AC 2009-1031: COMPETENCE IN ENGINEERING: A TALE OF TWO WOMEN

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Competence in Engineering: A Tale of Two Women

Abstract

This research examines persistence decisions among engineering undergraduates as a choice process which extends across all four years. Framed in motivational theory, this research focuses on competence beliefs, specifically students' beliefs about their ability to become practicing engineers and how this shapes their choice to pursue engineering degrees. The primary data are interviews collected longitudinally over a four-year period with five men and five women undergraduate engineering students at Technical Public Institution (TPub, pseudonym). Data from these interviews are triangulated with survey data for the same students. Although not started as a study to examine gender differences, gender-based patterns emerged from the data. Results showed that some women students with very good grades (GPA higher than 3.9), can still experience a lack of confidence with regard to practicing engineering. Moreover, these same women students redefine what it means to successful in engineering as part of their choice process to persist in earning an engineering degree. Implications are discussed in terms of future research and the classroom context. This study is part of a larger body of work, the Academic Pathways Study (APS), conducted by the NSF-funded Center for Advancement of Engineering Education (CAEE).

Introduction

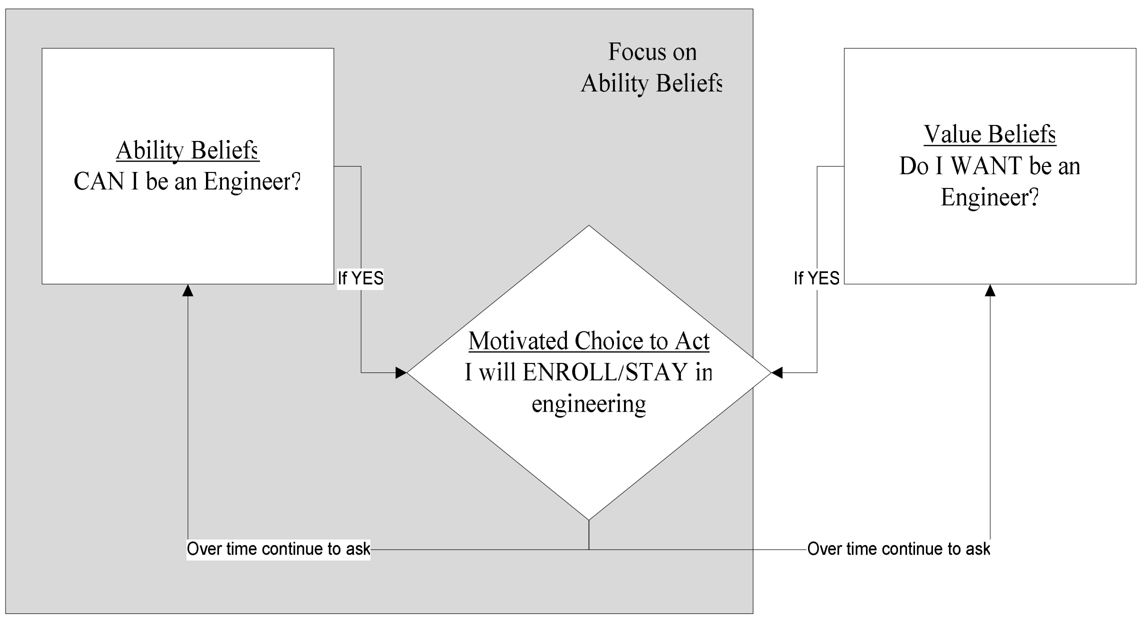
Which students persist in science, technology, engineering and math (STEM) fields? Looking for ways to increase persistence rates, we frequently research the characteristics that differentiate persisters and non-persisters. However, the choice to persist may not be as binary as these two terms would imply. The research reported here begins to unravel the complexities of persistence by looking at the choice to be an engineer as a process extending over time and involving continually motivated decisions. By taking the perspective of students who persist in earning engineering degrees, this research shows how students negotiate the choice process. This research focuses on ability beliefs which have been shown to be important in career decision-making processes particularly in STEM fields. [1-5] In particular, this study shows how two female participants, who, despite earning excellent grades, have recurring doubts about their engineering-related ability and negotiate the path to persistence by adjusting their definitions of what it means to be successful as an engineer.

This current study builds on and expands a previous study [6] by examining an additional six participants and focusing on similar research questions. Since qualitative research can be used to generalize to a theory [7], increasing participant numbers increases potential generalizability. In the previous work, Matusovich et al [6] asked, *How do students characterize success in their given engineering field? How do these characterizations develop and change with time? Do students believe they have these characteristics that they define as important to success?* Now the current study starts with the broader questions, *What are student's engineering-related ability beliefs and how do they change over the undergraduate years? How do these beliefs contribute to persistence choices?* Although the original study including ten participants did not focus on differences between genders, patterns emerged that could have implications for further research, for engineering education practitioners and for students. Those patterns are the subject of this paper.

Theoretical Framework

This research is framed in Eccles' expectancy-value theory. [8, 9] Eccles' theory suggests that choices to engage or persist in activities, such as becoming an engineer, are based on an individual's beliefs about 1) his or her ability with regard to that activity, and 2) how important that activity is to him or her. [8, 9] This study focuses on ability beliefs. A very simplified diagram representing the choice to be an engineer framed in Eccles' model is shown in Figure 1. The area shaded in gray represents the focus on competence beliefs for this research.

Figure 1: Simplified View of Eccles' Expectancy-Value Model [9]



Eccles' model uses the construct "expectancies for success" consisting of an individual's beliefs as to how well he or she will perform on an upcoming task. These success-related beliefs incorporate judgments about task difficulty and the individual's perception of his or her own ability [9]. For example, an individual may have a high expectancy of success, for receiving a high score on an upcoming math test if she believes the test will be easy and/or if she believes she has mastered the material being tested. In contrast, an individual may have a low expectancy of success for receiving a high score on an upcoming math test if he believes the test will be challenging and/or if he believes he has not mastered the material being tested. A key distinguishing feature of expectancy of success is that relates to beliefs about a future potential outcome. It is this future component that theoretically distinguishes *expectancies of success* from *self-concept of ability* which is perception of current competence. *Expectancies of success* are also theoretically distinguished from *self-efficacy*, an individual's beliefs about his or her ability to perform a task at a designated capability level [10]. However, researchers have argued these three constructs are difficult to differentiate empirically [11-14] and are often operationalized in such a way as to be equivalent.[12, 15] Following the examples set by these researchers, this study does not differentiate among the terms self-concept of ability, self-efficacy and expectancies of success and considers all under the single term *ability beliefs*. As shown in Figure 1, ability beliefs address the question, “Can I do this task?” or specifically in this study “Can I be an engineer?”.

Using the expectancy-value framework, researchers have shown that competence beliefs are linked to actual performance in an activity [9, 15], contribute to beliefs about what tasks are important [16, 17], decrease with increasing age for primary and secondary school children [16], and predict career aspirations.[18, 19]

Methods

This research incorporates multiple case study methods with each participant representing an individual case. Cases were examined both individually and collectively. The primary data source included interviews collected over a four year period with the same participants. The interview data was triangulated with survey data for the same participants. This study is part of a larger body of work, the Academic Pathways Study (APS), conducted by the NSF-funded Center for Advancement of Engineering Education (CAEE). Data collection strategies have been previously described for APS [20, 21] and specifically for Technical Public Institution (TPub, pseudonym).[22] Consequently, methods described herein relate specifically to the ten cases analyzed as part of this study.

Participants

The context for this research is a technical public university in the western mountain region of the United States. All participants in this study are undergraduate students at TPub majoring in ABET, Inc.[23] accredited engineering majors. Ten participants were purposefully selected from a potential pool of 16 participants as the ones who had completed all of the appropriate interviews and surveys. Although they were not intentionally selected to evenly represent both genders, participants included five men and five women. The six possible participants not included in this study were missing interview data due to having chosen to leave APS, engineering programs or TPub. Throughout this paper, pseudonyms are used to prevent possible identification of the participants. Using ten cases is believed to provide sufficient but not overwhelming diversity.[24]

In case study research, it is important to define case boundaries cases in space and time.[24, 25] For this study the bounds are ten participants at TPub pursuing engineering majors during the four-year period from 2003 to 2007.

Data Sources and Analysis

The primary data for this study includes semi-structured interviews. As suggested for multicase study research [7, 24, 25], these interviews were triangulated with an additional data source; survey data were available for all participants. Each data source is described along with the analysis process.

Analysis started with the semi-structured interview data. Data collection and the interview protocol have been described previously [6]. Cross-case analysis, as described by Miles and Huberman [26], was the guiding analysis method for the interview data. Stake [24], Patton [27], and Yin [28] were used as supplementary references. As suggested by this approach, each case was analyzed separately before looking for themes across the cases.

Interviews for Max, Joe, Hillary and Anna were analyzed first as described by Matusovich et al. [6] Interviews for these participants (a total of 16; 4 for each of the 4 participants), were read repeatedly and coded using Atlas Ti software. Open-coding strategies (developing codes inductively from the data rather than from theory [27]) were used. The result was a preliminary list of codes and associated definitions. This list was refined by examining them for uniqueness and combining them when sufficient overlap existed. This refined list was then reapplied to the 16 interviews. Findings from this analysis were previously reported. [6]

Data analysis then continued with the entire data set. As with the first four participants, the interviews (a total of 24; 4 for each of the 6 participants), were read repeatedly and coded again using open-coding strategies. This list of codes was again refined and reapplied to all 40 interviews. Using graphical displays as suggested by Miles and Huberman [26], themes were developed across the cases.

Based on data across all four years of interviews, students were rated with regard to their commitment to engineering. *Passionately committed* means the participant shows exceptional enthusiasm for their major or prospective future job. *Happily committed* means the participant is satisfied with their choice of major and looking forward to their future in engineering. *Committed with resignation* means the participant has accepted that they will be an engineer but they are not very excited about it. *Uncommitted* participants talk about careers unrelated to engineering even if they plan to finish their engineering degree.

As previously mentioned, interview data were triangulated with survey data. All study participants completed the Persistence in Engineering (PIE) survey in the fall and spring of the first three academic years and in the spring semester of their fourth year. PIE included Likert-type, multiple choice, and open-ended response opportunities with questions addressing general participant information as well as a targeted list of constructs including identity and motivational constructs. Survey development was detailed previously [29] and internal consistencies have been reported as Cronbach's alpha and range from 0.58 to 0.85. [30] PIE data were available for each participant and were used to triangulate the interview data.

Results

Based on the data analysis, two assertions can be made. First, women with consistently high grades can still doubt their engineering ability and have uncertainty about practicing engineering. Second, as part of the persistence choice process, some women redefine what it means to be an engineer to match their perceived abilities. The evidence for these assertions is provided in the following sections. Results focus on Anna and Leslie because they show the most complex patterns in their continued choice to stay in engineering. However, their results are presented in the context of all ten participants. As previously described, this study was not conceived as means to look at differences in how men and women experience the persistence process. However, gendered patterns emerge and are reported here as such.

Students with High Grades Can Still Doubt Their Engineering Ability

Anna and Leslie continually perform well as measured by having GPAs above 3.9. Yet these two students doubt their ability to practice engineering. While some of the other eight students may express uncertainty about what engineers do, these participants do not doubt their abilities. For example, during each annual interview, participants were asked if they believe they have the skills needed to be successful engineers. Max, Hillary, Mark, Will, Beth and Joe routinely report that they do have these skills. Marie and Tim report that they are uncertain what they will do as engineers but express no doubts in their ability. In contrast, Anna is uncertain about what engineers do and doubts her engineering-related skills and Leslie is certain about what engineers do but doubts if she has the skills needed to practice engineering. While two out of five women doubt their abilities, none of the five men expresses any doubt. Tim is the only male participant who is uncertain about what engineers do but he is confident in his ability to be an engineer.

Leslie and Anna are highlighted as the only two participants in the study doubting their own ability. As an example of the doubt expressed by Leslie and Anna, consider a quote from Leslie. Each year Leslie talks about engineers as having "mechanical intuition." When asked to clarify what she meant by mechanical intuition, Leslie responded:

> Just a sense of, well definitely it's like how machinery operates. Or, I think being able to visualize what's going on when you're talking about designing something. And, like I don't really visualize things that well. For example, in [specific class] we had problems and I just didn't understand how it. Like if you were to take that problem into the real life, like what would it look like. Or [specific class] is – is very visual as far as what's going on, but I don't see it. Does that make sense? (Leslie, 3rd year)

Leslie believes that engineers have an ability to spatially visualize engineering problems. She does not believe she has this ability and does not believe it is a characteristic she could develop with practice. Leslie doubts her ability to be an engineer at least partially because of her own perceived lack of mechanical intuition.

As described in the methods section, each participant was rated with regard to his or her certainty about what engineers do and his or her commitment to engineering. Table 1 shows these ratings. Participants are listed in order of decreasing grade point average (GPA). Notice that all five women have higher cumulative GPAs than any of the men. Also notice that three of the women are uncommitted to practicing engineering although one, Marie, maintains a steady pursuit of engineering. Leslie and Anna (gray table entries) have high GPAs in engineering classes yet doubt they have the skills to actually practice engineering. While it can be argued that GPA may not be the only measure of ability, it provides an accepted comparison or reference. Anna and Leslie, the two students who doubt their engineering abilities, perform consistently well throughout their four undergraduate years as measured by GPA. This suggests that Anna and Leslie look outside their classrooms to define the necessary tools and abilities required to actually practice engineering.

Table 1: Interview Ratings for Commitment to and Certainty about Engineering Careers

Name	GPA CUM	Commitment to Engineering[a]	Certainty About What Engineers Do
Hillary	3.94	Passionately Committed	Certain
Leslie	3.92	**Uncommitted and Changing**	Certain
Marie	3.91	**Uncommitted and Steady**	Uncertain
Anna	3.71	**Uncommitted and Changing**	Uncertain
Beth	3.38	Happily Committed	Certain
Max	3.23	Passionately Committed	Certain
Tim	3.14	Committed but Resigned	Uncertain
Joe	3.07	Passionately Committed	Certain
Will	2.96	Happily Committed	Certain
Mark	2.74	Happily Committed	Certain

[a] Ratings: Passionately Committed = exceptional enthusiasm for major or prospective future job, Happily Committed = satisfaction with choice of major, positive outlook towards a future in engineering, Committed with Resignation = acceptance of being an engineer but no expressed enthusiasm, Uncommitted and Changing = consider leaving engineering major and/or consider many different careers, Uncommitted but steady = uncertain about being an engineer but no alternative career plans either

Results from the persistence in engineering (PIE) survey are consistent with the ratings based on interview data. During the third through sixth semesters, participants were asked about their intentions to practice engineering. Results are shown in Table 2. Early on (in the third and fourth semesters) Mark, Will, Anna and Marie express negativity or uncertainty about practicing engineering. However, this uncertainty fades for Mark and Will. Anna alternates between *Not Sure* and *Probably Yes* indicating her persistent uncertainty. As evidence of her persistent uncertainty, Leslie initially indicates *Probably Yes,* then *Probably Not* and in the sixth semester says she is *Unsure.*

Table 2: Survey Results on Intentions to Practice Engineering

	Intention to Practice Engineering			
	3rd Semester	**4th Semester**	**5th Semester**	**6th Semester**
Hillary	Probably Yes	Probably Yes	Definitely Yes	Probably Yes
Leslie	Probably Yes	Probably Yes	**Probably Not**	**Not Sure**
Marie	Probably Yes	**Not Sure**	Probably Yes	Probably Yes
Anna	**Not Sure**	Probably Yes	**Not Sure**	Probably Yes
Beth	Probably Yes	Probably Yes	Probably Yes	Probably Yes
Max	Definitely Yes	Definitely Yes	Definitely Yes	Definitely Yes
Tim	Definitely Yes	Probably Yes	Definitely Yes	Probably Yes
Joe	Definitely Yes	Definitely Yes	Definitely Yes	Definitely Yes
Will	**Not Sure**	Definitely Yes	Probably Yes	Definitely Yes
Mark	**Probably Not**	Probably Yes	Probably Yes	Probably Yes

Redefining What it Means to be an Engineer

As previously described by Matusovich et al, [6] participants have different beliefs about what success in engineering means. These beliefs develop from their classroom, campus and internship experiences. Participants assess their ability against their beliefs about the specific skills needed to practice engineering. The four participants, Max, Hillary, Joe and Anna, as originally described by Matusovich et al [6] ultimately have positive ability beliefs with regard to engineering. However, Anna's path, as described, is a bit more tumultuous. As described previously, an additional six cases were added thereby building on the previously reported research. In five of the six cases, Mark, Will, Beth, Marie and Tim, ability beliefs are positive and stable similar to Max, Hillary and Joe. The remaining participant, Leslie, has a story similar to Anna's. Having been described in detail previously [6], Anna's story is only summarized here. Parallels are drawn with Leslie's story as appropriate.

Anna and Leslie recognize that they are good students but doubt their engineering abilities. Despite earning high grades, Anna is unsure of what it means to be an engineer and is unsure that she has the skills. Anna redefines her view of success in terms of her ability to learn; she is confident that she can learn whatever she needs to learn to be a good engineer. Ultimately Anna has positive beliefs about her ability to be an engineer but it is not based on her beliefs about her current level of engineering skills.

Like Anna, despite her lack of confidence in her specific engineering skills, Leslie persists in earning an engineering degree. Unlike Anna, Leslie believes she knows what engineering is and that she does not have the appropriate skills. However, she redefines her career goals based on what she believes are her abilities. For example, she believes teamwork is very important in engineering because team members can catch each other's mistakes. In her second year, she says

> …to be honest, I think I always visualize myself not really actually doing the engineering itself. But, being the support to someone else who does it. And like just know what they're doing, and being able to, you know if they need somebody to check their calculations and stuff. But, not actually be the one who's designing the project.

Leslie sees herself as one to check others' engineering work. She has confidence in her ability to be a support member on the design team. Furthermore, Leslie believes she is not good at the technical side of engineering but is good at writing, so in an informal conversation in her third year she says:

> 'cause there are [major] engineers who are working overseas and doing missions through that. And, maybe I wouldn't be doing the technical side but I'd be able to help them out. And, like I would know what they're talking about. And I can, you know, whether it's like helping them by writing the reports for them, or just something simple, you know. I don't know.

Leslie is not confident in her engineering skills, but is confident in her ability to participate in projects with other engineers.

In her fourth year, Leslie decides to finish her engineering degree and become a teacher. She plans to take a little time off after graduation and then work on her teaching credentials.

In summary, Leslie initially believes that, although she does not have strong engineering skills, by getting an engineering degree she can still be an effective helper to other engineers and can help write reports. Finally, she decides to pursue an alternate career but thinks that earning an engineering degree will make her better in this career than if she did not have an engineering degree. She reports no regrets related to persisting in earning an engineering degree. Leslie reframes her beliefs about success to incorporate earning an engineering degree as being successful rather than actually practicing engineering.

Discussion

This research makes several contributions to the literature from the perspectives of researchers, engineering education practitioners and students by: 1) demonstrating the need to help women develop positive competence throughout all four years of undergraduate engineering classes, and 2) providing insight into separating self-concept of ability and expectancies of success.

Helping Women Assess Their Ability Beliefs

All of the women had higher cumulative GPAs then the men. Of the five women participants, two (Anna, and Marie) are uncertain about what engineers do for career work. Two women (Anna and Leslie) express doubts about their engineering skills. Of the five men in this study, only Tim remains uncertain about what engineering is and he, like the other men in the study, was confident in his ability. These findings suggest women trail men in perceived engineering-related ability despite receiving better grades than the men.

These results are consistent with prior research related to gender differences in competence beliefs and measured competence in STEM fields which generally show women having lower competence but not lower course grades then men [4, 31-35]. The current research also supports Sax's suggestion that competence, as measured by grades, does not relate directly to self-assessments of ability. Finally, this research is also consistent with Sax's finding that "college grades may well be the single best predictor of student persistence, degree completion and graduate school enrollment". [36]

What is new about these findings is the longitudinal aspect of negotiating engineering-related competence beliefs exemplified by Anna and Leslie. Related findings by Pascarella and Terenzini [36] show declines in academic self-concept in the first year of college followed by a general increase. However, they report no mechanism or causality. This current study contributes evidence towards a mechanism of changes in self-perceptions of ability during college changing definitions of ability. During the four years, Anna and Leslie evaluate their competence and regularly adjust their definitions of what it means to be successful. Although confident in their classroom learning, these two women doubt their engineering abilities. A lesson for engineering education practitioners is that some female engineering students, and perhaps some students in general, need on-going help to bridge the gap between their classroom learning and their perception of the skills needed to practice engineering. Proper interventions could help them build useful definitions of success against which to more accurately gauge their ability. Since self-assessment of ability beliefs is a continuing process, positive competence beliefs must also be promoted in a longitudinal process.

Differentiating Expectancies of Success and Competence Beliefs

Expectancy of success describes a belief about a potential outcome, whereas *self-concept of ability* represents a perception of current competence [9] and the two have proven difficult to differentiate empirically. [12, 14] Dirkhauser and Stiensmeier [32] have shown some evidence of being able to make this distinction by demonstrating that relatively high self-concepts of ability in a specific activity increase expectancy of success in that activity.

The ways in which Anna and Leslie renegotiate their competence beliefs provide insight into these variables. Separating self-concept of ability from expectancies of success may be facilitated by also assessing the meaning of success to the individual, e.g., successfully doing engineering-related tasks, learning engineering or ability to work in an engineering-related profession. More specific questions related to competence beliefs may help differentiate the constructs of self-concept of ability and expectancies of success.

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