Factors relating to engineering identity

Kerry L. Meyers†, Matthew W. Ohland‡, Alice L. Pawley‡, Stephen E. Silliman† & Karl A. Smith‡

University of Notre Dame, Notre Dame, Indiana, United States of America†
Purdue University, West Lafayette, Indiana, United States of America ‡

ABSTRACT: Engineering identity is believed to relate to educational and professional persistence. In particular, a student's sense of belonging to the engineering community is critical to that path. The primary research questions were: 1) which students self-identify as engineers?; and 2) what are the key factors that relate to self-identification? To address these research questions, a cross-sectional study of all undergraduate engineering students at a medium sized, Midwestern private university was conducted in the spring of 2009. The majority of engineering students did self-identify as engineers, with educational progression, gender and future career plans all being significant attributes. The factors that students most frequently identified as being necessary to be considered an engineer were intangible in nature and included: making competent design decisions, working with others to share ideas and accepting responsibility. Students' self-identification as engineers can be linked to a sense of belonging to the engineering college, as well as organisational recognition.

Keywords: Engineering identity, persistence, professional persistence, engineering education

INTRODUCTION

Several notable national reports have raised concerns for global competitiveness and the connection to STEM education [1][2], lagging innovation compared to other nations, and the increased demand in the work force for scientists and engineers [2], declining interest among students in the US to pursue careers in engineering related fields [1], and lack of gender and ethnic diversity in engineering programmes and the engineering workforce as a whole [3][4]. These challenges have provided motivation for a variety of engineering education research endeavours, particularly research focused on recruitment and retention [5]. Recruitment efforts have led to research on exposure to engineering in P-12 settings [6][7]. Ohland et al found that while there is significant institutional variability in engineering persistence, persistence in engineering within each institution is generally high compared to persistence in other disciplines [8]. While institutional selectivity certainly plays a role, this finding also highlights the importance of policies, programmes and culture in describing institutional differences. In this work, the authors study institutional culture as manifested by how and when students identify with engineering at an institution.

Earlier Studies of Student Development in Engineering

Lichtenstein et al reported that only 42% of seniors definitely intend to pursue a career in engineering upon graduation, and follow-up interviews revealed that students were making decisions based on very limited information (a single experience or interaction) [9]. This led the authors question how and when engineering students identify as engineers. While earlier research espoused the values of establishing an engineering identity [10], it was only fairly recently that a cadre of researchers began to study engineering identity in earnest, including the qualitative work of Tonso [11], and the researchers affiliated with the Center for the Advancement of Engineering Education, who conducted a large scale study of engineering student development, including surveys and ethnographic interviews [12].

Tonso's work shows how gender and other variables (such as membership in a fraternity or sorority) affect the power and status of students, and makes it clear that one must consider the effect of gender when discussing engineering identity [11]. Capobianco's longitudinal case study of the development of professional identities of female undergraduate students at a large Midwestern university highlighted the importance of female role models in the process of *enculturation* [13]. Another important factor for engineering identity is having significant engineering related experiences, such as internships, over the course of the undergraduate experience [14][15]. Further, Tate and Linn's work shows that women, particularly minority women, have different perceptions of engineering education [16]. Walker showed that the technical workplace is gendered in Britain as well, in spite of considerable progress, the issues faced by women in technical professions are longstanding and resistant to change [17]. In that Tonso's work is focused on the relationships among students within the educational culture, it does not speak directly to the focus of this work, which is on how students identify with engineering [18]. Other research in engineering identity also focuses more on the identity of individual students [19-21]. For example, Loshbaugh and Claar's study of identity is concerned with specific elements of student identity that evolve from their participation in engineering programmes - introversion, intensity of focus, and application of specific knowledge - all embodied in the persona of *the geek* [20].

The importance of their work is in understanding how engineering students may be limited by adopting this persona, and indeed understanding how the profession itself may be limited to include only those who are willing to take on that persona. Based on their findings from case studies, Stevens et al questioned whether engineering education is a site for personal development and, particularly, note the dilemma of the development of impressions of *engineering* that students draw from coursework in physics, chemistry, and mathematics particularly, at an institution at which students apply to be admitted to the engineering majors near the end of the sophomore year [21].

This work extends the understanding of the identity of engineering students in a number of ways. The use of a quantitative study with larger numbers of students permits researchers to search for patterns that cannot be observed in smaller scale qualitative studies and permits greater confidence in the generalisability of the results. Noting that various researchers have recognised that the process of becoming an engineer is a developmental one [22-25], the authors have turned to developmental theory to understand this important process. Noting Tonso's definition of engineering identity as a *sense of belonging* [26], the authors have chosen to model the development of engineering identity as a stage theory of development that takes place over time.

Modelling Identity Development Using a Stage Theory

There is considerable evidence that stage theory makes sense in this context. Tonso's findings that there is a marked difference between first-year students and seniors in their ability to describe the *engineering identity* terrain leads the authors to believe that class level will be a factor in identity development, particularly, the distinction between first-year engineering students (who are identified differently at the institution studied) and students in the sophomore year of engineering and beyond [26]. Stevens et al also noted an increased sense of differentiation between engineers and non-engineers is present with each progressive year of engineering study, as evidenced by the language *us versus them* and *we versus they* [27], boundary language for an understanding of membership, identity and belonging. Stevens et al also found that the manner in which students are *labelled* engineers by universities and curricular structures (classes and degree programmes) was significant to how students viewed themselves and their commitment level to engineering [27], which further supports the authors' hypothesis of a developmental stage transition occurring during the college years. Noting that Stevens et al reported that the selection process for entering an engineering programme was significant (i.e. whether students self-select to enter the programme or if there was an application/acceptance process), selection into a set of first-year engineering courses followed by a natural articulation to the majors in the sophomore year should result in the formation of engineering identity to a greater degree (or at least more quickly) than the institution studied by Stevens et al that required an application/acceptance process at the end of the sophomore year.

This reported evolution of thought that takes place during the undergraduate engineering experience supports a theoretical foundation based on stage theory. Stage theory is rooted in developmental psychology [28], and has provided a foundation for many theories of human development over the past century. Stage theories characterise development as follows:

- There is a universal sequence of achievements that are qualitatively different for each stage of development [28][29].
- There are individual differences in: 1) the rate of development through stages; and 2) the final stage attained [28].
- The passage from one stage to the next is believed to be gradual [28].

Identity stage theory, originally introduced by Erik Erikson in the 1950s, is a psychosocial perspective on stage theory for identity based on both individual and social identification [30]. More recently, Chickering and Reisser published their seven vector theory for college student development, which still maintains a psychosocial perspective from Erikson, but softens the rigidity of a stage theory perspective, while maintaining the general developmental pattern as a progression [31]. And finally, engineering education research has also applied a psychosocial approach, one that considers the identification by an individual of themselves and an institution's classification of that individual, as Stevens et al did in their recent engineering identity publication [27]. Modern theories still maintain some of the ideals of identity stage theory in terms of a psychosocial nature (self and other) and a general progression or development that takes place over time.

Adapting Arnett's Work on *Emerging Adulthood*

Recognising the substantial sociological changes that have occurred in the United States over the past half century in terms of increasing number of students attending college, as well as later age for marriage and children, Arnett built upon the identity work of Erikson and others as a theoretical background for his theory of emerging adulthood [32-34].

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 [32]. Arnett's theory modernises the stage theory perspective on identity originally introduced by Erikson and Arnett's early publications offered a model for the current study design. Arnett's early publications were foundational to the eventual identification of emerging adulthood as its own distinct life stage.

A sample of college students was asked if they considered themselves adults. From a 40-item questionnaire, the three factors most frequently cited as being necessary to be considered an adult: 1) accepting responsibility for actions; 2) making independent decisions; and 3) establishing a relationship with parents as equals [35]. The authors use Arnett's work as a model because many of the same forces that influence the development of an identity as an adult affect the development of an identity as an engineer. In the current study, participants were directly asked if they considered themselves to be engineers and to indicate factors that were critical to engineering identity (behaviours, responsibilities, etc), directly paralleling Arnett's questionnaire format.

Research Hypotheses

The following four research hypotheses guided the study and subsequent analysis relating to the primary question, do engineering students consider themselves to be engineers?, including:

Hypothesis 1: In the same light as Arnett's study of emerging adulthood, a majority of engineering students surveyed will respond *In some ways yes, and in some ways no* to the question: *Do you consider yourself to be an engineer?* [35].

Hypothesis 2: Sophomores, juniors and senior engineering students, being further along in the engineering education curriculum, will be more likely to identify themselves as engineers than first-year students, in accordance with prior cross-sectional studies that demonstrate significant differences between first-year students and seniors in identity development [36-39]. The first year (and to a lesser degree second year) of an engineering curriculum is largely focused on mathematics and science prerequisites, and involve limited engineering course work or interaction with engineering faculty [21][40][41], decreasing students' likelihood to self-classify as engineers.

Hypothesis 3: Male students will be more likely to identify themselves as engineers than female students. This hypothesis is based largely on the issue of a general lack of sense of belonging for women and minority students in the field of engineering [16][42-45].

Hypothesis 4: Students' future career plans are related to their view of themselves as an engineer; those who have plans to continue in engineering as a career or education path are more likely to identify themselves as engineers, as this is an indication of an individual's self-concept or identity [46-48].

DATA COLLECTION AND METHODS

Setting

The survey was administered at a medium sized, Midwestern, private institution with the vast majority of students completing their undergraduate studies in four years and are between 18 and 22 years old. The institution is considered selective and is religiously affiliated. There is a 98% retention rate from first-year to sophomore year, and a 95% graduation rate university-wide. The overall student body is 53% male and 47% female, while the College of Engineering is approximately 72% male and 28% female. Due to the limited number of underrepresented minority students in the College of Engineering (<10%), results for underrepresented minorities could not be disaggregated.

All first-year students are admitted to the separate First-Year of Studies programme and select their major (engineering or otherwise) near the end of their first-year when they register for classes for the upcoming fall semester. With few exceptions, engineering students complete a standard first-year curriculum, including the two-semester course sequence *Introduction to Engineering*, taught by engineering faculty. In the sophomore year (after completing a minimum of 24 credits), students are institutionally recognised by their college (the College of Engineering in this case) and by their specific engineering discipline.

The minimum credit requirements for classification by grade level are: 24 - sophomore, 60 - junior, and 92 - senior. Engineering disciplines at the institution studied include: Aerospace and Mechanical Engineering, Chemical and Biomolecular Engineering, Civil Engineering and Geological Science, Computer Science and Engineering, and Electrical Engineering. Beyond admission to the University, there are no admissions criteria for entering any of the disciplines of engineering; it is based on student interest alone.

Population

The entire engineering student body, including all first-year students enrolled in the Introduction to Engineering Systems course, were invited to complete the Web-based survey, which yielded 701 responses, an overall response rate of 64%, which is higher than the 25-50% expected for a Web survey [49-51]. As a percentage, the lower-grade divisions (first-year and sophomore) had slightly higher response rates than the upper-grade division (junior and senior) students. Each grade division had a response rate over 50% and the data collected from the sample population are relatively representative of the overall engineering student population.

Based on a chi-squared test of independence, upper-division men were slightly underrepresented, while lower-division women were slightly overrepresented. A higher response rate for women (74% versus 61% for men) was observed, but is not uncommon [52] and is recognised as a limitation of the current study. Studies of survey response rates show gender is the single greatest predictor of survey completion [53]. Potential and actual respondents by grade level and gender are shown in Table 1.

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	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%

Procedures

The primary method for data collection was a survey assessment tool. The use of a survey benefits this work through a larger sample size and statistical analysis [14]. The results of this cross-sectional study of engineering students, administered through an on-line survey, are presented in the following sections.

Instrument

As described earlier, the survey instrument was adapted from an instrument originally developed by Jeffrey Arnett [35] that posed the question: *Are College Students Adults?* Arnett's original instrument was modified and parallels were developed for engineering identity. 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 education researchers of diverse backgrounds, a sociologist and an English teacher.

The survey was piloted to a focus group of upper-division students in January of 2009. Revisions were incorporated for a second pilot conducted with lower-division students and feedback from both of the focus groups was incorporated into the final version of the survey. The publication guide for constructing Web surveys of Dillman et al includes discussion of how to minimise sampling error and maximise coverage area [54].

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. Focus groups helped ensure that the questions were clearly interpretable by participants to minimise measurement error [54][55]. Finally, advertisement and incentives minimised non-response error. Pre-notification, email invitation by a credible source (the College of Engineering), and an email reminder notice were used to achieve desirable response rates [49][51]. The dependent variable came from the response to Question 1, below. The independent variables were from Questions 2-30 shown in Table 2.

Question 1: *Do you consider yourself to be an engineer?*

Response choices (3): Yes, In some ways yes and some ways no, or No

Questions 2-30: Indicate whether you feel each of the following is necessary to be considered an engineer.

Response choices (2): Yes or No

Table 2: Survey items: which factors define engineering?

	Please read the following statements and indicate whether you feel each is necessary to be considered an engineer
2	Being able to make competent design decisions
3	Being able to teach engineering content to another person
4	Speaking/communicating using accurate technical terminology

5	Feeling confident in engineering work without confirmation from others that the approach is technically sound
6	Making moral/ethical decisions considering all factors
7	Accepting responsibility for the consequences of actions
8	Making a long term commitment to a company
9	Making a long term commitment to a career
10	Being able to support a family financially
11	Establishing relationships with fellow engineers
12	Being able to work with others by sharing ideas
13	Committing to engineering as a major
14	Committing to the completion of an engineering degree
15	Avoiding procrastination on work responsibilities
16	Doing your best work - beyond the minimum requirements
17	Showing up for class/meetings prepared
18	Participating actively in meetings
19	Being able to lead a design team/initiative
20	Possessing a natural engineering ability
21	Excelling in subjects relating to mathematics and science
22	Completing the first-year of engineering
23	Gaining practical engineering experience while still an undergraduate
24	Serving as a mentor to another engineering student
25	Obtaining full-time employment
26	Completing an undergraduate engineering degree
27	Completing a graduate engineering degree
28	Completing of the 1st stage of professional licensure (FE: Fundamentals of Engineering Examination)
29	Completing of the 2nd stage of professional licensure (Professional Engineering Examination)
30	Reaching the age of 22

Additionally, several demographic and experience questions were asked and served as covariates. Demographic questions included: age, gender, class level (first-year versus sophomore, junior or senior), living arrangement (on or off campus), and engineering discipline.

Finally, several questions relating to a respondent's specific experiences: engineering related job experience, engineering research experience, employment during the school year, future educational plans, involvement in engineering organisations, involvement with a group of peers (a support network), and lastly a Likert-scale question asked by CAEE researchers: Do you plan to work, conduct research, continue study, or teach engineering for at least 3 years after graduation?

Data Analysis

The data analysis included descriptive statistics, such as frequency counts, chi-square tests and *t*-tests, as well as ordinal logistic regression modelling. Fifty-two incomplete survey responses were dropped from the analysis. This was a condition set by the Institutional Review Board, which required a notice to students on the opening screen of the survey that early termination of the survey indicated a student was no longer willing to participate in the study. While respondents could terminate the survey at any point, to advance in the on-line survey instrument, it was necessary to answer all questions on a Web page.

Descriptive statistics were used to identify potential differences among respondents on their self-classification as an engineer. Chi-square tests were conducted to determine if there was a statistically significant difference between responses to the dependent variable responses (*Do you consider yourself to be an engineer?*) for certain demographic and background experience questions.

Differences in responses by grade level were also conducted in accordance to the theoretical framework of student development. Results revealed no general relationship to grade level, but rather that the difference between first-year students and all other students was profound, confirming the value of exploring this difference. Further, this preliminary analysis was used to select independent variables to be included in the logistic regression model.

Spearman correlations were conducted to measure the relative associations between variables. Only three relationships were found to have correlations greater than 0.7 and those relationships were expected: age and grade level were highly correlated (0.9), the necessity of each of the two stages of licensure to be considered an engineer and commitment to completing an engineering degree and actual completion of a degree in engineering. Factor analysis, which is commonly used to reduce a large number of variables to a smaller subset of orthogonal explanatory variables, was not necessary because high variable correlation was not found to be an issue in the current study.

Logistic regression techniques were required due to the binary nature of the survey responses of interest [56]; the survey items that resulted in continuous variables were covariates. The dependent variable was the response to the opening survey question: *Do you consider yourself to be an engineer?* Because there were three possible responses to this question, an ordinal logistic regression technique was selected over a more traditional regression analysis approach (which would only consider two response choices). The logistic regression model included ten demographic and background experience items as explanatory variables. These ten items were included based on initial chi-square tests; those items found to be statistically significant on an individual basis were included in the model to determine their significance after controlling for other factors. The odds ratio, which is a measure of effect size, is reported for each independent variable. For a continuous variable, an odds ratio provides the increase in the relative probability of the dependent variable with one unit increase in the independent variable. When the predictor is a categorical variable, the odds ratio is the ratio of probability of graduation between two levels on the categorical variable [56]. For example, if the odds ratio estimate for considering oneself an engineer for class level (sophomores/juniors/seniors versus first-years) were 1.5, it would mean that sophomores/juniors/seniors were 1.5 times as likely to consider themselves engineers than were first-year students in the same study.

RESULTS

Preliminary Analysis: Descriptive Statistics

The frequency counts for the primary survey question, *Do you consider yourself to be an engineer?* were surprising. For all grade levels, nearly all of the responses were split between the categories of *Yes* (470 of 621 responses) and *In some ways yes, and some ways no (213 of 621 responses).* The very small area in each column at the top of Figure 1 (with no fill) represents students who responded, *No*, comprising only 18 of the 621 responses. The biggest difference between groups was between the first-year students (the two left columns) and all others (sophomores, juniors and seniors) with more first-year students reporting, *In some ways yes, and some ways no*, and fewer first-year students reporting definitively, *Yes*. By disaggregating by gender in the same figure, one can also see that female students are less likely to respond *Yes* and more likely to respond *In some ways yes, in some ways no* than male students at all grade levels.

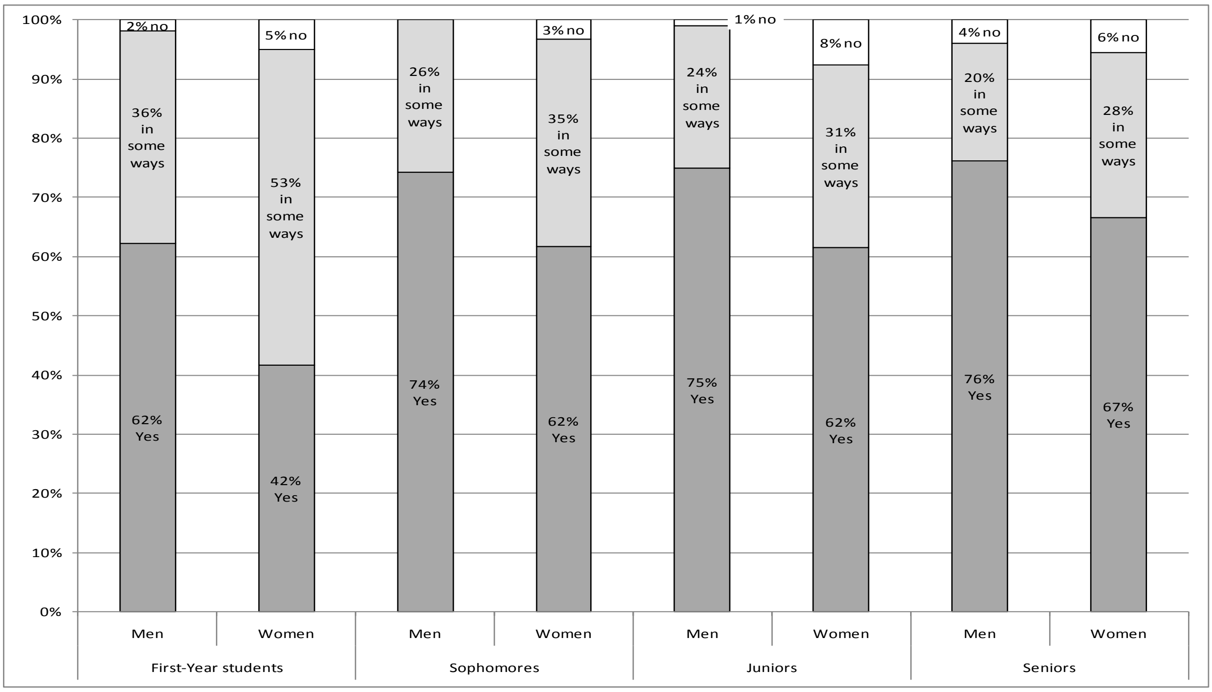

Figure 1: Survey responses to *Do you consider yourself to be an engineer?*

These results supported additional analyses to be based on the comparison between first-year students and all others and gender-based comparisons. Chi-squared tests also confirm there is a statistically significant difference by grade level ($\alpha<0.01$) and by gender ($\alpha<0.001$). Of particular note, only 41.7% of first-year women self-identified as engineers, they were the only sub-group with self-classifications below 60%. The current study calls attention to these differences, although it cannot offer more than speculative rationale and opportunities for further study.

The frequency counts and percentages, across grade levels, also offered insight into individual factors that students deemed most important to be considered an engineer. The responses ranged from the low end, with only 9.7% of students indicating that a graduate degree was necessary to be considered an engineer, to 98.6% of students indicating that making competent design decisions was necessary to be considered an engineer. The most commonly cited factors also included working with others by sharing ideas, accepting responsibility for the consequences of actions and speaking and communicating using accurate technical terminology.

First-year students were less discriminating in the factors they identified as necessary to be considered an engineer compared to sophomores, juniors and seniors. Statistical *t*-tests showed that first-year students were more likely to consider commitment to a company, commitment to a career, the ability to support a family financially, obtaining a graduate degree and licensure to be important factors in being considered an engineer. The *t*-tests for the demographic/background questions indicate that sophomores, juniors and seniors (as a collective group) were significantly more likely to live off campus, have worked in an engineering-related job, be employed during the school year, have secured professional employment, have conducted engineering research, and to be active in engineering organisations, indicating first-year students are distinct in several ways.

Logistic Regression Model

Noting that descriptive statistics and *t*-test indicate that several of the background factors were individually important to understanding who self-identifies as an engineer, those factors were considered simultaneously using logistic regression to control for the other factors. Table 3 summarises the results that show that women are less likely than men to self-identify as engineers. The odds ratio of 0.485 indicates that women are less than half as likely as men to self-identify as an engineer. Further, the model shows that sophomores, juniors and seniors are collectively 1.5 times as likely to self-identify as an engineer than first-year students. This is supported by the odds ratio of 1.561. Finally, students with future professional or educational work plans for 3 years post-graduation were 1.4 times more likely to self-identify as engineers than students who did not have future plans. Note that the reference category is *yes* to the self-identification question, so the comparison is to those that did not self-identify as an engineer (in some ways or no).

Table 3: Logistic regression model - background questions for self-identifying as an engineer.

Background Question	P	Standard Error	Odds Ratio	95% Confidence Interval
Class Level (First-Year vs. Soph, Ju, Sr)	0.019*	0.296	1.561	1.07-2.26
Engineering Discipline	0.154	0.230	1.289	0.91-1.83
Female	< 0.001***	0.092	0.485	0.33-0.71
Engineering related future career plans	< 0.001***	0.105	1.441	1.25-1.66
Engineering related work experience	0.138	0.249	1.322	0.91-1.91
Engineering research experience	0.161	0.286	1.347	0.89-2.04
Engineering organisational involvement	0.779	0.200	1.055	0.73-1.53
Core group of individuals for support	0.815	0.200	1.046	0.72-1.52

*p<0.05, ***p<0.001

DISCUSSION

All of the factors commonly cited as necessary for being an engineer are intangible, individualistic factors as opposed to a legalistic distinction such as licensure. These factors have notable similarities to Arnett's study, which identified similar intangible factors such as responsibility and decision making as considered necessary for being an adult [35]. The top six factors identified by students (across grade levels) are shown in Table 4, as a percentage of the respondents that agreed that a survey question was necessary to be considered an engineer.

Table 4: Survey items most frequently cited by students necessary to be an engineer.

Survey Question	Yes (%)
Being able to make competent design decisions	98.6%
Being able to work with others by sharing ideas	96.4%
Accepting responsibility for the consequences of actions	94.9%
Speaking/communicating using accurate technical terminology	93.0%
Completing an undergraduate engineering degree	86.4%
Making moral/ethical decisions considering all factors	86.3%

The similarity of these findings to those of Arnett suggests that the process of becoming an engineer is seen by engineering students to have strong parallels to the process of becoming an adult. As a result, students will benefit if academic staff devote some time to understanding what college students today face in conjunction with identity development, including feelings of optimism (many opportunities/possibilities), self-focus, transition and a lack of stability. This can be both exciting and overwhelming to a young person, and it behoves educators to recognise the complexity of this time period as it relates to educational and career decisions and to strive for understanding what can be done to support informed choices. This study offers insight into educational identity which relates to professional persistence [24]. Given the results presented for the current study, and recalling the literature discussed earlier, the research hypotheses are revisited:

Research Hypothesis 1: A majority of engineering students will respond to the question: *Do you consider yourself to be an engineer? In some ways yes, and in some ways no*. The authors reject this research hypothesis: More than 67% of respondents self-identified as engineers, which seems at odds with the fact that 86% of survey respondents indicated that completing an undergraduate engineering degree was necessary to be considered an engineer. The identity question, *Do you consider yourself to be an engineer?* was the first question on the survey and the survey structure did not allow students to go back to this question during the rest of the survey to review or change the response. It is possible that students do not clearly differentiate between educational and professional identities, a fact that educators could use to promote a sense of belonging.

Although the authors could not find literature addressing this issue, the focus on developing community among engineering students may have resulted in a culture in engineering that is different from the culture in other professional degrees by the fact that some faculty have been known to refer to engineering students as *engineers*. It seems that parallel designations of psychology student/psychologist, aviation student/pilot, law student/lawyer, or medical student/doctor are heard less frequently. Through small scale qualitative discussions, prior studies have verbally challenged students on their self-perceptions as engineers, but have reported mixed results; some students did self-identify as engineers and others did not [13][57]. Dannels further indicated that development of professional identity is fraught with complexity [57], and this research suggests that the development of an engineering identity is similarly complex. In the case of engineering, additional complexity results from the range of faculty beliefs of what engineering is [58]. The challenge of defining engineering is acknowledged by first-year engineering textbook authors as well [59], and gives students the opportunity to decide on their own. Unfortunately, it is normative interpretation and power that allows students to make claims about *who counts as a real engineer* and who does not [26].

The recent study of engineering identity of Stevens et al indicates identification as one of three components of engineering identity, specifically relating to how a student is *recognised* by an organisation as an engineer [27]. This would be the social portion of a psychosocial perspective on identity [30], relating to curricular structures. Specifically, the designation of selecting engineering or being selected within an undergraduate curriculum accounted for institutional differences in this identification process. Following the work of Stevens et al [27], institutional and curricular structures also seem to be a defining factor in the case of the current study, which were addressed in the second research hypothesis. An alternative claim or hypothesis may be appropriate: the majority of engineering students will self-identify as engineers if the institution recognises them that way. This is supported by Tonso's idea of the cultural experience of engineering in terms of a sense of belonging and being a part of something larger than one's self. As Bourdieu's theory of social capital [60] and other engineering identity studies have also recognised [26-27], identity is linked to a social recognition or categorisation.

Research Hypothesis 2: Sophomores, juniors and seniors will be more likely to identify themselves as engineers than first-year students. The authors find this research hypothesis is supported: According to the survey responses, there is a clear (statistically significant) division between first-year students and all other students (sophomores, juniors and seniors) as confirmed by chi-square tests, the logistic regression model and odds ratio.

First-year students differentiate from sophomores, juniors and seniors (these latter three are institutionally recognised as part of the College of Engineering) in identifying themselves as engineers much less frequently. This curricular structure is supported by prior engineering identity studies by Stevens et al in terms of *navigation* and *identification* through the curriculum [27] and Lichtenstein in terms of institutional differences associated with curriculum [9]. The authors believe that this also relates institutional classification of being within the college of engineering which relates to the social or cultural aspect of identity. The fact that there was not a clear distinction at each grade level may indicate that college grade designations are artificial identifiers of development in terms of stages, as such, one can see the largest distinction between the two extremes but much less in the middle.

Research Hypothesis 3: Male students will be more likely to identify themselves as engineers than female students. The authors consider this research hypothesis to be supported: Both the raw percentages (56.4% of women versus 71% of men over all grade levels) and the logistic regression model (negative for female respondents significant to $p<0.001$) recognised gender as a statistically significant factor. At all class levels, there was a higher percentage of men self-identifying as engineers (12-20% higher) than women. But gender may also have an interaction with class level, as it was shown that first-year women were much less likely than any other group to self-identify as engineers.

Other work has shown that female students (of all disciplines) enter college with lower self-efficacy; for example, female students rated themselves lower in academic ability and intellectual self-confidence than male students [61]. The study of women's self-efficacy in engineering programmes of Marra et al indicated a significant decrease in feelings of inclusion [62]. Strenta et al reported that although women were less likely to be retained in STEM disciplines, that gender was not significant when grades in introductory science and mathematics courses were considered [63]. The complexity of these differences cannot be boiled down in a single study, but collectively these prior studies offer insight into the differing background and experiences of women engineering students as compared to men that may relate to the current study, which finds a differential rate for self-identification of women as compared to men.

Research Hypothesis 4: A student with future career plans to continue in an engineering related field post-graduation will be more likely to self-identify as an engineer. The authors consider this hypothesis supported: The logistic regression models showed that a student's future engineering work plans was the most significant factor relating to student self-identification as an engineer, and further the effect size was large. While the current study has found a relationship between future work plans and self-identification as an engineer, causality cannot be claimed; rather it may be that, because students self-identify as engineers (feel they belong), they wish to continue in an engineering related field.

This hypothesis was based on the implication that an individual's self-concept or identity is related to the future career plans [46-48]. The publication of Lichtenstein et al based on the PIE survey, *An Engineering Major Does Not (necessarily) an Engineer Make* reported a minority percentage (42% overall) of seniors definitively planned on pursing an engineering-related path for the three years following graduation [9]. Differences were observed in that study between a selective private school, in which 54% were *probably or definitely going into engineering*, versus a technical public institution, in which 80% of students were *probably or definitely going into engineering*. The same question was posed in the current study and 76% of engineering student respondents indicated *probably yes* or *definitely yes*. The authors were surprised by this outcome, as it was presumed that the respondents would collectively reflect more similarly to the selective private school than the technical public school due to the diverse educational options offered at the study location. While the reasons for this are unknown, it is possible that students at this institution already demonstrate a strong engineering identity. A future multi-institutional study could explore this further.

CONCLUSIONS AND IMPLICATIONS

Career intentions have been shown to increase in clarity for students throughout their undergraduate engineering experiences [13], so it is not surprising that both career plans and class level influence self-identification. Overall the results of this study indicate both developmental and structural factors, such as organisational recognition, defining the differences observed in self-identification as an engineer. Developmentally, a difference between first-year students and others would indicate a very steep learning curve during that transition to the university and engineering studies, which did not appear uniform for the collective group of undergraduate engineering students. First-year students were less discriminating in defining the factors necessary to be an engineer, indicating several more factors than other students, but it was more difficult to discern a measurable difference in engineering self-identification at each class level. Considering theoretical foundations there could be a couple of considerations:

- Based on the results of this study, artificially equating stages to each grade level may not be applicable for most students the way that stages typically define a distinct behavioural or emotional difference between levels. The fact that first-year students separate so distinctly could mean that there is a stage difference at that point, but where the next common stage lies is beyond the scope of this study. Quantitatively, the background survey questions highlighted the differences between first-year students and others, as first-year students are not allowed to live off campus and are much less likely to have worked in an engineering-related job, participated in research, or be involved with engineering organisations (which are generally discipline-specific) due to lack of exposure, experience or educational background.
- Stage theory does serve as a meaningful framework for engineering identity development. But because of the uncertainties (rate and level achieved) in the translation from one stage to the next, it is not clear that stage theory is an exact fit, nor is it necessarily the only meaningful framework for the phenomena observed in this study, and there may be other alternative theories that offer meaningful insights as well. For example, Chickering and Reisser likewise recognise the gradual developmental process of identity formation [31]. As another example, the theory of emerging adulthood would similarly recognise identity development to take place over time, but that it continues past the college years in many cases, as young people begin to take responsibilities for their actions before achieving the next stage of adulthood. One aspect of Erikson's identity stage theory in which there has been long term agreement on the psychosocial aspects of identity involving *self* and *other* in which *other* relates to institutional recognition (among other things). The big picture implications for engineering educators are:

    1. What you call a student matters.
    Calling engineering students *engineers* may reduce their isolation and enhance feelings of community toward engineering, the only potential consequence is weakening student thinking about the expectations of the profession.
    2. The first-year is critical.
    This study shows how unique first-year students are relative to other students. For retention, it is important that the University engages first-year students and makes them feel welcome and a part of the engineering community from the beginning. Reflection on the practices for inclusion should be considered, likely from talking to current sophomore or junior level students in terms of what helped them feel a part of the community, but also extending discussions to students that have not continued in engineering, as much can be learned from those that did not feel they belonged. Retention has often received considerable notice in engineering as it is recognised that there is an outflow but very limited inflow. Educators can consider the programmes that could help such as learning communities, dormitory groupings, study groups, or even taking advantage of social networking (can people be included before they even arrive on campus?).
    3. Professional persistence is linked to identity.
    This study has shown that there is a relationship between a student's professional work plans and their self-identification as an engineer. The authors do not yet understand causality of this relationship, but it is important when the countries long term goals for global competitiveness are considered.

Considering both the results of the current study and the prior studies raises questions about institutional classification and the relationship to engineering identity. Although the results of these studies have shown consistencies, they are inadequate in understanding causality. In particular, does engineering identity lead to persistence and continuation in the College of Engineering or does continuation provide some portion of that identity through the institutional classification? This is a complex issue that requires further study. Further, how does this relate to other STEM fields; do science, mathematics or technology students experience similar trends? This too is an opportunity for future study.

LIMITATIONS AND FUTURE WORK

There are two primary limitations involved in the current study: 1) the single-site design; and 2) restricting the study to participants who have persisted in engineering. This research primarily relates to the experiences of traditional, full time college students at a single institution. While non-traditional, part-time, commuter and community college students are a growing group nationally, they are not the focus of the current study, as they have many unique attributes that in some cases makes their experiences inherently different [33][36], such as the span and completion rate of their undergraduate education [64].

Prior scholarly works have reported institutional differences in identity studies [9][13]. As such, a multi-site expansion of the current study to other dissimilar institutions both in terms of university characteristics and engineering curricular structure is needed to further investigate how students come to be identified as belonging to an engineering organisation. Additional dissimilar schools, that are urban, public, minority, non-Midwestern and/or large-enrolment would be likely considerations, as implemented by the Academic Pathways Study [46]. However; as indicated by prior studies, other programmes with dissimilar structures for admittance into the engineering college may offer the most differentiation in terms of engineering identity [27][41]. A few varying structures that should be considered include universities in which:

1. Entrance into a specific engineering discipline is immediate as a first-year student.
2. Entrance into the engineering college/discipline requires an application or grade point average for acceptance after first or second year.
3. A common programme for the first two years, and a discipline-specific study begins during the junior year (with or without application / acceptance).
4. A programme that includes different engineering/science disciplines.

The participants who were invited to take part in the current study were recruited only 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, nor did it include students from other institutions with diverse matriculation practices. Given the interest in how matriculation practices affect student outcomes, an investigation of this has been started recently, and will be led by Ohland [8]. Sense of belonging has been identified as a factor for persistence in STEM fields [42], and as such expanding the current study to include students who have not persisted in engineering would be meaningful.

REFERENCES

1. Augustine, N., *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future* (2005).
2. Duderstadt, J.J., *Engineering for a Changing World*. Ann Arbor, MI: University of Michigan (2007).
3. Chubin, D., May, G. and Babco, E., Diversifying the engineering workforce. *J. of Engng. Educ.*, 73-86 (2005).
4. Faulkner, W., Doing Gender in Engineering Workplace Cultures. I. Observations from the Field. *Engineering Studies*, 1, **1**, 3-18 (2009).
5. Colloquium, E.E., The research agenda for the new discipline of engineering education. *J. of Engng. Educ.*, Special Report, October, 3 (2006).
6. Brophy, S., Klein, S., Portsmore, M. and Rogers, C., Advancing engineering education in P-12 classrooms. *J. of Engng. Educ.*, July, 369-387 (2008).
7. Poole, S., DeGrazia, J. and Sullivan, J., Assessing K-12 pre-engineering outreach programs. *J. of Engng. Educ.*, January, 43-48 (2001).
8. Ohland, M., Sheppard, S., Lichtenstein, G., Eris, O., Chachra, D. and Layton, R., Persistence, engagement, and migration in engineering programs. *J. of Engng. Educ.*, July (2008).
9. Lichtenstein, G., Loshbaugh, H., Claar, B., Chen, B., Sheppard, S. and Jackson, K., An engineering major does not (necessarily) an engineer make: career decision-making among undergraduate engineers. *J. of Engng. Educ*. (2009).
10. Loui, M., Ethics and the development of professional identities of engineering students. *J. of Engng. Educ.*, 94, **4**, 383-389 (2005).
11. Tonso, K., *On the Outskirts of Engineering*. Learning Identity, Gender, and Power via Engineering Practice. Rotterdam, The Netherlands: Sense Publishers (2007).
12. Chen, H., Donaldson, K., Eris, O., Chachra, D., Lichtenstein, G., Sheppard, S. and Toye, G., From PIE to APPLES: The Evolution of a Survey Instrument to Explore Engineering Student Pathways. Paper presented at the American Society for Engineering Education (2008).

13. Capobianco, B., Undergraduate women engineering their professional identities. *J. of Women and Minorities in Science and Engng.*, 12, 95-117 (2006).
14. Meyers, K. Ohland, M., Pawley, A. and Christopherson, C., The importance of formative experiences for engineering student identity. *Inter. J. of Engng. Educ.* (2010).
15. Pierrakos, O., Beam, T.K., Constantz, J., Johri, A. and Anderson, R., On the development of a professional identity: engineering persisters vs engineering switchers. *Proc. Frontiers in Educ. Conf., 2009. FIE '09. 39th IEEE*, 1-6 (2009).
16. Tate, E. and Linn, M., How does identity shape the experiences of women of color engineering students? *J. of Science Educ. and Technol.,* 14 (2005).
17. Walker, M., Engineering identities. *British J. of Sociology of Educ.,* 22, **1**, 75-89 (2001).
18. Tonso, K., Teams that work: campus culture, engineer identity, and social interactions. *J. of Engng. Educ.,* 95, **1** (2006).
19. Baba, M. and Pawlowski, D., Creating Culture Change: An Ethnographic Approach to the Transformation of Engineering Education. Paper presented at the International Conference on Engineering Education, Oslo, Norway (2001).
20. Loshbaugh, H. and Claar, B., Geeks are Chic: Cultural Identity and Engineering Students Pathways to Their Profession. Paper presented at the American Society for Engineering Education (2007).
21. Stevens, R., O'Connor, K. and Garrison, L., Engineering Student Identities in the Navigation of the Undergraduate Curriculum. Paper presented at the American Society for Engineerig Education, Portland, Oregon (2005).
22. Felder, R. and Brent, R., The intellectual development of science and engineering students part 1: models and challenges. *J. of Engng. Educ.,* 93, **4**, 269-277 (2004).
23. Felder, R. and Brent, R. The intellectual development of science and engineering students part 2: teaching to promote growth. *J. of Engng. Educ.,* 93, **4**, 279-291 (2004).
24. Litzinger, T., Wise, J. and Lee, S., Self-directed learning readiness among engineering undergraduate students. *J. of Engng. Educ.,* 94, **2**, 215-221 (2005).
25. Reisslein, J., Sullivan, H. and Reisslein, M., Learner achievement and attitudes under different paces of transitioning to independent problem solving. *J. of Engng. Educ.,* 96, **1**, 45-55 (2007).
26. Tonso, K., *On the Outskirts of Engineering*. Rotterdam, The Neatherlands: Sense Publishers (2007).
27. Stevens, R., O'Connor, K., Garrison, L., Jocuns, A. and Amos, D., Becoming an engineer: toward a three dimensional view of engineering learning. *J. of Engng. Educ.,* July (2008).
28. Learner, R., *Concepts and Theories of Human Development*. Reading, Massachusetts: Addison-Wesley Publishing Company (1976).
29. Crain, W., *Theories of Development*. (5th Edn), Pearson Prentice Hall (2005).
30. Erikson, E. H., *Identity Youth and Crisis*. (1st Edn), New York: W.W. Norton & Company (1968).
31. Chickering, A.W. and Reisser, L., *Education and Identity.* San Francisco: Jossey-Bass Publishers (1993).
32. Arnett, J., *Emerging Adulthood: The Winding Road from the Late Teens Through the Twenties*. New York: Oxford University Press (2004).
33. Arnett, J., Emerging adulthood: a theory of development from the late teens through the twenties. *American Psychologist,* 55, **5**, 469 (2000).
34. Arnett, J., Emerging adulthood: what is it, and what is it good for? *Society for Research in Child Development, 1 #2* (Journal Compilation), 68-73 (2007).
35. Arnett, J., Are college students adults? Their conceptions of the transition to adulthood. *J. of Adult Development,* 1, **4**, 213-224 (1994).
36. Pascarella, E. and Terenzini, P., *How College Affects Students: Findings and Insights From Twenty Years of Research.* Ernest T. Pascarella, Patrick T. Terenzini; foreword by Kenneth A. Feldman. San Francisco: Jossey-Bass Publishers (1991).
37. Chubin, D., Donaldson, K., Olds, B. and Fleming, L., Educating generation net - can U.S. engineering woo and win the competition for talent? *J. of Engng. Educ.,* July, 245 (2008).
38. Constantinople, A. and Vassar, C., An Eriksonian measure of personality development in college students. *Developmental Psychology,* 1, **4**, 357-372 (1969).
39. Whitbourne, S., Jelsma, B. and Waterman, A., An Eriksonian measure of personality development in college students: a reexamination of constantinople's data and partial replication. *Developmental Psychology*, 18, **3**, 369-371 (1982).
40. Korte, R. and Smith, K., Portraying the Academic Experiences of Students in Engineering: Students' Perceptions of their Educational Experiences and Career Aspirations in Engineering. Paper presented at the American Society for Engineering Education, Hawaii (2007).
41. Lichtenstein, G., Loshbaugh, H., Claar, B., Bailey, T. and Sheppard, S., Should I Stay or Should I Go? Engineering Students' Persistence is Based on Little Experiance or Data. Paper presented at the American Society for Engineering Education (2007).
42. Seymour, E. and Hewitt, N., *Talking About Leaving: Why Undergraduates Leave the Sciences*. Bolder, Co.: WestviewPress (1997).
43. Foor, C., Walden, S. and Trytten, D., I wish that I belonged more in this whole engineering group: achieving individual diversity. *J. of Engng. Educ.,* 96, **2**, 103-115 (2007).
44. Lee, J.D., Which kids can *become* scientists? Effects of gender, self-concepts, and perceptions of scientists. *Social Psychology Quarterly,* 61, **3**, 199-219 (1998).

45. Tonso, K., Engineering Gender - Gendering Engineering: What About Women in Nerd-dom? Paper presented at the American Educational Research Association, SanDiego, CA (1998).
46. APS Academic Pathways Study Spring 2005 Survey. Retrieved 20 February 2006 from Center for the Advancement of Engineering Education (CAEE) (2005).
47. Eccles, J., Midgley, C., Wigfield, A., Buchanan, C., Reuman, D., Flanagan, C. and Mac Iver, D., Development during adolescence: the impact of stage-environment on young adolescents' experiances in schools and in families. *American Psychologist,* 48, **2**, 90-101 (1993).
48. Lent, R., Social Cognitive Career Theory: What Attracts Students to - and Keeps them in - STEM fields? A Theoretical Perspecitve [Powerpoint Presentation focused on Social Cognitive Career Theory]: University of Maryland (2007).
49. Dillman, D., *Mail and Internet Surveys: The Tailored Design Method*. (2nd Edn), Hoboken, NJ: John Wiley & Sons, Inc. (2007).
50. Deutskens, E., Ruyter, K., Wetzels, M. and Oosterveld, P., Response rate and response quality of Internet-based surveys: an experimental study. *Marketing Letters,* 15, **1**, 21-36 (2004).
51. Kaplowitz, M., Hadlock, T. and Levine, R., A comparison of Web and mail survey resonse rates. *Public Opinion Quarterly,* 68, **1**, 94-101 (2004).
52. Smith, W., Does Gender Influence Online Survey Participation? A Record-Linkage Analysis of University Faculty Online Survey Response Behavior (Research Report). San Jose, CA: San Jose State University (2008).
53. Sax, L., Gilmartain, S. and Bryant, A., Assessing response rates and nonresponse bias in Web and paper surveys. *Research in Higher Educ.,* 44, **4** (2003).
54. Dillman, D., Tortora, R. and Bowker, D., *Principles for Constructing Web Surveys*. Pullman, WA: Washington State University (1999).
55. Berdie, D., Anderson, J. and Niebuhr, M., *Questionnaires: Design and Use.* (2nd Edn), Metuchen, N.J.: The Scarecrow Press, Inc. (1986).
56. Agresti, A. and Finlay, B., *Statistical Methods for the Social Sciences.* (3rd Edn), Upper Saddle River, NJ: Prentice Hall (1997).
57. Dannels, D., Learning to be professional: technical classroom discourse, practice, and professional identity construction. *J. of Business and Technical Communication,* 14, **1**, 5-37 (2000).
58. Pawley, A., Universalized narratives: patterns in how faculty members define *engineering*. *J. of Engng. Educ.,* 98, **4** (2009).
59. Brockman, J., *Introduction to Engineering: Modeling and Problem Solving.* (1st Edn), Hoboken, NJ: John Wiley & Sons, Inc., 1 (2009).
60. Bourdieu, P. *The Forms of Capital*. In: Granovetter, M. and Swedberg, R. (Eds), The Sociology of Economic Life. (2nd Edn), 96-112 (2001).
61. Sax, L., *The Gender Gap in College: Maximizing the Development Potential of Women and Men.* (1st Edn), San Francisco, CA: Jossey-Bass (2008).
62. Marra, R., Rodgers, K., Shen, D. and Bogue, B., Women engineering students and self-efficacy: a multi-year, multi-institution study of women engineering student self-efficacy. *J. of Engng. Educ.,* 93, **1** (2009).
63. Strenta, C., Elliott, R., Adair, R., Matier, M. and Scott, J., Choosing and leaving science in highly selective institutions. *Research in Higher Educ.,* 35, **5**, 513-547 (1994).
64. Bozick, R. and DeLuca, S., Better late than never? Delayed enrollment in the high school to college tranistion. *Social Forces,* 84, **1**(2005) (2005).

BIOGRAPHIES

Kerry L. Meyers is an Associate Professional Faculty member in the College of Engineering at the University of Notre Dame where she serves as Co-Director of the First-Year Engineering Programme. She received her PhD in Engineering Education from Purdue University. She also has a BS and MS in Mechanical Engineering. She has several years of automotive industry design experience, but has since shifted her focus to engineering education, specifically working with first-year engineering students.

Matthew W. Ohland is an Associate Professor in Purdue University's School of Engineering Education. He received his PhD in Civil Engineering from the University of Florida in 1996. Dr Ohland is the Past President of Tau Beta Pi, the national engineering honour society, and has delivered over 100 volunteer seminars as a facilitator in the award-winning Engineering Futures programme. He served as Assistant Director of the NSF-sponsored SUCCEED Engineering Education Coalition and a NSF postdoctoral fellow. His research on the longitudinal study of engineering student development, peer evaluation and high-engagement teaching methods has been supported by over $11.6 million in funding from the National Science Foundation.

Alice L. Pawley is an Assistant Professor in the School of Engineering Education and an affiliate faculty member in the Women's Studies Programme at Purdue University. She has a BEng in Chemical Engineering from McGill University, and an MS and a PhD in Industrial and Systems Engineering with a PhD minor in Women's Studies from the University of Wisconsin-Madison. She is co-PI and Research Director of Purdue University's ADVANCE programme, and PI on the Assessing Sustainability Knowledge project. She runs the Research in Feminist Engineering (RIFE) group, whose projects are described at http://feministengineering.org/. She is interested in creating new models for thinking about gender and race in the context of engineering education.

Stephen E. Silliman is a Professor and Associate Chairman in the Department of Civil Engineering and Geological Sciences at the University of Notre Dame and was Associate Dean for Undergraduate Programmes in the College of Engineering from 2002-2008. He joined the faculty in 1986 after work at Princeton University (BSE, 1979) and the University of Arizona (MS 1982, PhD 1986). He is a groundwater hydrologist who has pursued research related to groundwater flow and chemical/microbial transport. For ten years, he studied water resource development and protection in Benin, West Africa. Undergraduate and graduate students have been involved in all aspects of these projects, and earlier work in Haiti. He is a prior recipient of multiple teaching awards including the ASEE International Division's Global Engineering and Engineering Technology Educator Award (2006) and the Illinois-Indiana Section Outstanding Teaching Award (2006).

Karl A. Smith is Cooperative Learning Professor of Engineering Education, School of Engineering Education, Purdue University West Lafayette. He has been at the University of Minnesota since 1972 and is in phased retirement as Morse-Alumni Distinguished Professor of Civil Engineering. Dr Smith has worked with thousands of faculty all over the world on pedagogies of engagement, especially cooperative learning, problem-based learning, and constructive controversy. He has co-written eight books including Cooperative Learning: Increasing College Faculty Instructional Productivity; Strategies for Energizing Large Classes: From Small Groups to Learning Communities; and Teamwork and Project Management (3rd Edn).