# Engineering Identities of Chemical and Industrial Majors After Students' First Year


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***Abstract*— This work-in-progress research paper explores the differences of engineering identity in second year chemical engineering and industrial engineering students. The study aims to seek similarities and differences in engineering identity after the College of Engineering's First Year program. The research questions investigated in this paper include: 1) What factors are related to chemical engineering self-identification? and 2) What factors are related to industrial engineering self-identification? To answer these questions, researchers collected data, using a modified version of the SaGE survey. The data was collected within a required sophomore level course for chemical engineers in summer 2017 and a required sophomore level course for industrial engineers in fall 2017. The results showed that there are differences in Industrial and Chemical Engineering students' identities by the sophomore level. Chemical engineering students seem to have established a chemical engineering identity by the beginning of their sophomore year at the university, whereas Industrial Engineering students are just beginning to form an engineering identity.**



***Keywords—engineering identity, first year programs, quantitative, engineering education***


## I. Introduction

This work-in-progress research paper investigates the similarities and differences of the engineering identities of Chemical Engineering (ChemE) and Industrial Engineering (IE) students. Engineering identity is "a particular type of role identity that students author during their experiences in engineering" [1, p. 1]. Many people may assume that most engineering students are similar, especially at colleges and universities where there are First Year Programs. First Year Programs have all engineering students take the same courses during their first year in college. First Year engineering students get put together as one big group, and they may or may not all have similar engineering identities. The presence of an engineering identity has been linked to persistence in engineering in multiple studies [2-7]. But there has not been as much research on what the engineering identities are after the First Year program (the beginning of the sophomore year). Furthermore, research completed by Godwin, et al [1] indicated a strong physics identity amongst engineering students. The research team had serious questions regarding the breadth of this finding across various disciplines.

This study looks at the similarities and differences of Chemical Engineering (ChemE) and Industrial Engineering (IE) students at the beginning of their sophomore year to explore if their engineering identities, and links to underlying identities in physics, math, chemistry, or biology, are similar through the First Year program. The authors are looking at these two majors because ChemE students seem to have a strong affiliation with their major and IE students do not seem to have a strong affiliation with their major within the first year. Additionally, the researchers wanted to investigate the link to underlying identities, anecdotally believing that neither ChemE nor IE students have an overly robust physics identity.

The researchers utilized the well-known survey instrument, SaGE, which was developed for previously cited research by Godwin, et al. [1]. Adjustments were made to the SaGE survey to allow for the collection of additional information on underlying identities (namely math, chemistry, and biology). The same survey format was utilized with the addition of these content areas.

## II. Literature Review

Science or Mathematics Identity has been described in terms of 4 factors: performance, competence, interest, and recognition [8-9]. A strong mathematics background has been linked to persistence in engineering [10]. Cass et al. found that mathematics interest, mathematics competence and performance, and mathematics recognition are significant predictors of the choice of an engineering career, after controlling for SAT/ACT math scores and demographics such as parental education [8]. The interaction between mathematics recognition and gender is also significant, indicating that a female who is recognized by themselves and others as a 'math person' is more likely to choose an engineering career as opposed to females who are not recognized by others as a 'math person'.

Calabrese-Barton, Kang, Tan, O'Neill, Bautista-Guerra, and Brecklin [11] recognized that the construct of identity is complex and difficult to study. They suggested the use of the term "identity work" to describe "the actions that individuals take and the relationships they form (and the resources they leverage to do so) at any given moment and as constrained by the historically, culturally, and socially legitimized norms,

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rules, and expectations that operate within the spaces in which such work takes place." [11, p. 38].

Identity work is shaped by how one recognizes self and how one is recognized by others. Calabrese-Barton et al. argue that identity work can be examined by focusing on "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." [11, p. 44]. Additionally, identity is not formed or changed in isolation; it is socially negotiated with others. When other people recognize and acknowledge the identity, then the identity is reinforced within the individual. The theory used in this study is explained below.

## III. Theoretical Foundation

'Role' identity theory is heavily based from sociological literature, and is used to describe individual behavior influenced by social roles which are defined by interpersonal relations and exchanges [12-13]. Some social roles may not be meaningful by themselves, but are created within context of other roles [13]. Roles are not only defined socially, but also through an individual's daily activities and interactions. Identity theory can also include a hierarchy of roles, where some roles are valued more than others. Role identity theory is often used to explore how individuals define themselves in their daily lives, and how their self-perceived adequacy is influenced by their interpersonal interactions.

For this study, we use role identity to explore how students self-identify with their sub-engineering fields of chemical and industrial engineering.

## IV. Research Questions

The research questions investigated in this paper include:

1) What factors are related to chemical engineering self-identification?

2) What factors are related to industrial engineering self-identification?

## V. Methods

Independent-sample t-tests were conducted to compare a number of different factors between students declared majors of ChemE or IE. An introductory course for each discipline was used to survey all students enrolled. Students were offered a small amount of credit for completing the altered SaGE survey. Students had the option to complete an alternative assignment for credit if desired.

The t-tests (test on means) used in this analysis states the null hypothesis (H_0) that the mean responses of the two populations are statistically, the same as one another (H_0: μ_1=μ_2). When this is not the case, the null-hypothesis was rejected, and instead concluded that there is a significant difference between the mean responses of the two populations. For all t-tests conducted, an alpha (α) of 0.05 was utilized.

In some cases, the two groupings will have mean responses that do not significantly differ from one another, but the way in which those responses are dispersed amongst the possible response options is quite different. Chi-Squared tests allow an analyst to determine differences in how the responses are dispersed (variance) between the two groupings. Pearson chi-squared tests were performed to examine the dispersion of response selections for a number of different factors included in the survey. An alpha (α) of 0.05 was utilized for the chi-squared tests.

## VI. Results and Discussion

The population of respondents showed a slightly higher percentage of females in the survey pool than in each of the respective departments as a whole. The institution in the study has seen increases in the number of female engineering students over the past 3 to 4 years. For the Fall 2017 term, the ChemE department was comprised of 33% female students in their undergraduate program and there were 18 (43%) female pool of respondents to the modified SaGE survey. The IE department was 42% female for that Fall 2017 term and had 22 (47%) of respondents from this group being female.

Racial distributions were very close to departmental actuals for this study. For the Fall 2017 term, the Chemical Engineering department under study was 214 (84%) white and 42 (16%) minority students as compared to 37 (88%) white and 5 (12%) minority breakdown from the pool of respondents. The Industrial Engineering department had 101 (74%) white and 36 (26%) minority for Fall 2017 term, as compared with 36 (78%) of white and 10 (22%) minority respondents from this group. Note: 1 person declined to answer the question about race.

The survey pool included a slightly larger percentage of Hispanic respondents that the overall breakdown of the two departments combined. For the survey, 6 (7%) of respondents replied that they were Hispanic. The two departments combined had a 4% Hispanic makeup of their undergraduate programs for the Fall 2017 semester.

There was a significant difference in the scores for factors for future career satisfaction for two variables, see Table 2. First, supervising others: ChemE ($M$ = 2.10, $SD$ = .983) and IE ($M$ = 2.76, $SD$ = .923); $t(84)$= -3.266, $p$ = .002. These results show that more IE students see supervising others as important to their career satisfaction than ChemE students. Second, inventing/designing things: ChemE ($M$ = 2.81, $SD$ = .804) and IE ($M$ = 2.26, $SD$ = 1.132); $t(83)$= 2.684, $p$ = .009. These results show that ChemE students view inventing/designing things as important to their career satisfaction. This result has also been reported previously as a major difference between ChemE and Chemistry students [14].

IE students have a drive to work on complex systems. However, since the area is so broad in nature, they are often more willing to work slightly outside of their chosen discipline, or merge various disciplines into new sub-specialties, than students from more specialized majors [15]. Responses from the IEs on this survey support this idea. On Question 3: "Please rate the current likelihood of your choosing a career in the following"; IEs were shown to be significantly more likely to give higher ratings to areas other than their chosen field of study and pursue work in the somewhat related field of Civil

Engineering or into a more general engineering field than ChemE students.

Additional information gleaned from this question includes other career choice options these students may (or may not) be willing to pursue. Both the test of means and the variance test for Question 3, shown on Tables 1-2, show differences in the careers paths the different disciplines are willing to pursue. IEs, though much more varied in their desire to pursue a career in math, overall are more open to the concept. Conversely, ChemE students' responses from the survey are fairly universal in their desire to avoid Math related careers.

ChemE students do show an increased proclivity towards the pursuit of Bioengineering fields and other fields related to the environment. ChemE's are also more interested in fields related to materials, though the responses for both disciplines are quite varied on this topic. Also, ChemE's are willing to deviate from the engineering fields, if that means they are able to maintain a career in Chemistry or Materials Science/Engineering. This is not surprising as there are similarities in the early curriculum for each of those disciplines. Another reason why the ChemE students may have trended higher for Materials Science/Engineering is that the students who took the survey were not only completing the introductory Chemical Engineering course, but also the Introduction to Materials Science course. IE students are also required to take the same Materials Science course, but not for another 2 semesters after the course in which they took the survey.

The relative focus of ChemE students to pursue careers in ChemE or closely related fields (Chemistry, Materials, Environmental) is significant when viewed in context of the changing nature of the field. A number of articles published over the past 15 years have questioned whether the field overall, and the practitioners within it, could maintain a coherent identity given the expansion of the field across fairly divergent areas [16]. During their introduction course, ChemE students were presented with alumni panels focused on various career paths including those that were more traditional within the field (petrochemical, polymers and materials, environmental, and distilled spirits) and those that would be considered more alternative (medical, dental, and entrepreneurial careers). Even with these presented options and interactions with practitioners within those fields, students are still focused on more traditional career pathways. This does suggest that their identity as chemical engineers have started to solidify.

Similarities between career choices for the two disciplines of ChemE and IE are also present. Both are equally willing to pursue Mechanical Engineering, Computer Science, and Aerospace related fields as careers. Both are also equally disinterested in pursuing Physics as part of their occupation. This is a somewhat interesting result as prior work indicated that Chemical Engineers have a higher interest and confidence in Physics, though that does not necessarily translate to interest in a career in the field [1, 14].

IEs are nearly universal in their desire to avoid ChemE and Chemistry related fields. These fields show incredibly high interest levels amongst the ChemEs. The same observation is made of Chemical Engineers in their interest in a career in Industrial/Systems engineering. While this is to be expected, it validates the use of this survey for the pool of respondents.

Tangentially related to this response, is the response to Question 19: "To what extent do you disagree or agree with the following:" which included a list of options dealing with a student's self-identification of personal qualities and preferences. These qualities/preferences included: "I prefer to focus on details and leave the big picture to others", "When problem solving, I focus on the relationships between issues", etc. Results from this question, shown in Table 2, showed the IEs more frequently and more consistently cite themselves as wanting to "focus on the big picture and leave the details to others". Industrial Engineers are frequently required to apply their methodologies to the big picture of a problem, in order to find a solution that melds the needs and findings of the various disciplines involved, in a way to optimize the system.

TABLE I. CHI-SQUARED TEST ON QUESTION 3 & 19

| Variable | | **Likelihood of Choosing a Career in a Specific Field** | | | | **Info** |
|---|---|---|---|---|---|---|
| | | ***n*** | ***df*** | ***X²*** | ***p*** | |
| 3.1 | Mathematics | 86 | 4 | 12.156 | .016 | ChemE skewed lower |
| 3.6 | Chemistry | 86 | 4 | 43.444 | .000 | Opposite spread |
| 3.7 | Bio-Engineering | 86 | 4 | 23.144 | .000 | ChemE skewed high |
| 3.8 | Chemical Engineering | 87 | 4 | 66.253 | .000 | Opposite spread |
| 3.9 | Materials Engineering | 88 | 4 | 28.466 | .000 | ChemE skewed high |
| 3.11 | Industrial/Systems Engineering | 86 | 4 | 73.335 | .000 | IE skewed high |
| 19.4 | I prefer to focus on the big picture and leave the details to others | 86 | 4 | 11.884 | .018 | ChE more spread |

Question 20, represented in Table 2, makes it very clear that ChemE students are interested in understanding natural phenomena, science, and that they are willing to make the scientific observations towards this understanding. These results pair very well with the confidence that ChemE students have in being able to conduct experiments, analyze the data and report on the results either through a lab report or on a test. While some may point to the fact that Chemical Engineers take more chemistry courses which would tend to lead towards a greater interest in those topics and a higher confidence in being able to carry out tasks related to those topics, it should be noted that by the time these ChemE students had taken the survey, they had the same number of general science courses as part of their curriculum.

TABLE II. T-TEST ON SURVEY QUESTIONS

| | Variable | Dept | Results from T-Tests | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | *n* | *M* | *SD* | *df* | *t* | *p* |
| Q1.4 | Supervising others | ChemE | 42 | 2.10 | 0.98 | 84.00 | -3.27 | 0.002 |
| | | IE | 46 | 2.76* | 0.92 | | | |
| Q1.7 | Inventing/designing things | ChemE | 42 | 2.81* | 0.80 | 82.93 | 2.68 | 0.009 |
| | | IE | 47 | 2.26 | 1.13 | | | |
| Q3.1 | Mathematics | ChemE | 40 | 1.48 | 1.24 | 84.00 | -3.12 | 0.002 |
| | | IE | 46 | 2.37* | 1.42 | | | |
| Q3.3 | Environmental Science | ChemE | 40 | 1.58* | 1.15 | 80.41 | 2.56 | 0.012 |
| | | IE | 46 | 0.96 | 1.07 | | | |
| Q3.4 | Biology | ChemE | 40 | 1.08* | 1.00 | 79.66 | 2.36 | 0.021 |
| | | IE | 46 | 0.59 | 0.91 | | | |
| Q3.6 | Chemistry | ChemE | 40 | 2.88* | 0.97 | 83.23 | 8.29 | 0.000 |
| | | IE | 46 | 0.91 | 1.23 | | | |
| Q3.7 | Bio-Engineering | ChemE | 40 | 1.88* | 1.02 | 83.91 | 4.43 | 0.000 |
| | | IE | 46 | 0.85 | 1.14 | | | |
| Q3.8 | Chemical Engineering | ChemE | 42 | 3.90* | 0.30 | 48.56 | 14.31 | 0.000 |
| | | IE | 45 | 0.96 | 1.35 | | | |
| Q3.9 | Materials Engineering | ChemE | 42 | 2.60* | 0.99 | 85.49 | 5.98 | 0.000 |
| | | IE | 46 | 1.22 | 1.17 | | | |
| Q3.11 | Industrial/Systems Engineering | ChemE | 40 | 1.05 | 1.04 | 55.33 | -15.49 | 0.000 |
| | | IE | 46 | 3.85* | 0.52 | | | |
| Q19.4 | I prefer to focus on the big picture and leave the details to | ChemE | 40 | 1.58 | 0.747 | 80.06 | -2.468 | 0.016 |
| | | IE | 46 | 2.07* | 1.083 | | | |
| Q20.1 | Understanding natural phenomena | ChemE | 39 | 3.08* | 0.984 | 83.96 | 2.48 | 0.015 |
| | | IE | 47 | 2.49 | 1.214 | | | |
| Q20.2 | Understanding science in everyday life | ChemE | 39 | 3.38* | 0.747 | 82.5 | 3.429 | 0.001 |
| | | IE | 47 | 2.72 | 1.036 | | | |
| Q20.5 | Making scientific observations | ChemE | 39 | 3.41* | 0.818 | 83.6 | 4.225 | 0.000 |
| | | IE | 47 | 2.62 | 0.922 | | | |
| Q21.2 | Conduct an experiment on your own | ChemE | 38 | 2.97* | 0.854 | 80.25 | 2.487 | 0.015 |
| | | IE | 45 | 2.49 | 0.92 | | | |
| Q21.3 | Interpret experimental results | ChemE | 39 | 3.31* | 0.655 | 84 | 3.605 | 0.001 |
| | | IE | 47 | 2.74 | 0.793 | | | |
| Q21.4 | Write a lab report/scientific paper | ChemE | 39 | 3.13* | 0.894 | 80.26 | 2.579 | 0.012 |
| | | IE | 46 | 2.63 | 0.878 | | | |
| Q21.5 | Apply science knowledge to an assignment or test | ChemE | 39 | 3.28* | 0.724 | 83.59 | 2.167 | 0.033 |
| | | IE | 47 | 2.89 | 0.938 | | | |
| Q21.7 | Get good grades in science | ChemE | 38 | 3.53* | 0.603 | 82.54 | 2.465 | 0.016 |
| | | IE | 47 | 3.15 | 0.807 | | | |

The difference observed here is not likely due to additional preparatory course work, but is more likely due to a difference in inherent attitudes towards the material. Prior works have highlighted the difference between Chemical Engineering and other disciplines with respect to higher indicators of general science identity, so this result is not entirely unexpected [14]. The magnitude of the difference between the two groups is somewhat surprising (shown in Table 2), as it has not been directly observed in prior studies.

## VII. CONCLUSIONS

The results revealed that Industrial Engineering students see supervising others as important to their career satisfaction and Chemical Engineering students do not. Chemical Engineering students see inventing/designing as important to their career and Industrial Engineering students do not. Industrial Engineering students were shown to be significantly more likely to give higher ratings to areas other than their chosen field of study and pursue work in the somewhat related field of Civil Engineering or into a more general engineering field than Chemical Engineering students.

Industrial Engineering students, though much more varied in their desire to pursue a career in mathematics, overall are more open to the concept. Conversely, Chemical Engineering students' responses from the survey are fairly universal in their desire to avoid mathematics related careers. Chemical Engineering students focus on pursuing careers in Chemical Engineering or closely related fields (Chemistry, Materials, Environmental). Neither group of students showed strong underlying identities in the area of physics, as compared to the other subjects investigated.

Chemical Engineering students seem to have established a chemical engineering identity by the beginning of their sophomore year at the university. Industrial Engineering students seem to have just started to form an Industrial Engineering identity by their sophomore year. These results have implications for the First Year programs that want to help students understand engineering, where some of the students may have an already established specific engineering identity that may be different from what the First Year program is teaching. The researchers do not yet know how this affects students during their first year in engineering. This disconnect between the students' engineering identity and the First Year program is worth investigating to get a better understanding of an all-encompassing engineering platform for First Year programs.

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