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Engineering Student's Mathematics Self-Efficacy Development in a Freshmen Engineering Mathematics Course*

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Engineering student's self-efficacy beliefs are strongly tied to their successful navigation of the engineering curriculum. Mathematics self-efficacy has been shown to be especially important to engineering student retention during the critical first two years of the curriculum. The purpose of this study is to investigate the changes in students' mathematics self-efficacy over the course of a freshman engineering mathematics course and examine the reasons that these changes occurred, using a mixed methods research approach. As a group, students' belief that they could solve mathematics problems (problem mathematics self-efficacy) improved, but their belief that they could be successful in future mathematics courses (courses mathematics self-efficacy) did not. Following individual analysis, differential factors for groups of students who increased, decreased, or remained the same in each construct are described. Educators can use results to incorporate efficacy-developing aspects of their mathematics courses.

Keywords: self-efficacy; mathematics self-efficacy; engineering retention

1. Introduction

In the United States, the retention of engineering students has been a constant issue for many decades [1, 2]. Similar trends in science and technology majors across Europe have spurred researchers investigating into how to increase the current numbers of research and professionally driven scientists [3]. Previous research on retention in undergraduate science majors has identified the first two years of college as the most critical time for retaining engineering students. Seymour and Hewitt [2] identify it as the 'primary period of risk.'

Mathematics courses are predominant during these first two years of the collegiate engineering experience, generally beginning with calculus. Additionally, students normally do not take statics and other subsequent engineering courses until the beginning of their sophomore year. This combination poses two retention-threatening concerns: 1) students fail to integrate themselves into engineering programs; 2) difficult weed-out mathematics courses cause students to feel as though they cannot succeed in engineering. As part of an effort to combat the poor state of engineering education, Wright State University has developed a course that serves as a prerequisite to engineering courses such as statics and electrical fundamentals. This allows entry and exposure to the engineering curriculum earlier than the traditional model, which places differential calculus as a prerequisite for statics [4]. Washington State University (WSU) has implemented a modified version of this course, with the goal of increasing retention of engineering students who do not place into calculus out of high school. The course (labeled 'EngrMath-Introductory Mathematics for Engineering Application,' or EngrMath) provides an alternative to the regular university pre-calculus course, with an additional focus on applying mathematics to engineering problems, and giving exposure to fundamental calculus concepts. The primary focus of WSU's course is to address the effect of the difficulty of mathematics courses on student persistence in engineering by providing a successful early mathematics experience. Although completion of EngrMath does not serve as a prerequisite to engineering courses as it does at Wright State University, the material from the Wright State University course was used in EngrMath because of its emphasis on students working out problems within the context of engineering.

EngrMath is designed to assist the student's transition from high school mathematics to college-level calculus, and provides a successful first mathematics course experience. For example, the course includes transitional material from pre-calculus to introductory calculus, a small class atmosphere with a focus on active learning, and access to social resources including other students, a teaching assistant, and a laboratory session, all in contrast to a more standard university pre-calculus, which is lecture-based and enrolls larger numbers of students. Support for WSU's transition course concept is identified in a study at Boise State University,

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which found that the persistence of engineering students was highly correlated to performance in first-time mathematics courses, regardless of course level [5]. The findings by Gardner *et al.* [5] are representative of the expectations of Self-Efficacy Theory, which predicts that people are more likely to perform tasks that they believe they can achieve [6]; beliefs that, in the case of incoming college students, are heavily dependant on their experiences during the first college semester [7]. By experiencing a successful first-time mathematics course, students develop a higher mathematics self-efficacy, or perceived mathematics ability, which increases the likelihood that students will choose science and mathematics-based educational pathways [8–10]. The objective of this study is to examine students' mathematics self-efficacy and the factors in EngrMath that influence mathematics self-efficacy through a mixed methods case study approach.

2. Mathematics self-efficacy and WSU's engineering mathematics course

Self-efficacy is a concept introduced by psychologist Albert Bandura, defined as 'beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments' [6, p. 3]. Researchers have used this concept to address the realm of mathematics self-efficacy (MSE), or a person's belief in his or her ability to successfully perform mathematics. Research across this topic has demonstrated that students with higher MSE are more likely to choose science and mathematics-based majors and careers [8–10]. Owing to the mathematics-intensive coursework in engineering, particularly in the vital early years of undergraduate study, engineering is a strong example of a field where a student's MSE affects decisions to persist or leave the course. MSE serves as a focal point from which to address retention in engineering.

In the engineering curriculum, calculus is generally identified as a first-year mathematics course, yet over 40% of first-year college calculus students fail the course [11]. Bandura [6] postulates that if failures are experienced before one's sense of self-efficacy is developed, the creation of future positive self-efficacy beliefs can be difficult. EngrMath intends to sidestep this initial negative experience on student MSE as a transition course from pre-calculus to calculus. We believe initial success in EngrMath will promote positive student MSE beliefs that will encourage persistence in engineering.

2.1 Research justification

Examining self-efficacy requires a focus on one specific context, such as mathematics, as individuals may have high self-efficacy in one area and low self-efficacy in another. Research that examines both measurement of and sources/processes that influence self-efficacy in collegiate mathematics courses is sparse, and necessary to develop theories of self-efficacy development and associated curricular implementations to positively influence self-efficacy.

Bandura has hypothesized four sources of influence on self-efficacy development, which include: mastery experiences, vicarious comparisons, social persuasions, and physiological and affective states. Mastery experiences involve a person's interpretations of his/her past performances, and are supported as the most powerful source of self-efficacy [10, 12]. Vicarious comparisons are a person's interpretation of his or her performance in comparison with the performance of another individual, and whether they conclude it to be a success or failure. Social persuasions refer to encouragements that a person receives from influential sources, including peers, teachers, and parents. Lastly, physiological or affective states are symptoms such as stress and anxiety that are stimulated as a result of a specific event or grouping of events. A study on freshman students' engineering self-efficacy [13] further validated Bandura's hypothesis by intentionally seeking student responses that did not fall within the confines of one of the four established sources, none of which was found. A study by Zeldin *et al.* [14] found that among the collegiate experiences that influenced the self-efficacy beliefs of successful men and women in STEM (science, technology, engineering, and mathematics) careers, physiological states were the only source not found to be of significant influence to their self-efficacy beliefs. Additionally, assessing physiological states relies on identifying cognitive associations between experience and emotion, and such associations are difficult to generalize, especially when different emotions can elicit similar physiological responses [6]. Consequently, physiological states were not investigated in this study.

Schunk [15] has advocated the need for research done in a class setting to understand the effects of teaching and learning on student self-efficacy. While MSE research has since addressed student self-efficacy in classroom settings, expansion into a college setting has been minimal. Hall and Ponton [16] examined the effects of a calculus course and a developmental mathematics course on the relative change of college freshman students' MSE. Although Hall and Ponton [16] identified changes in students' measured self-efficacy, they did not address *why* such changes occurred, or the influences on self-efficacy development. In a contrasting study, Hodges and Murphy [17] identified the most prominent sources impacting students' self-efficacy in an online college mathematics course. However, the extent of self-efficacy change was not addressed, nor were class-specific examples of identified sources discussed. There lies a gap between these two research endeavors that can be filled by a study that simultaneously measures student self-efficacy change and associated sources of self-efficacy in a college engineering mathematics course.

Further evidence of this gap lies in the extensive, largely independent research utilizing quantitative and qualitative methods. Historically, quantitative methods have been consistently used in MSE research among large populations to quantify changes in self-efficacy [16, 18], relationships between self-efficacy and other motivational constructs on specific outcomes [8–10, 19–21], and relative impacts of the four hypothesized sources of self-efficacy [10, 17]. However, these methods are restricted by their numerical outputs, as they cannot depict *why* such changes occur. Researchers have since proclaimed the need for qualitative methods [12, 15, 19], which have been less commonly used in MSE research to vividly describe the mechanisms/sources that influence people's self-efficacy [14, 22, 23]. However, their interpretive nature limits their population size, and has produced debate regarding their ability to generalize findings, as they cannot be objectively applied and replicated.

Unlike the historically common use of one sole methodology, mixed methods research allows the researcher to 'simultaneously ask confirmatory and exploratory questions and therefore verify and generate theory in the same study' [24, p. 33]. We aim to utilize a mixed method case study approach to provide a holistic accounting of students' self-efficacy development and answer the research questions below. In order to develop a well-founded, theoretical model that exercises a complete understanding of MSE, a sufficient body of diverse, applicable contextual research that includes both MSE changes and why those changes occur must first be conducted.

1. Does students' mathematics self-efficacy increase, decrease, or remain the same following their participation in EngrMath?
2. What are the prominent mechanisms/sources impacting EngrMath students' mathematics self-efficacy?

In this study, 'sources' are defined as the previously-mentioned categories classified by Bandura [6] as having influence on self-efficacy development. 'Mechanisms' are defined as the class-specific influences identified by students that fall within the established sources. We aim to address the challenge proposed by Bandura [6] by identifying mechanisms within the established self-efficacy sources that have resulted in different self-efficacy developments among the EngrMath students. Although the specific nature of EngrMath restricts the ability to generalize our findings, it will operate as an inaugural step towards engineering MSE application, incorporating contexts covered in beginning core engineering courses, and providing insight for the development of similar courses across the country.

3. Course details and eligibility

Eligibility standards for EngrMath were equivalent to those of WSU's standard pre-calculus course, based on the highest score of student SAT, ACT, and ALEKS mathematics placement tests. ALEKS is an online learning program that supplies instructors with resources to assign homework, quizzes, tests, and monitor student progress and areas that are in need of improvement. It is an intelligent testing system used for mathematics placement at WSU. EngrMath enrolled 27 students, four of whom had no prior exposure to pre-calculus, and half of whom had been exposed to calculus in high school, but tested at a pre-calculus level. Although the course was designed for students who had previously experienced pre-calculus, exceptions were made for students who placed higher, but who felt more comfortable taking a 'refresher' course before attempting college-level calculus, as well as for students who placed slightly lower than at the pre-calculus level. Enrollment was limited to students pursuing engineering, but did not distinguish between specific engineering disciplines.

EngrMath consisted of two 1-hour lecture periods and one 3-hour laboratory period per week. The first ten weeks of the course were dedicated to teaching pre-calculus concepts, including basic algebraic operations, exponents, radicals, exponential and logarithmic functions, linear and quadratic equations, graphing functions, trigonometry, 2D vectors, and systems of equations. The remaining five weeks focused on introducing students to calculus concepts of derivatives and integrals within the context of engineering problems. The course aimed to provide students with significant numbers of such contextual mathematics problems, and extensive opportunities for active learning during the lecture period.

The laboratories were arranged for the students to experience hands-on application concurrent with the concepts they were learning in the lecture period of a given week. The laboratories consisted of six application laboratories (Table 1) and three computer-based review laboratories. The computer-based review laboratories were designed to increase the students' familiarity with the workings of the

Table 1. Laboratory topics in EngrMath

• Lab 1—Exponential Growth and Decay	• Sampling performed to model exponential growth; Basic cell and graphing functions of Excel
• Lab 2—Application of Algebra in Engr.	• Measuring current, voltage, and resistance in multiple circuits; Linear and parabolic equations
• Lab 3—Application of Trigonometry in Engr.	• One-link and two-link arms to determine coordinates and angles using horizontal and vertical arm components; Right triangle properties; Law of sines/cosines
• Lab 4—Statics	• 2D vectors; Systems of equations
• Lab 5—Freefall Application of the Derivative	• Relationship of position, velocity, and acceleration; Theoretical versus measured values
• Lab 6—Spring Work Application of the Integral	• Concepts of work and energy related to spring displacement

ALEKS program, and provide them with practice problems relevant to the course topics covered prior to each laboratory. The ALEKS placement test is utilized for mathematics eligibility at WSU, and was therefore required of EngrMath students to determine their mathematics placement for the following semester. After 10 weeks in the course, pre-calculus concepts had been covered, and the ALEKS placement test was administered to the students. The students who did not place into calculus were given the option to retake the exam the following week. Students failing to test into calculus were required to enroll in a standard university pre-calculus course the following semester.

4. Methodology

A case study approach was employed, with the goal of gathering detailed descriptive data that would provide the opportunity to include rich descriptions of the participants' experiences in EngrMath. A case study design dictates studying a phenomenon within a particular context. In our case, we are studying the MSE phenomenon in the context of an engineering mathematics course. As a result of their dependence on context, case studies are concerned with studying multiple variables, as well as triangulating multiple analysis methods, in which individual responses are the unit of analysis [25]. In our case study, the goal was to collect information on each student in the course using multiple methods to allow for a pre- and post-assessment of their MSE. This would be used as an indicator of student efficacy change; and to study multiple variables (i.e. efficacy mechanisms/sources) that may have led to changes in their MSE. An overview of the data collection is shown in Fig. 1.

We assessed pre- and post-MSE using quantitative and qualitative measures to indicate changes in MSE that occurred, in addition to gathering qualitative descriptions of students' background mathematics experiences and experiences in the EngrMath course that may have contributed to their MSE development. Stronger inferences could be made for consistent results between both methodologies, and inconsistent or contradictory findings could yield meaningful inferences that would not be possible using a solely quantitative or qualitative methodology [24]. Students were reassured that all information would remain confidential, and that the surveys/interviews were not associated with their performance in the course, nor would they be evaluated until the course was over. The researcher did not look at the surveys until after the course was complete and final grades had been submitted. All qualitative analysis measures to identify changes in MSE and sources of MSE were performed prior to any quantitative measures in order to avoid any

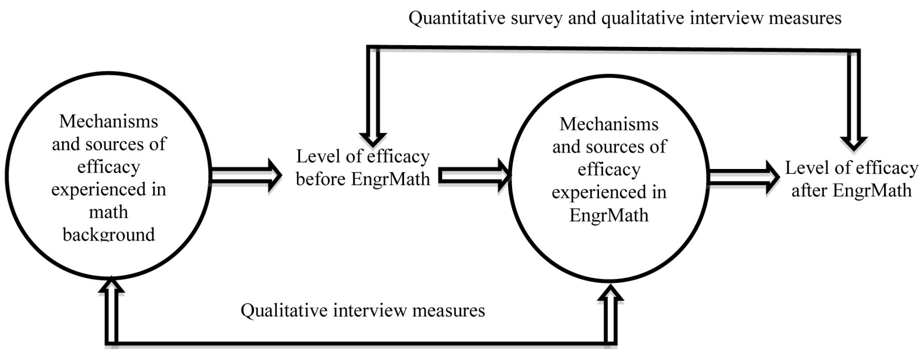

Fig. 1. Data collection timing and focus.

interpretive bias during analysis of students' interviews.

4.1 Quantitative survey

This study utilized the Mathematics Self-Efficacy Survey (MSES) developed by Betz and Hackett [8]. The survey was originally developed for the college setting, and has been widely used throughout MSE research. It consists of 52 questions within three MSE subscales, including mathematics problem-solving, everyday mathematics tasks, and mathematics courses, for which students must respond by rating their confidence for each question on a Likert scale ranging from *no confidence at all* (0) to *complete confidence* (10). The subscale topics address algebra and geometry-based mathematics problems, situations outside of the classroom that require mathematics, and the ability to get an A or B grade in various college-level courses involving mathematics. Both the full-scale original survey and its subscales were independently validated with coefficient alphas ranging from 0.90 to 0.96 [8]. Revised versions of the MSES have been tested with coefficient alphas between 0.90 and 0.95 [10, 21, 26].

Two revisions were made to the MSES for use in this study. The everyday mathematics tasks subscale was not included in the survey, because a student's perception of their ability to perform relatively simple everyday mathematics tasks like calculating discounts was deemed not to be directly related to the course content and to a student's decision to stay in or leave engineering. The second revision was made to the mathematics courses self-efficacy (C-MSE) subscale, in which 8 of the original 15 courses were not included. The courses not included, while involving mathematics, are not typically part of the engineering curriculum of most engineering disciplines, and include physiology, business administration, philosophy, computer science, accounting, economics, zoology, and biochemistry. The mathematics problem solving the self-efficacy (P-MSE) subscale includes concepts within algebra, geometry, and basic mathematics operations, and is considered relevant to the topics and procedures covered in EngrMath, therefore this scale was not modified for use in this study.

4.2 Qualitative interviews

The protocols followed a semi-structured, open-ended format, engaging students in questions that were designed to yield responses regarding MSE and the mechanisms/sources that influenced them. Both protocols contained specific questions that addressed the student's current level of MSE towards mathematics ability and upcoming mathematics class performance, which were analogous to the P-MSE and C-MSE subscales used on the MSES. The development of the pre-course interview protocol was based on Usher's [22] qualitative investigation of the sources of students' MSE, including questions addressing students' mathematics background and experiences, and their expectations for EngrMath [27]. The post-interview protocol was designed to elicit responses regarding students' experiences in EngrMath (i.e. mechanisms/sources) that influenced students' MSE. Sample interview questions for each protocol are provided in Table 2.

Each interview took place in a small, quiet room and lasted approximately 20 minutes. The pre-interviews were conducted by the EngrMath instructor and co-author (Burnham), which was appropriate because a relationship had not been established with the students, and little reason for bias in student responses existed. No evidence of student bias in responses or discomfort during the interviews was found. The pre-interviews were not read by the co-author until the final grades for the course were submitted. In order to avoid the large potential for bias in the final interviews, they were not conducted by the instructor/co-author, but by a graduate student with extensive experience on the topic of MSE and conducting qualitative interviews. The graduate student was briefed extensively on the interview protocol, and understood the responses

Table 2. Sample interview questions

Pre-interview protocol	**Post-interview protocol**
Efficacy sources and influence sample questions	
1. Tell me about a class that you felt confident in your ability to perform the tasks you were given.	1. What experiences have affected your confidence in math? How and why?
2. What have your teachers told you about how you are in math? Did that change how you feel about your ability in math?	2. Tell me about some positive and negative aspects of the class.
Current mathematics self-efficacy level sample questions	
1. If you were asked to rate your ability in mathematics on a scale of 1 (lowest) to 10 (highest), where would you be? Why?	1. If you were asked to rate your ability in mathematics on a scale of 1 to 10, where would you be? Why?
2. How do you feel about your upcoming college mathematics courses?	2. What mathematics class are you planning on taking during the spring semester? Tell me about your feelings towards this upcoming class.

each question was intended to elicit. All interviews were audio recorded and later transcribed for data analysis.

4.3 Data analysis

The first goal of the analysis (in response to the study's question 1) was to determine, quantitatively and qualitatively, if students' MSE had increased, decreased, or stayed the same. An initial analysis was conducted to determine if any correlation existed between students' responses to the P-MSE and C-MSE subscales, with the intention that, if students' responses on the surveys and interviews showed the same increase or decrease in self-efficacy towards mathematics ability and mathematics course performance, then the subscales would be analyzed as one aggregated subscale. However, no meaningful relations were found between students' responses to these scales for either methodology. This finding is supported by Bandura [6], who suggests that people possess different degrees of self-efficacy that are specific to the task in question. For example, self-efficacy towards a specific mathematics capability must be addressed separately from self-efficacy towards a different mathematics capability. Therefore, responses to each subscale were analyzed separately.

Both survey subscales were evaluated for internal reliability, where values of 0.85 and 0.90 were found for the pre- and post-P-MSE subscale, respectively, and values of 0.58 and 0.77 were observed for the pre- and post-C-MSE subscale, respectively. A paired sample t-test was performed using students' pre- and post-survey responses, where scores for the P-MSE and C-MSE subscales were analyzed independently. This was done as an initial means of determining whether the students experienced a statistically significant change in efficacy. Additionally, as is required by our case study methodology, we used a well-established statistical measurement for finding the standard error of difference between two samples (pre- and post- survey scores) to determine a statistically significant value of change for each student [28]. Individuals were deemed to have a changed MSE if the average scores on their pre- and post-surveys changed by more than the determined value for each subscale.

The purpose of the qualitative analysis, with specific regard to the first question of the study, was to identify students' P-MSE and C-MSE levels before and after EngrMath, for triangulation with the results of the quantitative method mentioned above. Our intent was to provide further perspective on each student's change in MSE by determining if a qualitative indication of change was made in addition or in contrast to quantitative changes. During this stage of analysis, special attention was paid to two types of student responses: statements of current MSE prompted by the current MSE level interview questions (see Table 2), and any such statement made as part of a response to any other question. In every case, students' responses addressed self-efficacy towards mathematics ability, and self-efficacy towards future college mathematics course performance (primarily their subsequent mathematics course). Responses were categorized and tabulated similar to Table 3, which illustrates typical student responses that were symbolic of each category.

Interpretation was limited to three different self-efficacy levels because, as Lent and Hackett [29] indicate, further increases in specificity would likely lead to corresponding decreases in external validity. Classification into more specific levels relies more heavily on interpretation, and higher degrees of interpretation would decrease the likelihood that similar results would be found by other researchers.

Internal consistency for student responses of self-efficacy toward future mathematics course performance was without error. During each interview, students' responses to multiple questions, each addressing future mathematics courses efficacy in a different way, all fell within the same self-efficacy level category. Internal consistency for students' self-efficacy toward mathematics ability was variable for approximately one-third of the class. In these cases, students gave responses depicting different levels of self-efficacy (primarily either 'high' and 'medium,' or 'low' and 'medium') depending on the variation of the question to which students addressed their mathematics ability. In these cases, special attention was paid to surrounding statements, and the tone and language that students used to answer questions throughout the interview. It was then determined which of the students' statements of self-efficacy were more accurately

Table 3. Types of mathematics self-efficacy responses

	High self-efficacy	Medium self-efficacy	Low self-efficacy
Mathematics ability	'I am good at mathematics'	'I am ok at mathematics'	'I am not that good at mathematics'
Mathematics courses performance	'I feel I will do well in future mathematics classes'	'I am unsure, but I think I will do all right in future mathematics classes'	'I am nervous for how I will do in future mathematics classes'

represented in each interview. A comparison between pre- and post-MSE levels was performed to identify if students' MSE increased, decreased, or remained the same. While changes are more difficult to detect qualitatively, as they may be more subtle and unable to be distinguished between three self-efficacy levels, students who *did* indicate a change were assumed to have experienced a larger magnitude of change than those who indicated no change.

For the purpose of addressing the study's second question—to identify mechanisms/sources of influence on students' efficacy—interview transcripts were coded following the pattern coding guidelines described by Miles and Huberman [30]. First-level coding involved funneling of the transcripts into broad sections of workable data, as well as allowing for familiarization with the data. The second round of pattern coding was performed through a self-efficacy lens, through which emergent mechanisms/sources were coded within the three self-efficacy sources under examination. This process required extensive exposure to interview data and the use of self-reflective measures of validity. Miles and Huberman [30] describe this as a way of thinking in which the researcher constantly challenges his or her own understanding with findings from multiple sources in order to elaborate on similarities or differences in their interpretations. This definition refers to things such as constantly cross-checking between relevant statements within a transcript, readdressing codes as they apply to multiple mechanisms/sources, and taking into consideration interpretations that reflect researcher bias.

In order to effectively and accurately depict our results, Mathison [31, pp. 16–17] suggests 'not only must the researcher report his or her data collection procedures but also the three levels of information [convergent, inconsistent, contradictory] from which explanations about social phenomena are constructed,' thus the 'plausibility of explanations are [made] public and open to discussion'. In this light, convergent, inconsistent, and contradictory findings between the surveys and interviews were examined in order to depict clearly how any conclusions were associated with trends identified in the results. Based on the change that was identified in each method, students were grouped into categories defined by their specific combination of MSE change, as shown in Fig. 2.

The groups were placed in one of three categories based on whether they experienced an overall increase, decrease, or no change in MSE. If a self-efficacy group indicated a change in self-efficacy for at least one of the methodologies, that group was categorized as 'increased' or 'decreased,' based on the change that was identified (groups 1, 2, 4 and groups 6, 8, 9 from Fig. 2, respectively). Only the group that exhibited no change in self-efficacy in both methodologies (group 5 from Fig. 2) was categorized as 'no change.'

Following categorization, the mechanisms/sources identified by students in the coding process described earlier were analyzed within each self-efficacy group (1–9 from Fig. 2) to identify whether individually recognized mechanisms/sources were more commonly identified in one specific group compared with others. This shed light on the most powerful influences on students' MSE in EngrMath, and how they potentially affected a student's expressed state of MSE. Although the P-MSE and C-MSE subscales were analyzed independently, the same mechanisms/sources of MSE could potentially affect students' perceptions of both P-MSE and C-MSE being measured, and were therefore discussed separately in terms of the subscale in which they were commonly identified. It was determined that if a mechanism was commonly identified by 75% or more of the students in self-efficacy groups with five or less students, and 60% or more of the students in self-efficacy groups with more than five students, the mechanism was said to be 'convergent' among the group, and was considered significant. Identification of convergent mechanisms in each self-efficacy group served as an initial filter to classify the most prominent mechanisms in EngrMath that likely influenced the specific self-efficacy outcome of the students in each group.

Based on the resulting number of students in each category for the C-MSE and P-MSE subscales, two different methods of analysis were used. For the C-MSE subscale, which resulted in a similar number of students in each category, each of the previously determined convergent mechanisms was compared by its proportional occurrence among the students

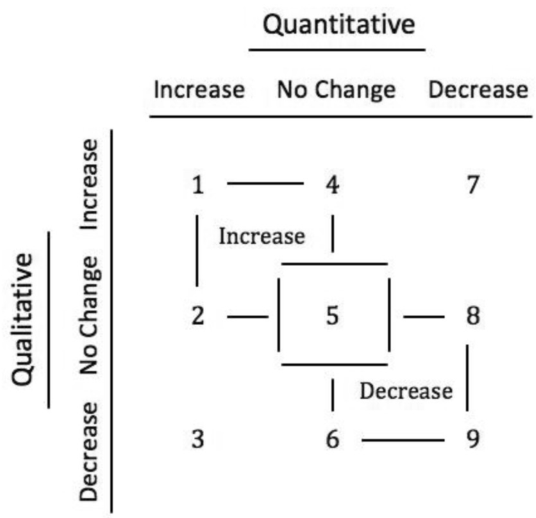

Fig. 2. Method of grouping students

Table 4. Paired sample t-test results

	Mathematics problem solving self-efficacy subscale		Mathematics courses self-efficacy subscale	
	Pre-	**Post-**	**Pre-**	**Post-**
Mean score	7.3	8.0	7.0	7.1
SD	1.0	0.66	0.90	0.89
Coefficient alpha	0.85	0.90	0.58	0.77
Significance	Significant at the 0.01 confidence level		Not significant	

who identified the mechanism in the increased, decreased, and no change categories, defined as its 'comparative proportion.' Mechanisms that had significantly higher proportions in one category than in others were passed through a second filter to determine if the percentage of students in the said category that indicated the mechanism consisted of an adequate number of overall students in the category (greater than 50%). This was done to safeguard against mechanisms that initially converged in only a single specific self-efficacy group with a small number of students. The number of students in each category in the P-MSE sub-scale was less balanced than the C-MSE sub-scale, with 15, 8, and 2 students in the increase, no change, and decrease categories, respectively. The 'comparative proportion' in this case could be misleading because 4 of 8 (50%) in the no change category is much different to 1 of 2 (50%) in the decrease category, despite being the same percentage of students. Because of this, a modified approach was used to determine explanatory mechanisms in each group. Both the number and proportion of students in a category citing a particular mechanism were considered when determining explanatory power. Specific cut-off numbers or percentages were not used, but both needed to be relatively high to consider the mechanism explanatory.

5. Results

The results of the paired sample t-tests for both of the survey subscales are tabulated in Table 4. The students' P-MSE increased from a mean value of 7.3 to 8.0, and was significant at the 0.01 confidence level. No significant group change was observed for the C-MSE subscale.

As mentioned in the 'Data Analysis' section, determining whether a change in self-efficacy occurred for each individual student required finding the standard error of difference for each subscale. The resulting values (at a 3σ confidence level) to be used as an indicator of individual efficacy change between pre- and post-survey scores are given in Table 5. Differences in average survey scores that were greater in magnitude than these values were categorized as 'increase' or 'decrease,' and differences of lesser magnitude were categorized as 'no change.' Table 6 summarizes how each student's MSE changed on the quantitative measures.

Table 5. Efficacy change indicator values

	$3\sigma_{diff}$ (99.7% confidence interval)
Mathematics problem solving self-efficacy	0.69
Mathematics courses self-efficacy	0.73

Based on the lack of statistically significant difference between pre- and post-C-MSE levels, it is understandable that the results from the analysis reported nearly two-thirds of the students as displaying no change in C-MSE. Furthermore, this helps to explain why the t-test gave such a report, because the number of students who experienced an increase was similar to the number who experienced a decrease.

The explanatory mechanisms/sources for each of the three efficacy change categories are presented in Tables 7 and 8, respectively addressing the C-MSE and P-MSE subscales. Background mechanisms/sources were only included if they were determined to be of direct influence on the students' MSE experiences in EngrMath. Mastery sources were found to be more prominent than any other source for the capabilities measured by each subscale. Vicarious comparisons and social persuasions were not found to have explanatory power in the formation of any student self-efficacy groups. (This finding will be addressed at the end of this section.)

Table 6. Quantitative changes in self-efficacy

	Number of students		
Survey subscale	**Increase**	**No change**	**Decrease**
Mathematics problem solving self-efficacy	15	10	2
Mathematics courses self-efficacy	5	17	5

Table 7. Mathematics courses self-efficacy explanatory mechanisms/sources

		QUANTITATIVE		
		INCREASE	NO CHANGE	DECREASE
QUALITATIVE	INCREASE	Groups 1, 2, 4 (10) Positive Mastery Experience - Placement Test - Understanding: Teacher's Instruction - Correcting Misunderstandings - Calculus Material - Understanding: HW: Outside Resources Negative Mastery Experience - Background: Lack of Recent High School Mathematics Exposure		7 (0) None Observed
	NO CHANGE		Group 5 (10) Positive Mastery Experience - Background: Always Excelled in Mathematics	
	DECREASE	3 (0) None Observed	Groups 6, 8, 9 (7) Negative Mastery Experience - Misunderstanding: Class Concepts	

5.1 Mathematics courses self-efficacy—C-MSE

5.1.1 C-MSE—Explanatory mechanisms for increased self-efficacy

There were six identified explanatory mechanisms that were prevalent among the students who experienced an increase in C-MSE. Successful performance on the placement test was understandably a highly recognized mechanism of influence on students' feelings regarding their subsequent mathematics course, which student 23 demonstrated in his comment:

I: 'How did you feel after taking the placement test?'

P: 'I feel confident to go on, like I can do good.'

For this student, his performance served as proof of his eligibility to advance and succeed in future mathematics courses. More specifically, for some students, having taken pre-calculus prior to EngrMath and performed poorly on the placement test initially, successful placement test performance was essential to their expressed improvement in C-MSE. As student 19 stated:

I: 'What experiences do you feel that you've had that have helped you prepare for the calculus class?'

P: 'Well just the extra courses that I've taken to get there, I didn't just place into it [calculus], I had to go through to high school, didn't place into it, then I had to come here [WSU], didn't place into in the beginning, and then I had to take another class [EngrMath] to place into it, so I just had that much more background to go into the class.'

This comment demonstrates that the placement test served as an important factor for the student to believe that he was ready to advance to calculus. Following completion of high school mathematics, the majority of students who entered EngrMath had failed to test into calculus. Students who experienced an increase in C-MSE sited their ability to overcome such failure in their first experience in the college setting as a factor.

Students for whom the instructor's teaching strategy was able to compliment their learning strategy experienced heightened C-MSE in EngrMath. Student 25 described the effects of this mechanism:

I: 'After taking the class, would you say your confidence in math has increased, decreased, or remained unchanged and why?'

P: 'I'd say increased because I mean I think [the instructor] is really good at going through like everything in detail and I honestly was able to like do all the homework and I felt like I knew what I was doing unlike other math classes.'

The student later attributes his preparation for his upcoming calculus class to the basic calculus concepts taught in EngrMath, with an emphasis on the instructor's ability to teach them. Since a teacher's instruction can heavily influence how students experience a course, being able to understand a teacher can likely influence a student's perceived ability to succeed in a course. Although future mathematics professors will possess their own unique styles of teaching, the students' ability to adapt and benefit from the instruction method in their first college mathematics course likely increased their perception of their ability to do so in future courses.

Although almost all of the students had been exposed to pre-calculus material prior to the course, students who increased their C-MSE explained that their experiences in EngrMath allowed them to correct misunderstandings left by previous classes. Student 14 described this experience when asked about his confidence development in EngrMath:

I: 'And would you say that Engineering 107 has helped your confidence in mathematics? Why or why not?'
P: 'Yes, because there [are] things that I didn't really get in the earlier mathematics classes through high school, and this helped me to fully understand and be more confident in doing it.'

Even more interesting was the fact that multiple students, who had previously taken a calculus course in high school, acknowledged that the four weeks of introductory calculus material taught in EngrMath allowed them to understand fundamental concepts that were previously confusing. Student 9 commented,

I: 'And do you think you'll be successful in [calculus]? Why or why not?
P: 'I think I'll be successful, I've taken a calculus class in high school but I didn't understand a lot of the concepts that engineering 107 taught me and now I do so I feel a bit better in that class.

By correcting previous misunderstandings, students felt better equipped for future mathematics classes that build on previously attained knowledge.

Aside from the combined effects of the calculus portion of the course with other self-efficacy mechanisms such as correcting misunderstandings, the calculus material taught in EngrMath proved very effective among students in this category. It was referenced as the primary material source responsible for students' preparation for calculus and increased C-MSE. It is understandable that such exposure would lead students to a heightened sense of self-efficacy towards their upcoming calculus course, because other equal-level standard curriculum courses present solely pre-calculus material. After learning calculus material in EngrMath, student 25 made the following comment regarding his upcoming calculus class:

I: 'What are your feelings toward [calculus]?'
P: 'I'm actually looking forward to it, I mean the basic calculus we're doing right now with derivatives and stuff I pretty much understand them . . .'

After being introduced to calculus, students felt they could begin their next course with material that they had recently learned, providing them with a more comfortable transition into their next mathematics course. This finding provides strong positive feedback for the transitional structure that was given special consideration in EngrMath.

The final two mechanisms indicated by the students in this category are special cases. Although they were not referenced by a significant number of students in this category, the conditions under which they were referenced implied a high likelihood of influence. The first mechanism was understanding the homework by the use of outside resources. The two students that identified this mechanism were the only two students in the class to do so, as well as the only two students who displayed an increase in C-MSE on both the quantitative and qualitative self-efficacy measures. By experiencing their first college mathematics course in an atmosphere in which they were able to positively experience the advantage of outside resources (tutors, internet, etc.), both students developed heightened feelings of confidence towards future mathematics courses. As Student 16 stated:

> 'I learned a lot about the tutoring centers here on campus. During the first few weeks of this class, I had to use those quite a bit. But I know I could use those for calculus too. So that's fine.'

His successful use of on-campus tutoring services, and knowing that they were available to help him in future mathematics classes increased his self-efficacy towards success in those future classes.

The second special-case mechanism was a lack of recent, relevant mathematics background exposure. Four students were in this category. The feelings expressed by each student are represented in this comment made by Student 12:

> 'I'm probably lower [in mathematics ability] because I took stats like the past couple of years. So, I haven't taken like an algebra-based course in awhile. So, I'll probably have to do some review to catch up. . . .'

This self-acknowledged need to catch up to a previously attained level of familiarity with relevant course topics may likely have contributed to the significant increase in C-MSE observed for these particular students. Because they had not recently experienced courses they felt were relevant to the upcoming EngrMath course, their exposure to the course significantly boosted their self-efficacy towards future college mathematics courses that utilize similar mathematical topics. This finding expands the transitional value of this course to include students who have not had recent algebra-based mathematics course exposure.

5.1.2 C-MSE—Explanatory mechanisms for no change in self-efficacy

The only mechanism that was significantly more prominent among the students that experienced no change in C-MSE was the belief that they had always been talented in mathematics. This finding not only explains the placement of students in this category, but also demonstrates that in such cases a lack of change in C-MSE is not interpreted as a failure of EngrMath to influence student's self-efficacy. For example, as student 10 described during his pre-interview:

I: 'How would you rate your confidence in math and why?'
P: 'Around eight or nine. I mean, I've always been pretty good at math. It's been one of my things. I don't know. My confidence is high, I guess.'

For this student, and the others for whom this comment is representative, after entering into EngrMath with high self-efficacy, they were able to maintain that level of self-efficacy throughout the course of the class. Furthermore, by not experiencing a decrease following their first college mathematics course, students' avoided the experience of a poor first-time college mathematics course performance and its associated negative self-efficacy effects during a critical educational transition period in which self-efficacy is highly vulnerable to influence [7]. The development of future positive self-efficacy beliefs, as well as persistence in engineering, was more likely for those students [5, 6]. Although these students ended EngrMath with a positive C-MSE experience similar to that of students whose C-MSE increased as a result of the course, the lack of relative C-MSE change probably contributed to the resulting lack of convergent self-efficacy mechanisms that help to influence change.

5.1.3 C-MSE—Explanatory mechanisms for decreased self-efficacy

Among the students whose C-MSE decreased, the only mechanism that significantly impacted this outcome was misunderstanding class concepts. For most of the students, conceptual misunderstanding was identified with regard to the calculus material in EngrMath. Student 6 demonstrated the overpowering effect of his difficulty in understanding calculus concepts:

I: 'Do you feel that you were successful in the EngrMath course?'
P: 'Somewhat, yeah.'
I: 'Somewhat.'
P: 'Got a good understanding of most things, but once it got into the hard stuff or the more advanced calculus or pre-calculus stuff, started to struggle a little bit.'

Later in the interview, when asked about his feelings toward his upcoming calculus class, he identified that he was *'a little scared for it.'* It is clear that despite understanding most of the topics in EngrMath, his specific misunderstandings of calculus concepts clearly had a dominating presence on his C-MSE development. This effect is similar to the previously established positive influence of calculus exposure toward students' increased C-MSE, whereas *not* understanding the calculus content of the course led students to show that even in the presence of some positive mastery experiences, negative mastery experiences can dominate the impact of a course on students' C-MSE. Misunderstanding class concepts had powerful negative effects on students' C-MSE, likely because such misunderstandings make it difficult to understand future topics that are required to build on those misunderstandings. The decrease in students' C-MSE may demonstrate that they did not feel their knowledge was adequate enough to build upon in subsequent mathematics courses.

5.1.4 C-MSE—Non-explanatory mechanisms

The influence of mechanisms in the class laboratory session as well as the mechanism of understanding class material were found to be in similar proportions in both the increased and no change C-MSE categories. It is especially interesting that misunderstandings in the laboratory session were almost equally as prominent in these two specific categories as were understandings in the laboratory session. When asked about his laboratory experience, Student 10 stated:

> 'Like the labs, like they kind of implement engineering ideas into the labs so it kind of needs like the mathematics that we use in the class and also like engineering ideas.'

However, later in the interview he responded:

> 'Yeah. I mean they went over the stuff we went over in class that week so I guess it kind of reinforced it, but it didn't relate enough to really help me.'

Although the student understood that the material was relating to engineering, he admitted that the context was too displaced for him to learn and benefit from the experience. Based on the increased and neutral C-MSE outcome of the students in these two categories, it is apparent that misunderstanding contextual application during the laboratory sessions did not have enough of an impact to negatively affect these students' C-MSE. As opposed to misunderstanding class concepts, it is possible that not understanding the application of such concepts in a particular context had less of an effect on students' perceived ability to succeed in future abstract, strictly mathematics courses. This modest amount of negative laboratory influence is mirrored in the influence of the positive laboratory experiences described by these students as well. Although some students whose C-MSE increased described a positive influence from their laboratory experiences, a similar number of students who experienced no change in C-MSE make the value of the mechanism less clear.

The final two mechanisms were recognized in similar proportions across each category, thereby holding significance to students' experience in EngrMath, but not possessing explanatory power to the self-efficacy outcome of any specific category. These included understanding homework by the application of classroom and textbook example problems. EngrMath was structured to provide extensive active learning opportunities, regularly utilizing classroom example problems. Although other sources are more clearly suggestive regarding their association with the abilities measured by the C-MSE subscale, it is unclear as to the direct effect of classroom and textbook examples on students' C-MSE. It is possible that students' ability to understand and apply and/or mimic classroom examples when working on homework gave them greater self-efficacy to follow the same procedure in future mathematics courses. While the influence of these mechanisms does not lend them to an explanation of any one group's self-efficacy experience, it does provide positive feedback for the active learning and example-rich structure of EngrMath.

Table 8. Mathematics problem solving self-efficacy explanatory mechanisms/sources

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="3">QUANTITATIVE</th></tr>
<tr><th>INCREASE</th><th>NO CHANGE</th><th>DECREASE</th></tr>
<tr><td rowspan="3">QUALITATIVE</td><td>INCREASE</td><td colspan="2" rowspan="2">Groups 10, 11, 13 (15)

Positive Mastery Experience
- Correcting misunderstandings
- Placement Test
- Calculus Material
Negative Mastery Experience
- Misunderstanding: Pace of Class</td><td>16 (0)

None Observed</td></tr>
<tr><td>NO CHANGE</td><td>Group 14 (8)
Positive Mastery Experience
- Preparation for Pre-calculus: Non-Specific Material from EngrMath</td></tr>
<tr><td>DECREASE</td><td>12*(2)
Positive Mastery Experience
- Placement Test
- Background: Always Excelled in Mathematics
Negative Mastery Experience
- Misunderstanding: Class Concepts</td><td colspan="2">Groups 15, 17, 18 (2)

None Observed</td></tr>
</table>

* Group 12 was the only group to display contradictory findings between both measures of self-efficacy. Therefore group 12 and the mechanisms they identified will be discussed independently of other groups.

5.2 Mathematics problem solving self-efficacy—P-MSE

5.2.1 P-MSE—Explanatory mechanisms for increased self-efficacy

Similar to the C-MSE subscale, by correcting misunderstandings, students were able to experience success in topics in which they had previously experienced failure, feeling as though they had broadened the range of their mathematical ability, and as a result increasing their P-MSE. Similarly, correcting such misunderstandings in calculus, or learning calculus material for the first time also promoted a corresponding increase in students' perceived mathematical ability. The placement test was the third and final mechanism that was dually prevalent among students whose self-efficacy increased in both the C-MSE and P-MSE subscales. Successful performance on the test was not limited to increased student perception of ability to succeed in future mathematics courses, but it was also instrumental in increasing the perception of their personal abilities to solve mathematics problems. This is evident in the following comment by Student 19:

I: 'Do you think [the placement test] impacted your performance [in the class] at all?'
P: 'I'd say yes to both a little bit of a positive and negative degree . . .Positive because I felt more confident in my math abilities after that. And then there was a catch 22 where when I felt a little too confident and I ended up getting some problems wrong that I shouldn't have.

Not only did this student's perception of his ability increase as a result of the placement test, but it increased to a level where he admittedly became overconfident in his own ability, demonstrating the powerful impact the placement test can have on students' P-MSE.

Misunderstandings that occurred in EngrMath due to the pace of the class were identified in this category as a special case, because only the two students who displayed an increase in P-MSE on both the quantitative and qualitative self-efficacy measures identified that problem. This provides for a very interesting analysis, because despite the students' well-substantiated increase, this convergent mechanism is a negative mastery source. However, although each student spoke of the pace of the class with a negative demeanor, their comments were followed by reassuring statements of success. Student 17 remarked:

> 'Because I believe he taught the class pretty well even though he went kind of fast on the material, but I still got it.'

Both students mentioned that they were also able to understand material and overcome their misunderstandings either during class or during teacher office hours. As Student 17 later commented:

> 'I would just say that like he kind of went too fast on the materials. I sometimes felt like he didn't explain it too well, but again, I could just ask him to expand on it.'

The combined mention of these positive and negative mechanisms provides insight into why the students' statements were reflective of an increased self-efficacy experience. These students experienced a fast-paced class that provided a consistent challenge for them, but only enough to allow them to overcome such challenges and experience success. Having multiple small successes by way of consistently overcoming small misunderstandings in EngrMath appeared to significantly improve their belief in their ability to persist and solve mathematics problems.

5.2.2 P-MSE—Explanatory mechanisms for no change in self-efficacy

Following the placement test, 24 out of 27 of the EngrMath students tested into calculus. The three students who did not test into calculus were among the students in this category. It is interesting to note that, while two of the students' C-MSE decreased following EngrMath, all three students displayed no change in P-MSE. These students felt better equipped for their upcoming pre-calculus class after having been exposed to material in EngrMath. Student 21 described this feeling:

I: 'How do you feel about your upcoming [pre-calculus] class?'
P: 'I'm actually pretty confident in it, because, like, this is [EngrMath], so . . . I think it's going to be really similar to stuff that I've already learned, so, like at first, the first part should be almost like a review, you know? And then, like, I'll be taking stuff that I'm pretty familiar with.'

This is significant, because despite these students' failure to test into calculus, the fact that their perceived mathematics ability did not decrease demonstrates the positive influence of EngrMath as a first-semester mathematics course. Not only did students experience pre-calculus material, they were additionally exposed to calculus material and engineering context problems, unlike many students in their future pre-calculus course. By maintaining P-MSE rather than diminishing it, this vulnerable first-semester EngrMath experience may encourage a higher likelihood of persistence than another class may have.

5.2.3 P-MSE—Non-explanatory mechanisms

The three mechanisms that were prevalent among similar proportions of the students in the increased and no change categories included understanding class material, and both understanding and misunderstanding laboratories. Although understanding class material was recognized by a higher proportion of the students in the increased P-MSE category, the proportion was not high enough above the proportion of students in the no change P-MSE category to be deemed significant. However, it is understandable that an increase in learned material would correlate with an increase in perceived mathematics ability, as is indicated by Student 9:

I: 'If you were asked to rate your ability in math on a scale from one to ten, where would you be and why?'
P: 'Probably a nine or a ten just because most of the concepts make a lot of sense to me right now.'

The effect of the laboratories was nearly the same for both the P-MSE and C-MSE subscales. Despite misunderstanding laboratories, students were able to increase or maintain their P-MSE, indicating that they did not associate high value with the laboratory session. It is likely that not understanding a contextual application of an understood concept is not as influential to students' belief in their ability to perform strictly mathematics problems. It is also very likely that some students *did* benefit by broadening their conceptual understanding to include new contextual applications. Student 11 describes one such instance:

I: 'Are there any other specific experiences in [EngrMath] that affected your confidence?'
P: 'I liked the labs just because, you know, you can apply it to actually doing it rather than just doing it on paper. It kind of helps you understand why, makes you feel like you're going to actually be using it.'

However, despite individual students' experiences, this mechanism was not identified to the extent that it explained their P-MSE outcome.

One mechanism that was frequently mentioned across each category was understanding the homework by application of classroom and textbook examples, which were described in a positive light by a large majority of students. It is clear that some students felt that the example problems improved their understanding and performance in the homework, which very likely contributed to an increase in P-MSE. Student 16 described this phenomenon below:

I: 'Would you advise future students of this class to take notes? Why?'
P: 'Definitely. Just like I said, you can use them when you are looking back at the homework because they're the same type of problems just different numbers. So you can follow them step-by-step and the more you do it, the more you understand it.'

It is important to note that whether such practices actually do benefit students' mathematics ability is irrelevant to MSE, because MSE is influenced by whether students *think* their ability is improved. Students who did not recognize this process as beneficial to their understanding likely did not improve their efficacy in such situations, an instance of which is described by Student 18:

> 'I guess, there's the difference when you see an example. Sometimes, you know that you have to do this [procedure] to work through it. And that'll give you a right answer, but you don't always understand why.'

Although there likely were situations in which example problems did help students to better understand the homework problems, these experiences did not differentiate between P-MSE categories.

5.2.4 P-MSE—Contradictory findings (Self-efficacy group 12)

Self-efficacy group 12 was the only group of the C-MSE and P-MSE subscales in which the quantitative and qualitative results contradicted each other. Since the group's true self-efficacy experience cannot be determined, the mechanisms identified cannot be deemed explanatory. They can provide insight into the resultant outcome of the group. Following their experiences in EngrMath, both students described instances of misunderstanding class concepts. However, prior to college, both students proclaimed that mathematics had always been a subject they excelled in and easily understood. Student 19 explains his experience:

I: 'After taking the class, would you say your confidence in mathematics has increased, decreased, or remained unchanged and why?'
P: 'It's decreased a little bit because I was always confident in mathematics in high school, so it was really easy for me and I came here [and] it wasn't as easy as I remember it being because I haven't taken mathematics in two years so.'

EngrMath challenged these students in a subject that they had been accustomed to excelling in, making it difficult for them to feel as though their abilities had improved. Despite this initial confusion about their mathematics experience, the stu-

Table 9. Common, non-convergent mechanism example quotes

Review of previously learned material	'I mean it was mostly a review for me because I took the class in high school so it just like reinforced my knowledge of the concepts.'
Engineering application problems	'[EngrMath] takes math and applies it to those real world concepts, I feel that like out in the real world, like I can kind of take those numbers and everything I need and know where to plug it into my equation . . .'

dents did indicate common positive self-efficacy mechanisms (such as the placement test) that help to explain their quantitative increase. This is further substantiated by considering each student's mathematics background. One student had not taken a mathematics course in two years, whereas the other had never been exposed to pre-calculus material (although this was not expressed by the student as a source of negative self-efficacy). Based on their backgrounds, it is likely that both students began the course with low P-MSE, experienced positive self-efficacy mechanisms, and substantially increased their P-MSE. However, their improvement was partially masked by a perceived decrease in general P-MSE based on the challenges they were not accustomed to experiencing. Because the two self-efficacy measures revealed contradictory findings, it is not possible to determine the overall effects of EngrMath on group 12's P-MSE.

6. Explanatory mechanisms—C-MSE vs. P-MSE

Among the explanatory mechanisms in EngrMath that were identified by a representative percentage of students in each category (not including those that were acknowledged as special cases), two were distinctly identified as explanatory in one subscale, but not the other. These include understanding the teacher's instruction and misunderstanding class concepts. Teacher's instruction played an instrumental role among students whose C-MSE increased. This may be because a teacher's instruction affects the progress and structure of a course, and is more influential on a student's judgment of ability to succeed in such an environment, rather than a reflection of their personal ability to solve math problems.

Similarly, misunderstanding class concepts played an important role in students' decreased C-MSE, but did not display the same effect for P-MSE. Recalling that this mechanism likely impeded students' C-MSE because future courses build on previously learned material, it could be that specific misunderstandings have less influence on student's P-MSE in light of all other topics that they do understand. Owing to their occurrence in only a single subscale, these mechanisms clearly played an important role in a specific kind of self-efficacy development of students in EngrMath.

7. Non-convergent mechanisms

Two mechanisms identified in the coding process that were not convergent in any group but were mentioned by over one-third of the students were the review of previously learned material, and engineering application problems, both of which were positive mastery sources. Example quotes of these mechanisms are provided in Table 9. Vicarious comparison and social persuasion sources were mentioned to a minimal extent following EngrMath. Different mechanisms within these two sources were commonly identified by one or two students on average, and in one instance by five students, which likely accounts for their failure to converge in any self-efficacy groups. Lastly, a large number of mastery experience mechanisms were coded but not reported due to their failure to converge in any self-efficacy groups.

8. Implications for educators

The findings of this study illustrate how different students interpret self-efficacy mechanisms/sources in different ways, as well as what instructional considerations might be made for future implementations of this and similar courses. EngrMath was effective for many different types of students, including those who had not recently experienced material relevant to the pre-calculus topics covered in EngrMath, students with prior calculus exposure, others who felt that they had always excelled in mathematics, and even students who failed to pass the placement test at the end of the course. Among students in increased self-efficacy categories, correcting misunderstandings was a mechanism that was explanatory in both subscales, whereas simply understanding class material was non-explanatory, and review of previously learned material was non-convergent for either subscale. Increased student involvement and learning output brought about larger benefits. Similarly, experiencing EngrMath as an environment that challenged students and encouraged consistent obstacle-success cycles had a more positive impact than one in which students simply felt that they understood the material. In order to develop challenging environments, teachers can encourage students to set incremental educational goals for themselves, which can create small successes as they overcome the obstacles that the goal creates. This will potentially lead students to become aware of their own misunderstandings and work toward correcting them, as opposed to simply learning the bare minimum amount of material with no motivational intent other than to get to the end of the topic. Lastly, to help students overcome their obstacles, teachers should consider making them aware of the vast resources available in the college setting (peer tutors, teacher office hours, etc.), but must involve students in the use of such resources so that they may feel more confident in using them in future mathematics courses.

The structure of the EngrMath course was associated with varying levels of influence on MSE. The calculus portion of the course was a strong positive influence, due to its transitional benefit in preparing students for calculus the following semester. However, the few students who recognized calculus concepts as a negative self-efficacy mechanism described such effects on their C-MSE as important. Teachers should understand the benefit of incorporating a transitional structure into their teaching agenda, on both a macro and micro scale. Providing students with transitional material from their current course to relevant subsequent courses, as well as helping to transition between class lectures/topics with review and/or preview material may influence student's MSE. In contrast to the transitional material, the laboratories and active learning structure of EngrMath did not provide explanatory power for the problem and courses self-efficacy outcomes of students in EngrMath. Although they were not explanatory, the mention of these mechanisms was significant, and therefore they did likely influence students' experiences in EngrMath. The laboratories were described in both positive and negative ways, while the active learning activities were positively received by a large majority of the students. Developing successful experiences for students using both of these mechanisms, while not playing a decisive role in a course's effect on student MSE, will likely help to foster a positive first-time college mathematics course experience.

9. Conclusions and future research

This study determined the effects of an experimental engineering mathematics course to foster a successful first-time mathematics experience to increase students' mathematics self-efficacy. From this study we determined that:

1. As a whole, students indicated a significant increase in mathematics problem solving self-efficacy, but no increase in mathematics courses self-efficacy. The wide variety of material exposure in EngrMath very likely expanded the range of mathematical topics that students felt equipped to handle, whereas understanding material in EngrMath appeared to have less impact on students' belief in their ability to understand material in subsequent classes.
2. Individually, students displayed consistent, inconsistent, and contradictory experiences of self-efficacy change in their responses to the surveys and interviews. These findings translated into student displays of increased, decreased, and no change in MSE. Analysis of these responses illustrate that students' self-efficacy was largely either increased or maintained in EngrMath.
3. Positive and negative mastery experiences were the most powerful self-efficacy sources in EngrMath. Class-specific mechanisms of influence were discussed previously.

Based on the already established predictive value of MSE to students' choice of science and math-related careers and majors, this study will act as an effective first step towards building a model that relates observed influences of course mechanisms and sources to student changes in MSE. This study is limited in the ability to generalize to a broader population due to the context dependence of the results. The mechanisms/sources that students described as influential to their MSE and their changes in MSE cannot be generalized beyond the content and conditions of EngrMath, but may be transferred to settings that share similar features to the one examined in this paper. However, in order to build a more generalizable and transferable theory of self-efficacy development as it relates to engineering mathematics, future studies must work within the MSE phenomenon, while diversifying the context into different college-level mathematics courses in order to identify similarities and/or differences with the mechanisms/sources identified in EngrMath. The research presented in this paper is based on a Master of Civil Engineering Thesis from Washington State University [32].

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