

"Inviteful" Engineering: Student Perceptions of Industrial Engineering

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Abstract: Interviews of twenty-six Industrial Engineering students and graduates were conducted during the first year of a three year study of the unexpected attainment of gender parity in the School of Industrial Engineering at the University of Oklahoma (OU). An analysis of the pattern of participant responses gives insight into industrial engineering (IE) student perceptions of IE. The perceptions were grouped into three broad themes: Career Profile, Discipline Profile, and Discipline Meta-Profile. The Career Profile includes the availability of multiple career paths and flexible careers in this discipline in addition to the potential for the attainment of status through entry into management. People-oriented, broad, and systems-oriented are terms that were used to describe the Discipline Profile. Discipline Meta-Profile is used to describe the participant's perception of other people's perceptions of industrial engineering (i.e. what IE students think other people think). These participants felt that other engineers think of IE as easy, or "imaginary" engineering. The participants also thought that the discipline is invisible, even to other engineers. While the meta-perception of IE might seem to be problematic for the discipline, many of the participants reject the meta-perception. Some participants recognized that IE's focus on people and systems is simply different than other engineering disciplines, not necessarily easier. Other participants felt the potential to enter into management outweighed the discipline meta-perception. One student summarized the response particularly well when he noted that IE is "*inviteful*" engineering.

Introduction

IE: does it mean "Imaginary Engineering", "Imaginative Engineering?"¹, or, as one of the participants in this study described it, "*Inviteful* Engineering?" The attitudes and behaviors expressed by students and faculty from both outside and within Industrial Engineering (IE) affect the perceptions that IE majors and potential majors have of IE as a discipline. In turn, this perception impacts the attractiveness of IE as a major and a career path.

The perception of IE surfaced in the context of a three-year study to examine reasons that the School of Industrial Engineering at the University of Oklahoma (OU) has achieved gender parity (award NSF-GDSE #0225228). The achievement of gender parity in this School was spontaneous, instead of being the result of a carefully-conceived and well-financed plan to

achieve this objective. The study has collected interview data from IE students at OU during the first year, and will collect interview data from OU engineering students in a variety of majors during the second and third years (2004-5). In the third year, the sample will expand to include IE majors from two other large engineering schools. By making comparisons between these populations across departmental and institutional boundaries, the study will identify the attributes of this program that have led to this unexpected, but desirable, result.

By interviewing students, we discovered common patterns in the way OU IE majors perceive their discipline. The patterns discovered in the analysis fell into three broad themes: Career Profile, Discipline Profile, and Discipline Meta-Profile. Career Profile addressed the types of environments in which IEs work, as well as the level of status they feel it is possible to attain. Within Discipline Profile, participants compared IE with other branches of engineering, indicating that IE is more people-oriented, broader, and more systems oriented. Discipline Meta-Profile emerged from students' perceptions of how other engineers perceive IE as a discipline. Participants used *soft*, *easy*, or *imaginary engineering* to express how they feel many of their peers think about IE. We analyzed the data for gender differences within each of these themes.

Methods

We recruited participants by email, by phone, and through announcements in courses for IE majors. We did not include freshmen in the sample because a larger proportion of freshmen tend to be unsure about their long-term goals. During their sophomore year, students are more (though not completely) settled into a major and yet still have fresh memories of their early experiences and factors that influenced their decisions. As our primary goal in the larger study is to examine issues related to gender patterns, we over-sampled women to be sure that a broad range of women's perspectives would be represented.

We conducted semi-structured, hour-long, individual interviews^{2,3} with 26 non-freshman IE majors from OU. We contacted 51 of 98 non-freshman, IE majors and interviewed 26 (51% of contact group and 27% of non-freshman, IE majors). The size of the data set is sufficient for three reasons: the fraction of available students interviewed, the fact that data saturation was achieved after approximately 20 interviews were analyzed, and standard practices in qualitative research.⁴

Students were asked to describe their experiences in IE, as well as what drove them to enter into the program. The interview transcripts were dissected to locate comments related to beliefs about and perceptions of IE as a discipline. During this process a broad range of perspectives was represented by a multi-disciplinary research team, which consisted of OU faculty with backgrounds in industrial engineering, computer science, chemistry and chemical education, mathematics education, women's studies, and anthropology.

The quotes below are excerpts from verbatim transcripts with the following modifications. We sanitized them to remove individually identifiable information by replacing identifiers with categories in parentheses (e.g. "Teri is enjoying this." would be replaced by "(spouse) is enjoying this."), edited them for readability (e.g., we removed most verbal pauses), and inserted necessary

explanatory information from context in brackets (e.g. "he lectured." would be replaced by "he [non-engineering faculty member] lectured.").

Table 1: Sample of IE Majors Interviewed at OU

	Sophomore	Junior	Senior	Alumnus	Total
Female	3	10	2	0	15
Male	3	3	4	1	11

The perceptions in this paper are from IE students at OU. As a result, the data in this paper will be reflective of both the discipline and the institution.

Career Profile

Our interview protocol included questions such as "What are your plans after graduation? Where do you see yourself in five years? How will your degree in IE fit into your goals?" These questions were emphasized more for students who were closer to graduation. Participant comments highlighted three categories: career goals, status potential, and multiple career paths.

Participants had varied career goals. In some cases, these career goals followed gender-based stereotypes. A number of female majors indicated that they plan to have a family and want to balance work and family in the future. For example, they would like to have the flexibility to work from either home or office:

"I even want a family; granted, an IE [degree] will allow me to have a family. I think it's something where potentially, even if I don't go into law school. If I were to stay in just IE, it's something where I could probably work from home on, even, I mean have my laptop and go into work if I needed to a couple of days a week. But, I don't see children being a problem as much as in other majors."
(female sophomore)

A male indicated that he wants to secure a well-paid position so that his wife will have a certain degree of autonomy:

"The thing that made me decide to do industrial engineering was that I wanted on a grand scale for my life to be a husband and I wanted to raise a family and I wanted to be a good provider and I wanted to provide a financially stable situation so that my wife could do whatever she wanted basically and (spouse) is seeing that benefit." (male senior)

Seven of the 26 participants (27%) indicated an expectation that an IE degree will directly facilitate attainment of status in their career. One sophomore male, all four of the senior men (for a total of 45% of the male participants), and two of the ten junior women (for a total of 13% of the female participants) made comments related to status potential: "industrial engineers will be their [other engineers'] bosses in the future" (male senior).

Comments about IE leading to multiple career paths came in two forms. Some students referred specifically to this characteristic of the discipline:

"What an industrial engineer does. Well that's another aspect [of] why I like it because you're not limited. When you have many IE's that are manufacturing people, many IE's that are [in] management, who are involved in business. I mean, it's just [that] the sky's the limit. Many companies that—I wanna move to California after I graduate—they're looking for industrial engineers. Because they are. . .so broad on what they do. They can solve problems. They can go into business. They can be management leaders and so forth. And so IE is not limited to just one area. I think whatever you need to get done, IE's can figure out how to do it." (male senior)

In other cases, students described a specific career path, but the aggregation of these comments highlighted the variety of career paths available to an IE major, including academia, business, law, and management.

Discipline Profile

During the interviews, participants were asked the questions, "How would you describe IE?" and "What are the qualities/skills that make a good industrial engineer?" Other questions also resulted in students sharing their perceptions of IE as a discipline. A few students listed sub-disciplines (e.g., ergonomics, operations research, manufacturing). Other responses, however, were more thematic. These responses fell into several categories, detailed below.

Of the 26 students included in the analysis, 14 (54%) described IE as the people-oriented engineering. One student used the phrase "human-based" (male junior) and another said that IE brought "... more of the science and the humanities kind of together ..." (male sophomore). However, different students focused on different interpretations of this theme. One participant explained that IE is about understanding how people work:

"... a lot of things in industrial engineering has to do with people and the way they think and how they perceive stuff and stuff like that." (female junior)

In addition to the emphasis on helping people, participants also mentioned an emphasis on working with people:

"All engineerings involve going out and, at, at some degree, talking to people, gathering information, um, but I think industrial engineering does more of the social interaction with people to get their input ..." (male junior)

In fact, several students said that professional industrial engineers need to be good communicators, especially relative to other engineering disciplines:

"... most of the jobs you're gonna be doing is other people's jobs. You know so, you have to be well communicated with them for them to know what you're expecting from them." (male senior)

Although the sample size was small, it was interesting to note that only 7 of the 15 female participants (47%) mentioned this people-oriented category, as opposed to 7 of the 11 males (64%).

Eleven participants (42%) also described IE as a broad discipline, requiring foundation knowledge in many areas of engineering:

"I mean you can do so many things in IE because basically you learn anything from all the engineering. You learn from mechanical, you learn from aerospace, you may, I mean you take all those classes ..." (female junior)

"I think I like the fact that industrial engineers, we take different courses other than like, mechanical engineers, they only take courses about how to build something. But we take courses from different majors and kind of get them together. Um, so we know a little bit of everything." (female junior)

"To be able to say I have a Bachelor's in Industrial Engineering and that means I have this domain knowledge. I understand supply chains; I understand quality and how to implement quality control efforts; I understand ergonomics; I understand a lot of the problem areas in a production or manufacturing environment ..." (male senior)

This breadth was seen to open many different career paths:

"Many companies ... they're looking for industrial engineers. Because they are, um, so broad on what they do. ... And so IE is not limited to just one area. I think whatever you need to get done, IEs can figure out how to do it." (male senior)

Only one of the six sophomores described IE as broad, presumably because they lacked sufficient experience to consider this a primary characteristic of the discipline.

On a more detailed scale, participants commented on specific attributes of IE as a discipline. For example, seven participants (27%) described IE as systems-oriented:

"... industrial engineers work a higher problem domain. I like to call it top level engineering ... we engineer the whole system." (male senior)

Seven participants (27%) said that IE is about problem-solving and six participants (23%) explained that IE professionals focus on efficiency: "...what we're really doing is making things more efficient and better and optimizing situations" (female junior). In other words, "... other engineers build and we tell them what they did wrong" (female junior) or "... we help re-design what they design" (male senior).

Table 2 below shows the proportion of participants who mentioned each characteristic. The gray shading highlights the categories that have the most notable differences by gender. In a study of computer science majors, Margolis and Fisher calculated that women tend to have a broader range of reasons for their interest in computer science than men do (pp. 51)². However, in our sample of IE majors, the opposite was true. The male participants on average mentioned 3.1 of the themes in the table below, whereas the female participants on average mentioned 1.4 themes.

Table 2: Discipline Profile Perceptions by Gender

	people-oriented	communicators	broad	systems-oriented	problem-solving	efficiency
female (n=15)	47%	7%	33%	13%	7%	20%
male (n=11)	64%	18%	55%	45%	55%	27%
total (n=26)	54%	12%	42%	27%	27%	23%

Discipline Meta-Profile

As part of the interview, students were directly asked "How is IE perceived by others in (and outside of) engineering?" to prompt discussion of discipline meta-profile. Other questions that revealed students' perceptions of others' views of IE include:

- How would you describe IE?
- What are the qualities/skills that make a good industrial engineer?
- How are those around you (family, friends) responding to your decision?

Students' experiences with other people's perceptions of IE fall into three categories: IE is invisible; IE is considered an easier engineering major; and the IE abbreviation is derogatorily interpreted as "imaginary" engineering.

Students perceived the discipline of IE to be invisible. By this they meant that people outside of the discipline were unaware of IE. Five out of 26 (19%) people interviewed expressed this perception. Three of the 11 males (27%) and two of the 15 female (13%) students commented on the invisibility of IE. Two of these five students (40%) acknowledged their own ignorance of the discipline before enrolling in engineering at the university.

"... A lot of people don't know what industrial engineering is, and they're like, well what exactly will you be *doing* once you graduate" (female sophomore)

One student noted that a factor contributing to the invisibility of the discipline is the fact that it is called by several different names.

"... like at (eastern university) they don't even call it industrial. They call it like systems something, ... it is essentially the same thing, but they call it something different ..."
(male sophomore)

While participants expressed the belief that IE is invisible to those in fields outside of engineering, they also thought that other engineers perceive IE as one of the easier disciplines within engineering. Nine of the 26 (35%) interview transcripts analyzed included some reference to the easiness of IE. This meta-perception was expressed by five male students (45%) and five female students (33%).

"... Yeah like the Chem-E's, they make fun of the industrial engineers for being like for stupid I.E., the stupid engineers ... Yeah, so all the Chem-E's that can't handle chemical, they drop to Industrial and they can't handle Industrial they go to business ..." (female junior)

Although there is no clear consensus on why IE is perceived as easier than other engineering disciplines, one speculation is based on the people-oriented nature of the discipline.

"... But I think people think that if you put a personal aspect to it, ... all of a sudden it's just easier because you can talk your way through something ..." (male sophomore)

Beyond simply being perceived as in an easier major, IE students are needled regarding their discipline. Eleven of the 26 (42%) participants reported hearing derogatory terms like *imaginary engineering*, *not-real engineers*, and *stupid engineers* in reference to their discipline. Nearly twice as many female students (53%) as male students (27%) reported this experience.

"... all the other engineers make fun of us. They call us imaginary engineers." (male senior)

"... A lot of people make jokes about, you know, business majors in denial, I think it's, I have the feeling they get that from ... maybe our classes can be a little more business oriented. We don't take so many of the technical, like the technical drawing classes. And things like that. But I think, I would say within the engineering discipline, IE tends to be the butt of the joke." (female sophomore)

Four different sources of this perception were identified by students: relatives, other students in the College of Engineering, company representatives, and faculty from other engineering disciplines. One participant identified his father-in-law as a source of this perception:

"... all they know is that their manager is an industrial engineer and that manager doesn't know squat. That's what my father-in-law has, he's got an industrial engineer that's useless when it comes to actual engineering work. And my father-in-law takes a dim view of the discipline ..." (male senior)

Students in other engineering disciplines also contribute to this perception:

"... I've heard this more at (other university) than here though, they think that IE's just kind of a slough. Like you have the engineers and then you have the IEs and then after that you have business or whatever. They don't regard it as highly ..." (female sophomore)

Company representatives can also play a role in the development of this perception:

"... I haven't done any job fairs here or anything but I have talked to people who have and they're just straight IE majors and that are really, really good students and really smart people ... that have been told by company representatives from large companies 'well, we have our engineers and we then we have our industrial engineers' basically, had been told to take a hike buddy, we don't need your kind, you know?" (male senior)

The most troubling source for this perception was from faculty in other engineering disciplines:

"... Yeah he [faculty member from other engineering discipline] literally said you know first of all you're IE, you're imaginary engineer, you're female, you should just ..., why are you even bothering ..." (female junior)

"... and he [faculty member from other engineering discipline] immediately starts off saying they're [industrial engineering majors] just going to work at McDonald's, that they're not real engineers ..." (female sophomore)

Table 3 below shows the proportion of participants who mentioned each theme. The gray shading highlights the themes that appear to have a difference by gender where the cell size is sufficient.

Table 3: Discipline Meta-Profile Perceptions by Gender

	invisible	easy	imaginary
female(n=15)	13%	33%	53%
male (n=11)	27%	45%	27%
total(n=26)	19%	38%	42%

The student response to the meta-perception of their discipline is mixed. Three of the ten students who mentioned that IE is perceived as an easier engineering discipline agreed with this perception (30%). Two of the eleven students who mentioned the perception that IE is not real engineering agree with this perception (18%) However, the majority of students who reported these perceptions rejected the discipline meta-perception (easy: 6/10, 60%; imaginary: 9/11, 82%). There are two interesting variants of the rejection. The first is the realization that understanding people and systems is different, but not necessarily easier, than understanding mathematical or scientific constructs.

"... I know our classes aren't easier because at first people would transfer their majors thinking or whatever that if they come to IE it'll be easier. We don't take the same courses, but they're just as difficult. Just on another level ..." (female junior)

Another rejection centers around the prediction that IE's will be the manager, or "boss," of other engineers in the workforce.

"... yeah a few people do kind of joke oh you're an imaginary engineer and of course that's when I just say oh I'll laugh all the way to the bank when I'm your boss and you'll cry ..." (female junior)

Conclusions and Future Work

Our interviews of IE majors at OU revealed patterns in the ways that these students perceive IE. After dissecting the verbatim transcripts, we sorted participants' comments into three broad themes: Career Profile, Discipline Profile, and Discipline Meta-Profile. Some of the results were more surprising than others, particularly related to gender differences. The profiles developed from the interviews can be used to inform various communities about IE.

Some of the participants talked about the Career Profile in ways predicted by the literature. For example, the women were more likely to refer to the importance of balance in their lives^{3,5}. Likewise, the male participants mentioned status potential more than the female participants did, although the fact that our male participants were generally farther along the degree-career path may account for some of the difference. The issue most striking to the non-IE members of the research team was the common perception of the variety of career paths made available by an IE degree. We have a sense that IE majors want to design their own jobs just as they would work on aspects of design in an industrial setting.

The Career Profile of IE could be used to focus the marketing of this discipline to potential majors, particularly to those who do not think of themselves as traditional engineers. For example, the potential for advanced professional status could be used to recruit students with interests normally aligned with business degrees. Emphasizing the potential for balancing a career and personal life could attract students pursuing other professions where this balance exists, such as Nursing or Education. The ability to design your own job could appeal to students in inter-disciplinary study programs. Since many of these other disciplines have a higher representation of women students, this type of marketing could improve the gender balance of the discipline as a whole. This observation is consistent with the NSF goal of attracting people from outside the SMET pipeline to these disciplines.

Overall, the IE Discipline Profile described by the participants is, as a field, focused on solving real problems for real people. The literature led us to believe that the "people-oriented" and "systems-oriented" characteristics of the discipline would be disproportionately important to women^{3,6,7}. However, in our sample, the male participants brought up "people-oriented" somewhat more often than the female participants. The difference was even more striking for the "systems-oriented" and "problem-solving" categories. Combined with Margolis and Fisher's findings about computer science students,² we take these results as evidence that the students who select into one field of engineering may be considerably different than the students who select into another field. We will have more data to either confirm or reject this hypothesis when the interviews of other OU engineering majors are completed in 2005.

We have been concerned that the Discipline Meta-Perception component that members of other engineering disciplines think that IE is "not really engineering" might discourage students from pursuing IE. However, IE majors themselves expressed a positive outlook for their futures and

enthusiasm for the discipline as a whole. In fact, the positive perceptions of IE appear to outweigh the needling sufficiently, such that students continue to be attracted to this major, sometimes away from other engineering disciplines. As one student (male sophomore) said, "I think it may be that industrial engineering seems more *inviteful*."

While the Discipline Meta-Perception of IE is not problematic to the students who were retained in this major, it is possible that it may have caused other students to leave IE or to reject IE as a possible major. Of the four sources for this perception that have been found, two are amenable to local change: the attitudes of other students, and the attitude of non-IE faculty within the College of Engineering. While changing attitudes cannot be done quickly or directly, behavior can be directly changed and can lead to a change in attitude in the long term. For example, it is possible that the attitudes of other students are the result of the attitudes of some non-IE faculty within the College of Engineering. The other two sources of this perception (family and industry), while outside local institutional control, could be influenced by improving public relations and education through the professional organization.

Analysis of early data shows clear trends among IE majors regarding many aspects of their chosen major. Some of these trends mirror the expectations developed from earlier studies of other STEM disciplines, while others are somewhat surprising. Further interviews of IE students, at OU and other institutions, as well as students from other engineering disciplines should clarify how these perceptions have contributed to gender parity in IE at OU, making IE "*inviteful*".

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