Providing a Voice: Qualitative Investigation of the Impact of a First-Year Engineering Experience on Students' Efficacy Beliefs

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ABSTRACT

This qualitative study explored the engineering self-efficacy beliefs held by students enrolled in their first engineering course at Purdue University. Findings from the thematic analysis of one-on-one interviews with 12 students enrolled in the course are presented. Results demonstrate the susceptibility of first-year engineering students' self-efficacy beliefs to the influence of performance comparisons based on the speed with which students were able to perform various tasks, the degree of contribution they were able to achieve when working with others, how much material they had mastered, and their grades. Gender differences were also identified in the way in which men and women were influenced by these experiences. Descriptions of how students made performance comparisons, including the logical progression from a specific experience through the modification of confidence in success, are offered.

Keywords: first-year engineering, retention, self-efficacy beliefs

I. INTRODUCTION

The U.S. has recently seen an increased demand for colleges and universities to produce more flexible, innovative engineering students (Council on Competitiveness, 2005; National Academies, 2007; Task Force on the Future of American Innovation, 2005). This call echoes the concerns of engineering educators who have recognized the need for research addressing issues that may adversely affect the diversity of the future engineering workforce (Steering Committee of the National Engineering Education Research Colloquies, 2006). Much research focus has therefore been placed on the achievement, interests, and persistence of undergraduate engineering students. These efforts have resulted in findings indicating that students' choices to both pursue and persist in engineering and their achievement and interest in the field are significantly influenced by their engineering self-efficacy beliefs (Bandura, 1977 and 1997; Pajares, 1996)—their confidence in their abilities to perform the tasks that they deem necessary to achieve success in the engineering environment.

The literature is rich with quantitative studies relating self-efficacy beliefs of science, technology, engineering, and mathematics (STEM) students to persistence (Brainard, Laurich-McIntyre, and Carlin, 1995; Lent et al., 2003; Robinson and McIlwee, 1989; Sax, 1994; Schaefers, Epperson, and Nauta, 1997), achievement (Hackett et al., 1992; Lent, Brown, and Larken, 1987; Lent et al., 2003; Schaefers, Epperson, and Nauta, 1997), and interest (Hackett et al., 1992; Lent, Brown, and Larken, 1987; Lent, Lopez, and Bieschke, 1991; Lent et al., 2003; Schmidt et al., 2001) in the fields. The results of these studies have equipped educators with reliable efficacy assessment tools (Assessing Women in Engineering, 2005; Bandura, 1997; Lent, Brown, and Larkin, 1986) and clear descriptions of the statistical link between positive self-efficacy beliefs and increased persistence, achievement, and interest. However, as noted elsewhere (Workman and Bodner, 1996), studies of this nature are limited because they reveal little about the *people* represented by the data. Still missing from the literature are the voices of the students explaining how they form specific efficacy beliefs. Thus, to date, there are few resources available to educators indicating how they might help students improve their confidence in engineering success.

The development of successful efficacy intervention strategies relies on understanding what can be done to promote positive self-efficacy beliefs among students. The first step toward addressing this issue involves explaining how students arrive at their efficacy beliefs. To best understand the sources and cognitive processing of students' self-efficacy beliefs, efficacy theorists have suggested using a discovery-oriented, qualitative approach (Pajares, 1997; Schunk, 1991). Such qualitative methodologies require fewer participants and allow for the detailed, in-depth analysis of participants' experiences that is needed to achieve the kinds of understanding sought in our work.

Self-efficacy theory defines four sources from which efficacy beliefs are developed: mastery experiences, vicarious experiences, social persuasions, and physiological states (Bandura, 1997). Efficacy beliefs are shaped by *mastery experiences* through the interpretation of one's performances on particular tasks. Both theory and research (Bandura, 1997; Zeldin, 2000) suggest that mastery experiences are the most influential source of efficacy. These types of experiences occur when "successes build a robust belief in one's personal efficacy" (Bandura, 1997, p. 80) or "failures undermine it, especially if failures occur before a sense of efficacy is firmly established" (Bandura, 1997, p. 80). Slightly less influential than mastery experiences are *vicarious experiences*, also called social comparisons. Manifested through the comparison of personal abilities to the perceived abilities of others, vicarious experiences play a more significant role in the formation of efficacy beliefs when individuals are unsure of their abilities in a certain area or have no experience in the area. *Social persuasions*—feedback received from others—can also influence self-efficacy beliefs. Those who are socially persuaded that they have the necessary skills to succeed are more likely to put forth effort and endure longer in the face of challenges than those who are not (Bandura, 1997). The *physiological states* people associate with their actions, such as enjoyment, anxiety, and other emotions, can also affect their self-efficacy beliefs. A student who associates high levels of stress with solving algebra problems, for example, is likely to have lower mathematics efficacy than a student who finds enjoyment in solving similar problems.

In defining the sources of self-efficacy, Bandura (1997) gives more attention to vicarious experiences than to any other efficacy source, perhaps because of the complexity of these types of experiences (Usher, 2006). He not only suggests that the influence of vicarious experiences is multifaceted but also notes that the perception of this influence will vary from person to person. A vicarious experience may be marked by raised efficacy upon witnessing someone of similar ability perform successfully or lowered efficacy upon witnessing the failure of a perceived equal. Because these experiences require individuals to assess the likelihood that they would be able to model the behavior of another, Bandura (1997) refers to this phenomenon as modeling. In the case of modeling, witnessed successes and failures increase in persuasive power with the degree of similarity people see between their own abilities and those of their peers. Vicarious experiences, however, are not always perceived in this manner. Often when people compare themselves to others who are engaged in similar activities, they experience heightened efficacy upon surpassing peers or diminished efficacy upon being outperformed. These types of vicarious experiences can be viewed as performance comparisons, rather than as modeling.

There is a nuanced difference between modeling and performance comparisons. During modeling experiences, an individual's focus is on assessing how similar his or her ability is to that of a peer (i.e., a potential model). Performance comparisons are more concerned with determining how much "better" or "worse" a person's performance was in comparison to those of his or her peers. Self-efficacy appraisal based on performance comparisons "vary substantially depending on the talents of those chosen for social comparison" (Bandura, 1997, p. 87) and individuals' perceptions of their own abilities. During the analysis of our data, we frequently identified the presence of performance comparisons among our participants; however, the influence of modeling did not emerge from the data. For clarity, we will therefore refer to vicarious experiences as 'performance comparisons' in the remainder of this work.

Several researchers have employed qualitative methods to investigate sources of efficacy. Lent et al. (1996) used a cognitive thought-listing technique to investigate the sources of early college students' mathematics efficacy beliefs. Using this technique, the researchers asked students to list all of the factors they considered when assessing their confidence in mathematics success. They concluded that mastery experiences were the most common and most influential efficacy source listed by men and women alike. Gender differences were seen only in the higher frequency with which women listed the influence of physiological responses. Others have used in-depth participant interviews (Zeldin, 2000; Zeldin and Pajares, 2000) and found that while men succeeding in mathematics-related fields were most likely to base their efficacy beliefs on past successes (i.e., mastery experiences), women based their beliefs on witnessing the successes of role models (i.e., modeling vicarious experiences) and verbal encouragement (i.e., social persuasions). The conflicting results from these two studies can likely be explained by noting that efficacy beliefs vary considerably depending on the situation in which they are assessed. The career professionals studied by Zeldin and Pajaries may have appraised their efficacy beliefs differently than the early college students studied by Lent et al. (1996). It is also possible that results produced from the use of cognitive thought-listing do not lend themselves to conclusive placement within self-efficacy theory. For example, Hutchison, Follman, Sumpter, and Bodner (2006) made use of cognitive thought-listing in their investigation of the efficacy sources that influenced first-year engineering students. That study revealed a host of factors that students considered in the formation of their efficacy beliefs (e.g., mastery of course material; motivation; teaming issues; computing abilities; help resources; problem-solving abilities; enjoyment, interest, and satisfaction associated with the course; and grades earned in the course), but lacked the in-depth descriptions of the influences required to definitively conclude *how* and *why* the students were influenced.

In this paper, we report findings from a study of the efficacy sources referenced by first-semester engineering students in the formation of their engineering efficacy beliefs. Semi-structured, open-ended interviews conducted during one-on-one discussions with students allowed us to study not only the types of efficacy sources considered by students, but also how students interpreted those experiences. These efforts have led to detailed descriptions of how students' experiences in a first-semester engineering course influenced their confidence in their ability to achieve engineering success. These data form the basis upon which we address two questions: (1) What experiences during a first-semester engineering course influence students' engineering efficacy beliefs?, and (2) How do students interpret those experiences when forming their engineering efficacy beliefs? Based on our characterization of the first-semester experience, we propose strategies educators might use to promote students' confidence in engineering success.

II. Research Design

A. Theoretical Grounding and Framework

This study was designed to enhance our understanding of engineering self-efficacy belief formation among first-semester engineering students. Underlying this goal was the need to identify variations in the experiences that students reflected on when assessing their self-efficacy beliefs. Based on these objectives, Bandura's (1997) self-efficacy theory was selected to guide the investigation. Using self-efficacy theory as our foundation, the study also reviewed how well the theory represents or predicts the actions of a specialized group of students—first-semester engineers.

As this study developed, it became clear that understanding how our participants' efficacy beliefs were formed would emerge only from a deep appreciation of the variations in the ways they had experienced the engineering learning environment. Motivated by a desire to understand "... the limited number of qualitatively different ways in which [students] experience, conceptualize, understand, perceive, apprehend, etc., various phenomena in and aspects of the world around [them]" (Marton, 1994, p. 4424) we chose to look at our data using a phenomenographical lens (Bodner, 2004; Marton, 1981, 1986, and 1994). This allowed us to focus on understanding the variations in the efficacy-influencing experiences described by students.

The study, grounded in self-efficacy theory and focused using a phenomenographical search for variation, employed thematic analysis (Braun and Clarke, 2006) in the investigation of interview data. Our analysis methods identified themes and patterns that could be used to organize and describe data in rich detail. Not "wedded to any pre-existing theoretical framework" (Braun and Clarke, 2006, p. 81), thematic analysis complemented both our work within self-efficacy theory and our use of a phenomenographical focus on variation. Using pre-established sources of efficacy proposed by Bandura (1997), our application of thematic analysis was grounded in self-efficacy theory. A phenomenographical perspective aided our identification of relationships and variation between the ways in which first-semester engineers had experienced each efficacy source.

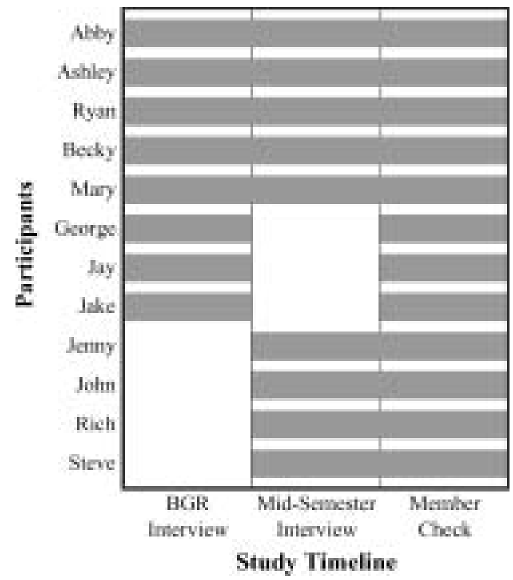

Figure 1. Study timeline illustrating the degree of each student's participation.

B. Participants

1) Recruitment: Before beginning participant recruitment, IRB approval was obtained from Purdue University's Human Research Protection Program. Student participation was completely voluntary and no incentives were used in the recruitment process. Participants were recruited in two stages, beginning with Purdue's freshman orientation, "Boiler Gold Rush" (BGR), which takes place the week before fall classes begin. The authors attended events targeted at first-year engineering students and were given the opportunity to explain the nature of the study and ask for volunteers. Eight students volunteered during this stage of recruitment and were subsequently interviewed prior to the start of the semester. These pre-semester interviews were conducted to establish a baseline for students' perceptions of and expectations for the first-year engineering environment.

Three months into the fall semester, mid-semester interviews were requested from all BGR participants. At this time, additional participants were recruited from ENGR 106, *Engineering Problem Solving and Computer Tools*, a two-credit course required of all first-year engineering students for matriculation into one of the university's engineering departments. The course covered engineering problem-solving, computer logic and the use of computer software (UNIX, Excel, MATLAB), teaming, and statistics and economics in an engineering context. The authors visited the ENGR 106 lecture hall approximately ten minutes before the start of class. The nature of the study was explained and student volunteers were recruited for participation.

Twenty-one students provided the authors with contact information so that mid-semester interviews could be scheduled. Student volunteers were contacted by the authors and interviews were set up with eight volunteers. These volunteers were selected, in part, on the basis of gender in order to obtain a roughly equal representation of men and women. Subsequent student follow-through resulted in interviews with four new student participants. Mid-semester interviews were also conducted with five pre-semester (BGR) participants; three BGR participants declined further participation in the study. Each student's level of participation is summarized in Figure 1.

2) Description: In the fall of 2004, when this study was conducted, the ENGR 106 population was 82.3 percent ($n = 1007$) male and 17.7 percent ($n = 217$) female. Twelve total students from the ENGR 106 population, seven men and five women, participated in various parts of this study. Arrival at data saturation (i.e., no new perspectives emerging from the data) in both pre- and mid-semester interview data indicated that no further participant recruitment was required. A detailed description of this determination is presented later during our discussion of data analysis. As summarized in Figure 1, BGR interview data were collected from eight students (four men and four women), while mid-semester interview data were obtained through nine interviews conducted with five women and four men. One male and four female participants completed both a BGR and a mid-semester interview. Minority participation included one African-American female (Jenny) and one South American male (Steve). The names used to refer to study participants are pseudonyms that were assigned to protect their identity.

Participation in this study was completely voluntary, thereby increasing the importance of establishing how well our student volunteers represented the first-semester engineering student body as a whole. One measure that was used to determine the degree to which our volunteers represented their ENGR 106 peers was their level of engineering efficacy. Engineering efficacy beliefs were measured by an efficacy instrument (Hutchison, Follman, Sumpter, and Bodner, 2006) modeled after the "strength of self-efficacy for academic milestones" scale (Lent, Brown, and Larkin, 1986) and the "academic efficacy scale" (Midgley et al., 1996). The instrument, administered to the entire ENGR 106 student body as a part of a larger study (Follman, Patrick, and French, forthcoming), included five 5-point Likert scale measures of engineering efficacy (e.g., "I am confident I can succeed in ENGR 106": 1 = do not agree and 5 = agree completely) that were tested and found to be internally consistent ($\alpha = 0.88$) (Cronbach, 1951). The average engineering efficacy scores measured by the instrument have been broken down by gender and are presented in Table 1 for both the ENGR 106 population as a whole and students interviewed for this study.

Not only were the average engineering efficacy ratings provided by interview participants and the ENGR 106 population statistically similar both overall and by gender, but parallel trends were also identified among the two groups. In both cases, men were found to rate their engineering efficacy beliefs significantly higher than women (based on *t*-tests, $p < 0.01$).

SAT overall and SAT mathematics scores were also used to determine the degree to which interview participants were representative of their first-semester engineering peers. No significant differences were identified between the SAT scores of interview participants and the ENGR 106 population. Table 2 illustrates how the participants compared to their classmates based on SAT scores. Also presented in the table is each participant's average engineering efficacy score.

The data presented in Table 2 demonstrate that while students of all ability levels (as measured by SAT scores) were included in the study, a complete representation based on gender was not achieved. Specifically, men with low SAT scores were not represented among our volunteers. Also suggested by the data in Table 2 is a potential correlation between the average efficacy scores and SAT scores of our male participants; a correlation that does not appear to exist with the women. Although our small number of interview participants prohibited us from further exploring these potential trends statistically, we are interested in exploring these trends with future research endeavors.

C. Data Collection

1) Interview Protocol: Semi-structured, open-ended interview protocols were developed for use in this study. The protocols were aimed at promoting in-depth participant discussion of the factors they considered in the assessment of their efficacy beliefs, including how they thought about those factors when forming their beliefs. To minimize the effect of our protocol on subsequent data collected, it was designed to provide structure to the order and wording of key interview questions while still granting the interviewer the flexibility to further probe students' experiences when additional detail was required (Patton, 2002).

The protocols, loosely based on a previous investigation (Zeldin, 2000; Zeldin and Pajares, 2000), were designed to methodically explore students' levels of efficacy as well as their experiences with each of the sources of efficacy suggested by self-efficacy theory. A version of the mid-semester protocol, which included all items used in pre-semester interviews, has been described in previous work (Hutchison, Follman, and Bodner, 2006). During both the pre- and mid-semester interviews, students were introduced to the interview setting by first being asked about what prompted them to pursue engineering. Their attention was then focused on their first-year engineering course, ENGR 106. They were asked (with verb usage dependant on which protocol was being used), "How would/do you define success in ENGR 106, or what would/do you have to do to consider yourself successful in the course?" and were told "I am interested in how you think you will do/are doing in your quest to achieve success. To what degree do you think that you will be/are being successful in 106 right now?" Once the students had been prompted to consider their ENGR 106 efficacy beliefs, each efficacy source was probed as shown by the protocol excerpt in Table 3.

The mid-semester protocol also asked students a variety of questions designed to elicit free responses regarding particularly memorable experiences in ENGR 106. Such discovery-oriented items included: "Think of a particular class that you have taken in which you felt extremely confident in your ability to achieve success. Tell me about this class. How were your experiences similar and different from those in ENGR 106?," "Are there things that could be done to improve the ENGR 106 experience?," and "What aspects of ENGR 106 do you think should be kept just how they are?" These questions led respondents to provide personal interpretations of events that they perceived to be meaningful in the development of their self-efficacy beliefs.

2) Interview Process: Pre-semester (BGR) interviews were conducted at locations convenient to and selected by the student

	Interview Participants		Overall ENGR 106 Population	
	Men	Women	Men	Women
Mean	3.9*	3.2*	3.52**	3.24**
Median	3.8	3.0	3.9	3.4
Standard Deviation	0.52	0.33	0.80	0.79

Table 1. Average engineering efficacy ratings (,** denotes significant difference between men and women, p < 0.01).*

Class Rank	SAT Scores – Overall	SAT Scores – Math
	Above 1320	*Above 690*
Top 25% of Class	• Abby (3.0) • Jay (3.4) • Becky (3.4) • John (4.0) • Rich (4.8)	• Abby (3.0) • Ryan (3.6) • Mary (3.0) • Steve (4.2) • Rich (4.8)
	1180 – 1320	*620 – 690*
Middle 50% of Class	• Mary (3.0) • Steve (4.2) • Ryan (3.6) • George (3.6)	• Jay (3.4) • George (3.6) • John (4.0)
	Below 1180	*Below 620*
Bottom 25% of Class	• Ashley (2.8) • Jenny (3.6)	• Ashley (2.8) • Jenny (3.6) • Becky (3.4)

Table 2. The interview participants, divided into three categories on the basis of overall and mathematics SAT scores, with self-efficacy scores for each student given in parentheses next to the pseudonym (data not available for Jake).

volunteers (e.g., dormitory lounges, cafeterias) while mid-semester interviews were conducted in the authors' offices. All interviews were audio-taped and later transcribed. At the beginning of each interview, students were reminded of the purpose of the study, the measures that would be taken to maintain their confidentiality, and the voluntary nature of their participation. Semi-structured interviews were conducted with each participant based on either the pre-semester interview guide or the mid-semester interview guide. The pre-semester interview consisted of a subset of questions taken from the mid-semester protocol. Interviews ranged in length from 40 to 90 minutes.

E. Data Analysis

This study was designed to gain a better understanding of how influential experiences were processed by first-semester engineering students in the formation of their self-efficacy beliefs. Aligned with this goal and the study's grounding in self-efficacy theory, first-level coding, a method used for summarizing segments of data (Miles and Huberman, 1987), was achieved by coding our data based on the theory's four established self-efficacy belief sources (i.e., mastery experiences, vicarious experiences, social persuasions, and physiological reactions). A fifth code ("other") was also created for use on experiences that were found to fall outside of the sources described by Bandura (1997). Each interview transcript was read and experiences described by our participants were assessed to determine whether they should be classified as mastery experiences, vicarious experiences, verbal/social persuasions, physiological responses, or another type of experience falling outside of those described by self-efficacy theory. Although our analysis included active attempts to identify new experiences that were not described by Bandura's theory (1997), the "other" code was never used in the coding process. Each experience described by our participants was found to fit within the framework of self-efficacy theory. Table 4 presents the criteria used to assess which first-level category described each experience.

Following first-level coding, pattern coding (Miles and Huberman, 1987) was used to identify themes describing the various ways in which each self-efficacy source was experienced. These themes were identified based on how the source was described as influencing a participant's self-efficacy. This level of coding was therefore conducted with a phenomenographical focus. Each description of an experience was read and compared to other participants' experiences. The relationships and variations between experiences were considered and each experience was either grouped with similarly described experiences under a common code or used to create a code for a previously unidentified type of experience. The themes coded during pattern coding thus emerged from the data, in contrast to first-level coding which was dictated in large part by self-efficacy theory. Although this comparative process was ongoing throughout the analysis of all interview transcripts, no new themes arose beyond the analysis of one pre-semester and four mid-semester (two men and two women) transcripts. We interpreted this as an indication that we had reached sufficient data saturation to provide a descriptive picture of the efficacy-influencing experiences present in the first-semester engineering environment, and no additional participants were recruited for the study. The codes used during pattern coding were initially generated by one researcher. They were then presented to a group of researchers who discussed, modified, and finalized an agreed upon coding scheme. The finalized sets of themes established for each self-efficacy influence are summarized in Table 5.

During both first-level and patter coding, only one researcher was responsible for coding. Reliability in the coding process was achieved using peer debriefing (Creswell and Miller, 2000), a technique that involves periodic reviews of the research progress by someone familiar with the study. During peer debriefing sessions, coding and interpretation of the data were continually challenged and questioned, requiring that the validity of these be both defended by the researcher and supported by peers. Revisiting this challenge-defend-support process over time added credibility to the study.

Because this study was concerned with not simply *what* experiences influenced participants, but also *how* and *why* the students were influenced, only descriptions of experiences that were linked to some discussion of the resulting effect on self-efficacy beliefs were included in the data analysis. For example, when asked to describe an experience that had affected her confidence in success, Ashley reported:

> Oh, I feel like I'm definitely behind. Well, because like this last project we had to do . . . I had no idea what we were doing, but this other kid who was in my group—the one that's really smart—he had taken computer programming in high school already, so he like knew what to do. He's like, "Here, I know how to do this" . . . I had no idea. And so it seems like kind of a set back that everyone else like had a head start on it that I don't have. So, that's frustrating.

Interview Question	Source Probed
What experiences have contributed to how confident you are that you will be/have been successful in ENGR 106? How did these experiences affect you?	Mastery experiences / Vicarious experiences
How have other people influenced how you think you will do/are doing in ENGR 106?	Vicarious experiences / Social persuasions
What have people said to you that has affected your confidence in your success in ENGR 106?	Social persuasions
When thinking about [or doing] ENGR 106, how do you feel?	Physiological states

Table 3. Excerpt of questions included in both interview protocols.

First-Level Category	Defining Criteria	Example Quote
Mastery Experience	• Success or failure • Personal determination of success or failure not based on comparisons	"…I can use MatLab now. I didn't know what MatLab was at the beginning of the year…"
Vicarious Experience	• Attempt to model behavior / assess capability to achieve similar outcomes to those achieved by another • Comparison of personal performance to that of peers	"…I had no idea what we were doing, but this other kid…he had taken computer programming in high school already, so he like knew what to do..."
Verbal / Social Persuasion	• Verbal or nonverbal feedback from family, friends, peers, faculty, etc.	"I'll call my parents, I'm like, 'Oh… I failed another test;' they're like, 'It's okay, just get through it…"
Physiological Response	• Emotional response to an experience • Personal trait (i.e., drive or motivation)	"…people will be like… 'Are you done?' I'm like 'No!', 'cause it just like takes me more time to do stuff . . . aah – it's just frustrating…"
Other	• Experience not described above	None identified

Table 4. Criteria used in first-level coding process.

Self-Efficacy Source (First Level Code)	Characterizing Theme of Influence (Pattern Code)	Description of Themes
Mastery Experience	Technical Skill Mastery	Success / failure with an engineering technical skill (e.g., programming, problem-solving)
	Professional Skill Mastery	Success/failure with an engineering professional skill (e.g., teamwork, time management)
Performance Comparison (Vicarious Experience)	Comparison by Speed	Assessing success/failure based on speed of personal performance compared to speed of peers' performance
	Comparison by Contribution	Assessing success/failure based on the degree to which contributions could be made during teamwork
	Comparison by Amount	Assessing success/failure based on amount of personal mastery compared peers' mastery
	Comparison by Grade	Assessing success/failure based on personal grades compared to grades of peers
Verbal/Social Persuasion	Verbal Feedback	Verbal feedback from family, peers, instructors
	Nonverbal Feedback	Nonverbal (e.g., body language, actions) feedback from peers or instructors
	Course Policies	Perception of course policies as messages from instructors
Physiological State		Emotional responses to experiences in the learning environment (e.g., frustration with grading policies, satisfaction from a success) or character traits such as being driven/motivated

Table 5. Description of themes coded during the pattern coding process.

Ashley's response was coded because it included both an experience (writing code) and a description of how it affected her (she became frustrated because she was behind). It was first coded as a performance comparison based on the conclusion that she was comparing her coding abilities to those of her classmates. In the subsequent round of pattern coding, Ashley's quote was coded as a 'comparison by amount' because of her explanation that her self-efficacy was influenced by the fact that she did not know as much about programming as her peers. In contrast, a number of our participants' experiences were not coded during data analysis because they were not described in enough detail to make transparent the nature of their influence on self-efficacy. Steve, for example, was asked about the kinds of thoughts or feelings that came to mind when he thought about ENGR 106; he responded by saying, "Homework, *lots* of homework, lots of homework. And like you need a lot of time to accomplish everything that is asked—that the class asks you to do. But besides that, like I don't *hate* the class." It is not clear from Steve's statement how the large volume of homework influenced his confidence in success. He does not say whether he viewed it as a motivating challenge or stressful discouragement. Had the interviewer further probed Steve's response, we may have been able to make this determination, but since we have no data indicating how this experience influenced Steve, we chose to not code this and other incomplete descriptions of an experience.

To ensure the reliability and validity of our qualitative findings, a practice known as member checking (Creswell and Miller, 2000) was used to establish that our interview participants had been accurately represented within the study. This process required that we provide each participant with a copy of his or her interview transcripts along with the inferences the authors had drawn from the transcripts. The participants were then asked to assess the accuracy of the authors' conclusions. Our participants were individually contacted via e-mail and asked to member check the analysis of their interviews. In the e-mail, the concept of member checking was explained to the students. They were provided with their pseudonyms, a copy of their coded transcripts, an explanation of the codes, and a copy of this manuscript. Students were then asked to review the material and assess whether or not they felt they were accurately understood and represented. They were further informed of ways in which they could contact the researcher (i.e., by e-mail, phone, or in person) with concerns or clarifications. Nine of the 12 participants replied via e-mail confirming simply that they had been accurately represented (e.g., "This looks good to me.") and did not express any need for clarification. Of the remaining three participants, one corrected an inaccurate SAT score reported for him and the other two provided an update on their most recent engineering experiences in addition to reporting that they felt they had been represented accurately.

III. Results

The analysis of pre-semester and mid-semester interviews allowed us to generate two independent descriptions of beginning engineering students' self-efficacy beliefs. When viewed together, the results from the two separate interviews paint a clear picture of how students' exposure to their first college-level engineering course—ENGR 106—influenced their confidence in their ability to achieve engineering success. Here we present the results from pre-semester interviews as a baseline for comparison with the results obtained from mid-semester interviews, discussed later. In our presentation of the results, we will often refer back to particularly articulate participants. Thus, although the excerpts presented may come from only a portion of the students interviewed, they represent trends identified among all of the participants.

A. In the Beginning

Prior to entering the engineering curriculum, all eight of the pre-semester participants reported feeling quite confident in their ability to achieve success in the engineering environment. During their interviews, students explained that this confidence was based almost solely on their past successes—previously obtained mastery experiences. Over and over, the excited, yet anxious, students echoed the sentiments of Abby when asked what experiences made them confident that they could achieve success in ENGR 106:

> Well, [ENGR 106] can't be as hard as AP physics was last year,… and I did okay in that, so, I mean, I go in with high hopes and I think I might be okay…and then just what people said, it sounds to me like it's going to be similar amounts of work as [AP physics] and, I mean I feel pretty prepared coming in from my high school, but then again, college is a completely separate thing, so, I mean, it could be to my disadvantage to think that way, but, we'll see…

Similarly, when Jake was asked what he based his confidence in success on, he discussed his experiences on his high school's academic decathlon team:

> Um, well, in high school I was on the academic decathlon team and I really didn't think I belonged there …There [were] 10 events and I was on 'interview' and I really didn't think that I was a good interviewee and, turns out I got one of the best scores in the whole competition and that just really surprised me. And, gave me a lot more confidence…

Like Abby, Ryan drew his confidence from previous experiences with high school courses:

> My junior year, I had a lot of hard classes all at the same time and it came to a crunch time where, at the end of the year I had several humongous projects all due at the same time and…like, if you have a certain GPA the school allows you to take like one day off to do whatever, so I took the day off and I spent the whole day working on these projects and then I spent the whole weekend working on these projects …It's just…if I know I need to get something done now, I'll do it …

Interviews with these students on the verge of beginning their engineering education revealed a commonly held conception: they had arrived at Purdue planning to study engineering and they had no doubts that they would be as successful as they had been in their past academic endeavors.

B. The Changing Tides

Of the nine students who talked with us prior to embarking on their engineering education, five (one man and four women) returned three months later to talk about their experiences in the engineering environment. They were joined by four new study participants (three men and one woman). Though mid-semester interview responses revealed many themes describing the impact of engineering students' first-semester experiences on their engineering efficacy beliefs, performance comparisons were paramount and are, therefore, our main focus here. Performance comparisons emerged as dominant based on students' responses when directly asked what one experience, or type of experience, had been the most influential on their confidence in ENGR 106 success; seven of the nine mid-semester interview participants described a performance comparison. The two remaining students, Becky and Steve, reported non-verbal feedback and mastery experiences, respectively, as most influential. The dominant influence of performance comparisons in the ENGR 106 environment was further evident in students' often passionate descriptions of these types of experiences and was confirmed during the member checking process.

As is illustrated by many of the interview excerpts that follow, performance comparisons among ENGR 106 students seemed to have the ability to override the potential effects of all other self-efficacy influences. Consider, for example, Ashley's comment:

> …in lab, we always have to write these scripts and like I can do it eventually—but some of the people will be done like ten minutes later; they'll be like, 'Are you done?' I'm like 'No!' … it's just frustrating…"

Or Rich's statement: "I'm good with math…and so I'm confident because I do things quicker than most other people... Both Ashley and Rich actually mention the mastery of material—Ashley in stating that she can eventually write code and Rich in describing himself as being skilled at math—but, as demonstrated by their quotes, neither seemed to recognize this mastery as an important consideration in the formation of their self-efficacy beliefs. Instead, they placed importance on how that mastery compared to what they perceived their peers had accomplished.

Although performance comparisons clearly had the greatest influence on interview participants, it is important to emphasize that these students discussed instances when they were influenced by other self-efficacy sources (i.e., mastery experiences, social persuasions, and physiological states) as well. Moreover, the experiences they described were often multifaceted. For example, many students expressed physiological reactions, such as frustration, anger, or satisfaction, to experiences that were otherwise classified as mastery experiences, performance comparisons, or social persuasions.

Excerpts from mid-semester student interviews are used to best illustrate the influence of performance comparisons and to provide evidence for a potential gender variation in students' perceptions of these experiences. Following the discussion of performance comparisons, examples of students' experiences categorized as mastery experiences and social persuasions are briefly presented. Physiological responses are not directly addressed due to the finding that they were nearly always linked to another self-efficacy source; examples of physiological states are therefore interwoven throughout the following excerpts.

1) Performance Comparisons: An exploration of students' discussions concerning the ENGR 106 experience revealed that across nearly every facet of the course, participants drew upon their perceptions of how they compared to their classmates as a significant basis for the formation of their engineering efficacy beliefs. In each of these discussions, the students described using one of four factors as a basis for their comparisons: the speed with which they were able to perform, the nature and extent of their contributions during team activities, how much material they had mastered, and their grades. Also identified was a gender difference in the way in which men and women experienced performance comparisons.

Speed of Performance. Many students explained that the amount of time it took them to learn new material or complete assignments in comparison to their classmates was a significant factor in the assessment of their self-efficacy. Ashley, who came to ENGR 106 with little background in using computers and no programming experience, explained that her inability to learn new material quickly had the strongest influence on her confidence in course success, causing her to lose confidence in her engineering abilities:

> I'd have to say how fast I learn; because some people seem like they just catch on so, like so quick. And I'm just kind of like slow or something 'cause I can't like figure it out right away. Um, like in lab, we always have to write these scripts and like I can do it eventually—but some of the people will be done like ten minutes later; they'll be like, "Are you done?" I'm like "No!", 'cause it just like takes me more time to do stuff and … aah—it's just frustrating. The whole class is.

Rich, an experienced programmer, spoke of the positive influence his ability to solve problems quickly had on his self-efficacy:

> [I have confidence in my ENGR 106 abilities] because I'm good with math, a lot of the problem-solving in math is figuring out a way to solve a mathematical problem and so it's—I do things quicker than, than most other people here.

These interview excerpts illustrate that when students perceived themselves as performing more quickly than their peers, their engineering efficacy beliefs were heightened, but slower performances led to doubts in their abilities to achieve engineering success.

Degree of Contrizbution. Students also compared themselves to their classmates based on the degree to which they could contribute to team work, the extent to which they were forced to seek help when working in groups, and the frequency with which they were able to provide answers to others' questions. A beginning programmer at the start of ENGR 106, Ryan discussed his ability to contribute more than his share of the work to a team project as an efficacy-building experience:

> …in this last project … there were two parts to it; one to do this and one to do that; and like, I was like, "Okay, you two, you work on this one and I'll work on this one, and we'll put 'em together and be done." And I finished mine like really quickly and they just couldn't get anything done with the other one, so—I started writing my own version of it and then the TA tells them, "Keep trying," but then I sort of just said, "I'll do it." It put a huge workload on me, but, I mean, we got it done.

Jenny noted that her self-efficacy beliefs were also influenced by the degree to which she was able to contribute to teamwork and the balance she was able to achieve in the number of questions she asked and was able to answer while working with others:

> Um, sometimes, ah, just being able to work, just being able to like study or work in a group and to feel like you're needed is encouragement; because if you go to a study session with maybe a group of five and you're always the one asking the questions or if I'm always the one asking the questions then that would make me feel bad or if I went to a meeting and I wasn't really able to contribute because I didn't know what to do or what to say, that would make me feel bad. But to know that I can answer other people's questions and still have questions of my own and be able to be an effective communicator and contributor during projects . . . that's how I get encouragement. Because it's never a directly, "[Jenny], you're doing a good job," but just to know that I'm able to, um, I guess kind of, ah, like we're equally yoked.

Like Ryan, Jenny saw her self as a contributor to group work situations and was thereby encouraged that she could achieve engineering success.

Material Mastered. Students also frequently reported comparing how much of the material they had mastered to what they perceived their classmates had learned. Steve mentioned that he was able to evaluate himself on this basis when working in a group: "When you compare [yourself] to other people and you see that maybe you're one step ahead or something, like . . . when you do group projects or group homework, [then you know that you are being successful]." Rich similarly described a positive influence on his self-efficacy beliefs based on his conclusion that he knew more than his teammates:

> Ah, usually, I'm confident that I'm going to do well because of how everyone else does; I assume that . . . [the ENGR 106 instructors] are not going to fail everyone. There are kids in my group that are bright and they're getting D's, and if I know more than them, then that makes me feel confident.

Abby explained that her confidence in ENGR 106 success was damaged by the perception that she did not know as much as others in the class:

> . . . [my confidence in my ENGR 106 abilities is influenced by] the people that I go to for help because they understood it more than I do, and so it's kind of like gauging, "Well, they're smarter than me; I must not be doing that well," and so you kind of compare yourself but sometimes you try not to.

Interestingly, when they spoke of this type of influence, students never discussed how they determined what knowledge their classmates had accumulated or how well they had mastered that knowledge.

Grades. Students often used grade comparisons to determine their confidence in ENGR 106 success. In addition to speaking further about the influence of the speed with which she learned new material and the extent to which she was forced to seek help, Ashley explained that her self-efficacy was also influenced by how her grades compared to the class average:

> . . . every time, like, you get your grade on something. You always look at the average and like compare yourself to the average. And then, other people like, if we'll be working on problems together . . . and if they're understanding it, like, more quickly than I am, I'm kind of like, "Hey, how'd you do that?" And I try to have them, like, explain it to me. So, it kind of affects me when they know what they're doing and I don't.

Ryan discussed that he became increasingly confident in ENGR 106 success based on the inferior grades he witnessed his classmates achieving:

> Just, other people I see in my class—ah that aren't getting near as good grades and ah, . . . some of the kids that I have close in grade, they still don't really understand stuff or they do stuff halfway or, you know, so, I kind of use that to measure how I'm doing.

Grade comparisons seem to be the most straightforward, traditional way in which students compare themselves to their peers; however, among our participants, this type of comparison was less prominent than the other identified types of performance comparisons.

Gender Differences. Men and women alike frequently described the influence of performance comparisons on their self-efficacy beliefs; however, they often relayed very different experiences. Three of the four mid-semester male participants only described having their self-efficacy *positively* influenced by their perceived superiority in comparison to their classmates. Only John described experiences during which he felt he had been out performed by his peers. When Rich was asked why he was very confident that he would achieve success in ENGR 106, he described his experiences while working with classmates during computer lab sessions:

> Within my lab group, I'm always the one that knows how to do things. When they have a question, they always ask me even though I'm usually not paying attention. Especially when they're messing around with the computer; "Hey Rich, how do you do this?"
>
> Ryan expressed similar thoughts on a broader scale:
>
> The big thing is just, like, how I'm doing compared to everyone else because you're competing—essentially you're competing with all the people for a job. So, if I'm doing better than a lot of them, then I'm feeling pretty good, I guess.

Alternatively, women were most often negatively influenced by performance comparisons. Men usually perceived themselves as knowing more than their classmates, while women were more likely to determine that their abilities were inferior to those of their peers. Abby talked about feeling this way when she worked with her ENGR 106 team:

> . . . comparing myself to somebody else is like making me feel not so confident. So that would be like right up there on the negative side 'cause, like, we just switched teams in 106, and there's this guy in my new team that just understands

computer coding, and I just don't, and he sits there and spits out these scripts, and I'm like still writing my name. So I mean yeah that's a different situation… .

Even in instances for which women described being positively influenced by a performance comparision, the nature of the positive influence was quite different from experiences described by men. Instead of feeling more confident in their ability to succeed in ENGR 106 because they were in some way better than their peers, women found confidence in knowing that there were others of similar ability:

> I think [our problem-solving abilities are] kind of almost all on the same level except for the people who have taken kind of programming before. Everyone else is like "I have no clue either". I'm like, "Okay, well, at least I know I'm not the only one". So that's kind of comforting knowing that other people are like in the same boat as me (laugh). [Ashley]

At first glance, these excerpts may give the impression that our male participants were merely smarter than our female participants. We believe, however, that this was not the case and that although men and women alike experience both positive and negative performance comparisons, it is the men who tend to recall positive experiences and the women who tend to focus on negative experiences. This interpretation of our data is further discussed later.

2) Mastery Experiences: When reporting mastery experiences, ENGR 106 students discussed success or failure with technical engineering tasks (e.g., programming, problem-solving) and engineering professional skills (e.g., teamwork, time-management). As predicted by self-efficacy theory, students expressed feelings of heightened efficacy upon mastering one of these tasks and feelings of lowered confidence in success upon experiencing failures. The influence of this self-efficacy source is illustrated below using examples of students' remarks regarding their mastery of technical skills. Similar discussions of professional skill mastery also arose from the interview data but were not as descriptive and are therefore not presented here.

When she began her study of engineering, Abby had no experience using MatLab. Upon reflecting on how far she had come in her ability to use the program, "she reported feeling more confident" that she could succeed in engineering:

> I was studying my work at the beginning of the semester … I'm making steps forward. Whether or not it's where I should be, I'm not so sure, but I can use MatLab now. I didn't know what MatLab was at the beginning of the year … so I feel like I'm making a few steps forward and learning new things.

Her ability to use the MatLab program was not, however, always a positive influence:

> I can get a problem, and I think I know what to do. I'll sit down and write MatLab script with it …And, I'll get a number and like it's not positive and I know it's supposed to be positive. I get frustrated …It makes me [think] I can't solve them right. Not even the first time I try or the second time I try. Like four or five times I'm still not getting it … There are times when I do get it right but …

Interestingly, Abby seemed to put little importance on the fact that she had conceptually mastered concepts. For example, she was able to recognize that the number she had computed *should* have been positive—a considerable achievement itself. This knowledge did not, however, seem to counteract the effects of struggling with programming.

Like Abby, Ryan discussed his mastery of new ENGR 106 material as instrumental in the formation of his confidence in engineering success:

> I came into the class not being able to do anything with programming; and now I'm pretty, I feel pretty good at MatLab, where like I did most of the prime program for our last project which was like programming intensive. So, I think I'm doing pretty good.

Unlike Abby, Ryan never discussed an instance for which he came to doubt his mastery of the material. These were consistent trends identified among men and women. For each positive mastery experience achieved by a woman, one or two failures were described as challenges to the potential formation of positive self-efficacy beliefs. Men, however, rarely noted failures as negative self-efficacy influences. Although this does not necessarily indicate that men did not experience failure in the ENGR 106 environment, it does suggest that they were not as affected by failure as women.

3) Performance Persuasions: Verbal and nonverbal feedback that students received from instructors, peers, and family were also described as influential on confidence in first-year engineering success. These experiences, however, were discussed much less frequently than mastery and performance comparison. Participants described the influence of three different aspects of performance persuasions: verbal feedback from instructors, peers, or family; nonverbal feedback from peers or instructors; and perceptions regarding the messages ENGR 106 instructors were intending to send through the establishment of various course policies.

Most participants described receiving positive verbal feedback from peers, family, and instructors which reportedly provided a boost to their engineering efficacy. Ashley, for example, explained the relief she felt at receiving reassurance from her parents that they would remain proud of her even if she no longer maintained the 4.0 GPA that she had in high school:

> I'll call my parents, I'm like, "Oh, I didn't do good, I failed another test," and they're like, "It's okay, just get through it. All you need is to pass—like we don't want you to—you don't have to get 4.0 anymore, just-just pass." So it's kind of reassuring to think—"Okay, I don't have to—I just need to pass". Like, that's my goal.

Only female students described being affected by the nonverbal actions of others. When asked about factors that might make her question her ability to succeed in the ENGR 106 environment, Mary discussed the perceived lack of faculty interest in students' success.

> …just the fact that you're on your own. The faculty, well the majority of the faculty, don't really care to help you. I don't know if they don't care or they don't have time… maybe the ratio of faculty-to-student is just too big…

Women did not, however, always perceive nonverbal feedback as negative. Abby, for example, noted positive experiences with her TA:

> . . . my TA is phenomenal . . . He wants to be there and it shows. A lot of people are like, "Oh my TA is terrible. They hand us worksheets and if you have problems they're kind of like, 'I don't know figure it out.' " [My TA] takes time, not even just in lab. Like, I had questions and he made an appointment to see me outside of class, and I sat down and talked to him about how loops worked for hours. I understand loops now! So like you know, he really genuinely cares I think.

Students also interpreted the practices and policies used in ENGR 106 as a type of nonverbal message being sent by those in charge of the course. For example, roughly half of the participants, a mixture of both men and women, perceived the grading policies used in ENGR 106 as a weed-out tactic employed by the ENGR 106 instructors. Becky explained this perceived message:

> Um, the grading of the quizzes that they give us in lecture (laugh), I don't know I feel like a lot of the times they just find excuses to take points off because they're trying to weed people out or whatever . . . a lot of the grading is pretty ridiculous and it's discouraging for me . . .

It is interesting to note the number of students who held on to this perception (i.e., ENGR 106 as a weed-out course) despite repeated attempts by faculty to explain to them that this was not the case.

IV. Discussion

Pre-semester student interviews revealed that, upon entering the engineering environment, our participants were quite confident in their ability to achieve engineering success. This is not surprising when one considers repeated examples from prior research suggesting that self-efficacy beliefs strongly influence the choices people make (Bandura, 1997; Betz and Hackett, 1981; Hackett, 1985; Lent, Brown, and Hackett, 2000). Because these students had chosen to pursue a career in engineering, self-efficacy theory would predict that they would enter the university setting with strong engineering efficacy beliefs. Participants consistently reported previous high school successes as the most influential basis for their engineering confidence. This trend has also been identified in previous investigations (Bandura, 1997; Lent et al., 1996a and 1996b; Matsui, Matsui, and Ohnishi, 1990) that have suggested mastery experiences to be the most common and the most influential source of self-efficacy.

After three months in the first-year engineering environment, interview participants reported very different bases for their confidence in ENGR 106 success. Instead of continuing to focus on mastery experiences associated with their coursework, many of our participants were found to focus predominantly on the vicarious experience of performance comparisons. Although our data show that these students were in fact experiencing mastery in ENGR 106, those experiences were no longer the focus of their discussions. Rather, numerous instances were identified for which the students interviewed compared their own understanding of course material, teaming experiences, computing abilities, abilities working assignments, problem-solving abilities, and help seeking experiences to those of their classmates. This change in the students' perceptions of their experiences when assessing their self-efficacy beliefs might be attributed to the different contexts in which pre- and mid-semester interviewees discussed their experiences. Participants who were interviewed prior to the start of the semester reflected on their high school experiences which had been completed months earlier and were largely confirmed successes marked by the students' successful graduations from high school. In contrast, mid-semester participants were forced to consider ongoing ENGR 106 experiences that had not yet come to a final endpoint. The differences identified in how the students discussed the experiences that shaped their engineering efficacy at different points in the semester might be interpreted as suggesting that mastery experiences require some maturation time before students are able to recognize them as such. Another study investigating the self-efficacy beliefs of students more advanced in the undergraduate engineering curriculum has, however, demonstrated that second-year students were quite capable of recognizing their mastery experiences as they occurred (Hutchison, 2007).

The suggestion that first-semester engineering students base their self-efficacy beliefs predominantly on performance comparisons, rather than on mastery experiences, is at odds with a number of previous studies that have investigated the mathematics self-efficacy beliefs of first- and second-year college students (Lent, Lopez, and Bieschke, 1991; Lent et al., 1996; Matsui, Matsui, and Ohnishi, 1990). Those studies surveyed students in an introductory psychology class, asking them to respond to items regarding their mathematics efficacy. Surveys were usually administered within the first half of the semester. Their results are consistent with our findings among pre-semester participants; prior to actually entering the learning environment, self-efficacy was most influenced by previous high school mastery experiences. Yet, upon entering the engineering environment, our students modified the way in which they formed their self-efficacy beliefs. The inconsistencies between our results and those of Lent et al. (1991 and 1996) and Matsui et al. (1990) can likely be explained by the lack of a mathematical context in a psychology classroom—where the latter studies were carried out. Since the psychology students were not in the midst of using their mathematical abilities in new and challenging ways, they may not have been assessing their mathematical efficacy in the same context in which ENGR 106 students assessed their engineering efficacy. This assumption is consistent with the importance Bandura (1997) places on the context in which self-efficacy is assessed.

The findings from our work demonstrate the susceptibility of our interview participants' self-efficacy beliefs to the influence of performance comparisons. While self-efficacy theory claims that mastery experiences are the most influential source of self-efficacy, it also maintains that in situations for which individuals have little or no experience, they may be left to gauge their adequacy on little else than the performance of others (Bandura, 1997). Thus performance comparisons may act as the primary factor in the self-assessment of engineering abilities among first-semester college students who are likely unfamiliar with situations such as those experienced in ENGR 106. Solving open-ended problems, computing, programming, attending large lectures, taking notes, interacting with TAs and many other practices common to the collegiate environment may all be new to these students, creating conditions that foster the use of performance comparisons in the formation of self-efficacy beliefs.

Also of interest in these results are the different experiences men and women reported with regard to performance comparisons. Men most often reported confidence in ENGR 106 success based on their perception of their abilities to outperform their classmates. Such reports suggested that for each instance in which men perceived that they had outperformed their classmates, their self-efficacy in the course was strengthened. In contrast, women often lacked confidence because they did not feel they could perform at the same level as their peers. When comparing their abilities to those of their classmates, women most often perceived that their performances were inferior, an assessment that usually lead to diminished self-efficacy.

It seems quite unlikely that our female participants never experienced positive performance comparisons and similarly, that their male counterparts never experienced negative comparisons; however, this is what their interview excerpts would appear to suggest. We propose an alternative interpretation of the data. Specifically, we believe that although men and women alike experience both positive and negative performance comparisons, men are more likely to focus on positive experiences while women tend to reflect on negative experiences. We further contend that this interpretation may be particularly useful in explaining statistically identified gender-efficacy trends. For example, as we develop future research designed to further explore the potential SAT score/efficacy score/gender correlations described earlier (Table 2), the results presented here could prove clarifying to quantitative results.

Self-efficacy research has long demonstrated differences in men and women's underlying levels of efficacy. This was true even among our participants and the ENGR 106 population as a whole (Table 1). In a study of engineering students at 17 institutions Besterfield-Sacre, et al. (2001) found that across nearly all institutions studied, men rated their confidence in their basic engineering knowledge and skills, problem-solving abilities, and engineering abilities statistically higher than women. Similarly, a study (Hutchison, 2007) that investigated the self-efficacy beliefs of first-year students mid-way through their first semester in engineering found that men reported significantly higher course and computer self-efficacy than their female peers. This study also found that men rated themselves significantly higher than women when asked to compare themselves to their classmates. These studies support the assumption that because men are more likely to conclude that their abilities surpass those of their classmates, they tend to be more confident in their engineering abilities. This is a direct demonstration of the positive influence performance comparisons have on men. Women, however, are prone to underestimating their abilities, leading to adverse effects on their self-efficacy beliefs.

Others (Hackett and Betz, 1981; Lent et al., 1991) have postulated gender differences in self-efficacy might be explained by variations in efficacy sources accessed by men and women. The results of their work support our assumption that men and women perceive themselves quite differently when considering the experiences upon which they build their self-efficacy beliefs. These findings are consistent with the current state of knowledge in the gender literature. Numerous reports (Assessing Women in Engineering, 2005; Hawks and Spade, 1998; Seligman, 1990; Seymour and Hewitt, 1997) have suggested that men tend to attribute their successes to their internal abilities and their failures to external factors; whereas women are more likely to attribute their failures to their own abilities and their successes to external factors. This gender literature offers a plausible explanation for our finding that women in ENGR 106 perceived more failures while in the course than their male peers. Consistent with our findings, Margolis and Fisher (2002) found that, "not only do women perceive male students as knowing more computer science, but many experience men doing it with greater ease . . . " From their investigation of the factors that influenced students' decisions to drop-out of a chemistry doctoral program, Workman and Bodner (1996) similarly reported that women did not believe they had the ability to juggle multiple responsibilities as well as their peers, while men did not see this as an issue.

In addition to being extremely informative in the field of engineering education, these results also lend further credence to self-efficacy theory. The findings presented here support the theory's claims on a number of levels and demonstrate its applicability to engineers. Although we set out to determine whether any new sources of self-efficacy could be identified among our first-semester engineering students, we were able to find none. Moreover, we found significant evidence that the persuasive power of vicarious experiences out ways that of mastery experiences in situations for which individuals have little experience, as asserted in self-efficacy theory. The results of this work therefore support future use of the theory in the engineering education environment.

V. Implications for Educators

These results offer educators insights into how they might promote the development of positive self-efficacy beliefs in their students through the to creation of proactive measures and intervention strategies. This study has confirmed that when students find themselves in situations for which they perceive their performances to be inferior to those of their peers, they become less confident in their ability to succeed in a course. We have demonstrated, for example, instances for which they perceive their speed of performance or learning to be slower than that of their classmates. Educators must therefore find ways to alleviate the pressures students experience upon encountering perceived unfavorable comparisons. Perhaps one of the most effective approaches to addressing this issue might be efforts by faculty to remind their students that they each come from different social and educational backgrounds that have prepared them to take different approaches to their engineering coursework. Furthermore, explaining to students that this is not only acceptable, but actually preferred because of a desire for diverse engineering solutions might hold promise for easing students' concerns about how they compare to their peers. Other curricular changes that might prove effective include efforts to remove bases that students often use to make comparisons. Our students, for example, frequently doubted their abilities to succeed in engineering because they were unable to complete computer programs in allotted computer lab time. Perhaps removing the necessity for such activities to be completed in a given time frame would help ease speed of performance comparisons.

The need for students to begin experiencing and confirming mastery as soon and as often as possible is also demonstrated in these findings. First-year students base their self-efficacy on vicarious experiences because they have few mastery experiences on which to reflect; however, this can be dangerous to the formation of accurate efficacy. When students base their confidence in success on performance comparisons, they risk forming inaccurate self-efficacy beliefs based on incorrect assessments of their peers' abilities. For example, students who underestimate the abilities of their classmates may end up with falsely high self-efficacy. Alternatively, overestimating peers' abilities could result in unnecessarily low self-efficacy (Bandura, 1997). The importance of providing students with examples of experiences for which they have experienced mastery is therefore clear. In order to promote students to move beyond performance comparisons to the use of mastery experiences in the formation of their self-efficacy beliefs, educators must provide students with clear, concise feedback allowing them to realize that they have in fact achieved mastery.

VI. Conclusions

Interviews with first-semester engineering students have revealed the considerable influence of performance comparisons on the self-efficacy beliefs of ENGR 106 students. Students repeatedly evaluated their confidence in engineering success by assessing their abilities and comparing them to those of their classmates based on speed of performance, nature and extent of group work contributions, amount of material mastered, and grades. In addition, gender differences were identified in the ways in which men and women perceived performance comparisons. This evidence of the widespread use of performance comparisons in efficacy belief formation supports the claim of self-efficacy theory that vicarious experiences are significantly more influential on people who have little experience in an area, as is the case for first-semester engineering students. In addition, this study failed to identify any new sources of self-efficacy among engineering students. These results therefore give further credence to self-efficacy theory and its use within the engineering environment.

The findings from this work provide engineering educators with a deeper understanding of how their students perceive the engineering environment and use their engineering experiences to shape their confidence in engineering success. By using this understanding to make modification to their classroom environments, educators have the opportunity to impart efficacy-building experiences on their students. Ultimately, these efforts hold promise for improving the achievement, success, and retention of early engineering students.

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