First to Second Year Identity Emergence in Industrial and Chemical Engineering Students

Dr. Jacqueline C. McNeil, University of Louisville

Dr. McNeil is an Assistant Professor for the Department of Engineering Fundamentals at University of Louisville. Research interests include diversity in engineering, persistence, retention, co-op experiences, and longitudinal data. Contact email: j.mcneil@louisville.edu

Dr. Erin Lynn Gerber, University of Louisville

Erin L. Gerber, Ph.D., P.E. is an Assistant Professor of Industrial Engineering at the University of Louisville. Her previous research covers the areas of resource allocation, workforce planning, and logistics and distribution. She was awarded a B.S., M.Eng, and Ph.D. all in Industrial Engineering, from the University of Louisville, J.B. Speed School of Engineering.

Her doctoral work focused on the development of the LoDI Index, which is released by the Logistics and Distribution Institute at the University of Louisville every month. The index is also featured in the FRED report and is utilized by various national corporations each month. Dr. Gerber is a member of Golden Key International Honours Society, the Institute of Industrial and Systems Engineers, and the Society of Women Engineers. She also serves as the faculty advisor for the UofL student chapter of IISE.

Dr. Gerold Willing, University of Louisville

Gerold (Jerry) A. Willing is an Associate Professor in the Chemical Engineering Department at the University of Louisville. He received a Bachelor of Science Degree in Chemical Engineering from the University of Wisconsin-Madison and a Ph.D. degree in Chemical Engineering from Auburn University. Dr. Willing's expertise lies in the development of complex fluid systems for practical applications and characterization of their properties and stability. He has additional interests in water utility infrastructure materials and their impact on water quality, electroactive hydrogels, soft-lithography techniques, Peer-Led-Team-Learning, and development of a students engineering identity.

Ms. Mary Elizabeth Mills, University of Louisville

©American Society for Engineering Education, 2019

First to Second Year Identity Emergence in Industrial and Chemical Engineering Students

1. Introduction

This research paper explores two aspects of engineering identity formation. First, the formation of engineering identity within the engineering student's first-year is examined. Students have to choose a major within or immediately after their first year at the university, and therefore should be developing an interest or identity within the First-year. Second, this paper discusses the changes from First-year to sophomore year for chemical engineering and industrial engineering students. This work is significant as the development of an engineering identity has been positively linked to persistence in engineering [1-7]. Uncovering the traits and experiences that lead to the development of a stronger engineering identity could aid in the creation of new strategies in the education and retention of engineering students that are specifically targeted to each of the individual disciplines.

Researchers collected data at a large, public research institution in the southeastern United States, using a modified version of the SaGE survey. Adjustments were made to the SaGE survey to allow for the collection of additional information on underlying identities (namely math, chemistry, and biology) in addition to Physics. The same survey format was utilized with the addition of these content areas. The data was collected at the beginning of a required First-year introductory to engineering course in fall 2017 and at the end of students' first department specific course in their sophomore year: sophomore level courses for chemical engineers in summer 2018 and for industrial engineers in fall 2018. All possible two-way comparisons between the three student groups are evaluated and discussed within this paper. This study adds to the broader research of engineering identity by focusing on two particular engineering disciplines, chemical and industrial, and allowing for investigation of additional STEM disciplines as components/predictors of the development of engineering identity.

Information gleaned from this work will help formulate future research assessing the development of engineering identity (1) within specific engineering disciplines, and (2) over time throughout collegiate study. If commonalities can be found in past experiences, influencers, etc for students with strong engineering identities, it may become possible to tailor information sessions and activities for middle and high school students, to assist in the development and/or realization of stronger engineering identities at an earlier age.

2. Literature/Background

Engineering identity has been identified as a way to improve recruitment, retention, and persistence in engineering programs [1-7]. Kendall, Choe, Denton, and Borrego created a table in their engineering identity paper, showing many engineering educators have used Multiple Identities framework in their research [8]. The developed research that defines engineering identity is based on the following framework, an individual's perceptions of their competence or performance, engineering interests, and a public form of recognition as an engineer [2-3,6]. Godwin, Potvin, Hazari, and Lock tested predictions of pursuing engineering with structural equation modeling using the Sustainability and Gender in Engineering (SaGE) survey [9]. SaGE includes math, physics, and general science identities; some of those identities have been shown to overlap with engineering identity [10]. Mathematics identity has four dimensions: performance, competence, interest, and recognition [11-12]. Cass, Hazari, Cribbs, Sadler, and Sonnert have found that performance and competence overlap, and can be grouped together [13].

Researchers have suggested the term "identity work" to define actions, relationships, and resources used or constrained to form identities [14]. One's identity is influenced by recognition from themselves and others. Identity work is examined through "key events that appear to carry meaning over time and/or space and how the products of identity work at one event are (or are not) transferred to other events." [14, p. 44]. Identity work is socially constructed and reinforced by others and the individual.

Identity and its development have been the topic of investigation for more than a decade. In most cases though, the development of STEM identity in general, and engineering identity in particular have been investigated as though they were common among all disciplines. This aggregation starts early, in that STEM careers are typically undifferentiated in high schools, though this is beginning to change through the adoption of the next generation science standards. It has only been in the last 5 to 6 years that the variation of identity development among the various disciplines within engineering has received any significant attention. One of the more studied disciplines with respect to identity development has been chemical engineering. Initial studies have indicated that the development of identity in chemical engineering students across the different dimensions is different than many other engineering disciplines [15], but it is also different from that of [general] chemistry, the most closely related physical science discipline [16].

While prior experiences in chemistry courses was not significantly different between chemistry and chemical engineering students [16], it should not be surprising that those experiences were different than the other engineering disciplines [15]. On the other hand, chemical engineering students tended to participate in science and engineering-based hobbies more so than their counterparts in chemistry [16], but there was no significant difference observed between chemical engineering students and other engineering majors [15]. These experiences lead to differing career goals between chemical engineers and the other two groups. Chemical engineering students reported more often that they wanted to address energy, climate change, and water supply in their career than both chemistry students and other engineering majors [15-16]. While the general findings were that chemical engineering students have more in common with physical science students than other engineering students, they do form their own distinct group in terms of identity development when compared to the other two groups [16]. More recent work has shown that even within the chemical engineering student population, the development of identity can vary significantly based on gender identity as well as race and ethnicity [17]. These studies strongly suggest that further work needs to be done on the development of identity within each of the engineering disciplines as further similarities and differences are expected to be discovered.

3. Theoretical Foundation

Sociological literature has identified "role" identity theory, which describes social roles in individual behavior, interpersonal relations, and social exchanges [18-19]. The meaning of social roles may be enhanced within the circumstances of other roles [19]. A person's role is defined socially and through their daily activities and relationships with others. Identity role theory does include a hierarchy of roles as some roles are valued more than others, depending on the individual and the interpersonal interactions they have with others.

Many researchers have noted that engineering identity is developed over time, thus the researchers in this study use the stage theory [20-23]. Prior research has found that students with a common First-year year, that move into their selected major in the sophomore year, have an enhanced engineering identity compared to those at institutions with an application process at the end of the sophomore year [24]. Stage theory describes development as: a universal sequence of achievements that are qualitatively different for

each stage of development [25]; individual differences in the rate of development through stages and the final stage attained [25]; passing from one stage to the next gradually [25].

4. Research Questions

The research questions addressed in this paper include:

1) What are the differences between First-year and sophomore students' career goals and past experiences?

2) What are the differences in students' STEM identities between First-year and sophomore year?

3) What are the notable differences between chemical engineering and industrial engineering students in their sophomore year?

5. Methods

Researchers collected data at a large, public research institution in the southeastern United States, using a modified version of the SaGE survey. Adjustments were made to the SaGE survey to allow for the collection of additional information on underlying identities (math, chemistry, and biology) in addition to physics. The same survey format and questions were utilized with the addition of these content areas, (restating the same questions while changing "physics" to math, chemistry, and biology). The data was collected within a required First-year introductory to engineering course in fall 2017 at the beginning of the semester. Students took the survey again during their first department specific course as sophomores for chemical engineers in summer 2018 and for industrial engineers in fall 2018, near the end of the respective semesters. This was done to see the effect of students' first full year in engineering had on their identity formation. This engineering college has a three semester full-year academic year (fall, spring, and summer semesters).

Students received a small amount of credit for completing the survey in the sophomore level courses. The credit was less than 5% of their overall grade for the course and students were offered an alternative assignment for the same amount of credit if they did not want to complete the survey.

Independent-sample tests of the means (t-tests) were done to see if there were any differences between the cohort of first-year students and each of the cohorts of industrial and chemical engineering students in their sophomore year, which is when students start their engineering major courses, because there is a common first-year program in the institution where the data was collected. For all t-tests conducted, an alpha (α) of 0.05 was utilized. Indexes were formed for questions that had a common topic, and are discussed in the various sections below. Type 1 errors are a concern for independent sample means statistical tests on each question from the SaGE survey. However, using only aggregate question indexes would cause a loss of information on some of the more specific differences detected. The authors chose to accept the type 1 error rate, in an effort to glean more targeted information that helps understand the differences between First-year and sophomore year students.

In some cases, Chi-Squared tests were conducted to determine differences in how the responses are dispersed (variance) between the cohorts. These Pearson chi-squared tests were performed to examine the dispersion of student responses for different questions in the survey. An alpha (α) of 0.05 was utilized for the chi-squared tests.

6. Results and Discussion

6.1 Career Choice Preferences

How important are the following factors for your future career satisfaction?

When comparing responses for Industrial Engineering to Chemical Engineering students for this question, no significant differences were found. However, there were differences between the overall responses from the aggregate group of First-year students from the introductory level course (ENGR 110) to each of the respective disciplines on a few of the individual components of this question.

When comparing the ENGR 110 responses, to responses from a segment of those [Chemical Engineering] students one year later, three areas were shown to have significantly different responses. For part 1, the Chemical Engineering students were less interested in *making money* as an important factor for their career satisfaction than were the First-year group as a whole. Responses to parts 13 and 14 show that they also weight *Making use of my talents and ability*, as well as *doing hands on work* lower than the First-year group.

Industrial Engineering students' responses show that they are more interested in *supervising others* (part 4) than are the First-year students. However, IEs are less interested in *Inventing/Designing things*, as well as *Applying math and science* as components to future career satisfaction. Some of these results are not surprising as, anecdotally, IE's have a greater tendency towards supervisory/managerial roles.

Please rate the current likelihood of choosing career in the following:

Chemical and Industrial majors were compared for their likelihood of choosing a career in specific areas. According to the t tests run for this question, Chemical Engineering students are significantly more likely to choose careers in Chemistry, Chemical Engineering, and Materials Engineering than were Industrial Engineers. The highest likelihood for any of these three careers was Chemical Engineering, with a mean of 4.7 out of 5; followed by Chemistry, which a mean of 3.8 out of 5.

Related to this question, Chemical Engineering students were also significantly more likely than Industrial Engineers to choose careers in Biology or Bioengineering. However, the mean likelihoods for Chemical Engineering students to select careers in these fields was still low, with means of 2.2 and 2.7 respectively. Industrial Engineering students showed means of 1.7 in both of these fields.

There was only one career choice option that was significantly preferred by Industrial Engineering students, which was Industrial Engineering (ChemE $\mu = 2.5$ vs IE $\mu = 4.8$). Additionally, though the difference in means between IEs and ChemEs did not differ significantly for likelihood of selecting a career in Environmental Science, the distributions between the two did show a significant difference in the Chi Squared tests. This test showed that the distribution for responses from Industrial Engineers was more highly skewed toward a negative response for careers in Environmental Science than were Chemical Engineering students.

When comparing the two disciplines to their collective class as First-year students, Chemical Engineering sophomores were more likely to select a career in the field of Environmental Science, Chemistry, Chemical Engineering, or Materials Science. Chemical Engineering sophomores were less likely than their collective First-year unit, to pursue many other engineering fields (Civil, Mechanical, Electrical and Computer, and Aerospace) or the field of Computer Science. This is not surprising, as the First-year class as a whole, would have a larger representation of students who have already selected to work in these other engineering fields.

The only field that Industrial Engineering students showed a greater preference for than their collective First-year class was Industrial Engineering. Other fields that showed a statistically significant difference, and were more strongly preferred by the First-year unit include: Physics, Chemistry, Bio-Engineering, Chemical Engineering, Mechanical Engineering, Electrical and Computer Engineering, Aerospace Engineering, and Computer Science.

Which of these topics, if any, do you hope to directly address in your career? (Mark ALL that apply.)

For this question, responses of "Yes" were coded as a value of 1, and "No" as a value of 2 for analysis. Therefore, the higher the average for a student group, the *less* that group wishes to address the related topics in their career. Chemical Engineering students were more interested in addressing climate change and/or water supply issues than Industrial Engineering students. Industrial Engineering students were more interested in addressing issues of poverty and opportunities for future generations than were Chemical Engineering students.

In viewing the 2017 Cohort as a First-year group, as compared to the subsects of these students as Chemical Engineering sophomores, there are many areas where significant differences were detected for this question. The sophomore ChemE students were less likely to desire addressing issues of *Terrorism and War*, *Space Exploration*, *Cyber Security*, and *Virtual Reality*. Chemical Engineering sophomores show a great distaste for the latter two options with a mean of 1.96 for addressing *Cyber Security* (First-year mean = 1.73) and 1.91 for working with *Virtual Reality* (First-year mean = 1.75).

Chemical Engineering sophomores were more interested in directly addressing *Climate Change*, *Water Supply Issues*, and *Energy*. These are common Chemical Engineering applications, which supports the pathway selected by these students.

Similar to the ChemEs, Industrial Engineering students also showed a greater disinterest in *Space Exploration* and *Cyber Security* than did their combined First-year group. IEs did show an increased proclivity towards dealing with issues related to *Human Health*, *Poverty and distribution of wealth and resources*, and *food availability*.

6.2 Related Experiences/Abilities

How frequently have you done the following activities outside of formal courses (any time period)?

Answers to this question took the form of an estimated number of times each student completed the listed activity (9 activities). Numerical responses were aggregated for each of the nine activities listed, and a mean number for each was calculated. For this question, the only activity that had a significantly different mean response when comparing Industrial Engineering students to Chemical Engineering students, was for part 8, which asked how many times the students were required to *explain a science and/or engineering topic to an expert*, such as a professional or a teacher. On this question, Chemical Engineering students were shown to have completed this task at a higher mean rate (2.7) as compared to Industrial Engineering students (1.9). However, when the Chi Squared test was run for this part of the question, it was noted that the two groups had very different distributions to their responses. Industrial Engineering students were heavily skewed on the low end, showing that few of them were ever required to complete this task. Chemical Engineering students on the other hand, were more spread out, showing that some of these students have had several such experiences, while some had few to none.

When comparing the collective First-year group to the two sophomore disciplines, Chemical Engineering students were shown to participate in *Engineering/Science clubs, camps, or competitions* and to have *Explained science/engineering topics to experts* both to a significantly greater degree.

Both ChemEs and IEs showed significantly smaller tallies for *Tinkering with things* than did the overall First-year group. This is not surprising, since this may be more indicative of characteristics of other disciplines, such as Mechanical Engineering.

Industrial Engineering sophomores had significantly fewer instances of *Participating in other Science/Engineering hobbies* and *read/watch science fiction programs or literature* than did the First-year group.

To what extent do you disagree or agree with the following:

This question asked about general preferences, strengths, and personal attributes the students identified within themselves. Only one part of this question showed to be significantly different between the two sophomore student groups. On part 6 of the question, "*I identify relationships between topics from different courses",* Chemical Engineering students had a higher mean, showing that they tended to *Strongly Agree* with this statement more than did the Industrial Engineering students. Interestingly, neither group (ChemE nor IE) showed to have significantly different responses from the overall First-year group for part 6 of this question.

Chemical Engineering students showed greater agreement than the First-year group for part 7 (*I analyze projects broadly to find a solution that will have the greatest impact*), part 9 (*when problem solving, I focus on the relationships between issues*), and part 12 (*when problem solving, I optimize each part of a project to produce the best results*).

The only part of this question where Chemical Engineering sophomores had a significantly lower level of agreement than their combined First-year class was on part 5 (*I hope to develop my expertise in one specific field*). Even though part 5 was flagged as statistically significant, both the First-year group, and the Chemical Engineering sophomores had means suggesting most agreed or strongly agreed with this statement (First-year mean = 3.63, ChemE mean = 3.28; means represent the average responses from a 4 point scale).

The only part of this question where Industrial Engineering sophomores had a significantly different mean response from the First-year group was on part 5 (*I hope to develop my expertise in one specific field*). IEs too were shown to "agree less" with this statement than the First-year group, with a mean response of 2.92. Though this is significantly less than the First-year mean of 3.63, it was not significantly different from the mean of the Chemical Engineering sophomores.

Please rate your general interest in the following areas:

Options given for this question included measures of self-confidence in various stages common to the scientific/engineering processes. There were three portions of this question where Chemical Engineering students were shown to have significantly higher means that Industrial Engineering students. These include: (*1) Understanding natural phenomena; (2) Understanding science in everyday life;* and *(5) Making scientific observations.*

Part 1: *Understanding natural phenomenon*; also showed as significantly different between the [combined] First-year group and both of the individual sophomore discipline-specific groups, but with opposing results. Chemical Engineering sophomores were significantly more likely to show interest in

this part of the question, while Industrial Engineering students were less likely that the First-year group to have a strong interest in this.

Parts 2 and 5: Industrial Engineering sophomores were also significantly less interested in *Understanding science in everyday life*, and in *Making scientific observations.*

6.3 Confidence in STEM related areas

How confident are you in your ability to do the following:

Topics polled as part of this question related to steps in the implementation of the scientific process. Responses to this question were analyzed individually, as well as in the form of an aggregate scale. Three of the individual parts of this question were shown to be significantly different between the two sophomore student groups. For all three of these parts, Chemical Engineering students had a higher mean, showing they view themselves as more confident in these areas than Industrial Engineering students. The three areas were: *(2) Conduct an experiment on your own*, *(3) Interpret experimental results*, and *(4) Write a lab report/scientific paper.* Chemical Engineering students also showed statistically higher means for the same three areas over their combined First-year class. In addition to these, Chemical Engineering sophomores also had a significantly higher mean for *(1) Design and experiment to answer a scientific question*, as compared to the First-year group.

Responses for all portions of this question were aggregated for each of the student groups, providing an overall score related to confidence in scientific application for each discipline. When the mean aggregate scales were compared, it again showed that the Chemical Engineering students had a significantly higher mean confidence than the Industrial Engineering students. These results are not shocking, as the Chemical Engineering discipline requires more work in lab based experimentation, including the completion of lab reports, than does the Industrial Engineering curriculum.

To what extent disagree or agree with following statements as they pertain to BIOLOGY/CHEMISTRY/PHYSICS/MATH. (One question set for each discipline.)

<u>Analysis of individual question means:</u>

Sophomore ChemEs versus Sophomore IEs

To summarize this extensive set of questions, conclusions of responses for each discipline will be listed and discussed separately. The first discipline covered was Biology. Overall, based on responses to questions 7 and 8 (*I am confident that I understand this subject [BIOLOGY] in class,* and *I am confident that I understand this subject [BIOLOGY] outside of class*) it can be seen that Chemical Engineering students are more confident in their understanding of Biology compared to Industrial Engineering students. However, other portions of the question asked students if they see themselves as a "Biology person". Both groups showed a strong tendency to disagree with this statement, showing that although ChemEs are confident in their understanding of the topic, they do not identify with the field overall.

The next discipline covered was Chemistry. Unsurprisingly, Chemical Engineering students were shown to be significantly more confident in their responses to all sixteen portions of this question. This shows that they are more confident in their understanding of and ability to perform tasks related to the field of Chemistry. Additionally, it shows that they, along with others, see themselves as "Chemistry people".

The third discipline discussed was Physics. There were some interesting results within this section. Based on responses to portions 11 and 16 (*I understand concepts I have studied in this subject [PHYSICS},* and *I can overcome setbacks in this subject*) Industrial Engineering students are more confident in their physics abilities than Chemical Engineering students. Both student groups polled are required to take the same physics courses as one another. Based on question c1 (*I see myself as a PHYSICS person*) neither group identifies with the field in general.

The final set of questions for this portion were regarding Mathematics. The interesting result in this section was that none of the individual questions within this section had significantly different means between the two discipline-specific student groups. Furthermore, both groups had high values on the math identity questions. This shows that both ChemEs and IEs have high confidence in their mathematical abilities, and also "see themselves as MATH people".

Sophomore ChemEs compared to Combined First-year Class

An interesting result from the analysis shows that responses for these groups on all questions from the Biology category are statistically similar. When evaluating responses for these two groups in the Chemistry category, it is not surprising that the Chemical Engineering sophomores overwhelmingly show higher levels of confidence in these courses. The only part of the Chemistry section that was not significantly different between ChemE sophomores and the combined First-year class was on item b15 *I feel invisible in this class*. Response means for the groups showed that both felt equally *visible* with the First-year mean at 3.81 and the ChemE mean at 4.10 on a 5 point scale.

Chemical Engineering Sophomores showed significantly lower values on 9 of the subsections for Physics. These include c1 *I see myself as a physics person,* c2-c5 *My parents/friends/teachers see me as a physics person,* c6 *I am interested in learning more about this subject,* c9 *I enjoy learning this* subject, c11 *I understand concepts I have seen in this subject,* c12 *Others ask me for help in this subject,* and c13 *I wish I didn't have to take this subject* (response reversed from negative).

For the Math section of question 22, only two components showed statistically different between these two groups, both of which were also lessened within the sophomore Chemical Engineering group. These were: d5 *My teacher sees me as a math person,* and d6 *I am interested in learning more about this subject*.

Sophomore IEs compared to Combined First-year Class

Industrial Engineering Sophomores showed statistically smaller means for 10 of the questions in the Biology section than did the combined First-year class. These include a3 and a5 *my relatives/teachers see me as a biology person,* a6 *I am interested in learning more about this subject,* a7 *I am confident that I can understand this subject in class,* a8 *I am confident that I can understand this subject outside of class,* a9 *I enjoy learning this subject,* a10 *I can do well on exams in this subject,* a11 *I understand concepts I have studied in this subject,* a12 *Others ask me for help in this subject,* a14 *This subject makes me nervous* (response reversed from negative).

Similar results were found for the Chemistry section, where IEs held significantly lower means on parts b1 – b13 and on b16. This showed that these students are overall less confident with their abilities in the field of Chemistry, and that they and others are less likely to recognize them as "Chemistry people". The remaining two sections where IEs did not prove to be statistically lower (b1 and b14) were both shown to be statistically similar between the two groups.

There were three components within the Physics section that were shown to have a statistically significant difference. Again, the IE means for all three were statistically smaller than means for the overall First-year class. These components were: c6 *I am interested in learning more about this subject*, c9 *I enjoy learning this subject*, and c13 *I wish I didn't have to take this subject* (response reversed from negative).

An interesting result from this portion of the analysis, was that within the Math category *none* of the components were significantly different from the combined First-year group to the sophomore Industrial Engineering group. All means between these two groups were relatively high for all components of this question, ranging from the lowest at 3.37 to a maximum of 4.18 (on a 5 point scale). This suggests that the majority of engineering students at both levels (First-year and Sophomore) have moderate-to-high levels of confidence in their mathematical abilities, and a tendency for recognition by themselves and others as "Math people".

Analysis of aggregate scales:

For each of the four disciplines (Biology, Chemistry, Physics, and Math), three aggregate scales/subscales for ChemEs and for IEs were also calculated and compared. The first subscale for each included questions 1-6 for each discipline and is referred to as the "Identity Subscale" for that discipline. The second subscale was comprised of the responses for questions 7-16 for each discipline and is referred to as the "Efficacy Subscale" for that discipline. Finally, and "Overall Scale" for the discipline was calculated for each group, which includes responses for all questions.

There were only two disciplines that had aggregate scales/subscales which were proven to be significantly different between the two sophomore student groups. The first was for Physics. When analyzing the Identity Subscale for Physics (questions c1-c6), it was found that Industrial Engineering students hold a significantly higher Physics Identity than Chemical Engineering students. Also, the Overall Scale for all Physics related questions was significantly higher for Industrial Engineering students than for Chemical Engineering students.

The other discipline with significant differences on the scales was for Mathematics. Industrial Engineering students were shown to have a significantly higher Identity Subscale than Chemical Engineering students, even though when each question is viewed individually, there are no significant differences. Additionally, IEs were found to have a significantly higher Overall Scale for all Math components than ChemEs.

In your opinion, to what extent are the following associated with the field of engineering?

Reponses for this question include the student's opinions on how the field of engineering is linked to societal concerns such as *Creating economic growth*, and *Protecting the environment.* There were no significant difference found between mean responses from the two sophomore discipline-specific groups. However, each group had at least one area where the mean response for their group differed from the mean responses of their collective class as First-year students.

There was only one significant portion of this question for Chemical Engineering Sophomores on part 10 *Feeling a moral obligation to other people*. The Sophomore ChemE's showed a significantly higher level of agreement with this statement, with a mean response of 4.13 on a 5 point scale. The First-year group had a mean of 3.73. This was also one of the sections that showed as significantly different for Industrial Engineering Sophomores. The mean for IEs was 4.14.

In addition to part 10 of this question, there were four other components that showed significantly different means between the Sophomore IEs and the First-year group. The Sophomore IEs showed larger

means for all of these parts of the question, which included: *(1) Creating economic growth, (5) Caring for communities, (6) Protecting the environment,* and *(12) Data analysis.*

To what extent do you disagree or agree with the following:

Questions in this set included statements regarding the correlation students draw between Science, Engineering, and/or Technology they are learning now, and their future career success. Only one portion of this question was shown to have a significant difference between the two sophomore groups. On part 6 of the question, *Learning science has made me more critical in general*, Chemical Engineering students had a significantly higher response (towards *Strongly Agree*) than did Industrial Engineering students.

When comparing the two discipline-specific sophomore groups to the collective First-year group, both showed to be significantly different for multiple segments, but only one segment was common between the two sets of comparisons. This was part 10: *Science and technology are the cause of most environmental problems.* Both Sophomore groups were shown to agree with this statement more than the First-year group.

In addition to the significant difference found on part 10, Chemical Engineering students also had significantly larger means, showing a higher level of agreement, with parts *(6) Learning science has made me more critical in general,* and *(13) Scientists are completely neutral and objective*.

The Industrial Engineering Sophomores had one additional area of significance for *(18) Scientific theories develop and change all the time*. On this question, the older IE group had a much lower mean, showing they do not agree has highly with this statement as do the First-year students; though both the sophomore IEs and the First-year group had mean responses toward that showed overall agreement with the statement (IE mean = 3.89; First-year mean = 4.23).

To what extent do you agree or disagree with the following?

Portions of this question aim to gage the students' opinions on learning Math and the effect it will have on their futures, and the future of society as a whole. None of the components for this question showed to have significantly different responses for the two discipline-specific Sophomore groups. But each group had significant differences from the mean responses of the combined First-year group.

Chemical Engineering Sophomores, had statistically different, smaller mean responses for parts *(3) Mathematics is helpful in my everyday life,* and *(14) Mathematics will provide greater opportunities for future generations.*

Sophomore Industrial Engineering students had statistically different, smaller mean responses for *(7) Mathematics makes our lives healthier, easier, and more comfortable,* and *(8) Mathematics is a solution to nearly all problems*.

6.4 Personal/Familial relationships

Anecdotally, it has been noted that many engineering students decide to pursue the field because they knew someone (family member, family friend, role model, etc) who was an engineer. Some of the questions on this survey aim to ascertain if there are differences in this perceived phenomenon between these two disciplines.

What is the highest level of education for your parents/guardians?

All students answering this question were provided the ability to specify an education level for as many as 2 female and 2 male parents/guardians. The only portion that was shown significantly different between the two Sophomore discipline-specific groups, was related to Male parent/guardian education levels. On this portion of the question, Industrial Engineering students, on average, had male parents/guardians with significantly higher levels of education than Chemical Engineering students.

None of the responses for Chemical Engineering sophomores were shown to be significantly different from responses of their collective First-year class. However, one portion was significant when comparing the First-year group to the Sophomore IEs. That was part 3, which asked for the education level of *Male parent/guardian 1*. On these responses, the Industrial Engineering Sophomores had a mean response just over a value of 4 (4.028). The response of 4 refers to the attainment of a Bachelor's degree, while the next response, 5, refers to a Master's of higher. The mean response for the First-year group was 3.602. Which places it between the previously mentioned reference of 4, and a value of 3, which corresponds to *Some College or Associates/Trade degree*.

Are any members of your family employed in the following professions?

This question was analyzed first by each combination of relationship type and profession. Then subscales for each type of relationship were created for the various fields for comparison. For the majority of the combinations, Industrial Engineering sophomores were shown to have significantly higher numbers of Mothers, Fathers, and Siblings employed in the related fields (*Medical/health professional*, *Scientist*, *Engineer*, and *STEM careers*) than Chemical Engineering sophomores. IEs also had a significantly higher number for Fathers and Siblings in the field of Teaching than did the Chemical Engineering students polled. However, for the last field specified, *Non-science related career*, Chemical Engineering students had a significantly higher number of people in the category of "*Other Relative"* than did Industrial Engineers. All other combinations for *Other Relative*, and for *Non-science related career* were statistically the same between the two groups.

When comparing the sophomore groups to their First-year class on these individual question sections, Chemical Engineering students only had two areas that were significantly different from the First-year group. These showed that the ChemE's had a lower portion of *Mother/Female guardians* under the category of *Scientist,* and a higher instance of *Other relative* under the category of *non-STEM career*.

For the Industrial Engineering sophomores, the vast majority of the combinations for the various types of family members and professions showed to be significantly different than responses from the First-year group. When looking at the portions that were shown to be significant, all portions showed to have higher means for the sophomore IEs than for the First-year students with the exception of combinations that refer to the category of *Other relative*.

In this way, IE's have significant, higher instances that the First-year group of *Mother/Father/Siblings* in the following careers: *(1) Health Profession, (2) Scientist, (3) Engineer, (4) Teacher,* and *(5) other STEM career.* IE's had significant, lower instance of *Other relative* in the following careers: *(1) Health Profession, (3) Engineer,* and *(6) other non-STEM career.*

Regarding the Scales/Subscales for these responses, Industrial Engineering students were shown to have significantly higher subscales than the Chemical Engineering sophomores for the following categories: Mothers in STEM Career, Fathers in STEM Career, Siblings in STEM Career, and All Family

Relationships in STEM Careers. This is very interesting and suggests that students who decide to pursue the field of Industrial Engineering are commonly influenced by their family members.

When comparing discipline-specific sophomore students to the First-year students, the Chemical Engineering students had one area of statistical significance that included a larger mean for the ChemEs than for First-year. This was on their All Family Relationships in STEM Careers Scale; where ChemE students had a mean of 2.25 as compared to the First-year mean of 1.28, shown in Table 1.

Also shown in Table 1, there were two other subscales flagged as significantly different, Chemical Engineering students had lower means than First-year students. These were on Mothers in STEM Career and Fathers in STEM Career subscales.

Table 1: First-year and chemical engineering student differences in family careers.

First-year (FY) to ChemE			**Results from t-tests**					
Variable		**Survey**	***n***	***M***	***SD***	***df***	***t***	***p***
28 Scale◇	All family relationships STEM careers	FY	387	1.28	1.265	66.33	-3.33	.001
		ChemE	61	2.25*	2.211			
28 Mom Scale	Mom STEM careers	FY	387	.80*	.585	446	4.46	.000
		ChemE	61	.44	.533			
28 Dad Scale◇	Dad STEM careers	FY	387	.83*	.570	76.78	4.44	.000
		ChemE	61	.46	.621			

* denotes the higher score

◇ Levene's test indicated unequal variances; degrees of freedom were adjusted

Industrial Engineering sophomores had four scales and subscales that were significantly different than the First-year group. All Family Relationships in STEM Careers Scale was much higher for Industrial Engineering students as the First-year students had a mean of 1.28 and Industrial Engineering sophomores had a mean of 5.51, shown in Table 2. For the other three subscales, Moms in STEM Career, Dads in STEM Career, and Siblings in STEM Career subscales, the IE students still showed larger means, though not as high as the All Family Relationships in STEM Careers Scale.

Which of the following people have contributed to your choice of a career path? (Mark ALL that apply.)

Results from this question reinforce the results from the previous question. It was found that Industrial Engineering students reported significantly higher instances of their Siblings, Other relatives, and/or a Professional Contact contributing to their choice to pursue their selected field than did Chemical Engineering students. This shows that not only are they more likely to have been around such people, but that they found these people compelling when choosing their own careers.

Chemical Engineering students were shown to have a significantly higher instance of being influenced by a Chemistry teacher when selecting their career field when compared to sophomore IEs. This result also showed significant for the ChemEs when compared to the First-year class. Though in this comparison, the Chemical Engineering Sophomores had significantly different, and smaller means for citing either a *(6) Contact with someone in that major/career,* or a *(12) Other teacher* as contributing to their career choice.

Table 2: First-year and industrial engineering student differences in family careers.

First-year (FY) to IE			Results from t-tests					
Variable		**Survey**	***n***	***M***	***SD***	***df***	***t***	***p***
28 ◇ fam scale	Total family members in STEM careers	FY	387	1.28	1.265	37.36	-8.94	.000
		IE	37	5.51*	2.854			
28 ◇ mom scale	Mom in STEM career	FY	387	.80	.585	36.48	-2.61	.013
		IE	37	1.76*	2.229			
28 ◇ dad scale	Dad in STEM career	FY	387	.83	.570	36.45	-2.51	.017
		IE	37	1.76*	2.229			
28 ◇ sib scale	Sibling in STEM career	FY	387	.41	.644	36.63	-2.98	.005
		IE	37	1.46*	2.129			
29 total	Total number of people contributed to career choice	FY	387	4.08	2.901	422	-2.25	.025
		IE	37	5.22*	3.163			
29 fam◇	Total number of family members contributed to career choice	FY	387	1.45	1.228	37.82	-2.47	.018
		IE	37	2.43*	2.398			

* denotes the higher score

◇ Levene's test indicated unequal variances; degrees of freedom were adjusted

Industrial Engineering Sophomores were also significant in citing higher instances of their *(1) Mothers*, *(3) Siblings*, and *(4) Other relatives* as having contributed to their career choice. The First-year group showed significantly different and higher instance of a *(9) Biology teacher*, or *(10) Chemistry teacher* contributing to their choice of field.

Finally, regarding the Scales/Subscales for this question, Industrial Engineering students again had significantly higher values for the Family Subscale compared to that of ChemEs; showing higher numbers of IEs reported family members as influential to their choice in career path, and also for the Total Scale; showing that IEs experiences more and/or different types of people that effected their choice of career path than did ChemEs.

In comparing each of the discipline-specific sophomore groups to the First-year group, none of the means were significantly different for the Chemical Engineering – First-year comparisons. Industrial Engineering students showed significantly different, and higher means, compared to the First-year, for both the Total Scale and the Family Subscale.

7. Conclusions

Students starting their studies in engineering have certain ideas about what they want to do for their career and what they think engineering is, these ideas change throughout students' First-year in engineering. The assumptions First-year students have do change throughout the First-year, depending on which

engineering major students gravitate towards. Overarching ideas gleaned from this work falls into four main areas described separately below. These areas are: Career Goals, Past Experiences, Confidence and Identity, and Outside Influencers.

7.1 Career Goals

Unsurprisingly, Chemical Engineering students are more interested in career fields related to Chemistry, while IEs are more interested in only the specific field of Industrial Engineering. Slightly more surprising is the fact that Chemical Engineers are mildly more willing to move outside of their main area to pursue Biology or Bioengineering work than are IEs.

Chemical Engineers are more interested in other fields of Environmental Science or Materials Science than the First-year group overall, and are overall, less likely to pursue other engineering fields (Civil, Mechanical, Electrical and Computer, and Aerospace) or Computer Science.

Related to career intentions, both ChemEs and IEs agree less with the statement *I hope to develop my expertise in one specific field* than does the First-year class, which indicates that after an additional year of study, both groups are less interested in limiting the scope of their studies.

Regarding what students are looking for in their careers, ChemEs are less interested in *making money*, *making use of my talents and ability*, and *doing hands on work* than are the First-year students. While IEs are more interested in *supervising others*; but are less interested in *Inventing/Designing things*, and *Applying math and science* than the First-year group.

In looking at applications of work, ChemEs were more interested in areas of *Climate Change*, *Water Supply Issues*, and *Energy;* areas that closely relate to their field of study. IEs and ChemEs alike showed a great disinterest in work related to *Space Exploration* and *Cyber Security* applications. IEs were more interested in *Human Health*, *Poverty and distribution of wealth and resources*, and *Food availability*.

7.2 Past Experiences

Chemical Engineering students seem to have had more exposure to talking about/explaining scientific topics to others compared to IEs. ChemEs are also more confident than both IEs and the overall First-year class, with activities that commonly take place in a lab setting such as conducting an experiment, interpreting experimental results, and writing lab reports. This may be due to their higher level of exposure to these activities, or it may speak to something within their desire to pursue a field that requires these undertakings more readily.

ChemEs were also shown to have participated in Engineering/Science clubs, camps, or competitions more than Industrial Engineering students, though not more that the First-year class as a whole. This suggests that Industrial Engineers may participate in this specific type of activity less than students interested in other engineering disciplines. In fact, IEs also had fewer instances of *Participating in other Science/Engineering hobbies* and *read/watch science fiction programs or literature* than the overall First-year group.

7.3 Confidence and Identity

Chemical Engineering students and the overall First-year group both are significantly more confident in the application of Scientific Principles than IEs. IEs are also less interested in Physics, enjoy Physics classes less and are cited as wishing they did not have to take Physics courses at a greater rate than the First-year group.

ChemEs are more confident than both IEs and the First-year group in the area of Chemistry. ChemEs are also more confident in their understanding of Biology compared to IEs, though theirs measures on confidence in Biology were similar to the aggregate group of First-year students. However, neither Sophomore group strongly identifies as "Biology people".

Contrary to previous work, which did not differentiate between the engineering disciplines, Chemical Engineers, showed significantly lower values than the overall First-year students related to Physics Identity, and Confidence in Physics. Interestingly Industrial Engineers have a significantly higher Physics Identity than do Chemical Engineers. Although IEs appear to be more confident in their physics abilities than ChemEs, neither group identifies with the field in general.

Additionally, IEs also show a higher level of Math Identity than ChemEs. IEs are also shown to be, overall, more confident in the area of Mathematics. Although IEs had higher confidence scales, both ChemEs and IEs have relatively high levels of confidence in their mathematical abilities, and also "see themselves as MATH people". This idea does also hold for the First-year group, which would lead one to believe that all, or almost all engineers identify as "Math People" while only engineers in select disciplines identify as "Physics", "Chemistry", or "Biology" people.

7.4 Outside Influencers

IEs were shown to have significantly higher subscales than both ChemEs and the First-year group for: Mothers in STEM Career, Fathers in STEM Career, Siblings in STEM Career, and All Family Relationships in STEM Careers. This is very interesting and suggests that students who decide to pursue the field of Industrial Engineering are commonly influenced by their family members. Industrial Engineering students, on average, also had male parents/guardians with significantly higher levels of education than both Chemical Engineering students and the overall First-year class.

Chemical Engineering students, on the other hand, were shown to have significantly higher instances of being influenced by a Chemistry teacher when selecting their career field, when compared to both sophomore IEs and to the First-year class.

References

[1] K. L. Tonso, "Teams that work: Campus culture, engineering identity, and social interactions," JEE, vol. 95, 1, pp. 25-37, 2006.

[2] B. M. Capobianco, B. F. French, and H. A. Diefes-Dux, "Engineering identity development among pre-adolescent learners," JEE, vol. 101, 4, pp. 698-716, 2012.

[3] H. M. Matusovich, B. E. Barry, K. Meyers, and R. Louis, "A multi-institution comparison of identity development as an engineer," ASEE Conf. Proc., 2011.

[4] Q. Li, H. Swaminathan, and J. Tang, "Development of a classification system for engineering student characteristics affecting college enrollment and retention," JEE, vol. 98, 4, pp. 361-376, 2009.

[5] J. Jorgenson, "Engineering selves: Negotiating gender and identity in technical work," Mangement Communication Quarterly, vol. 15, 3, pp. 350-380, 2002.

[6] X. Y. Du, "Gendered practices of constructing an engineering identity in a problem-based learning environment," EJEE, vol. 31, 1, pp. 35-42, 2006.

[7] K. L. Meyers, M. W. Ohland, A. L. Pawley, S. E. Silliman, and K. A. Smith, "Factors relating to engineering identity," Global Journal of Engineering Education, vol. 14, 1, pp. 119-131, 2012.

[8] Kendall, M. R., Choe, N. H., Denton, M. E., & Borrego, M. J. (2018, June). Engineering Identity Development of Hispanic Students. In 2018 ASEE Annual Conference & Exposition, Salt Lake City, UT.

[9] A. Godwin, G. Potvin, Z. Hazari, and R. Lock, "Identity, critical agency, and engineering: An affective model for predicting engineering as a career choice," JEE, vol. 105, 2, pp. 312-340, 2016.

[10] J. C. McNeil, E. L. Gerber, G. Willing, and M. Mills, "Engineering Identities of Chemical and Industrial Majors After Students' First Year," In IEEE Frontiers in Education, 2018.

[11] C. A. Cass, Z. Hazari, J. Cribbs, P. M. Sadler, and G. Sonnert, "Examining the impact of mathematics identity on the choice of engineering careers for male and female students," IEEE-FIE Conf. Proc., pp. F2H-1, 2011.

[12] Z. Hazari, G. Sonnert, P. M. Sadler, and M. C. Shanahan, "Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study," Journal of Research in Science Teaching, vol. 47, 8, pp. 978-1003, 2010.

[13] Cass, C. A., Hazari, Z., Cribbs, J., Sadler, P. M., & Sonnert, G. (2011, October). Examining the impact of mathematics identity on the choice of engineering careers for male and female students. In Frontiers in Education Conference (FIE), 2011 (pp. F2H-1). IEEE.

[14] A. Calabrese Barton, H. Kang, E. Tan, T. B. O'Neill, J. Bautista-Guerra, and C. Brecklin, "Crafting a future in science: Tracing middle school girls' identity work over time and space," AERA, vol. 50, 1, pp. 37-75, 2013.

[15] A. Godwin, G. Potvin. "Chemical Engineering Students: A Distinct Group Among Engineers," *Chemical Engineering Education*, **2013**, 47, 145-151.

[16] A. Godwin, G. Potvin. "Living In Two Worlds: Comparing Chemical Engineering Students To Other Engineers And Chemists," *Proceedings of the120th ASEE Annual Conference and Exposition,* Atlanta, GA, 2013.

[17] A. Godwin, D. Verdin, A. Kirn, D. Satterfield. "The Intersection of Gender And Race: Exploring Chemical Engineering Student's Attitudes," *Chemical Engineering Education*, **2018**, 52, 89-97.

[18] B. E. Ashforth and S. A. Johnson, "Which hat to wear?: The relative salience of multiple identities in organizational contexts," Social Identity Processes in Org. Contexts, Jan., pp. 32-48, 2001.

[19] J. E. Stets and P. J. Burke, "A sociological approach to self and identity," Handbook of Self and Identity, Guilford Press, pp. 128-152, 2003.

[20] Felder, R. M., & Brent, R. (2004). The intellectual development of science and engineering students. Part 1: Models and challenges. Journal of Engineering Education, 93(4), 269-277.

[21] Felder, R. M., & Brent, R. (2004). The intellectual development of science and engineering students. Part 2: Teaching to promote growth. Journal of Engineering Education, 93(4), 279-291.

[22] Litzinger, T. A., Wise, J. C., & Lee, S. H. (2005). Self-directed Learning Readiness Among Engineering Undergraduate Students. Journal of Engineering Education, 94(2), 215-221.

[23] Reisslein, J., Sullivan, H., & Reisslein, M. (2007). Learner achievement and attitudes under different paces of transitioning to independent problem solving. Journal of Engineering Education, 96(1), 45-56.

[24] Stevens, R., O'connor, K., Garrison, L., Jocuns, A., & Amos, D. M. (2008). Becoming an engineer: Toward a three dimensional view of engineering learning. Journal of Engineering Education, 97(3), 355-368.

[25] Crain, W. (2005). Erikson and the eight stages of life. Theories of development: Concepts and applications, 5, 277-302.