

AC 2007-1656: THE CHANGING TIDES: HOW ENGINEERING ENVIRONMENTS PLAY A ROLE IN SELF-EFFICACY BELIEF MODIFICATION

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The Changing Tides: How Engineering Environments Play a Role in Self-Efficacy Belief Modification

Abstract

Self-efficacy beliefs are the beliefs people hold about their abilities to complete the tasks that they deem necessary to achieve success. Efficacy beliefs influence the choices people make, the effort they put forth, and the degree to which they persist in the face of obstacles. Attempts to understand how students shape their efficacy for learning are therefore invaluable to educators. Previously, we used qualitative measures to investigate the self-efficacy beliefs of first-year engineering students. That study revealed that early engineering students most frequently based their confidence in success on social comparisons – their perceptions of how their engineering abilities compared to those of their classmates. In an extension of that study, we have expanded our investigation to include nine second-year engineering students. One-on-one interviews with five women and four men are compared to discussions with first-year students. These comparisons have shed light on how students build and modify their efficacy beliefs as they advance in the engineering curriculum.

Second-year students were interviewed while enrolled in *Chemical Engineering Calculations* (CHE 205) during the fall of 2005 or the spring of 2006. CHE 205 is the first discipline-specific engineering course in the chemical engineering curriculum at Purdue University. Results, based on a phenomenographical analysis, were compared to those obtained previously from interviews with first-year engineering students. This comparative analysis provided insights into how adaptation to college life and experience with discipline-specific coursework influence engineering students' efficacy beliefs. The open dialogue we have achieved with these students has provided us with rich, personal accounts of how students perceive the second-year engineering learning environment. Findings can help educators understand how the learning environment they create might dictate the choices, effort, and persistence exhibited by their students. Informed by such an understanding, modifications to the engineering learning environment, aimed at promoting positive efficacy beliefs, are suggested. Ultimately, these modifications hold promise for increasing diversity in engineering, improving student satisfaction and success, and increasing student retention.

Introduction

In recent years, there has been a growing call for colleges and universities to produce more flexible, innovative engineering students.¹⁻³ This call echoes the concerns of engineering educators who have recognized that the retention issues plaguing the field may be adversely affecting the diversity of the future engineering workforce. Aimed at improving the retention and success of students in the field, research efforts have been focused on the choices, achievement, and interests of undergraduate engineering students. These efforts have resulted in findings indicating that students' choices to pursue and persist in engineering, and their achievement and interest in the field, are significantly influenced by their engineering self-efficacy beliefs^{4,5} – their confidence in their abilities to perform the tasks that they deem necessary to succeed in the engineering environment.

Numerous studies have made thorough use of quantitative measures assessing students' science, technology, engineering, and mathematics (STEM) efficacy beliefs and relating them to their persistence,⁶⁻¹³ achievement,^{6, 7, 14, 15} and interest^{6, 14-17} in the fields. The findings from these studies have equipped educators with reliable efficacy assessment tools^{4, 18, 19} and clear descriptions of the predictive power in the link between positive self-efficacy beliefs and increased persistence, achievement, and interest. Still missing from the literature, however, are useful descriptions of the heuristics with which students form specific efficacy beliefs. 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 intervention strategies relies on understanding what can be done to promote positive self-efficacy beliefs among students. The first step towards addressing this issue involves explaining how students arrive at their efficacy beliefs.

Bandura's self-efficacy theory defines four sources from which efficacy beliefs are developed: mastery experiences, vicarious experiences, social persuasions, and physiological states.⁴ Efficacy beliefs are shaped by *mastery experiences* through the interpretation of one's performances on particular tasks. Mastery experiences, suggested by both theory and research to be the most influential source of efficacy,^{4, 20} occur when "successes build a robust belief in one's personal efficacy" and "failures undermine it, especially if failures occur before a sense of efficacy is firmly established".⁴ Slightly less influential than mastery experiences, *vicarious experiences*, also called social comparisons, 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* can also influence self-efficacy beliefs. Those who are socially persuaded that they have the necessary skills to succeed are likely to put forth more effort and endure longer in the face of challenges than those who are not encouraged.⁴ The *physiological states* people associate with their actions, such as anxiety, stress, fatigue, and other emotions, can also affect their self-efficacy beliefs.

To best understand the sources and cognitive processing of students' self-efficacy beliefs, efficacy theorists have suggested that a discovery-oriented, qualitative approach is required.^{21, 22} One study taking this approach has found that while men succeeding in mathematics related fields are most likely to base their efficacy beliefs on mastery experiences, women base their beliefs on vicarious experiences and social persuasions.^{23, 24} Another investigation of first-year engineering students has found that men and women alike appear to place significant weight on vicarious experiences, specifically social comparisons, when forming their engineering efficacy beliefs.^{25, 26} The findings resulting from the study of first-year engineering students are in agreement with self-efficacy theory which states that there are "conditions under which self-efficacy appraisals are especially sensitive to vicarious information. The amount of uncertainty about one's capabilities is one such factor".⁴ Vicarious experience can therefore become more influential than mastery experiences when, "people have had little prior experience on which to base evaluations of their capabilities,"⁴ as is the case among beginning engineering students. The current work extends the investigation of first-year engineering students' efficacy beliefs to include second-year students. Due to the comparative nature of this longitudinal study, the methods employed here parallel those used in the investigation of first-year students.^{25, 26} The qualitative study is designed to develop our understanding of how second-year students build and

modify their efficacy beliefs as they advance in the engineering curriculum. Semi-structured, open-ended interviews with students have led to detailed descriptions of the second-year engineering experience and how its various components act to influence their confidence in their ability to achieve success.

Research Design

Theoretical Grounding and Framework

Designed to increase the retention and success of engineering students, this study sought to identify means by which engineering educators can assist their students in the development of more accurate efficacy beliefs. As such, self-efficacy theory was selected as the guiding theoretical construct. In the development of self-efficacy theory, Bandura recognized the importance of a theory's ability to promote change through its predictive powers. He therefore included in his theory guidelines for the measurement of and promotion of desired changes to self-efficacy beliefs.⁴ We aimed to build an understanding of how engineering educators might best promote positive change in the efficacy beliefs of their students, a goal that was complimented by self-efficacy theory.

Through this study, we sought to identify factors that affected students' efficacy beliefs and to understand how students cognitively process those factors. The investigation was therefore conducted through a phenomenographical lens. Phenomenography is the study of, "...the limited number of qualitatively different ways in which we experience, conceptualize, understand, perceive, apprehend, etc., various phenomena in and aspects of the world around us".²⁷ Previous work has established that efficacy beliefs can vary by gender as well as among members of the same gender.^{13, 23, 28} It was therefore appropriate that we used phenomenography to investigate the variety of ways that students perceived the engineering environment rather than using a phenomenological focus in an attempt to identify a single essence students might associate with the environment.

Participants

Participants in this study were second-year chemical engineering students enrolled CHE 205, *Chemical Engineering Calculations*, at Purdue University. CHE 205 is a three-credit course required of all chemical engineering students for progression in the department's curriculum. The course covers introductory material and energy balances on chemical processes. Conducted in the fall of 2005 and the spring of 2006, the study looked at an overall CHE 205 population that was 64.6% (n = 64) male and 35.4% (n = 35) female. Differences between the two course sections included in the study are described in Table 1.

Table 1. Description of courses from which study participants were drawn.

Semester	Fall 2005	Spring 2006
# of Students	60	39
% Men	66.7%	61.5%
% Women	33.3%	38.5%
% Coop Students	6.7%	25.6%
Instructional Method	Lecture	Lecture + In class discussion groups
Homework Format	Independent completion	Completed in groups

Nine students from the fall 2005 / spring 2006 CHE 205 population, four men and five women, were interviewed for this study. Of the nine participants, one man and two women were recruited from the spring 2006 section of the course; the remainder of participants came from the fall 2005 section. No differences could be identified among the interviews obtained from students enrolled in the different course sections. One student, Abby, was a participant in this study as well as in our previous investigation of first-year students.^{25, 26} Pseudonyms were assigned to each of these participants to ensure confidentiality. Table 2 illustrates how the participants' SAT / SAT equivalent scores compared to those of the entire fall 2004 cohort with which they entered the College of Engineering.

Table 2. SAT / SAT equivalent overall and math scores of participants compared the distribution of scores for the entire 2004 College of Engineering cohort (SAT scores were not available for transfer students Paul and Britney).

	SAT / SAT Equivalent Overall Scores	SAT / SAT Equivalent Math Scores
Bottom 25% of Class	<i>Below 1180</i>	<i>Below 620</i>
	• Rachel	• Ben • Rachel
Middle 50% of Class	<i>1180 – 1320</i>	<i>620 – 690</i>
	• Ben	• Shelby
Top 25% of Class	<i>Above 1320</i>	<i>Above 690</i>
	• Shelby • Michelle	• Abby • Michelle
	• Nate • Juan	• Nate • Juan
	• Abby	

Procedure

Participants were recruited mid-semester during the fall of 2005 and spring of 2006. All students enrolled in CHE 205 during these two semesters were assigned to take an on-line survey as part of a required homework assignment. The results of this survey, qualitatively designed to assess students' perceptions of the CHE 205 learning environment, are reported elsewhere.²⁹⁻³¹ Upon completing the survey, students were given the option to volunteer to provide a more in-depth description of their experiences in CHE 205 through a one-on-one interview. All student volunteers were subsequently interviewed. Interviews were conducted in the authors' offices, audio-taped and later transcribed. At the beginning of each interview, students were reminded of the motivation behind the study, the measures that would be taken to protect their confidentiality, and the voluntary nature of their participation. Semi-structured interviews were conducted with

each participant based on an interview guide (see Appendix A) modified from previous work.^{25,}
²⁶ Interviews ranged in length from 40 to 150 minutes.

Instrument

Often, research in the area of self-efficacy makes use of structured surveys designed to quantitatively measure students' efficacy beliefs and assess efficacy influences. This study, alternatively, employed an interview protocol designed to provoke in-depth participant discussion of the factors they considered in the assessment of their efficacy beliefs and how they weighted those factors to form their beliefs. To ensure that each participant was asked similar questions in a similar order while still allowing for flexibility to probe students' responses with follow-up questions, a semi-structured, open-ended interview protocol was developed. The interview was administered following the same procedure used in previous work;^{25, 26} the order and wording of the protocol were strictly adhered to with each participant to minimize its effect on the patterns found in the subsequent analysis of interview transcripts.

The protocol used in this study was slightly modified from that administered in a previous work.^{25, 26} Modifications to the original protocol included replacing references to a first-year engineering course with references to the second-year course, CHE 205. Several additional exploratory questions were also included in the modified protocol; these new questions are highlighted with italicized type in Appendix A.

As noted in earlier work,^{25, 26} the protocol was designed to methodically explore students' efficacy beliefs as well as each of the sources of efficacy suggested by self-efficacy theory. Students were introduced to the interview setting by first being asked about what prompted them to pursue engineering. Their attention was then focused onto their second-year engineering course, CHE 205. They were asked, "How do you define success in CHE 205, or what do you have to do to consider yourself successful in the course?" and were told "I am interested in how you think you are doing in your quest to achieve success. To what degree do you think that you are being successful in 205 right now?" Once the students had been prompted to consider their CHE 205-efficacy beliefs, each efficacy source was probed as shown by the protocol excerpt in Table 3.

Table 3: Excerpt from interview protocol.

Interview Question	Source Probed
What experiences have contributed to how confident you are that you will be successful in CHE 205? How did these experiences affect you?	Mastery experiences / Vicarious experiences
How have other people influenced how you think you are doing in CHE 205?	Vicarious experiences / Social persuasions
What have people said to you during CHE 205 that has affected your confidence in your success?	Social persuasions
When thinking about or doing CHE 205, how do you feel?	Physiological states

A variety of questions designed to elicit free responses regarding particularly memorable experiences with engineering and CHE 205 were also included in the protocol. Such discovery-oriented items included: “Tell me a memorable story that could really help me understand how you came to pursue engineering,” and “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 CHE 205?” These questions led respondents to discuss the foundations of their engineering-efficacy beliefs and to provide personal interpretations of events that they perceived to be meaningful in the development of those beliefs.

Analysis

The methods of data analysis used in this study paralleled those used in our previous work investigating the efficacy beliefs of first-year engineering students.^{25, 26} First-level coding, a method for summarizing segments of data,³² was achieved using self-efficacy theory’s four efficacy belief sources and two additional categories for sources falling outside of those described by the theory. Pattern coding³² was then used to group those summaries into smaller sets of themes based on the how the source was described as influencing efficacy. To best understand how these students were affected by the experiences they described, focus was placed on those descriptions of experiences that were linked to some discussion of the resulting effect on the student’s efficacy beliefs.

One strategy frequently used to ensure the reliability and validity of qualitative data is member checking. The practice is used to ensure that interview participants are accurately represented within a study. This is accomplished by providing each participant with a copy of their interview transcripts and the inferences the authors have drawn from the transcripts so that accuracy of conclusions can be confirmed.³³ In the case of this work, conclusions have been drawn based on a preliminary analysis of interview transcripts; member checking is currently underway, but has not yet been completed.

Results

When the findings from this study were compared to those from previous work involving first-year engineering students,^{25, 26} the results clearly demonstrated that as students advance in the engineering curriculum and experience new learning environments, they begin to modify the way in which they process sources of efficacy. While the influence of verbal persuasions and physiological states were present in students’ discussions, we focus here on two important changes noted between first- and second-year students: a shift in the way in which working with others was perceived and a shift in the perception of mastery experiences. Most of the CHE 205 students interviewed discussed the influence of the same types of social comparisons described by first-year students; however, the second-year students also frequently described the influence of new sources of efficacy. Analysis of interviews with CHE 205 students showed that like first-year students,^{25, 26} second-year students’ continued to base their efficacy beliefs on the degree to which they were able to contribute in group work environments. These once competitively charged comparisons, however, had in many cases been traded for comparisons that fueled feelings of camaraderie. The grades-based social comparisons made by first-year students^{25, 26}

were rarely discussed by second-year students, suggesting that once students were able to acclimate to the engineering environment, these types of comparisons lost their influence. As was seen among first-year students, some second-year students still discussed the influence of how they compared to their classmates with respect to the amount of material they had mastered and how quickly the mastery occurred. Growth, however, was identified in the way second-year students processed these experiences. Often, they were able to move past these comparisons to recognize and emphasize small yet significant mastery experiences that were frequently overlooked or disregarded by first-year students.

Here, excerpts from interviews with students enrolled in CHE 205 serve as illustrative and comparative points in the discussion of the modification of these engineering students' efficacy beliefs as they advance in the engineering curriculum.

Shift in the perception of contributions when working with others. When discussing how they assessed their confidence in course success, first-year engineering students frequently referenced the degree to which they were able to contribute knowledge when working with others. These students described either a heightened sense of efficacy based on their ability to contribute to team efforts or diminished confidence in success when they repeatedly required the assistance of their peers during group work.^{25, 26} This type of vicarious experience remained an influence among CHE 205 students as well. Ben, an international student in CHE 205, described doubts in his ability to succeed in the course because he seemed to always be the person in his homework group asking questions and not understanding.

...we're sort of set up in like this group project where um, you're working with a group on your homework and...I go in, personally, like reading the homework in advance and try to do it by myself but whatever I don't understand, like I can't – I don't feel comfortable going in and asking my partner about it, if he knows it – if I'm lucky enough to have a partner that actually understands it because, I mean, I'll ask a question over – you know, I can only ask a question so many times before it gets irritating, like when I don't understand it or something like that. I wish I was doing better, I guess.

Similarly, Brittany, a pre-pharmacy student who transferred to chemical engineering, discussed how she felt less confident in CHE 205 success because she was not able to answer the questions of others as effectively as some of her peers were.

[I feel less confident in CHE 205 success] if I ask [my peers] for help and they really know what's going on. I'm like "Oh, okay, well why didn't I figure it out?" Or, I'm afraid I'll have no idea what they're talking about, but they'll sit there and explain it to me – which I appreciate a lot – but I just wish I could do that too.

The perception that how much assistance one contributes to or requires from a group work experience remained a dominant efficacy influence among CHE 205 students; however, it was not discussed as frequently as was a new, more positive perception of this type of experience. Rarely expressed by first-year students,^{25, 26} the influence of feelings of camaraderie and support experienced while working with others were

frequently discussed by CHE 205 students. Michelle, for example, discussed feeling more confident in CHE 205 success because working with her peers allowed her to see that there were others in the class with abilities that were similar to her own.

I have, um, one friend in class that – we’re like on the same page...if we sit down, we’ll both sit and like, “Oh, I don’t get this,” and then we’ll just feed off one another and we’ll come up with the answer, just like magic. It’s like, “Oh, I see this,” and then she’ll see something that I didn’t see and so like together we can piece it all together; it’s wonderful. And that makes me feel a lot better. ‘Cause, you know, there are other people like me. That makes me feel better.

Megan similarly expressed the positive influence of mutual support among her peers.

Working with other people and just seeing where those people are – helping other people and explaining – working in a group really helps...It’s like, “Well, if they can get this then I think I can get it too.” And definitely having other people explain sometimes really helps because they might have a different way of going about it than the book and [the professor] have gone about it, and it’s like, “Oh, gosh, that makes a lot of sense.”

Shift in perception of mastering material. Interviews with CHE 205 students revealed that, like first-year students²⁵, second-year students often gauged their confidence in course success by comparing how much course material they had mastered – and how quickly they were able to master it – to what they perceived their classmates had learned. Ben, for example, described why he felt more confident that he could succeed in his Spanish class than he did in CHE 205.

[Spanish] feels a lot more open than ChemE does. For example, generally in [CHE 205], you come in and there won’t be that much participation in a class, like everybody’s just sitting there and you’ll be afraid to ask a question or some people will ask questions and you can only ask them so many times before you show others you’re stupid or being viewed as stupid or not, you know, like just not being fast enough or something like that where you don’t feel comfortable asking questions as opposed to Spanish where you constantly have the comfort.

Similarly, Juan expressed the frustration he felt when he was not able to learn as much and as quickly as some of his peers.

[CHE 205] made me feel good at first ‘cause all we were doing was process variables like volume, temperature, and pressure and that was easy. We were just like, “Okay, $PV = nRT$, easy stuff.” And then, when it got more complicated we all – we were kind of like a chromatograph, you know, some of us would go faster...follow the solvent faster; others would kind of lag behind and kind of get stuck half way, you know, and the solvent would be racing ahead. And then once all of the separations became clear, I kind of felt like, “Man, why am I not getting this?” It was making me frustrated. You know, “Why can’t I understand? Why can’t I see the pattern everyone else is seeing here? Why can’t I pick out the

information that I need immediately and just write down an equation and just do it? Why not? Why not?" It was so frustrating.

Like first-year students, CHE 205 students were clearly still influenced by their perception of how their abilities to learn the material compared to those of their classmates; however, it was apparent from interviews with the second-year students that their confidence in success was no longer completely dominated by the influence of others. The second-year CHE 205 students were instead able to look past their perception of how they compared to their peers and begin to base their confidence on a new source of efficacy – personal mastery experiences. Shelby, for example, described a boost in her confidence in CHE 205 success based on her recognition of how far she had come and how much she had learned since the beginning of the semester.

At the beginning I was just like, how do-how do you expect me to know some of this stuff. Like, I haven't taken a class on this material before and it kind of was like – the first couple weeks it was just like you're expected to know how to do it and I was like, "but I haven't been taught this material before", like "what do you want from me", and ah, now I'm starting to see a little bit more correlation between what we did at the beginning of the semester, 'cause you have to build on it so now the stuff at the beginning was really easy and, um, the stuff that we're learning in stuff now is um, better than before So, um, it's a progression like I am-I can tell that I'm learning and I'm doing better...I think based on our exam grades, I feel more confident because from the first one to the second one, I-I did do a lot better. So, that, um, it's exciting to see because it's like "oh, yeah, I actually do get something that's going on". Um, it makes me more inclined to ...you know once I understand something, I'm more into it and I'm more inclined to be like "oh, now I see where we're going with that", but if I'm lost, then I'm just lost the whole way, so....

Michelle spoke about her confidence in her problem-solving abilities being only "six and a half [out of ten]" because of areas she still struggled in; however, she too remained optimistic based on the fact that she recognized she was learning: "...I still have problems doing recycle so, I don't really understand that. I'm better than I was before when we first learned it, but, there are still tricky aspects. Um, I absolutely don't know everything, that's for sure. I'm still in the process of learning."

Juan also provided an interesting description of how he had been influenced by this type of mastery experience. He explained the positive influence of having mastered certain portions of material and the doubt that arose from recognizing areas with which he still struggled. This excerpt illustrates his advanced ability to identify not only areas where he was succeeding, but also where the gaps in his understanding lied.

I'm going along at a good pace. Ah, I feel-I feel pretty good now because we're kind of tapping the meat of this class. We're doing energy balance – combine that with mass balance – that's basically what the class ultimately tries to teach you, right – can you do both of them at the ah, simultaneously? So I feel pretty good because I've – I've got the grasp on mass balance; I've got the grasp on energy

balances. And, I understand the basic nuts and bolts of, you know – you’ve got Hess’s Law – we go through a process any number of ways and things like that. It’s the little details that trip me up though. For example, I like to be able to visualize – say there’s a pre-heater in this problem for example. I would like to see what a pre-heater is and what’s going on in it. Is there mixing of stuff in the pre-heater, or as a heat-exchanger – is the water that you’re bringing in for cooling – is that mixing with the – with the hot, ah, toluene vapor, let’s say. Are those two mixing at all, is there any kind of condensation of the water, is the water as a vapor, or you know, things like that. Since I don’t have experience working in a chemical plant or anything like that, I can’t visualize it ‘cause I don’t know what these things really are. All I see is a box and you know, heat-exchanger written on it. So, in terms of that, I don’t feel very successful because I don’t understand exactly what’s going on in the process. I can tell you “yeah, you know, 222 units of energy got transferred,” but from what to what, and by what means, and to what membrane, and to what wall, or tube, or whatever. I don’t understand what’s going on there. And when I don’t understand, like when I can’t visualize stuff like that, it’s also difficult for me to say whether something is, for example, all vapor, all liquid, did something condense because it’s under an extraordinary circumstance, you know stuff like that; which may not apply to me now, but if I don’t learn it now when am I gonna learn it?

Discussion

When compared to previous similar work investigating the self-efficacy beliefs of first-year engineering students,^{25, 26} the findings presented here illustrate a significant shift in second-year chemical engineering students’ perceptions of the sources on which they base their efficacy beliefs. First-year students were found to rely primarily on social comparisons known as vicarious experiences when asked about the experiences that influenced their confidence in success in an engineering course. By comparison, second-year chemical engineering students retained this tendency to reflect on vicarious experiences; however, their perception of the experiences illustrated a gradual shift from seemingly competitive comparisons to comparisons that led to feelings of camaraderie and the formation of peer support networks. Moreover, CHE 205 students were also influenced by an experience described much less frequently by first-year students: personal mastery of material.

One of the first longitudinal, qualitative investigations of engineering students’ efficacy beliefs, this study supports the tenants of self-efficacy theory within the engineering environment. Bandura’s theory claims that mastery experiences are the most influential source of efficacy beliefs. It also maintains, however, that for instances with which individuals have had little opportunity to confirm or disprove their abilities, they may be left to measure their abilities against those of others.⁴ The results presented here and in previous work^{25, 26} illustrate this trend among first- and second-year engineering students. These students enter the engineering environment with little or no experience solving open-ended problems, computing, programming, attending large lectures, taking notes, interacting with TAs, and other experiences common to the engineering environment; conditions that efficacy theory describes as fostering students’ use of vicarious experiences. After one year of experience in the engineering

environment, however, second-year students appear more able to recognize when they have mastered a concept and where they lack understanding. These students are therefore able to begin placing more emphasis on mastery experiences, the most influential source of efficacy predicted by theory.

Beyond their explanation by self-efficacy theory, these results are further justified by students' different interpretations of the first- and second-year engineering environments. First-year students were often inclined to describe their first engineering course as a "weed-out class." At Purdue University, all first-year students enter the First-Year Engineering Program; upon completing the requirements of this program, students are eligible to apply to the engineering professional school (e.g. chemical, mechanical, civil, etc.) of their choice. Based on their perceptions that it was not possible for all first-year students to be granted admission to an engineering professional school, feelings of competition may have been fostered among first-year engineering students that catalyzed their use of social comparisons.^{25, 26} By their second year in the engineering environment, the students studied here had been accepted into the chemical engineering professional school and no longer expressed feeling as though they could still fall victim to the weed-out process. Instead, CHE 205 students frequently described their professors as "encouraging", motivating (e.g. "...he implied to me that he felt like I could succeed...so I was like "okay, well if he thinks I can maybe I actually can."), and "...animated ; it kind of keeps you awake 'cause he walks into the class and all of a sudden he's just very happy and just telling us...like what designs he's making or what companies he's been talking to or as soon as he walks in the class that's the first thing he tells us to get us like interested." This is in stark contrast to first-year students who rarely discussed their instructors in this way.

Group work was also emphasized differently in the first- and second-year environments. First-year students were assigned to teams for the computer lab portion of the course. Quizzed at the end of each lab session over the tasks that they were assigned to complete, these groups were often forced to rush through lab assignments with little regard for how well each student understood the material they were covering. In contrast, second-year students worked homework problems in both assigned (spring 2006 section of CHE 205) and unassigned (fall 2005 section of CHE 205) groups. With fewer time restraints placed on their group work, the CHE 205 students were likely much more inclined to spend significant amounts of time assisting group members who were not understanding the course material.

It is likely that once accepted into an engineering professional school where they felt fewer competitive pressures, second-year students were able to reduce the focus they placed on how much "better" or "worse" their course performances were compared to those of their classmates. In addition, different group work formats offered more opportunities for students in CHE 205 to provide and receive peer support. These differences in CHE 205 therefore offered students with opportunities to change their focus within the learning environment and allowed them to recognize peers of similar ability and focus on their own personal mastery experiences.

These results strongly suggest that students' efficacy beliefs are directly impacted by their learning environment. The illustrated shift in efficacy belief influences offers educators insights into how they might promote the development of positive efficacy beliefs among their students. It is clear that, in part, only time can provide students with the personal experiences necessary to

promote the use of mastery experiences in the formation of efficacy beliefs. However, it is also obvious that attempts on the part of educators to remove strong competitive feelings from the classroom may also go far in helping students base their beliefs on sources that will lead to the formation of more accurate efficacy beliefs. When students base their confidence in success on social comparisons, they risk forming inaccurate efficacy beliefs based on incorrect assessments of their own or their peers' abilities. For example, students who underestimate the abilities of their classmates may end up with falsely high efficacy. Alternatively, overestimating peers' abilities could result in unnecessarily low efficacy.⁴

The results presented here suggest ways to remove competitive pressures from the classroom may be to (1) change practices that could give the perception that it is only possible for a limited number of students to succeed, (2) encourage supportive group work interactions, and (3) make significant efforts to be an active supporter of each student's success. An unhealthy competitive nature may be introduced into the learning environment when, for example, grading is done on a curve or when any competition is designed that involves "few winners and many losers."³⁴ Supportive group work interactions have been shown to arise when students are encouraged to work together cooperatively rather than to compete as individuals.³⁵ Finally, the work reported here supports previous findings suggesting that students' confidence and motivation can be improved by instructors who demonstrate enthusiasm, interest in their students as individuals, and active involvement with their students.³⁶ Incorporating such practices in the classroom may be the first step educators can take to promoting the formation of more accurate efficacy beliefs among their students.

Conclusions

Interviews with second-year chemical engineering students have revealed that while vicarious experiences still play a considerable role in the formation of engineering-efficacy beliefs, the students also appear to place significant importance on mastery experiences. First- and second-year engineering students alike routinely assessed how their abilities compared to those of their classmates in determining their confidence in course success. However, unlike first-year students who often assessed only if they were doing better or worse than their peers, second-year students frequently included a different vicarious experience in their discussions – the positive influence of identifying others of similar ability. Moreover, second-year students described the influence of personal mastery experiences with much more frequency and conviction than first-year students. This shift from being influenced largely by social comparisons to the inclusion of master experiences supports the claim of self-efficacy theory that mastery experiences will often not become influential until an individual has established familiarity in a given area.

The insights gained from this next step in understanding how students process efficacy belief sources are invaluable to educators. This information can act to guide the formation of proactive measures and intervention techniques for the promotion of positive self-efficacy beliefs among students, aimed at ultimately increasing their achievement, success, and retention.

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Interview Questions – Fall 2005 / Spring 2006

(Italicized font indicates questions that were added to the originally created protocol)

Background information

- What engineering professional school are you in?
- What made you choose this engineering discipline?
- *What did people say to you when you told them you were going to pursue engineering? (verbal persuasions)*
- *What have people said to you along your pursuit? (verbal persuasions)*

Definition of success in CHE 205 and course efficacy

- I'm really interested in how students view success in class.
 - Can you tell me about your thoughts? How do you define success in CHE 205? What do you need to do to consider yourself successful?
 - If you had to rank these things, which is most important?
- I'm also interested in how you think you're doing in your quest to achieve success in CHE 205.
 - To what degree are you achieving success in CHE 205?
 - Why do you believe this?
- On what experiences are you basing your judgment? (mastery experiences)
 - What experiences have contributed to how confident you are that you will be successful?
 - How did these experiences affect you?
- How have other people influenced how you think you're doing? (vicarious)
- What have people said to you during CHE 205 that have affected your confidence in your success?
 - How have people (family, teachers, peers) encouraged you to succeed in the class? (social influences)
 - How have people (family, teachers, peers) discouraged you from succeeding in the class? (social influences)
- How does CHE 205 make you feel? When thinking about CHE 205, how do you feel? When doing CHE 205, how do you feel? (physiological)
- Of all of this feedback you're getting (list their mastery, vicarious, social, and physiologic experiences), is there any one thing or any couple of things that really affects your beliefs about your abilities more than the others?
- What can instructors do to promote your success in CHE 205?
- I'm also interested in understanding how you think the general CHE 205 population feels about success. How do you believe other people in your class define success in CHE 205?

Narrative

- *Tell me a memorable story that could really help me understand how you came to pursue engineering.*

Think of a time you felt really confident about your performance in a particular class. It could be either a class you're taking now or one you've taken in the past.

- Tell me about it.
- What about it makes you feel confident?
- How was your experience in this class different than your experience in CHE 205? How is it similar?

Success (in college, and does it “fit-in”)

- Finish this statement: When I'm looking back on my college days, I'll think I was successful at Purdue if _____.
- How do you believe your peers would finish this statement?

Satisfaction with engineering

- *Think about the rest of your education here, at Purdue.*
 - *What are the important tools you think you'll need to be successful?*
 - *Do you feel the things you are learning in CHE 205 are relevant and important for your success in your future classes?*
 - *What aspects of the course are particularly relevant?*
 - *What aspects do you feel will be useless?*
- *Think about what you foresee yourself doing as a “real world engineer.”*
 - *What are the important tools you think you'll need to be successful?*
 - *Do you feel the things you are learning in CHE 205 are relevant to the skills you'll need as a “real world engineer?”*
 - *What aspects of the course are particularly relevant?*
 - *What aspects do you feel will be useless?*
- In what ways are you satisfied with your experience in CHE 205? Tell me things you're satisfied with regarding CHE 205. (Don't prompt and see what they give you. If not much, prompt for aspects of environment, content, team, etc.)
- In what ways are you dissatisfied with your experience in CHE 205? What are some things you're dissatisfied with regarding CHE 205?
- Do you enjoy CHE 205? Why?

Problem Solving Efficacy – What is it? Why? How do you assess it?

- How would you rate your CHE 205 problem-solving abilities? (Are you excellent at solving problems, good, fair, poor?) Why?
- How do you go about solving a problem? How do you know that you've solved a problem?
 - How do you rate your abilities with each of these aspects?
 - Why?
- How do you assess your abilities to solve CHE 205 problems?
 - In/Out of class experiences?
- Describe the things that make it harder for you to solve CHE 205 problems.
- Describe the things that make it easier for you to solve CHE 205 problems.

- What besides your problem solving ability affects your ability to get a high grade in CHE 205?
 - Which of these abilities do you view as most important? As least important?
- How do you know when you understand something? For example, how do you know when you're ready to take a test in the subject?

How does comparison with peers affect efficacy beliefs?

- Compare your CHE 205 problem-solving abilities with those of your CHE 205 classmates.
 - If you could group your classmates into different groups, what would the different types of groups be, which group do you consider yourself part of, which groups are the majority and which groups are pretty much the minority?

Class Efficacy – What is it? How do you assess it?

- Fill in the blank: I believe I have the ability to get a grade of ___ in my CHE 205 class.
- What experiences (in-class or out-of-class) have influenced your beliefs in your CHE 205 problem-solving abilities?
- If someone asked you for evidence to convince them that you have the ability to get a grade of ___ in CHE 205, what would you tell them?
 - Give me an example of something that proves you can solve CHE 205 problems.
 - What evidence might contradict this? Give me an example of something that contradicts this.
 - Why do you value the one experience over the other?
- What grade do you think you deserve in CHE 205? Why?
- At the end of the semester, what grade do you think you will receive in CHE 205?
 - What is helping you earn it?
 - What makes it difficult to get an A in CHE 205?

Engineering Degree Efficacy – What is it? How do you assess it? How is it different from class efficacy?

- Do you believe you have the ability to earn an engineering degree from that school?
 - Why do you believe this?

Engineering Career Efficacy – What is it? How do you assess it? How is it different from class efficacy?

- Do you think you'll be successful as an engineer in the “real world”?
 - Why?
 - How are you defining success?

Are you an imposter?

- How do you relate to the following sentiment?

I don't belong here...I'm clever and hard--working enough to have faked them out all these years and they all think I'm great but I know better...and one of these days they're going to catch on...they'll ask the right question and find out that I really don't understand...and then...and then.... The tape recycles at this point, because the consequences of them (teachers, classmates, friends, parents,...) figuring out that you are a fraud are too awful to contemplate.

- On a scale of 1 to 5, where 1 is that you don't relate at all to this statement and 5 is that you completely relate to this statement, to what extent do you relate to this sentiment?
 - Can you elaborate on this?

Other

- Who/what do you look to for support as you go through your training to be an engineer?
- Are there other things we can do to improve your CHE 205 experience?
- Are there things regarding your CHE 205 experience that you'd like us to keep just as they are?
- Is there anything else about CHE 205 that you did not get a chance to share during the interview and would still like to share with me right now? / Is there any question I did not ask that I should have asked?