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The Importance of Formative Experiences for Engineering Student Identity*

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The motivation for the current study was to examine the experiences that contribute to engineering identity both in terms of educational and professional pathways; this was accomplished through both qualitative and quantitative means. A cross-sectional study of undergraduate engineering students was conducted at a medium-sized Midwestern private university. A large-scale survey of all undergraduate engineering students, ~1100, yielded responses from ~700 students during the spring of 2009. Survey questions were based on a study approach defining adulthood by Jeffrey Arnett, but specifically applied to engineering identity as a parallel but unique instrument. Engineering identity from a student perspective was assessed, both in terms of self-identification (do engineering students consider themselves to be engineers?) and identifying factors that are "necessary" to be considered an engineer. A qualitative inquiry followed to better inform the quantitative survey results. Individual student interviews across class levels and engineering self-identifications were conducted as a collection of case studies. While it was not surprising to find that individual student experiences contribute to an overall sense of belonging to the college, it was interesting that key experiences such as internships and undergraduate research were not found to be statistically significant predictors of engineer self-identification. Student interviews offered insight into this finding; those experiences were formative, but there is a bi-directionality to these experiences–they can be either affirming or discouraging. Students cited experiences that were positive, challenging learning opportunities as reaffirming their engineering identity as it relates to future career plans. Conversely, negative student experiences were also formative but were related to non-identification and dissuaded students from future engineering related career plans. Finally, the implications for an institution's curricular structure as it relates to engineering identity are discussed as are suggestions for promoting multiple student experiences before graduation and formal assessment of those experiences.

Keywords: engineering education; identity; professional persistence; student experiences

1. INTRODUCTION

MAINTAINING GLOBAL COMPETITIVENESS is a core motivation for engineering educational research, which relies on a recognized need for well-trained scientists and engineers in the US workforce [1, 2]. The challenge is in meeting the needs of society given declining student interest in fields such as engineering which results in fewer graduates, especially among women and minorities [3]. So among those recruited into engineering programs, educators are focused on retaining those interested students through an undergraduate educational path with the hope they will continue along a professional engineering path [4, 5]. Engineering has long been known for its rigorous expectations; it was once believed that students who left engineering simply could not handle the academic challenge, but more recently in looking deeper at who is leaving engineering it is clear that many students are leaving in good academic standing [6]. So what causes some students to stay and others to leave with the same academic preparation and / or achievements? The authors believe that identity is a factor in this, and for students, believing that they are a part of something bigger than themselves and that they conform to their beliefs as to what it means to be an engineer. Engineering identity has been studied by others [7, 8] and is believed to be on a theoretical basis psychosocial [9, 10], meaning that it involves both psychological views of oneself as well as social or cultural views as to how others view them.

In a general sense, identity is difficult to directly observe or measure, as is articulated by James Marcia who operationalized Erik Erikson's psychosocial stage theory of identity:

> Because identity is assumed to be, as Erikson stated "an inner configuration," it is not amenable to direct observation. What can be observed are behaviors, i.e. statements of thoughts and self-reflections, that should be present if an underlying identity is present [11].

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This observational issue, in conjunction with the belief that identity formation and reformation takes place over a lifetime [9, 12–15], is the fundamental reason why direct field observations are not an approach that social scientists normally consider for identity study. Prior identity research has largely focused on qualitative interviews, quantitative measures such as identity status [16] and identity style [17], or a mix of these. Engineering identity has not specifically been studied to nearly the same extent; three notable prior studies of engineering identity will be discussed in further detail including qualitative studies by Stevens et al. and Tonso, as well as a mixed method study by the Center for the Advancement of Engineering Education [18, 19].

Stevens et al. conducted person-centered ethnography to depict identity in becoming an engineer [7]. The study explored a psychosocial perspective on how disciplinary knowledge, identification, and navigation of pathways through the engineering curriculum can be applied as an analytic framework. The university and curricular structures of "labeling" an engineer were found to be significant, "how institutions officially identified students as engineers had a profound effect on students' identification of themselves as engineers and on their futures and commitment to the field." They found that sense of belonging increased over the progression of engineering curriculum with an "increasing solidarity with other engineering students and increasingly reported differences between themselves and other college students." Finally, institutional curricular differences were shown based on whether students select engineering as a degree program, or if they apply and are selected to be in the engineering college (in their first or second years of college) [7].

Tonso took an ethnographic approach to developing descriptions of the characteristics, as defined by engineering students, associated with engineering identities, and the hierarchy that is associated with a scale of socializing and academics. These engineering roles or identities are associated with a higher status within that culture and include (in increasing order): nerds → academic achievers → Greeks. Tonso indicated that increasing status and prestige affords free-loading and other undesirable qualities [20] associated with power and gender of the university's engineering culture [20, 21]. Engineering, as a culture, has been associated with different hierarchies and perceptions that influence identity. Engineering students express a "superiority" over other majors because of the difficulty associated with the discipline, and the belief that their hard work in studying engineering, in making social sacrifices, affords them a prominent and prosperous lifestyle in the future [22].

The Center for the Advancement of Engineering Education [4] conducted the Academic Pathways Study (APS) focused on questions relating to skills, identity, education, and workplace [19]. Quantitative findings from this indicate that only 42% of seniors definitely intend to pursue a career in engineering upon graduation, and qualitatively reported "during the span of students' tenure as undergraduates, their thoughts about career options were strongly swayed—we could even say disproportionately swayed—by a single experience, such as an internship, interaction with faculty or even staff, or advice from a mentor" [23]. And Jain and associates likewise suggested the need to make connections between current engineering students and professionals as a motivational approach to support persistence through the engineering curriculum [5]. Though CAEE has considered "identity" questions focused on motivation for studying engineering and plans for professional persistence in a large scale endeavor, a body of literature for quantitative assessment of factors contributing to engineering identity from a student's perspective is lacking. This result links directly to the research hypothesis in the current study:

Research Hypothesis: Students who have had certain key experiences (summer internships and undergraduate research) will be more likely to self-identify as engineers.

To answer the above-mentioned research question, a framework from Jeffrey Arnett, foundationally linked to Erikson, was adapted for engineering identity. Arnett's original study [24] offered understanding of a critical question of identity from the perspective of college students as to what it means to be an adult. Arnett conducted a large-scale survey of college students and asked them: Do you consider yourself to be an adult?, and then followed on by asking students which of a variety of factors (emotional, behavioral, etc.) were necessary to be considered an adult. His studies involved a 40-item questionnaire in which college students identified

(1) accepting responsibility for actions,
(2) making independent decisions, and
(3) establishing a relationship with parents as equals

most commonly in defining adulthood.

Arnett has considered the historic and cultural implications of the answers to this question, which have shifted from a defining point, such as marriage, to a less definitive time when a person achieves certain "individualistic qualities of character" such as responsibility and independence. These studies served as the foundation for his theory of emerging adulthood [25–27]. Emerging adulthood as roughly the ages of 18–25, "a time of life when many different directions remain possible, when little about the future has been decided for certain, when the scope of independent exploration of life's possibilities is greater for most people than it will be at any other period of life course" [25] (p. 469). Arnett contends that identity exploration is the primary factor that defines emerging adulthood; this can be seen in college students "floundering" with a college major, and even switching majors one or more times [25, 26]. Arnett's theory "modernizes" the stage theory perspective on identity originally introduced by Erikson, so Arnett's early publications offered a model for the current study design. Within the context of engineering, this theoretical perspective and approach is applied to questions related to engineering identity and what factors are viewed by engineering students as critical to self-identification as engineers. Understanding what experiences and factors are formative for students to identify with engineering can guide educators towards supportive structures that promote educational and professional persistence.

2. METHODS

The primary methods for data collection were:

(1) a survey assessment tool and
(2) individual interviews

Survey administration offers advantages of larger sample sizes and statistical analysis to identify trends within the data; the drawback is the lack of depth afforded by standardized questions [28]. Interviews and focus groups, however, provide rich data sets that can give insight into the views, meanings, and experiences of engineering students that could not be captured in a survey alone [28, 29]. These methods, both qualitative and quantitative, were used in conjunction to support and strengthen the findings of each through triangulation [28, 30].

2.1 Setting

The administration site for the current study was a medium-sized, Midwestern, private institution with a traditional student composition, i.e. the vast majority of students completing their undergraduate studies in four years and are in the age range of 18–22. The overall student body is 53% male and 47% female, while the College of Engineering is approximately 75% male and 25% female.

In terms of institutional structure, first-year students are admitted to the separate First-Year of Studies program regardless of their intended future major. Students select their major (whether engineering or something else) near the end of their first-year when they register for classes for the upcoming fall semester. With few exceptions, students who are considering an academic pathway within engineering complete a standard first-year curriculum, including the two-semester course sequence "Introduction to Engineering." They then pass into the college of their selection in their sophomore year. From sophomore year until graduation, students are institutionally recognized by their college, which, in the case of this study, is the College of Engineering; and by their specific engineering discipline within. But beyond admission / selection into the university as a whole, there are no admission or selection criteria for entering any of the disciplines of engineering; rather it is based on student interest alone.

2.2 Population

The entire engineering student body, including all first-year students enrolled in the Introduction to Engineering Systems course, were potential survey participants. The Web-based survey administration yielded 701 responses, an overall response rate of 64%, higher than suggested for a web survey (25–50%) [31–33]. As a percentage, the lower-class divisions (first-year and sophomore) had slightly higher response rates than the upper-class division (junior and senior) students. Overall, 74% of women and 61% of men invited to take the survey participated. The difference in response rate by gender is not uncommon and is recognized as a limitation of the current study; studies of survey response rates indicate similar findings of higher response rates among females [34] with gender being the single greatest predictor of survey completion [35]. A table summarizing the potential and actual respondents by class level and gender is shown in Table 1.

2.3 Quantitative portion of the study

2.3.1 Instrument

The survey instrument was adapted from Arnett [24] relating to self-identification as an adult. Arnett's original instrument was modified and parallels were developed for engineering self-identification. In light of the changes to the questions in this instrument, construct validity was strengthened by multiple reviews and revisions by experts. Expert reviewers included four engineering educa-

Table 1. Comparison of Potential to Actual Survey Responses

	Potential respondents			**Actual respondents**			Response Rates
	Number of male engineering students	Number of female engineering students	Total respondents	Male respondents	Female respondents	Total respondents	
Senior	207	54	261	101	39	140	53.6%
Junior	181	56	237	104	39	143	60.3%
Sophomore	188	76	264	136	60	196	74.2%
First-year	252	83	335	162	60	222	66.3%
Totals			1097			701	63.9%

tion researchers of diverse backgrounds, a sociologist, and English teacher.

The survey was piloted on paper to a focus group of upper-division students in January of 2009. Revisions were incorporated for a second pilot conducted with lower-division students a few days later. Feedback from both of the focus groups was incorporated into the final version of the survey. Dillman et al.'s publication guide for constructing web surveys includes discussion of how to minimize sampling error and maximize coverage area [36]. In the current study, these concerns were addressed by soliciting participation from the entire population, in this case the engineering student body during the spring semester 2009. Further, ensuring that the questions were clearly interpretable by participants minimized measurement error [32, 37], and was addressed through review and revision of the intended instrument by student focus groups. Finally, advertisement and incentives minimized non-response error. Multiple contacts were suggested to achieve desirable response rates, including a pre-notification [32, 33].

The dependent variable was the self-identification question, which was the first question on the survey (note that students could not return to this screen to change their answer after progressing through the survey): Dependent Variable: Do you consider yourself to be an engineer? Response choices (3): Yes, In some ways yes and some ways no, or No. The background questions relating to student experiences (in addition to engineering discipline, class level, and gender) served as the explanatory variables and are shown in Table 2.

The quantitative data were analyzed statistically using the software package STATA [38]; it included frequency counts / tabulations, correlations, and ordinal logistic regression modeling. Frequency counts were used to evaluate the number of affirmative student responses for a survey question in terms of proposed criteria defining engineering. Correlations between survey items were analyzed to confirm question independence. Spearman correlation analysis of the survey questions showed that the questions were in fact independent. There were five items that had correlations greater than 50%, and they were relationships that would be expected such as age and class level. This confirmation of factor independence was critical to regression modeling and to support a model with many co-variants.

Regression modeling was used to evaluate the criteria with the highest predictive power for self-identification as an engineer. Logistic regression techniques were employed given the binary nature of survey responses [39]. A stepwise regression model was developed with six explanatory variables relating to background experiences, class level, and gender. The number of variables in the regression model was increased systematically (one at a time) by adding variables to the model. This was done to confirm the robustness of findings as each additional independent variable was included.

2.4 Qualitative Portion of the study

The qualitative interviews served as a collection of case studies. Case study is the theoretical framework for this research study [40] and it is also the technique utilized for analysis [28]. "A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" [41]. There were 12 individual cases that made up the case study that included analysis both within and across cases. This approach was selected because there are clearly identifiable cases that are "bounded" within the context of undergraduate engineering students during the spring of 2009, but the contextual location of the university cannot be separated from the student experience. Case studies are typically based on multiple sources of data, in this case including a survey, individual interviews, and background information [40]. Having a large number of cases, as in the current study, there is concern that the overall analysis can be "diluted" because each case is explored to less depth [40]; however, given the nature of the current study, which is very focused on questions relating to a student's sense of belonging as it relates to engineering identity, the nature of the inquiry is quite focused. The interview protocol included the following questions for all participants, but given that the interviews were semi-structured the follow-up questions were unique to each participant:

University in General:

(1) In your time at the university, can you describe a time that you felt you really belonged to a group?
(2) To contrast this experience, can you describe a

Table 2. Background Questions—Independent Variables

Question	Response choices
Have you conducted engineering research?	Yes/No
Have you previously worked in an engineering related job?	Yes/No
Are you active in any Engineering Organizations?	Yes/No
Engineering Discipline	Aerospace & Mechanical/Electrical/Civil/Chemical/Computer/Undecided
Class level	First-year/Sophomore/Junior/Senior
Gender	Male/female

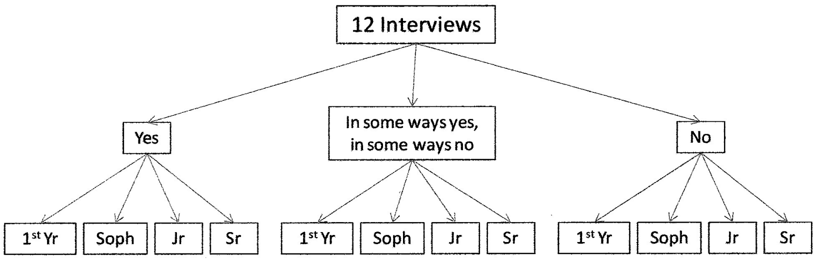

Fig. 1. Initial Interview Selection Approach.

time since being at Notre Dame that you felt that you did not belong to a group?

Within Engineering:

(3) As an engineering student, can you think of a time where you really felt you belonged?
(4) Can you think of a time, as an engineering student, where you did not feel you belonged?
(5) Can you think of the first time that you "felt like an engineer?"
(6) Is there a certain experience that made you feel like you weren't an engineer?

Engineering students were selected as interview participants by a method of both similarity and difference in sampling groupings according to class level and response to the self-identifying question of being an engineer. The selection pool of potential interview participants was limited to those who responded affirmatively to the final survey question, "Are you interested / willing to participate in a follow-up interview?" Three subgroups were established on the basis of the survey question response (Yes / In some ways / No), to the question do you consider yourself to be an engineer? These subgroups were further subdivided into four class levels (nearly all students at this university graduate within four years, so no "fifth-year seniors" are included). Lastly, the sample included a cross-section of the five engineering disciplines and a split of male and female students that were approximately representative of the gender split in engineering at the university. There was one deviation from the interview selection approach, because there were no sophomore students that responded no to the self-identification question and yes to the interest in being interviewed question; as an alternative, two sophomore level students from the 'in some ways' self-identification were interviewed. This sampling strategy is depicted graphically in Fig. 1. Each participant was individually interviewed; that interview was subsequently transcribed by a professional, and a formal coding and analysis process was conducted. Another independent coder, a counseling psychologist, also evaluated each interview. For each example provided by the interview participant, the response was initially coded according to the categories originally introduced in Arnett's study [24] including: role transitions, cognitive, emotional, behavioral, biological, legal / chronological, and responsibilities. A primary code and in many cases a secondary code were identified as part of the within-case analysis [40, 42]. The researcher and additional independent coder worked separately to evaluate the interview responses, but collaborated to discuss the codes assigned and come to consensus for analytic triangulation [28]. The coding scheme went through multiple revisions throughout the analysis process as part of the consensus building meetings. Once all coding was completed for the within-case analysis, the cross-case analysis began. The cross-case analysis involved a form of thematic analysis across-cases, a method of both similarity and difference [28]. Specifically there were two key areas for comparison: (1) by class level or progress towards degree completion and (2) by engineering self-identification.

3. DISCUSSION

The collective cross-sectional study of undergraduate engineering students identified the three most frequently cited criteria to be considered an engineer. Consistent with Arnett's findings, the top three most frequently cited factors that define engineering were intangible in nature and included:

(1) ability to make competent design decisions
(2) capability to work with others by sharing ideas and
(3) maturity to accept responsibility for the consequences of one's actions

Interestingly, completion of an engineering degree, a tangible factor of institutional recognition, was the fifth most highly indicated factor by students (behind four intangible factors).

Survey results to the primary question, "do you consider yourself to be an engineer?" are summarized in Table 3 below. It was hypothesized that the majority of respondents would indicate that they

Table 3. Summary: do you consider yourself to be an engineer?

Response	Percentage
Yes	67.1
In some ways yes, and some ways no	30.4
No	2.6

Table 4. Summary: do you consider yourself to be an engineer? By class level and gender

	First-year			Sophomore			Junior			Senior		
	All	Male	Female	All	Male	Female	All	Male	Female	All	Male	Female
Yes	56.8%	62.3%	41.7%	70.4%	74.3%	61.7%	71.3%	75.0%	61.5%	74.3%	76.2%	66.7%
In some ways	40.5%	35.8%	53.3%	28.6%	25.7%	35.0%	25.9%	24.0%	30.8%	21.4%	19.8%	27.8%
No	2.7%	1.9%	5.0%	1.0%	0.0%	3.3%	2.8%	1.0%	7.7%	4.3%	4.0%	5.6%

are an engineer "in some ways," yet the results showed the vast majority of students definitively self-identified as an engineer (with very few respondents indicating that they did not consider themselves to be an engineer). Table 4 further breaks the results, showing a differential rate for self-identification by class level and gender. Specifically for class level first-year students are distinct from Sophomores, Juniors, and Seniors in terms of self-identification with 57% of first-year students and 72% of more experienced students definitively self identifying as engineers. Theoretically this speaks to the power of the "social" aspect of psychosocial identity, it matters what you call students and more specifically the curricular and institutional structures that classify students within departments. It also calls to mind the development and transition that is likely taking place during the first-year of school, with a very steep learning curve for integrating into a university and a particular academic unit. Women are also much less likely to self-identify as engineers; this was found across class levels with 58% of women versus 72% of men on average self-identifying as engineers. These clear differential rates indicate that these are critical co-variants in understanding engineering identity, and must be included in the regression models.

Regression modeling enabled evaluation of survey items for statistically significant differences while controlling the other variables. Based on the clear distinction between first-year students and more experienced students, class level was included in the model, but was collapsed into a binary factor between first-year students and all other students (sophomores, juniors, and seniors combined). A stepwise regression model was developed that systematically added new explanatory variables; the model began with research experience as the only explanatory variable. And while research experience was initially significant, the result was not robust; as soon as another explanatory variable was included in the model it was no longer significant (and remained insignificant as each factor was added). Next, engineering related work experience (such as an internship) was included as an explanatory variable and it was significant in helping to explain engineering self-identification; however, as each additional explanatory variable was added to the model it became less and less significant (it was not significant to a 0.05 level once gender was included in the model). Experience in an engineering organization was included in the model but did not offer much in the way of explanatory power. Additional control variables were added to the model and confirmed that there was no difference by discipline, and class level and gender were both added to the model and were both statistically significant. The stepwise model is shown in Table 5. In the final model, only Class Level and Gender were significant. To better interpret the data collected through the survey, qualitative interviews of twelve engineering students were conducted. A theme mentioned by almost every interview participant related to a reflection on what it means to be an engineer and a comparison of themselves to assess: do I fit that role? These reflections are foundational to identity; the following student quote articulates this point succinctly:

> I'm just not that good at programming. I don't know, it doesn't click with me for some reason. And, a lot of people are decent at it. And then you have some people that are really good at it, and people that really like it. And, I'm not either of them. I don't get it the way I'm supposed to or something. So, that's a bit of a drawback. Electrical engineers are supposed to be proficient at programming anyway.—Sophomore

Table 5. Stepwise regression model for engineering student self-identification

Engineering research experience	Engineering work experience	Engineering organizational involvement	Engineering discipline	Class level (first-year vs. others)	Gender
2.83*	—	—	—	—	—
1.84	2.69**	—	—	—	—
1.81	2.60*	0.30	—	—	—
1.88	2.64*	0.25	0.79	—	—
1.49	1.97*	−0.25	0.64	2.47*	—
1.67	1.74	0.95	0.71	2.31*	−3.96***

where significance is denoted by a<0.05*, a<0.01**, a<0.001***

This student was concerned about a specific skill, programming, and his interest and ability relative to his peers and his engineering discipline, electrical, specifically.

The primary research question in this paper relates to student engineering experiences such as summer internships, undergraduate research, and engineering organizational involvements and the hypothesis that the likelihood of self-identifying as an engineer would increase for students with those experiences. This hypothesis was rejected, according to survey responses in the logistic regression models, after controlling for other demographic factors such as class level and gender, none of these experiences was a statistically significant explanatory variable for students to self-identify as an engineer. It was believed that student participation in internships and research experiences would indicate a healthy exploration of their interests for the future. In the case of engineering, these experiences have been indicated in helping clarify the path for students in terms of selecting and confirming their intended field of study [43]. As an example, Stevens and associates reported on a formative experience in which a positive engineering work experience affirmed a student's professional path and future work plans [7]. However,. Lichtenstein's recent study talks about key experiences being either positive or negative [23], which in a large-scale study such as this may offset each other statistically, such that even very limited experience(s) had profound impact on students' future career plans. This is a clear situation in which the qualitative data helped to inform the quantitative results. In the current study, there were indications that these types of experiences were formative, as the following three quotes indicate:

> Research Example:
> I was in Boston by myself presenting research in front of PhDs. And, it was pretty scary, you know? And it was probably the most frightening time in my life—I'm not kidding you. But you know I got through it, and ended up networking with a few of the PhDs afterwards. I said, this is definitely for me.

> Senior Internship Examples:
> I've done two internships. One was more business-y. It was supplier quality. And the second one was design. And, I really like engineering work, in the sense that, the work that you're actually doing and the projects, and the design and everything. But, the actual day-to-day life of an engineer, and in industry from what I've experienced, is not something that I'm so keen on. Probably in the sense that there's a lot of work that I'm not interested in doing. And I don't know if it's just that I'm not patient enough to work on one thing for long enough. But, if that's what, an engineer meant, then I probably wouldn't want to be an engineer.

> Senior Engineering Organization Example:
> I was on the concrete canoe team last year. And we got really into it. We were all paddlers for the team. And so we'd go out and train in the lake nearby and stuff. So it was a lot of fun, and I mean, you really felt like you were really part of that group.

These student quotes offer insight into the complexity of the impact of these experiences on students view of themselves and their assessment of their conformity with the sorts of things that they believe engineers do (or should do) relative to their skills, abilities, and interests. The engineering organization example makes it clear that being involved with the concrete canoe team was a positive and inclusive experience, yet other students interviewed were much less enthusiastic about their experiences with engineering organizations. This may actually speak to the nature or level of the involvement in an organization; a student who is fully engaged in an ongoing project is quite different from attending a planning meeting each semester for the free pizza. While no definitive conclusions can be drawn, future work should consider the organizational involvement / level of commitment involved as an important covariate. Additionally, exploration of an alternative hypothesis that these key experiences could be either affirming or dissuading should be pursued. The current study only asked if students had research or internship experience, but not whether that experience was positive or negative, affirming a direction for a student one way or another (but potentially directionally inconsistent).

While focus group interviews with students did not reveal that any distinction was necessary between defining engineering from an educational versus a professional standpoint, evaluating the students' qualitative responses indicates a relationship to both in terms of engineering identity which cannot be easily deciphered. Many might argue that degree completion is required to be considered an engineer, while others would say a degree is not enough but rather licensure is necessary. And although it does not seem to be directly addressed in the literature, engineering may be different from other professional degrees in that faculty have been known to refer to engineering students as "engineers." You would not be likely to hear parallel designations of psychology student/ psychologist, aviation student / pilot, law student / lawyer, or medical student / doctor. Capobianco conducted a study of undergraduate women engineering students and their professional identities, and asked two female engineering students a question relating to their self-perceptions as engineers, resulting in mixed responses [44]:

> Capobianco: Would you describe yourself as an engineer at this point in your academic program? Why or why not?

> Student 1's language would indicate yes: I feel as though I could apply myself more to be a better engineer. Right now if you put me in the hall with everyone, I would be average. I don't think that I am above average as far as being an engineer. I think that I could take engineering a bit more seriously.

> Student 2 would not: I definitely would not qualify . . . or call myself an engineer yet.

Another example comes from a publication by Dannels in which a student in a capstone design course was questioned about a comment made about being a "real engineer" [45]:

> Dannels: You are not a real engineer? I mean, you are designing this stair climb assist device right? That is real, yes? What, you become a "real" engineer when you graduate? You are not a real engineer now?
> Student: Nope, this is school. This isn't real.

This interaction makes it clear that in this student's mind graduation from an undergraduate program is necessary to be considered an engineer, yet Dannels line of questioning seems to challenge this belief. Finally, Dannels concludes, "the process of knowledge construction, then, is a complicated weave of disciplinary identities, values, rhetorical purposes, and technical content" [45]. The current research study would support Dannels' conclusion of complexity of engineering identity. And this complexity is furthered by the range of faculty beliefs of what engineering is; Pawley conducted a study of how different faculty members define engineering and found that some consistent yet unique themes emerged (applied science and mathematics, problem solving, and making things) [46]. Many engineering educators are challenged to define succinctly what engineering is to students, as articulated in the following quote from an Introduction to Engineering textbook

> Engineering is a profession as diverse as society's needs. Engineers work in every conceivable business setting, from large corporations and factories to small start-up companies and consulting firms. [47].

The apparent diversity of understanding of what engineering is probably contributes to the lack of clarity about who is an engineer, as many professional titles include "engineer" without necessarily having a formal educational credential. Weighing in on this subject, Tonso reported that it is normative interpretation and power that allows claims to be made as to "who counts as a real engineer" and who doesn't [8].

Most would agree that educational and professional experiences such as research and internships are significant to engineering student learning and development, yet these experiences were not found to be statistically significant predictors of engineering identity in the current study. Follow up interviews revealed that key experiences such as these are formative, but they do not necessarily affirm students towards professional persistence in engineering. Ideally, internship and research experiences are more than just résumé builders for students, but what assessment is done for these programs to ensure that they are meaningful experiences? Internship experiences are typically coordinated through a university placement service but are left to students to negotiate with industry partners. Formal assessment of internship experiences could be conducted for the mutual benefit of a university placement office, the engineering college, companies, and students, using these assessments to develop relationships with the industry partners that offer the most challenging and interesting opportunities to students (potentially offer those partners the first opportunity to meet with students for recruitment). These assessments would help engineering educators to understand the direction of these experiences as they pertain to professional persistence. Likewise, assessment of research experiences would benefit the engineering educational community at large. Universities vary in the requirements and formality of undergraduate research experiences, however; all too often the experience is driven by the faculty advisor and may or may not be at an appropriate expectation level for the student. Regardless, how that experience is internalized by the student to affirm or dissuade a student's future career plans warrants study.

Finally, the indications that students are making decisions with limited information can be remedied by promoting multiple experiences for each student. This suggestion might seem to be an "obvious" benefit that is difficult to put into practice, but the experiences do not necessarily have to take the form of paid internships for an entire summer or semester-long research projects. Rather these experiences could be 1–2 week unpaid "externships" over school breaks to offer enough exposure to help students form perceptions of engineering that helps to represent the vastness of the profession. Promoting multiple experiences for each student, where possible, would enable motivated students to make informed decisions rather than weighing one experience unnecessarily high. The limitation of this idea is resources, as there would be associated administrative costs as well as efforts from faculty, staff, and administrators. From the current study we offer two primary recommendations for increased professional persistence (or at least more informed decision making):

(1) formal assessment of student internship and research experiences
(2) educators and administrators should consider ways to encourage multiple experiences for each student's growth, development, and informed decision making.

Limitations and future work

There are two primary limitations involved in the current study:

(1) the single-site design
(2) restricting the study to participants who have persisted in engineering.

Expanding the study to other dissimilar institutions would likely extend our understanding of the institutional factors that relate to engineering identity. For example, considering other programs that require additional application for acceptance into a discipline program, this has been referred to as gate keeping. What impact does it have on self-identification and persistence? The participants who were invited to take part in the current study were recruited from students who have persisted in engineering. Although the survey was administered to all currently enrolled engineering students, it did not include students who may have started in engineering and changed to another major. Sense of belonging has been identified as a factor for persistence in STEM fields [6], and as such expanding the current study to include students who have not persisted in engineering would be meaningful.

While the current study has contributed to community understanding of engineering identity, there is considerable opportunity to further explore how experiences influence educational and professional persistence. Specifically is the formal assessment of the direction of student experiences in, but not limited to, the following areas: engineering organizational involvement, undergraduate research experience, and engineering related work experiences? Talking with students many times throughout their educational experience makes it possible to consider the evolution of their views of themselves and how they believe they fit in as engineering students and their intentions for professional persistence.

4. CONCLUSIONS

The factors and experiences that contribute to self-identification are wrought with complexities, but, from an educational perspective we now recognize that it matters what we call students and how we classify them as this contributes to the social portion of psychosocial identity. And further individual experiences seem to go through an individual reconciliation in terms of a comparison between what a student believes is important and relevant to engineering and what they actually see, feel, or experience as this relates to the psychological portion of psychosocial identity. Despite the bi-directional nature of these experiences, it seems that additional experiences during undergraduate study will result in a more informed choice (or at least recognition that engineering and being an engineer in practice can mean many things). Considering the overwhelming number of students that did self-identify as engineers raises the question, does it matter what students call themselves? We would argue that it does not matter, but it is relevant to consider self-identification as an indication of a student's sense of belonging to the engineering community which relates to persistence. If inclusive practices can help increase retention and persistence it seems like a relatively simple recognition that faculty should be aware of. Modifying curricular structures such as "gates" for acceptance is much more involved but could also be considered at institutions with serious retention issues. If how the organization and hierarchy within refers to you makes an affirmation that you belong to something bigger than yourself, why not do it? Other ideas for promoting experiences that may affirm or inform engineering identity such as multiple experiences and assessment of those experiences requires considerably more effort, but would mean much to the preparation of young engineers and we suspect it would have significant implications for professional persistence.

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REFERENCES

1. N. Augustine, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future*, National Academies Committee on Prospering in the Global Economy of 21st Century—Committee on Science, and Public Policy, Editor. 2005, National Academies Press: Washington, D.C.
2. J. Duderstadt, *Engineering for a Changing World*, in *A Road Map to the Future of Engineering Practice, Research, and Education*, 2008, University of Michigan: Ann Arbor, MI. p. 131.
3. NSF, *National Science Foundation: Bachelor's Degrees by field and sex 1998–2007*. 2009 [cited 2010 05/10/2010]; Bachelor's Degrees in Engineering—2007: 68,274 engineers / 55,621 male / 12,653 female. Available from: http://www.nsf.gov/statistics/wmpd/pdf/tabc-4.pdf
4. CAEE, *Center for the Advancement of Engineering Education*. Research—Learning—Teaching—Diversity—Community 2008 [cited 2008 10/25/2008]; Available from: http://www.engr.washington.edu/caee/
5. R. Jain, B. Shanahan, and C. Roe, Broadening the Appeal of Engineering—Addressing Factors Contributing to Low Appeal and High Attrition. *International Journal of Engineering Education,* **25**(3), 2009, pp. 405–418.
6. E. Seymour, and N. Hewitt, *Talking About Leaving: Why Undergraduates Leave the Sciences*. Bolder, Co.: Westview Press. 1997, pp. 429.
7. R. Stevens, K. O'Connor, L. Garrison, A. Jocuns, and D. Amos, *Becoming an Engineer: Toward a Three Dimensional View of Engineering Learning.* Journal of Engineering Education, 2008 (July 2008).
8. K. Tonso, *On the Outskirts of Engineering*. Learning Identity, Gender, and Power via Engineering Practice. Rotterdam, The Netherlands: Sense Publishers, 2007.
9. E. Erikson, *Identity Youth and Crisis*. first ed. 1968, New York: W.W. Norton & Company. p. 336.

10. E. Erikson, *Identity and the Life Cycle*. W. W. Norton & Company. 1980, p. 191.
11. J. Marcia, *Theory and Measure: The Identity Status Interview*, in *Capturing identity: quantitative and qualitative methods*, M. Watzlawik and A. Born, Editors. University Press of America: Lanham, MD, 2007.
12. K. Keniston, *Youth and Dissent: the rise of a new opposition*, New York: Harcourt Brace Jovanovich, 1971.
13. J. Kroger, *Identity Development: Adolescence Through Adulthood*. 2nd ed. 2007.
14. D. Levinson, *The Seasons of a Man's Life*, New York: Knopf, 1978.
15. J. Marcia, *Identity in Adolescence*, in *Handbook of Adolescent Psychology*. 1980. p. 159–187.
16. J. Marcia, Development and Validation of Ego-Identity Status. *Journal of Personality and Social Psychology*, **5**, 1966, pp. 551–558.
17. M. Berzonsky, Identity Style: Conceptualization and Measurement. *Journal of adolescent research*, **4**(3), 1998.
18. APS, *Academic Pathways Study Spring 2005 Survey*. Center for the Advancement of Engineering Education (CAEE), 2005.
19. H. L. Chen, K. M. Donalson, O. Eris, D. Chachra, G. Toye, G. Lichtenstein, and S. D. Sheppard, *From PIE to APPLES: The Evolution of a Survey Instrument to Explore Engineering Student Pathways*, in *American Society for Engineering Education*. ASEE: Pittsburg, PA, 2008.
20. K. Tonso, *Teams that Work:* Campus Culture, Engineer Identity, and Social Interactions*. Journal of Engineering Education,* **95**(1), 2006.
21. K. Tonso, *Engineering Gender—Gendering Engineering: What about women in nerd-dom?* in *American Educational Research Association*. SanDiego, CA: AERA. 1998.
22. R. Stevens, D. M. Amos, L. Garrison, and A. Jocuns, *Engineering as Lifestyle and a Meritocracy of Difficulty: Two Pervasive Beliefs Among Engineering Students and Their Possible Effects*. in *American Society for Engineering Education Annual Conference*. Honolulu, Hawaii. 2007.
23. G. Lichtenstein, H. G. Loshbaugh, B. Claar, H. L. Chen, K. Jackson, S. D. Sheppard, An Engineering Major Does Not (Necessarily) an Engineer Make: Career Decision-making Among Undergraduate Engineers. *Journal of Engineering Education,* **98**(3), 2009.
24. J. Arnett, Are College Students Adults? Their Conceptions of the Transition to Adulthood. *Journal of Adult Development*, **1**(4), 1994, pp. 213–224.
25. J. Arnett, Emerging Adulthood: A Theory of Development From the Late Teens Through the Twenties. *American Psychologist,* **55**(5), 2000, pp. 469.
26. J. Arnett, *Emerging Adulthood: The Winding Road from the Late Teens Through the Twenties*. New York: Oxford University Press, 2004.
27. J. Arnett, *Emerging Adulthood: What is it, and What is it Good For?* Society for Research in Child Development, **1 #2**(Journal Compilation). 2007, pp. 68–73.
28. M. Patton, *Qualitative Research & Evaluation Methods*. 3 ed. Thousand Oaks, CA: Sage Publications, 2002.
29. I. Seidman, *Interviewing as Qualitative Research: A Guide for Researchers in Education and Social Sciences*. 3 ed. New York: Teachers College Press, 2006.
30. J. McMillan and S. Schumacher, *Research in Education: Evidence-Based Inquiry*. 6 ed. Pearson Education, 2006.
31. E. Deutskens, K. De Ruyter, M. Wetzels, P. Oosterveld, Response Rate and Response Quality of Internet-Based Surveys: An Experimental Study. *Marketing Letters*, **15**(1), 2004, pp. 21–36.
32. D. Dillman, *Mail and Internet Surveys: The Tailored Design Method*. 2nd ed. Hoboken, NJ: John Wiley & Sons, Inc. 2007, pp. 523.
33. M. Kaplowitz, T. Hadlock, and R. Levine, A Comparison of Web and Mail Survey Resonse Rates. *Public Opinion Quarterly*, **68**(1), 2004, pp. 94–101.
34. W. Smith, *Does Gender Influence Online Survey Participation? A Record-Linkage Analysis of University Faculty Online Survey Response Behavior*. San Jose State University: San Jose, CA. 2008, p. 21.
35. L. Sax, S. Gilmartain, and A. Bryant, Assessing Response Rates and NonResponse Bias in Web and Paper Surveys. *Research in Higher Education,* **44**(4), 2003.
36. D. Dillman, R. Tortora, and D. Bowker, *Principles for Constructing Web Surveys*. Washington State University: Pullman, WA. 1998, p. 16.
37. D. Berdie, J. Anderson, and M. Niebuhr, *Questionnaires: Design and Use*. 2nd ed. Metuchen, NJ: The Scarecrow Press, Inc, 1996.
38. STATA. *STATA: Data Analysis and Statistical Software*. 1996-2008 [cited 2008 1/3/2008]; Data analysis, management, graphics, matrix language, linear models, survey statistics, multivariate methods, multinomial and probit. Available from: http://www.stata.com/
39. A. Agresti and B. Finlay, *Statistical Methods for the Social Sciences*. 3rd ed. Upper Saddle River, NJ: Prentice Hall. 1997, pp. 706.
40. J. Creswell, *Qualitative Inquiry & Research Design: Choosing Among Five Approaches*. 2nd ed. Thousand Oaks: Sage Publications, 2007.
41. R. Yin, *Case Study Research: Design and Methods*, 2nd ed. Vol. 5, Thousand Oaks, Sage Publications, 1994.
42. A. Huberman, and M. Miles, *The Qualitative Researcher's Companion*, Thousand Oaks, CA: Sage Publications, 1994.
43. G. Lichtenstein, H. Loshbaugh, B. Claar, T. Bailey, and S. Sheppard, Should I Stay or Should I Go? Engineering Students' Persistence is Based on Little Experiance or Data, in *American Society for Engineering Education*, ASEE: Hawaii, 2007.
44. B. Capobianco*,* Undergraduate Women Engineering Their Professional Identities. *Journal of Women and Minorities in Science and Engineering*, **12**, 2006, pp. 95–117.
45. D. Dannels, Learning to be Professional: Technical Classroom Discourse, Practice, and Professional Identity Construction. *Journal of Business and Technical Communication,* **14**(1), 2000, pp. 5–37.

46. A. Pawley, Universalized Narratives: Patterns in How Faculty Members Define "Engineering". *Journal of Engineering Education,* **98**(4), 2009.
47. J. Brockman, *Introduction to Engineering: Modeling and Problem Solving*. 1 ed. Hoboken, NJ: John Wiley & Sons, Inc. 2009, pp. 588.

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