2006-1344: SELF-EFFICACY BELIEFS OF FIRST-YEAR ENGINEERING STUDENTS: IN THEIR OWN WORDS

Mica Hutchison, Purdue University

Mica A. Hutchison is a Ph.D. candidate in the Department Engineering Education and the Department of Chemistry with research interests focused on engineering education and the retention of engineering students. She received her B.S. in Chemical Engineering from the University of Idaho in 2002. Her research is directed by Dr. George M. Bodner and Dr. Deborah K. Follman.

Deborah Follman, Purdue University

Deborah K. Follman is an Assistant Professor in the Department of Engineering Education at Purdue University. She received a B.S. in Chemical Engineering from Cornell University in 1994 and a Ph.D. in Chemical Engineering from North Carolina State University in 2000. Her research interests include engineering education and gender equity, specifically regarding self-efficacy, issues of gender on student cooperative learning teams, and curriculum development.

George Bodner, Purdue University

George M. Bodner is the Arthur E. Kelly Professor of Chemistry, Education and Engineering at Purdue University, where he is head of the Division of Chemical Education in the Department of Chemistry and a member of the faculty of the newly constituted Department of Engineering Education.

Self-Efficacy Beliefs of First-Year Engineering Students: In Their Own Words

Abstract

Numerous studies have used quantitative self-efficacy measures to predict the choices, achievement, and interests of undergraduate engineering students. Self-efficacy theorists, however, argue that a discovery-oriented, qualitative approach is required to better understand the sources and cognitive processing of students' self-efficacy beliefs - their beliefs about their abilities to complete the tasks that they deem necessary to achieve a desired outcome. This study has therefore employed qualitative measures to investigate the self-efficacy beliefs of first-year engineering students enrolled in ENGR 106, *Engineering Problem-Solving and Computer Tools*, at Purdue University. Here, findings based on the phenomenographical analysis of one-on-one interviews with nine students enrolled in the course in the fall of 2004 are presented. These findings provide insight into how aspects of the course environment influence the formation of first-year engineering students' efficacy beliefs. Results demonstrate the susceptibility of first-year engineering students' self-efficacy beliefs to the influence of social comparisons. Descriptions of how students make social comparisons, including the logical progression from a specific experience through the modification of confidence in success, are offered.

Introduction

As engineering educators become increasingly aware of the demand for a diverse engineering workforce of the future, retention issues plaguing the field have drawn added attention. Focus has therefore been placed on the choices, achievement, and interests of undergraduate engineering students. Researchers have suggested 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 – their confidence in their abilities to perform the tasks that they deem necessary to succeed in the field.[1, 2]

The richness of the literature surrounding the assessment of science, technology, engineering, and mathematics (STEM) students' self-efficacy beliefs and the relationship of those beliefs to persistence, [3-10] achievement, [3, 4, 11, 12] and interest[3, 11-14] in the fields is in stark contrast to the lack of investigation into the heuristics with which students form specific efficacy beliefs. The literature has provided educators with reliable efficacy assessment tools[1, 15, 16] and clear descriptions of the predictive power in the link between positive self-efficacy beliefs and increased persistence, achievement, and interest. This important body of research has made possible the identification of students who are likely to struggle in the face of obstacles and potentially leave the field of engineering. These students are the most important audiences for intervention strategies. The development of successful intervention strategies relies on understanding what can be done to promote positive self-efficacy beliefs among students, however, there is little research to draw from in this area. The first step towards addressing this issue entails explaining how students arrive at their efficacy beliefs.

Self-efficacy theory defines four sources from which efficacy beliefs are developed: mastery experiences, vicarious experiences, social persuasions, and physiological states.[1] 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[1, 17], occur when "successes build a robust belief in one's personal efficacy" [1] and "failures undermine it, especially if failures occur before a sense of efficacy is firmly established".[1] 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.[1] The *physiological states* people associate with their actions, such as anxiety, stress, fatigue, and other emotions, can also affect their self-efficacy beliefs.

To date, studies aimed at identifying the determinants of students' self-efficacy beliefs have been primarily quantitative in nature. Efficacy theorists, however, suggest that a discovery-oriented, qualitative approach is required to best understand the sources and cognitive processing of student self-efficacy beliefs.[18, 19] The current investigation therefore employs qualitative methods to better understand how first-year engineering students interpret their experiences when assessing their engineering efficacy. Semi-structured, open-ended interviewing in one-on-one discussions with students have led to detailed descriptions of the first-year engineering experience and how its various components act to influence students' confidence in their ability to achieve success.

Research Design

Theoretical Grounding and Framework

This study is grounded in Bandura's social cognitive theory, with specific focus on self-efficacy theory. Within any field of study, a theory's worth is based on its ability to elicit change in the field through predictive power. Recognizing this, Bandura has asserted that the value of self-efficacy theory is in the guidelines it provides for both the identification of self-efficacy beliefs and the promotion of desired changes to these beliefs.[1] The ultimate goal of this research is to identify means by which educators can promote the development of more accurate self-efficacy beliefs among their students in order to increase retention and success; self-efficacy theory therefore proves to be a valuable approach to these efforts.

Designed to identify the factors affecting students' self-efficacy beliefs and the cognitive processing of those factors, this investigation was conducted with a phenomenographical focus. Phenomenography is a study of, "…the limited number of qualitatively different ways in which we experience, conceptualize, understand, perceive, apprehend, etc., various phenomena in and aspects of the world around us".[20] It has been established that men and women have different self-efficacy beliefs and that these beliefs vary further among members of the same gender.[10, 21, 22] It is therefore apparent that there is not a single essence, which would be investigated with a phenomenological approach, associated with the undergraduate engineering experience. Rather, how students perceive the experience will vary, falling into several categories of perception and lending this study to a phenomenographical focus.

Participants

The participants for this study were first-year engineering students enrolled ENGR 106, *Engineering Problem Solving and Computer Tools*, at Purdue University. ENGR 106 is a two-credit course required of all first-year engineering students for admittance into an engineering professional school. The course covers engineering problem-solving, computer logic and the use of computer software (UNIX, Excel, MATLAB), teaming, and statistics and economics in an engineering context. In the fall of 2004, when this study was conducted, the ENGR 106 population was 82.3% (n = 1007) men and 17.7% (n = 217) women.

Nine students from the ENGR 106 population, four men and five women, were interviewed for this study. Pseudonyms have been assigned to each of these participants to ensure confidentiality. Table 1 illustrates how these students compared to their first-year engineering classmates based on overall SAT scores and SAT mathematics scores.

Table 1. SAT / SAT equivalent overall and math scores of participants compared the distribution of scores for the entire class.

	SAT / SAT Equivalent Overall Scores	**SAT / SAT Equivalent Math Scores**
Bottom 25% of Class	*Below 1180*	*Below 620*
	• Ashley • Jenny	• Ashley • Becky • Jenny
Middle 50% of Class	*1180 – 1320*	*620 – 690*
	• Mary • John • Ryan • Steve	• John
Top 25% of Class	*Above 1320*	*Above 690*
	• Abby • Becky • Rich	• Abby • Mary • Rich • Ryan • Steve

Procedure

Participants were recruited mid-semester in the fall of 2004. The authors visited the ENGR 106 lecture hall approximately ten minutes before the start of lecture. The nature of the study was explained and student volunteers were recruited for participation. Twenty-one interested students provided the authors with contact information so that interviews could be scheduled. Student volunteers were contacted by the authors and interviews were set up with thirteen volunteers. These volunteers were selected based on gender in order to obtain a roughly equal representation of men and women. Subsequent student follow-through resulted in interviews with nine students.

Interviews, conducted in the authors' offices, were 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). Interviews ranged in length from 40 to 90 minutes.

Instrument

The majority of research in the area of self-efficacy has employed structured surveys as the predominant method of data collection. This study, however, aimed to gain 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. In order to ensure that each participant was asked similar questions in a similar order while still allowing the flexibility to probe students' responses with follow-up questions, a semi-structured, open-ended interview protocol was developed. Care was taken to follow the order and wording of the protocol to minimize its effect on the patterns found in the subsequent analysis of interview transcripts.

The protocol, loosely based on a previous investigation,[23] 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 first-year engineering course, ENGR 106. They were asked, "How do you define success in ENGR 106, 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 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 2.

Table 2: Excerpt from interview protocol.

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

The 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 efficacy beliefs.

Analysis

This main goal of this study was to gain a better understanding of how influential experiences were processed by first-year engineering students' in the formation of their efficacy beliefs. Based on this goal, first-level coding, a method for summarizing segments of data,[24] 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 coding[24] 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.[25] 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

The analysis of ENGR 106 students' interview responses revealed many themes surrounding the effect their experiences as first-year engineering students had on their self-efficacy beliefs. Here, we focus on one theme that was found to emerge as a predominant influence among all of the interview participants: social comparisons. An exploration of students' discussions concerning the ENGR 106 experience has revealed that across nearly every facet of the course, students draw on their perception of how they compare to their classmates as a significant basis for the formation of their engineering-efficacy beliefs. Numerous instances have been identified for which these students compare 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. Students' discussion of these factors support and explain the findings of a previous study that used a qualitative survey to identify sources of first-year engineering students' efficacy beliefs.[26] In each of these discussions, students described using one of four factors as a basis for their comparisons: the speed with which they were able to perform, the degree of contribution they were able to achieve, how much material they had mastered, and their grades.

Below, excerpts from student interviews are used to best illustrate the influence of these four bases of comparison.

Speed of performance. Many students explained that the amount of time it took them to learn new material or complete assignments in comparison to how long their classmates required was a significant factor in the assessment of their efficacy. Ashley, who came to ENGR 106 with little background in using computers and no programming experience, explained that her inability to learn the new material quickly had the strongest influence on her confidence in course success, leading to the development of negative efficacy beliefs.

> I'd have to say how fast I learn [the material affects my confidence in succeeding the most]; 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.

Alternatively, Rich, an experienced programmer, spoke of the positive influence his ability to solve problems quickly had on his 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 [in the class].

Degree of contribution. 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 the development of positive efficacy beliefs due to his ability to master the skill, noting that he was able to complete programming assignments more quickly than his teammates. He further explained his ability to contribute more than his share of the work to the team project as a second factor in this efficacy-building experience.

> …and like, 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've, I think I'm doing pretty good. …And like, like in this-this last project, I wrote one of the - like 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, 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 described that her efficacy beliefs were also influenced by the degree to which she was able to contribute to teamwork and the balance between the questions she asked and those that she was able to answer:

> 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.

Material mastered. Students also frequently reported comparing how much of the material they had mastered to what they perceived their classmates had learned. Interestingly, when they spoke of this factor, students never discussed how they determined what knowledge their classmates had accumulated. 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 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 everyone else is – [the ENGR 106 instructors] are not going to fail everyone. Because there are kids in my group, they're bright, they're getting D's, and if I know more than them, then that makes me feel confident.

Comparing her knowledge to those from whom she sought help, 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.

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 efficacy was also influenced by how her grades compared to the class average:

> [Other people influence how I think I'm doing in ENGR 106] 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.

Discussion

The findings presented here demonstrate the susceptibility of first-year engineering students' self-efficacy beliefs to the influence of vicarious experiences. While self-efficacy theory claims that mastery experiences are the most influential source of 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.[1] Thus social comparisons may act as the primary factor in the self-assessment of engineering abilities among first-year 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 ENGR 106 environment may all be new to these students, creating conditions that foster the use of vicarious experiences in the formation of efficacy beliefs.

These results offer educators insights into how they might promote the development of positive efficacy beliefs in their students through the development of proactive measures and intervention strategies. Students' suggestions that they become less confident in their ability to succeed in a course when they do not learn new material as quickly as their classmates can be addressed in engineering courses. Taking steps to convince students that the speed with which they learn does not govern their success can go far in building efficacy. Alleviating the pressure students feel upon comparing themselves to fast learners or learners for whom the material is a review can also be effective in assisting the development of accurate efficacy beliefs. Further, the findings presented here advocate the development of group work activities that focus on providing opportunities for students of all levels and learning styles to contribute to the group experience, a realization that can be achieved through the implementation of experiential learning theories, such as Kolb's,[27] in the engineering curriculum. Group exercises that offer students the occasion to both get questions answered as well as getting experience in answering the questions of others should also be developed. In addressing relatively simple issues such as these, educators have the opportunity to impart efficacy-building experiences on their students.

Conclusions

Interviews with first-year engineering students have revealed the considerable influence of vicarious experiences on the self-efficacy beliefs ENGR 106 students. Students repeatedly evaluated their confidence in their success by assessing their abilities and comparing them to those of their classmates when trying to learn and understand course material, working in teams, using the computer, problem-solving, working assignments and receiving help. This widespread evidence of the use of social 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-year engineering students.

The insights gained from this next step in attempts to better understand 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.

Bibliography

1. Bandura, A., *Self-Efficacy: The Exercise of Control*, W. H. Freeman and Company, New York, 1997.
2. Pajares, F., "Self-Efficacy Beliefs in Academic Settings," *Review of Educational Research*, vol. 66, no. 4, 1996, pp. 543-578.
3. Lent, R. W., S. D. Brown, J. Schmidt, B. Brenner, H. Lyons and D. Treistman, "Relation of Contextual Supports and Barriers to Choice Behavior in Engineering Majors: Test of Alternative Social Cognitive Models," *Journal of Counseling Psychology*, vol. 50, no. 4, 2003, pp. 458-465.
4. Schaefers, K. G., D. L. Epperson and M. M. Nauta, "Women's Career Development: Can Theoretically Derived Variables Predict Persistence in Engineering Majors?," *Journal of Counseling Psychology*, vol. 44, no. 1997, pp. 173-183.
5. Sax, L. J., "Retaining Tomorrow's Scientists: Exploring the Factors that Keep Male and Female College Students Interested in Science Careers," *Journal of Women and Minorities in Science and Engineering*, vol. 1, no. 1994, pp. 45-61.
6. Brainard, S. G., S. Laurich-McIntyre and L. Carlin, "Retaining Female Undergraduate Students in Engineering and Science: 1995 Annual Report to the Alfred P. Sloan Foundation," *Journal of Women and Minorities in Science and Engineering*, vol. 2, no. 1995, pp. 255-267.
7. Robinson, J. G. and J. S. McIlwee, "Women in Engineering: A Promise Unfulfilled?," *Social Problems*, vol. 36, no. 5, 1989, pp. 455-472.
8. Eccles, J. S. and A. Wigfield, "Motivational Beliefs, Values, and Goals," *Annual Review of Psychology*, vol. 53, no. 2002, pp. 109-132.
9. Seymour, E. and N. Hewitt, *Talking about Leaving: Why Undergraduate Leave the Sciences*, Westview Press, Boulder, CO, 1997.
10. Margolis, J. and A. Fisher, *Unlocking the Clubhouse: Women in Computing*, The MIT Press, Cambridge, 2002.
11. Hackett, G., N. E. Betz, J. M. Casas and I. A. Rocha-Singh, "Gender, Ethnicity, and Social Cognitive Factors Predicting the Academic Achievement of Students in Engineering," *Journal of Counseling Psychology*, vol. 39, no. 4, 1992, pp. 527-538.
12. Lent, R. W., S. D. Brown and K. C. Larkin, "Comparison of Three Theoretically Derived Variables in Predicting Career and Academic Behavior: Self-Efficacy, Interest Congruence, and Consequence Thinking," *Journal of Counseling Psychology*, vol. 34, no. 3, 1987, pp. 293-298.
13. Lent, R. W., F. G. Lopez and K. J. Bieschke, "Mathematics Self-Efficacy: Sources and Relation to Science-Based Career Choice," *Journal of Counseling Psychology*, vol. 38, no. 4, 1991, pp. 424-430.

14. Schmidt, J., R. W. Lent, L. Schmidt, P. Mead and D. Bigio, "Social Cognitive Theory as an Approach to Understanding Retention in Engineering Majors," *2001 ASEE Annual Conference Proceedings*, American Society for Engineering Education: Albuquerque, NM, 2001.
15. Lent, R. W., S. D. Brown and K. C. Larkin, "Self-Efficacy in the Prediction of Academic Performance and Perceived Career Options," *Journal of Counseling Psychology*, vol. 33, no. 3, 1986, pp. 265-269.
16. Assessing Women in Engineering (AWE) Project 2005: Self-Efficacy; AWE Research Overviews, 2005.
17. *From Scarcity to Visibility: Gender Differences in the Careers of Doctoral Scientists and Engineers*, National Academy Press, Washington, 2001.
18. Schunk, D. H., "Self-Efficacy and Academic Motivation," *Educational Psychologist*, vol. 26, no. 1991, pp. 207-231.
19. Pajares, F. Current Directions in Self-Efficacy Research. In *Advances in Motivation and Achievement*; M. Maehr and P. R. Pintrich, Eds.; JAI Press: Greenwich, CT, 1997; Vol. 10; pp 1-49.
20. Marton, F. Phenomenography. In *The International Encyclopedia of Education*; 2nd ed.; T. Husen and T. N. Postlethwaite, Eds.; Pergamon: Oxford, 1994; Vol. 8; pp 4424-4429.
21. Zeldin, A. L. Sources and Effects of the Self-Efficacy Beliefs of Men with Careers in Mathematics, Science, and Technology. Thesis in *Educational Studies*; Emory University, 2000.
22. Besterfield-Sacre, M., C. J. Atman and L. J. Shuman, "Characteristics of Freshman Engineering Students: Models for Determining Student Attrition in Engineering," *Journal of Engineering Education*, vol. 86, no. 2, 1997, pp. 139-149.
23. Zeldin, A. L. and F. Pajares, "Against the Odds: Self-Efficacy Beliefs of Women in Mathematical, Scientific, and Technological Careers," *American Educational Research Journal*, vol. 37, no. 1, 2000, pp. 215-246.
24. Miles, M. B. and A. M. Huberman, *Qualitative Data Analysis: A Sourcebook of New Methods*, Sage Publications, Beverly Hills, CA, 1987.
25. Creswell, J. W. and D. L. Miller, "Determining Validity in Qualitative Inquiry," *Theory into Practice*, vol. 39, no. 3, 2000, pp. 124-130.
26. Hutchison, M. A., D. K. Follman and G. M. Bodner, "The Factors Affecting First-Year Engineering Students' Self-Efficacy Beliefs," *Journal of Engineering Education*, vol. 95, no. 1, 2006, pp. 39-47.
27. Kolb, D. A., *Experiential Learning: Experiencing as the Source of Learning and Development*, Prentice Hall, Englewood Cliffs, NJ, 1984.

Appendix A – Interview Protocol

Background information

- Where are you from? What made you decide to try engineering?

Definition of success in ENGR 106 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 ENGR 106? 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 ENGR 106.**
    - To what degree are you achieving success in ENGR 106?
    - Why do you believe this?
- On what experiences are you basing your judgment? *(mastery experiences)*
- How have other people influenced how you think you're doing? *(vicarious)*
- 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 ENGR 106 make you feel? (When thinking about ENGR 106, how do you feel? When doing ENGR 106, how do you feel?) *(physiological)*
- Of all of this feedback you're getting (list their mastery, vicarious, social, and physiological 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 ENGR 106?
- **I'm also interested in understanding how you think the general ENGR106 class feels about success in ENGR 106.**
    - To what How do you believe other people in your class define success in ENGR 106?

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 ENGR 106? 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 Midwestern University if ________________.
- How do you believe your peers would finish this statement?

Satisfaction with engineering

- In what ways are you satisfied with your experience in ENGR 106? Tell me things you're satisfied with regarding ENGR 106. *(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 ENGR 106? What are some things you're dissatisfied with regarding ENGR 106?
- Do you enjoy ENGR 106? Why?

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

- How would you rate your ENGR 106 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 and why?
- How do you assess your abilities to solve ENGR 106 problems?
    - In/Out of class experiences?
- Describe the things that make it harder for you to solve ENGR 106 problems.
- Describe the things that make it easier for you to solve ENGR 106 problems.
- What besides your problem solving ability affects your ability to get a high grade in ENGR 106?
    - 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 E106 problem-solving abilities with those of your ENGR 106 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 ENGR 106 class.
- What experiences (in-class or out-of-class) have influenced your beliefs in your E106 problem-solving abilities?
- If someone asked you for evidence to convince them that you have the ability to get a grade of ___ in ENGR 106, what would you tell them?
    - Give me an example of something that proves you can solve ENGR 106 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 ENGR 106? Why?
- At the end of the semester, what grade do you think you will receive in ENGR 106?
    - What is helping you earn it?
    - What makes it difficult to get an A in ENGR 106?

Professional School Efficacy – What is it? How do you assess it? How is it different from class efficacy?

- What professional school do you want to go to?
- Do you believe you have the ability to fulfill the freshman engineering requirements and gain admission to the professional school of your choice?
    - Why do you believe this?
- Prove it to me that you do/don't have the ability to fulfill the requirements.
- What makes it difficult to fulfill the professional school requirements?
- What makes it easier for you to fulfill the requirements?
- What do you find most stressful about your experience in Freshman Engineering?
- What do you find most enjoyable about your experience in Freshman Engineering?

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

- Assuming you get in to the professional school of your choice. 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?
- Could 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 ENGR 106 experience?
- Are there things regarding your ENGR 106 experience that you'd like us to keep just as they are?
- Is there anything else about ENGR 106 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?