AC 2008-950: WILL I SUCCEED IN ENGINEERING? USING EXPECTANCY-VALUE THEORY IN A LONGITUDINAL INVESTIGATION OF STUDENTS' BELIEFS

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Will I Succeed in Engineering? Using Expectancy-Value Theory in a Longitudinal Investigation of Students' Beliefs

Abstract

This multi-case study qualitatively and inductively examines undergraduate engineering students' expectancies for success as engineers as well as how these expectancies change from freshmen through senior years at a public technical institution in the western United States. The theoretical framework is expectancy-value theory, developed by Eccles, Wigfield and their colleagues, which suggests that achievement-related choices result from the intersection of an individual's expectancy for success in a given situation and the value they assign to success in that situation. Longitudinal data analysis, based on semi-structured interviews conducted over four years with four students (two male and two female), addresses the following research questions: 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? Results show success beliefs do change over the four years. First-year students give generic responses that are not specific to engineering. By the third and fourth year, students who have interned have: 1) more specific, concrete beliefs about success that are grounded in personal, authentic experiences, and 2) can more accurately assess their abilities citing specific evidence. Additionally, the data demonstrate that students who lack confidence in skills they perceive to be important to successful engineers can still have a positive expectancy of success in engineering. The results generally support Eccles' model with one modification.

Introduction

Engineering students have been described as "dogged".[1] Students who succeed in engineering studies are called "persisters".[2] Engineering itself is described as having a "meritocracy of difficulty".[3] Based on these descriptions (and perhaps the testimonials of engineering students everywhere) earning an engineering degree is viewed as a challenging undertaking. So what drives engineering students to continue to navigate the difficult path? Many researchers have asked this question as evidenced by an exceptionally large number of literature citations containing the terms "engineer" and "motivation". Yet the question remains uncertain. The expectancy-value framework proposed by Eccles [4] has the potential to enlighten persistence choices.

As defined by Schunk, Pintrich and Meece, "Motivation is the process whereby goal-directed activity is instigated and sustained."[5] Motivational constructs have long been studied in attempts to explain achievement related behaviors especially with regard to academic settings. In particular, expectancy-value theory as proposed by Eccles and her colleagues, has been shown to contribute to task engagement and persistence decisions such as intentions to continue with a particular course of study or pursue a certain major.[4, 6]

Eccles and her colleagues first formally proposed the expectancy-value model of achievement motivation in the context of a National Institute of Education [7] study focusing on gender differences in achievement behaviors in mathematics. [4] A current version of the model is shown in Figure 1. [8] The model suggests that achievement behaviors, such as task choice and persistence decisions, are shaped both by the expectancy for success on the task and the subjective value or importance associated with task completion. It is not the reality associated with task completion that is important in this model but rather it is an individual's perceptions of that reality which shapes achievement behaviors. [4] As diagramed, Eccles proposed that a variety of factors contribute to shaping expectancy of success and subjective task values. Of particular importance to this study are the relationships between achievement-related choices of pursuing engineering and the associated expectancies for success in engineering, both as an engineering student and with regard to a future career in engineering.

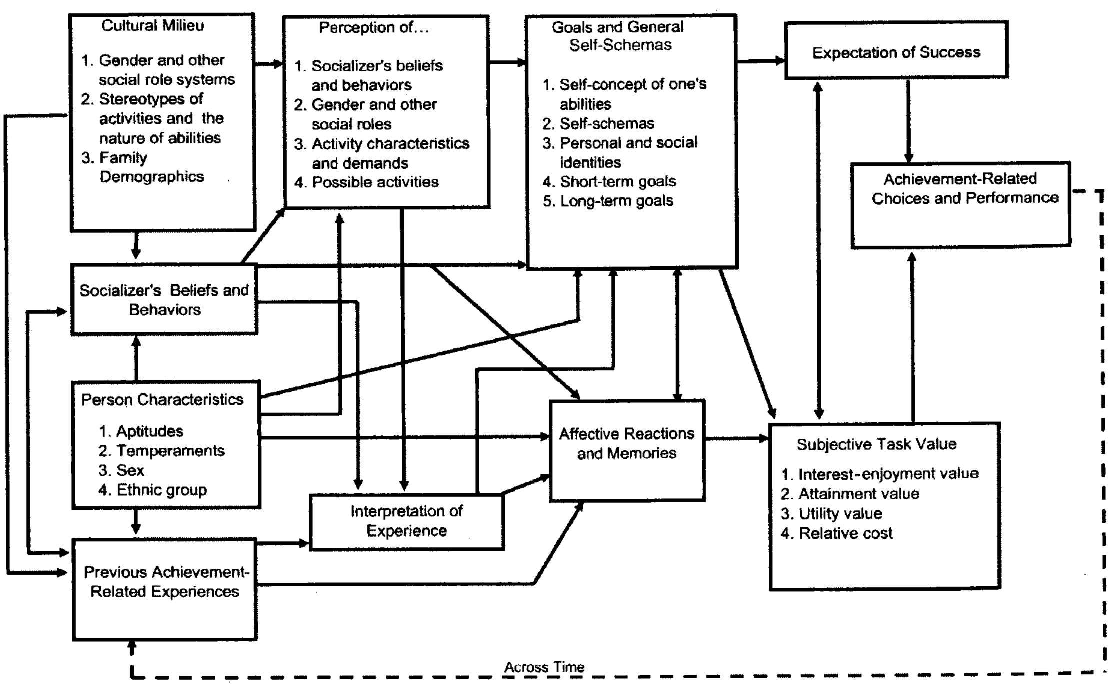

Figure 1: Eccles' expectancy-value model of achievement choices [8]

Expectancies can be defined as one's belief as to how well he or she will perform on an upcoming task or in a future event. [5] Expectancies include one's perception of both his or her ability and the task difficulty. [4] Numerous studies have examined expectancies of success. [6, 9, 10] Important outcomes include: 1) evidence supporting higher expectancies for success as being linked to better task performance [4, 9], 2) competence beliefs shown to contribute to subjective task values [10], 3) competence beliefs found to decrease with age in primary and secondary school children [10], and 4) expectancies predict career aspirations although gender differences are mediated by gender-role stereotyping. [6, 11]

The expectancies that this study focuses on are students' beliefs about their ability to be successful in their chosen fields of engineering. Case study methodology is used to qualitatively and inductively examine longitudinal interviews collected over four years with four students (two male and two female) to address the following research questions: 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? A unique aspect of this study is that it looks at success as defined from the student perspective rather than an externally imposed definition of success. This approach gives the students a voice. Understanding students' motivational factors, particularly success-related beliefs, in pursuing engineering degrees and careers can help shape curricular and persistence intervention decisions by providing the student stakeholder perspective.

This study is part of a larger body of work, the multi-institutional, multi-method Academic Pathways Study (APS), conducted by the Center for Advancement of Engineering Education (CAEE). The overall broader purpose of APS is understanding undergraduate student experiences as they learn engineering.

Methodology

Multi-case methodology is used in a qualitative longitudinal examination of expectancy of success. The strengths of multi-case research are deeper exploration of and additional context for the individual cases. [12, 13] This allows for greater generalizability of results which, although not typically a goal of qualitative research, remains a practical concern in considering how to apply findings. [12] Defining the case is critically important in case study research. Stake suggests that a case must be a noun or "a thing" or "real things that are easy to visualize, however hard they may be to understand". [13] Creswell suggests that a case study must be clearly bounded by space and time. [14] The bounds for this study are two male and two female engineering students at Technical Public Institution (TPub) from the Fall 2003 to Spring 2007. The primary unit of analysis is the case so each case is analyzed separately before all are analyzed together.

Participants

For APS, TPub students were recruited through a variety of methods. Volunteers were selected to intentionally over-sample underrepresented groups and were paid for participation. Recruiting and sampling methods for TPub have been described previously. [15] Of the 40 students originally participating in APS, a subset of eight students was identified for more in-depth study. These students, identified as the "high contact group", participated in semi-structured interviews, ethnographic observations and informal conversations in addition to the on-line, semi-annual surveys completed by the other 32 participants.

This analysis includes data from a sub-set of the participants recruited for APS at TPub including two male and two female participants in the "high contact" group. One of the students is Hispanic and the balance are Caucasian. The four cases represent extremes in attitude and coping strategies. Pseudonyms have been assigned to protect the students' identities.

Data Collection and Analysis

This analysis uses semi-structured interviews as the primary data source. Starting as freshmen, each high contact group participant was interviewed in the spring semester each year for four years by one of two interviewers. Semi-structured, one-on-one interviews allowed the students to respond freely and allowed the researchers to follow-up on responses and probe deeper as needed. The interview protocol included a loosely structured framework of guiding questions prompting the students to think about topics central to the overall APS objectives if such topics did not rise naturally in conversation. The following is a sampling of questions of central importance in this analysis:

- Think about your professors here at [Name of Institution]. What would you say they think it means to be a good engineer?
    - How does that fit with your own image of a good engineer?
- Okay, let's imagine it's a few years from now, and you've graduated with a degree in (student's planned major).
    - What's next for you?
        - Or, if not planning on becoming an engineer, explore why they've made this decision.
    - What do you imagine yourself doing on a day-to-day basis?
        - Or, if not planning on becoming an engineer: What do you imagine engineers do on a day-to-day basis?
    - What would you say it takes to be a good (insert student's career choice)?
    - How are you at (insert characteristics student mentions)?
    - Are there things about yourself that you think you need to work on to become a successful (xxx)?

The interviews were audio-recorded and transcribed. The interviews (a total of 16) were then coded using Atlas Ti software. Patterns and themes were inductively developed on an individual case basis then compared across cases. Cross-case analysis, as described by Miles and Huberman [12], was the guiding analysis methodology.

Results

<u>How do students characterize success in their given engineering field and how do these characterizations change with time?</u>

Students were asked to describe the skills needed to be successful in engineering. This question was sometimes asked in general and sometimes asked with regard to their specific major. Overall, responses were not field-specific as much as they were based on the individual's personal experiences.

Students' characterizations of success are based on their experiences

In first-year interviews, the skills students cite as important for success may come from previous jobs or other significant life experiences. For example, Max believes that being able to work with and understand other people is an important characteristic for being a good engineer. He thinks he is "really, really good" at this skill because he has "had so many jobs for someone his age". He jobs have included being a waiter, being part of a hot air balloon chase crew and selling boats and jet skis at a marina. These jobs would bring him in contact with many different types of people. As a first-year student he has not had his own experiences with engineering in a professional context and draws on skills gained in other jobs.

Joe and Anna's stories are similar to Max's. Joe identifies communication as an import skill for success in engineering. Joe says he learned good communication skills through his many years as a Boy Scout. Scouting was an important part of his life before entering college. Anna includes passion as important to being a successful engineer. She explains choosing her major in part based on the passion she has developed, or not developed, for different subjects.

Hillary's description of the skills needed to be a successful engineer is more specifically tied to engineering. Hillary talks about the oil industry in Alaska:

> I think it takes a lot of breadth of knowledge, you have to know the chemistry and the physics, but you also have to be able to do the economics and write the papers and write the proposals, um, I think it definitely takes good communication, especially in the oil industry where you have so many different people coming together because you have geologists and geophysics people and, and mechanical engineers, and petroleum engineers, and chemical engineers, and you have a different view on the whole thing than each one of 'em does, and you have to be able to put all of that together, and then after you do that, you have to be able to put in terms everyone can understand and then tell the public about it, at least in-, in Alaska we have disclosure laws that tell six months before you're gonna drill, you have to be like exactly where you're gonna drill and stuff and then you have to be able to communicate to those people that what you're doing's really good, so I think you definitely have to be a good writer, a good speaker, um, be able to, to persuade others.

Although longer and more detailed than the responses by the other students, Hillary's response is still generic in the sense that it is not tied to one of her own experiences. It is not clear that she knows what "the papers" and "the proposals" are or that she knows *how* the various types of engineers and scientists listed interact. Hillary's description could be her version of what someone else has said they do as an engineer.

Students' characterizations of success change with classroom, campus and internship experiences

As the students take engineering classes, participate in campus activities and complete internships, their beliefs about the skills needed to be successful engineers change. The most marked change is observed in the two students, Max and Hillary, who have extensive internship experiences. Their beliefs about the skills needed, and their evaluations of themselves against those skills, are more concrete and grounded in their own personal, authentic experiences.

By her third year, Hillary has had several internships. Her description of the skills required to be a good engineer are more specific to her own experiences than they were in the first year:

> I think it takes a lot of being able to kinda' look outside the box. Because our field is so broad, and you can do so much, that you almost have to be a generalist. And, you almost have to be able to just simplify, dumb things down, and say, "Okay, well generally this is this kinda' problem, so here's kinda' what you

> would do with it. And, generally this is this kinda' problem." And, be able to divide things up like that.

She is talking about taking about an approach to solving problems- breaking them down into types of problems that she knows how to solve. This becomes clearer as she talks about this approach as a skill that she needs to develop:

> I think just the experience, like you need to see a lot of problems before you can be a really good chemical engineer. And, you need to see all the different situations. And, I just don't think, comin' out of college you have that experience yet.

This internship was in an environment that is similar to the one in which she hopes to work after graduation. Hillary has shifted from a generic first-year response to beliefs based on her own authentic experience.

Max has a similar level of engagement with internships in a professional environment in which he hopes to work. In his third year, Max says you have to "know your stuff", be "business-oriented" and "be willing to take phone calls in the middle of the night". In his fourth year, he defines very specific skills such as determining who should be awarded contract work. Max's responses are not lengthy or detailed. They are tied to his own authentic experiences.

Anna and Joe have not had any internships. Joe engages in a variety of engineering-related activities on campus such as building and maintaining a trebuchet for TPub's spring engineering celebration. Anna engages in art, poetry and guitar in her spare time. Joe and Anna's descriptions of the skills needed to be successful engineers change with time and relate to experiences they are having on campus.

In his third year, Joe talks about balancing skills and knowledge with "willingness to learn and explore". During this time he is trying to decide if he should pursue industry or research and his interview responses reflect his struggle with this decision. His basis for distinguishing the between two career avenues is not clear.

By her fourth year, Anna's beliefs about skills needed for success are more grounded in engineering. Similar to Hillary's answer in the first year, Anna's answers are generic. Anna talks about having "many, many skills: writing skills; people skills; management skills; skills to be aware of, of umm, the project as a whole and where you're going with it" and "being able to deal with the real world". She uses the popular buzz words such as "people skills" but it is not clear what she means by this because it is not tied to examples. "Real world" is another buzz word. It suggests she will behave differently when working than she does in school but it is not clear that she knows how this will be different.

Experiences also play a role in helping students assess their skills

Students' experiences are also important in helping them assess their own skills against the skills they believe are important. For example, Hillary uses a specific case from her internship as she describes her need to learn to ask for help. She also credits her internship with helping her learn to "think outside the box" which is something she thinks she is "pretty good" at doing:

> I think the internships have helped a lot. Because in class you have everything you need to know in the, in the problem statement to solve that problem. And, in the real world you don't. You're going and talking to the geologists and getting, well this is about what the permeability of this rock is, and stuff like that.

Her beliefs about skills do not come only from her internships.

Hillary also finds creativity important and thinks her professors help drive development of this skill. When asked what her professors say are the skills needed to be a good engineer, she responds:

> I think creativity. Especially if you'd ask the chemical engineering professors. Like, they're all real into creativity. And, like, we get these projects and you have to do X, Y, and Z, for the first half of the project. And the second half is like, "Figure out something interesting to do with this system." And so, they're, they're real into creativity.

Anna's story, discussed in great detail in the next section, provides another example on how experiences shape self-assessment of skills. Anna declares that she does not know what skills are needed to be an engineer and is unable to assess herself against such skills.

<u>Do students believe they have these characteristics that they define as important to success?</u>

As discussed in the previous section, Max and Hillary, develop beliefs about the skills needed for success that are grounded in experiences similar to those they hope to pursue as professions. They also have more evidenced-based evaluations regarding their skills. Hillary and Max can identify what they do well and what they need to improve.

By his fourth year, Max believes he has all the skills needed to be a successful engineer. He is confident in what he has learned through his internships and indicates that there are no skills he needs to work on. Max has a job offer and plans to start the Monday after he graduates from TPub. Max has a high expectancy of success as an engineer.

In her fourth year, Hillary can identify what she is good at doing and she can still identify specific skills where she needs work in order to be a successful engineer. She already has a job offer which she is very excited about. She too has a high expectancy of success.

At the time of the final interview during his fourth year, Joe does not have a job offer. As described in the previous section, his beliefs about the skills needed to be a successful engineer are relatively general in his third year and not grounded in a particular experience. However, he generally has a positive assessment of his skills. He is anxious about getting a job but is confident that he has chosen the right field as evident in this exchange with the interviewer during his fourth year:

> [I]: Do you have any experiences that confirmed your decision to major in engineering?
>
> [Joe]: Well I think this whole senior project thing has really just kind of said hey, yah. That's, that's what you're doing. I mean I've used all the things that I've learned on the project and I like it.

[I]: Have you had any experiences that raised doubt about your decision?
[Joe]: Not really. I mean it, I think I'm where I need to be.

Joe has a positive expectancy of success in his career based on his academic experiences.

Anna's story is different from the others. Anna is unsure of what she wants to do for a career, has a lack of confidence in her laboratory skills, and still has a positive expectancy of success in engineering. Throughout her interviews, Anna talks about many careers that interest her and remains uncommitted to a particular career. By her fourth year, she has decided it makes the most sense for her to get a job as an engineer and earn money towards reducing her undergraduate debt before deciding what she really wants to do as a career.

By her fourth year, Anna is still unclear of what skills are needed as an engineer and she lacks confidence in her ability in laboratory settings. However, she is confident in her ability to learn and pass tests. Anna has been on the President's list nearly every semester. When asked what is hard for her at TPub, Anna talks about trying to be less anxious and learning to have confidence in her abilities:

> Getting over the anxieties for a test. Getting over the umm, not thinking I'm good enough…Getting over umm, being intimidated by a challenge. I'm still intimidated by it, but to the point of where umm, I still don't have as much confidence in a lab as some. And I think, I just don't wanna' mess things up. But umm, kind of having more faith in the stuff I know, because I, I do study, you know. So, when I know something, or I feel like I know something I should be able to be like, "No, this is, you know." Umm, so being more assertive I think in what I think and know.

Based on what Anna is saying and what she has heard from others, the interviewer suggests a descriptive expression, the "arrogance of the engineer". Anna explains:

> So, I would agree that there does seem to be a lot of arrogance of the engineer 'cause it's, you do have to. You've gotta' be like, "Okay, we're going to do this, this, and this. What suggestion do you have? Okay." And then make the decision. And I don't trust myself enough I guess, at least at this point to be able to umm, be like, especially in the lab I don't trust myself. I think some people trust themselves more, and they just do it. And, if they mess up, that's okay. But I, I have a harder time doing that.

Anna believes an engineer needs to be able to make decisions and move on but also expresses a lack of confidence in her ability to do this. Anna recognizes this as a skill she needs to develop to succeed in engineering.

Anna's lack of confidence is related to laboratory experiences. She offers an explanation for why she struggles so much in this area:

> …I still struggle to pinpoint exactly why I do this. And, like why I freeze up. But, I think, like I can study material for an exam a couple of days before, and read the book, and go through the notes, and take the exam and do well. So, I think academically that's why I've succeeded because I can take tests. Umm, in the lab it's a little different. It's more of a common sense thing. And I, I don't know, I kinda' feel like I think in circles. It's not very linear, you know? Umm, I, I think sometimes my analytical skills are more right-sided than they are left-

> sided. But, I still have the ability to memorize stuff and think, you know, somewhat logically in an exam. My work may be like this, but I get to the answer eventually. And so, umm, I think that's where I lack in the lab with, with that kind of by your seat, on the fly kinda' stuff. Because it isn't that linear thought that you needed for turning in the exam of the principles, it's twisting those. And, once you twist 'em, the map, the mental map of everything in my mind of where, of what leads to what, kinda' disintegrates because you've started somewhere else.

Anna is confident in her ability to study for tests and learn course content material. She struggles in applying what she has learned in the laboratory. She calls it a "common sense thing" and describes how the lab is "twisting" what she has learned for exams. However, she knows she can get to the answer eventually.

Despite her lack of confidence, Anna has a positive expectancy of success as an engineer. In her third year, she says she does not really know what skills engineers need but she is confident that once she figures it out she can learn what she needs to know:

> I think I'll be okay. I think I, I have like I said, I have more confidence in being able to learn something that I need to learn. Um, so I think I'll be okay. Uh, like I say, I don't really know what to expect, so it's hard to say for sure, like, "Yeah, I'll be great." But um, I'm always willing to give it a shot now, so I think, I think I'll be okay. I can't say that I'll be great. I can't say that I'm gonna' fail miserably, but at least, I'll have the confidence at least to apply and tell them, like this is what I know. Hopefully, that'll be enough.

It is hard for Anna to assess her abilities against a set of skills she cannot define. However, she still has a positive expectancy of success because of how she defines success; she believes she can learn whatever she needs to learn to be successful in an engineering career.

Anna's job search also provides insight into her expectancy of success. In her fourth year, she talks about job applications:

> I haven't really gone and looked at industry quite yet. I think that I know I can get a job somewhere. And so, that's not as much of the challenge as I'd be getting into like a national lab because those are crazy competitive and a lot of people wanna' go there.

She believes she could secure a job in industry but instead is considering national labs. Despite a lack of confidence in her ability in the laboratory setting in school, she seeks a highly competitive job in a professional laboratory setting indicating a positive expectancy of success.

Discussion

The four students represented here all have positive expectancies of success in engineering. This is not surprising since they are all on track to graduate in engineering as of mid-spring semester of their final year. Notably some have more positive expectancies than others. More importantly, the students have different beliefs about what success means which develop from their classroom, campus and internship experiences.

Early in their undergraduate years, having little personal experience with engineering in a professional context, students draw on pre-college experiences such as previous jobs or other activities in defining the skills needed to be successful as engineers. The skills they cite, such as communication and working with others, tend to be generically applicable to many careers. They may also rely on "scripted" versions of what it means to be a successful engineer. As the students progress through their undergraduate years taking engineering classes, participating in campus activities and completing internships, their beliefs about the skills needed to be successful change. Students with more internships have more specific beliefs grounded in evidence from personal, authentic experiences. These students can more accurately assess their abilities.

Of particular interest is the finding that students can have a lack of confidence in their "engineering" skills, an unclear vision of their future career and still have a positive expectancy of success in engineering. In this case, Anna based her expectancy of success on her belief in her ability to learn whatever she needs to learn rather than on an engineering-specific skill set. This finding highlights the need to also consider the subjective task value portion of Eccles' model. Expectancy-value theory [4] suggests that achievement-related choices result from the intersection of: 1) expectancy for success, an individual's subjective beliefs about the probability for success in a given situation, and 2) values, their reasons for choosing or continuing with a given activity. Although Anna has a positive expectancy of success in engineering, the question is raised about why she might want to persist since she is unsure about what career she really wants and about what skills she might need as an engineer. Examining Anna's task values could help explain her persistence choice.

Applying these results to Eccles' model, it is possible to begin fleshing out the interconnections of factors hypothesized to contribute to determinations of expectancy of success. Figure 2 shows a subsection of Eccles' [8] expectancy-value model of achievement choices (from Figure 1) that has been adapted to show aspects highlighted by the results of this study. Extracting just a portion of the model does not suggest that other aspects are less important. We cannot truly separate the model into pieces anymore than we can isolate a student from their gender, family demographics, etc. However, the data analysis herein only informs in detail certain aspects of the model.

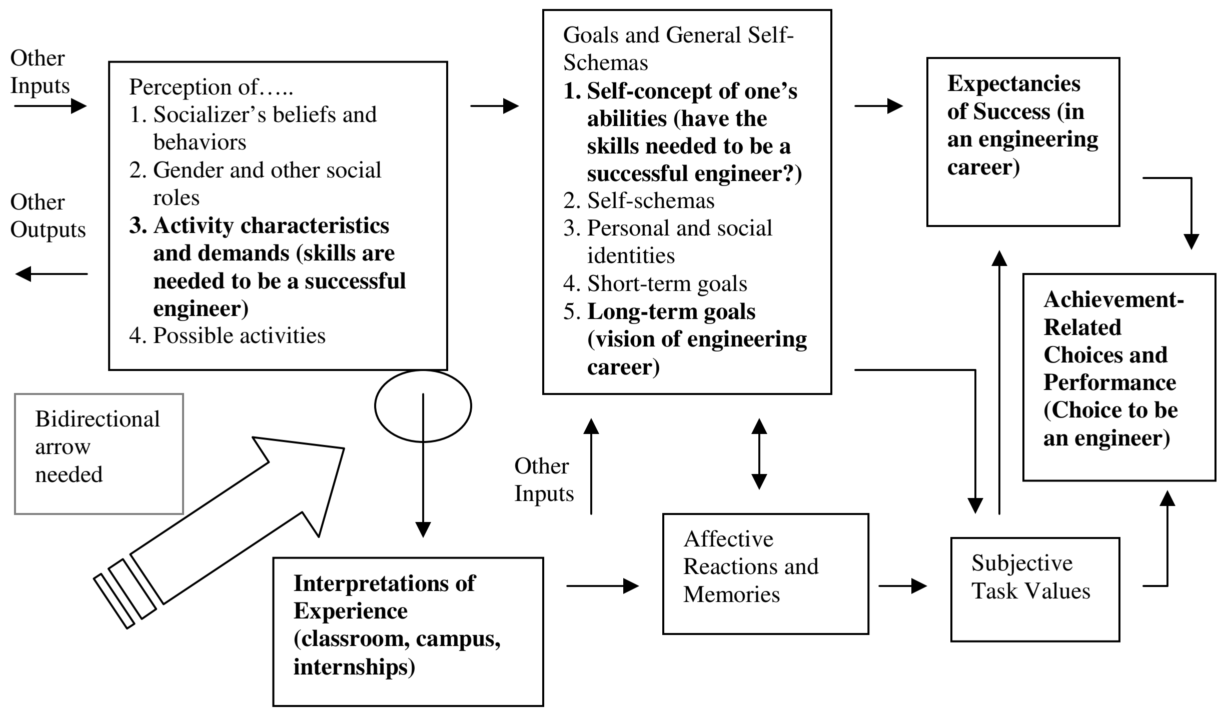

Figure 2: Adaptation of Eccles' [8] expectancy-value model of achievement choices with bold text indicating factors highlighted by the results of this analysis

As noted in Figure 2, the results of this study suggest modifying Eccles' model [8]. The model currently shows a unidirectional arrow from "perceptions of activity characteristics and demands" to "interpretations of experience". Using a bidirectional arrow instead expresses how students' interpretations of classroom, campus and internship experiences can also impact their beliefs about the skills needed to be successful engineers.

Conclusion and Future Work

This study supports and further informs Eccles' expectancy-value model of achievement motivation. Future research needs to include exploring the role of subjective task values in the choice to pursue engineering. Filling this void is important for two reasons: 1) expectancy of success only represents half of the model with subjective task values contributing directly to achievement-related choices, and 2) subjective task values also shape expectancies of success.

Results of this study can inform curricular change by providing fundamental information on the experiences of the college student. By showing ways in which students' expectancies of success as engineers are shaped by their classroom, campus and internship experiences, this study provides a broader context for curricular change. The results suggest the need to authentically expose students to a variety of engineering career possibilities so they can develop accurate perceptions of what engineers do, the skills needed, and their own abilities. The results also suggest students need help bridging the gap between the relevance of what they are learning in the classroom and what they will be doing as engineers in the future.

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