within Bandura's categories of sources of self-efficacy beliefs, mastery experiences are the most influential. Eight significantly influential factors affecting students' confidence in their success in ENGR 106, seven of which that can be either directly or indirectly categorized as a function of mastery experiences on the part of the student, have been identified. The factors identified as affecting students' response to the statement: "I

am confident I can succeed in ENGR 106," include understanding or mastery of the material; drive or motivation toward success; teaming issues; computer abilities; the availability of help and ability to access it; issues surrounding doing assignments; student problem solving abilities; and enjoyment, interest, and satisfaction associated with the course and its material. With the exception of drive and motivation, all of these factors can be linked to mastery experiences, suggesting that classroom and curricular practices should be structured to allow students many opportunities for achieving and confirming mastery of material. Explicitly, this study suggests work should be done toward boosting women's confidence in their abilities to use a computer, program, and problem solve. Likely, because women appear to respond so positively to help, this will best be achieved through providing help resources that allow students opportunities for mastery experiences in these areas.

While this study is a first step in gaining understanding of the sources of student self-efficacy beliefs, more needs to be done to make possible a description of the cognitive processing leading up to the formation of these beliefs. Student survey responses have been explicitly categorized, however, many of these responses require more investigation. For example, it remains unclear as to whether students citing "help" as a factor are affected by encouragement received from those providing help, mastery experiences brought about through help, the vicarious experience of seeing the abilities of others, or any other host of possibilities. Further, many students mentioned understanding as strongly affecting their confidence in success, however, elaboration on what understanding is to the students and how they achieve it is needed. To gain such insight, one-on-one interviews with students are being conducted. Analysis of these interviews will lead to improved insight into and better understanding of the shaping of self-efficacy beliefs. This knowledge will allow for the creation of learning environments designed to promote students' self-efficacy beliefs and thereby increasing students' confidence, success, and retention.

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