

A Multi-Institutional Study of Student Perceptions of Industrial Engineering

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Abstract – In a previous paper [1], we described students' perceptions of industrial engineering (IE) as a field, but that analysis was based on 26 interviewees from only one institution. In this paper, we expand that set to 117 students at four institutions and 12 faculty. As part of the interview protocol, we asked participants to describe IE as a field and characteristics of effective IEs, as well as to discuss their perception of what non-IEs think of IE. From the initial and expanded data sets, we have identified attributes that students commonly use to describe the field, such as *people-oriented* and *about efficiency*. We examined the data for gender and institution differences, finding only one consistent difference: men were more likely than women to mention the *status potential* afforded by an IE degree. It was striking that so many aspects of IE that are attractive to women are also appealing to men.

Index Terms – beliefs, gender, industrial engineering, qualitative research

CONTEXT

We have been studying the gender parity achieved by the School of Industrial Engineering at the University of Oklahoma (OU). This parity was striking in comparison to a national proportion of women around one-third and to considerably lower proportions of women in other areas of engineering. Much of the research related to gender in science, technology, engineering, and mathematics (STEM) has tended to focus on failure (i.e., loss of students from these fields) and to combine all STEM fields together. In contrast, we have focused on success rather than failure (gender parity rather than loss) and on one specific discipline (IE) rather than STEM overall. Two factors are emerging as the primary contributors to a high proportion of female majors: attributes of IE as a field and attributes of the department culture in IE at OU. This paper focuses on the attributes of IE as a field contributing specifically to the gender success of IE at OU and to the relative gender success of the discipline more generally.

In a previous paper [1], we described students' perceptions of IE as a field, but that analysis was based on 26 student participants from one institution. In this paper, we expand that set to 117 undergraduates at four institutions and 12 faculty. The increased sample size and representation of multiple institutions allow us to address the question: "Are there differences, by gender or institution, in the ways students describe IE as a field?" The four participating institutions were

large research universities. In addition to OU, the other three institutions were a public university in the southwest (SU), a semi-public university in the east (EU), and a public university in the midwest (MU).

From our early work in this research project, we learned that a substantial proportion of IE majors (53% of 45 interviewees) selected IE as major because characteristics of the degree were appealing [2]. This result continues to underscore the importance of identifying salient characteristics of a field and making those characteristics visible to potential majors and those people who influence students.

Early in our work, we were able to identify and quantify the characteristics most often mentioned by students when they describe IE as a field. From our initial set of 26 interviewees at OU, participants described IE as:

- *people-oriented* (54%),
- a *broad* discipline (42%),
- enabling *status potential* (27%),
- *systems-oriented* (27%),
- about *problem-solving* (27%),
- about *efficiency* (23%), and
- requiring good *communication* skills (12%).

From that early data set we found possible gender differences in the categories *people-oriented*, *status potential*, *systems-oriented*, and *problem-solving*, with male participants mentioning these aspects of IE more than females. In addition, the 26 participants in that early part of our research also described their beliefs about how non-IEs' perceive IE. These comments fell into the following categories:

- *imaginary* (42%)
- *easy* (38%)
- *invisible* (19%)

We found a possible gender difference in the category *imaginary*, with the female participants mentioning this idea more than the males.

It turned out that the participants in our expanded data set of 117 interviewees at four institutions used the same sets of ideas to describe IE, but some of the potential differences seem to have washed out with the larger data set. In addition, the faculty emphasized a somewhat different set of characteristics. In this paper, we present the results from this expanded data set, including a more intricate consideration of gender, institution, and faculty vs. student differences.

METHODOLOGY

The qualitative methods [3] for data collection and analysis in this project were based on methods used successfully in the seminal work by Seymour and Hewitt [4] and in the discipline-specific work by Margolis and Fisher [5]. Specifically we interviewed 117 students (sophomores, juniors, and seniors) at four institutions, asking them questions about their experiences, preferences, and decisions. As this is part of a study of gender in IE at OU, we oversampled for female and OU students. Details about the student participant pool are shown in Table I. In addition, we interviewed 12 faculty at OU.

TABLE I
STUDENT PARTICIPANT DEMOGRAPHICS

	OU	SU	EU	MU	total	percent (of 117)
female	26	15	12	15	68	58%
male	23	6	7	13	49	42%
total	49	21	19	28	117	
percent (of 117)	42%	18%	16%	24%		

Each 60- to 90-minute interview was semi-structured, framed by a specific set of questions, but allowed to flow in directions led by the participant. Audio recordings were transcribed professionally; transcriptions were checked by members of the research team for accuracy and completeness. Using the qualitative analysis software, NVivo™ (<http://www.qsrinternational.com/>), team members read through the transcripts, marking passages with key words called *codes*. To produce an authentic analysis, the codes were developed from student responses rather than from a pre-determined set. Responses that were similar in meaning, as interpreted by the researchers, were marked with the same key words. NVivo allows searches on key words and produces matrices that can then be analyzed for tallies and other patterns.

The interview protocol included questions such as "How would you describe industrial engineering?" and "What are the qualities or skills that make a good industrial engineer?" Responses to these questions obviously contributed to the data set for this paper. However, participants also often described IE as a field in the context of answering other questions; these spontaneous comments were also included in the data set for this paper.

One can surmise that the small number of male students interviewed at SU and EU precludes the use of some statistical analyses such as contingency tables. Thus, instead of *significant differences*, we discuss interesting, substantial, and meaningful differences, or similarities.

RESULTS

This section is divided into two subsections determined by our previous work [1]: *discipline profile* and *discipline meta-profile*. The first is a description of IE as a field as perceived by IE majors and faculty. The latter is a description of what IEs say that non-IEs think about IE as a field.

Discipline Profile

After producing tallies for the ideas participants used to describe IE or IEs, we focused our more detailed analysis on the descriptors mentioned by at least 50% of the student participants from at least one institution. The descriptors in this set, and the detailed proportions by gender and institution, are listed in Table II. The first set of proportions, for the descriptor *people-oriented*, explicitly includes the fractions; the denominators shown here are the same for corresponding cells throughout the table. As this table can be difficult to extract results from, we present relevant bar charts to discuss each descriptor in detail.

TABLE II
PROPORTION OF STUDENT PARTICIPANTS USING SPECIFIC DESCRIPTORS FOR IE OR IES

	OU	SU	EU	MU	total
people-oriented					94/117 = 80%
female	18/26 = 69%	11/15 = 73%	12/12 = 100%	13/15 = 87%	54/68 = 79%
male	16/23 = 70%	5/6 = 83%	6/7 = 86%	13/13 = 100%	40/49 = 82%
total	34/49 = 69%	16/21 = 76%	18/19 = 95%	26/28 = 93%	
efficiency					77%
female	69%	80%	92%	80%	78%
male	70%	83%	100%	69%	76%
total	69%	81%	95%	75%	
business					64%
female	65%	80%	75%	40%	65%
male	74%	50%	43%	62%	63%
total	69%	71%	63%	50%	
breadth					61%
female	58%	67%	50%	73%	62%
male	52%	50%	71%	69%	59%
total	55%	62%	58%	71%	
problem-solving					56%
female	50%	67%	33%	53%	51%
male	52%	100%	100%	38%	61%
total	51%	76%	58%	46%	
communicators					51%
female	31%	80%	67%	67%	56%
male	30%	67%	43%	62%	45%
total	31%	76%	58%	64%	
systems-oriented					49%
female	58%	60%	50%	27%	50%
male	52%	50%	29%	46%	47%
total	55%	57%	42%	36%	
status potential					47%
female	27%	40%	67%	40%	40%
male	57%	67%	57%	54%	57%
total	41%	48%	63%	46%	

People-oriented was the most mentioned descriptor of IE, with 80% of the student participants using some variant of this idea. Figure 1 shows the distribution for this descriptor broken down by institution and gender. This descriptor was the most common even disaggregating by gender (79% of the female student participants, 82% of the males). We note that a substantially higher proportion of student participants used this descriptor at EU and MU (95% and 93%) compared to OU (69%). Looking more closely at institution responses, however, we see that *people-oriented* was the top descriptor

only for MU, because the other three institutions each had at least one other descriptor tied for most-mentioned or mentioned more often. At OU, there was not a noticeable gender difference in the proportions of student participants who described IE as *people-oriented* (69% and 70%). We do observe a gender by institution difference in the use of this descriptor by all 12 of the female student participants at EU and all 13 of the male student participants at MU.

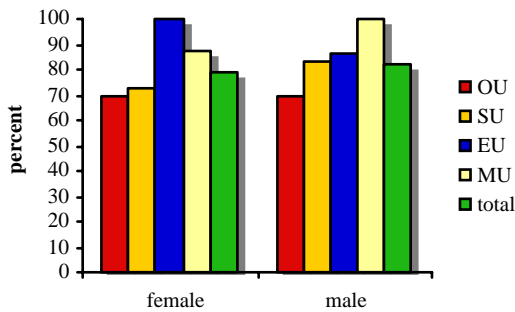


Figure 1
PERCENT OF STUDENT PARTICIPANTS WHO DESCRIBED IE AS PEOPLE-ORIENTED.

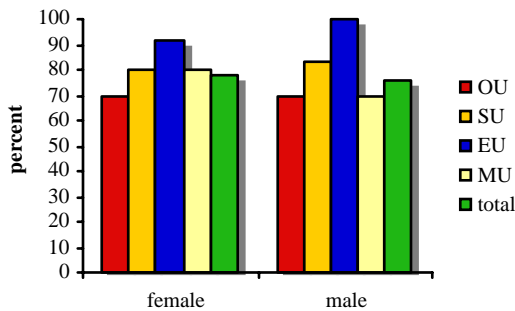


Figure 2
PERCENT OF STUDENT PARTICIPANTS WHO DESCRIBED IE AS BEING ABOUT EFFICIENCY.

In the aggregate, 77% of the participants described IE as being about *efficiency*. The detailed distribution for this descriptor is shown in Figure 2. Disaggregated by gender only, there was no noticeable difference in the use of *efficiency* as a descriptor (78% of the female student participants, 76% of the males). As with *people-oriented*, EU had the highest proportion of student participants using this descriptor, 95%, and OU had the lowest, 69%. Also of note, SU was the only one of the four institutions at which participants used *efficiency* as a descriptor more often than they used *people-oriented* (81% vs. 76%). *Efficiency* was mentioned least by female and male student participants at OU (69% and 70%), as well as by the males at MU (69%); in contrast, it was mentioned by all 7 of the males at EU.

IE was related to *business* by 64% of the participants, some of whom described IE as a cross between engineering

and business. In the aggregate, there were not noticeable gender differences (65% females, 63% males). Figure 3 indicates that this descriptor was offered the most by the female student participants at SU and EU (80% and 75%) and the least by the females at MU and the males at EU (40% and 43%). This observation brings to attention a substantial gender difference at EU, with 32% more women mentioning the *business* aspects of IE. A similar gender difference of 30% appears in the SU tallies. A gender difference in the other direction exists in the MU data, with 22% more males using this descriptor.

Student participants also described IE as a *broad* field (61%), encompassing many ideas and sub-disciplines and requiring foundation knowledge in many areas of engineering. This descriptor had the lowest institution spread, with a high of 71% of the MU student participants vs. a low of 55% from OU mentioning *breadth*. As evident from Figure 4, this aspect of IE was mentioned the most by the female and male student participants at MU (73% and 69%), as well as by the females at SU (67%) and the males at EU (71%). In fact, SU and EU appear to have moderate gender differences opposite from each other.

The descriptor *problem-solving* was mentioned most by student participants at SU (76%) and least by MU (46%). This particular descriptor also has a noticeable gender difference in the aggregate: 10% more men than women overall described IE as related to *problem-solving*. Looking more carefully at the gender by institution proportions, as conspicuous in Figure 5, we note that the all 13 male student participants combined at SU and EU used this descriptor; in contrast, only 67% and 33% of the females at these two institutions referred to IE this way. At MU, on the other hand, 15% more females described IE as about *problem-solving*. As above, there was not a noticeable gender difference with OU student participants.

In describing what characteristics or skills make a good IE, 51% of the student participants said *communication* skills. This descriptor had the largest institution spread, offered by 76% of the students participants at SU vs. only 31% at OU. This descriptor also had a moderate aggregated gender difference, with 11% more female than male student participants mentioning this idea. In fact, Figure 6 indicates that across all four institutions, a higher proportion of females than males referred to IEs as good *communicators*; this difference ranged from 1% at OU to 24% at EU.

Slightly less than half of the student participants (49%) described IE as *systems-oriented*. Evident in Figure 7 is another gender by institution difference: this descriptor was mentioned the most by female student participants at SU (60%, vs. 50% males) but least by female student participants at MU (27%, vs. 46% males) and the males at EU (29%, vs. 50% females).

The most striking gender difference occurred with the descriptor *status potential*. Student participants used words like "boss" and "management" to indicate their perception that IEs tend to move into high-status roles. In the aggregate, 47% of the student participants described IE or IEs using such words. Disaggregating by gender only, we find that only 40%

of the females discussed these ideas whereas 57% of the males did, despite a noticeably higher proportion of women at EU who mentioned this aspect of IE. This gender difference was consistent at three of the four institutions, including OU, but was reversed at EU.

The faculty participants used a similar set of descriptors.

However, they were more inclined to emphasize *efficiency*, *breadth*, and *problem-solving* (11/12, 92%, each). In addition, 11 of the 12 faculty participants (92%) noted the central role of mathematics or statistics, which very few student participants brought up.

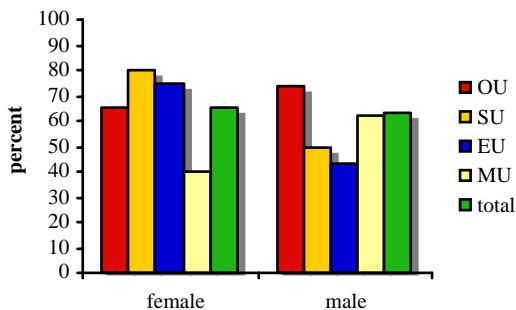


Figure 3

PERCENT OF STUDENT PARTICIPANTS WHO DESCRIBED IE AS RELATED TO BUSINESS.

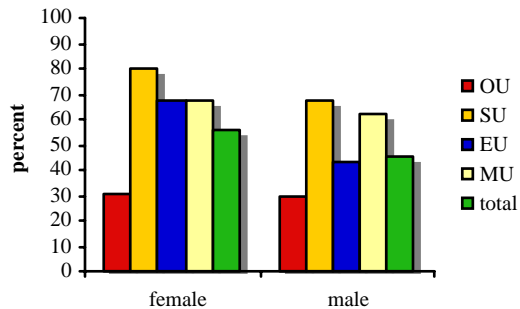


Figure 6

PERCENT OF STUDENT PARTICIPANTS WHO DESCRIBED IES AS BEING GOOD COMMUNICATORS.

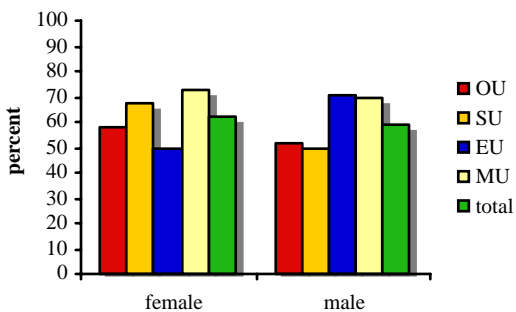


Figure 4

PERCENT OF STUDENT PARTICIPANTS WHO DESCRIBED IE AS BROAD.

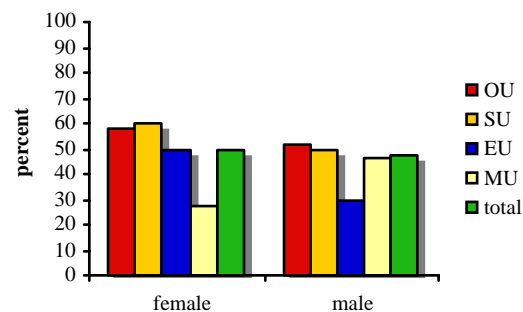


Figure 7

PERCENT OF STUDENT PARTICIPANTS WHO DESCRIBED IES AS SYSTEMS-ORIENTED.

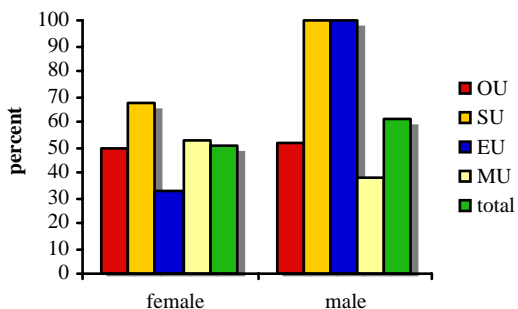


Figure 5

PERCENT OF STUDENT PARTICIPANTS WHO DESCRIBED IE AS ABOUT PROBLEM-SOLVING.

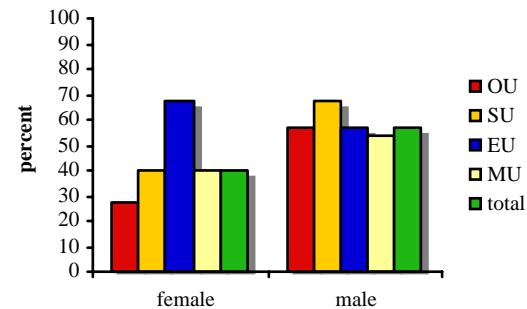


Figure 8

PERCENT OF STUDENT PARTICIPANTS WHO DESCRIBED IES AS HAVING STATUS POTENTIAL.

Discipline Meta-Profile

This section is about perceptions of perceptions. That is, we asked student participants what non-IEs think of IE. Thus our results here are a report of our participants' perceptions of how non-IEs perceive IE. To capture the idea of these meta-perceptions, we chose the phrase *meta-profile*.

TABLE III
PROPORTION OF STUDENT PARTICIPANTS DESCRIBING WHAT THEY HAVE HEARD NON-IEs SAY ABOUT IE

	OU	SU	EU	MU	total
easy					68%
female	54%	87%	75%	60%	66%
male	61%	83%	86%	77%	71%
total	57%	86%	79%	68%	
invisible					60%
female	23%	80%	67%	73%	54%
male	43%	100%	86%	85%	67%
total	33%	86%	74%	79%	
imaginary					52%
female	54%	53%	58%	53%	54%
male	43%	83%	86%	23%	49%
total	49%	62%	68%	39%	

The most common meta-perception brought up by our student participants (68%) was that non-IEs think IE is the *easy* engineering. Our participants resisted this characterization by pointing out that they complete much of the same coursework as students in other areas of engineering. We see a substantial institutional difference in proportions, with 57% of the OU student participants mentioning this idea vs. 86% of the SU student participants. Aggregating by gender, we do not see a substantial difference (66% of the females vs. 71% of the males). However, from Figure 9, we note that at all institutions except SU, this idea was mentioned by a higher proportion of males than females, and by a considerable margin at both EU and MU (11% and 17%).

One reason suggested by some student participants for the perception that IE is easy is that people outside of IE – including faculty, students, employers, and family members – are unaware of or do not understand what IE is or what IEs do. Some of our participants acknowledged their own earlier ignorance of the discipline. We labeled this category *invisible*, meaning that IE is not yet detected as much as other areas of engineering. An aggregate of 60% of the student participants made comments that we classified in this category. What is striking about Figure 10 is that we originally constructed this category from interviews at OU, but student participants at the other three institutions mentioned these ideas in much higher proportions than the OU students did (86%, 74%, 79% vs. 33%). It is also noteworthy that the male student participants at all four institutions described this phenomenon in substantially higher proportions than the females did, yielding a 67% male vs. 54% female aggregated difference.

Of course the IE majors in our study had heard IE referred to as *imaginary engineering*, but only 52% of the student participants mentioned this repartee. In the aggregate, there does not appear to be much of a gender difference, but the interesting aspects of the gender proportions are more conspicuous in Figure 11. We note that institutional spread for

females was only 5%, ranging from 53% to 58%. For men, however, the institutional spread was substantial, with only 23% of the MU male student participants mentioning this phrase compared to 86% of the EU males. In fact, 11 of the 13 male student participants at SU and EU discussed this phrase.

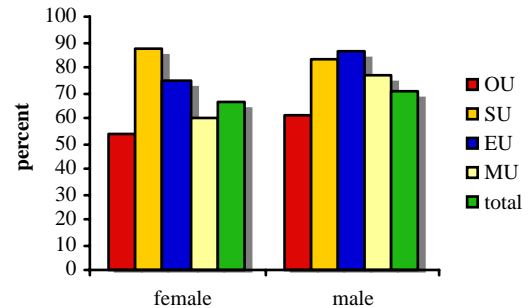


Figure 9
PERCENT OF STUDENT PARTICIPANTS WHO SAID NON-IEs DESCRIBE IE AS EASY.

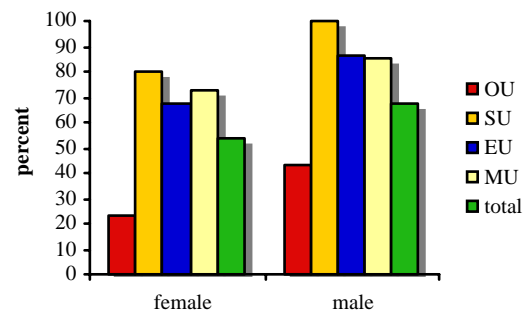


Figure 10
PERCENT OF STUDENT PARTICIPANTS WHO INDICATED THAT IE IS INVISIBLE.

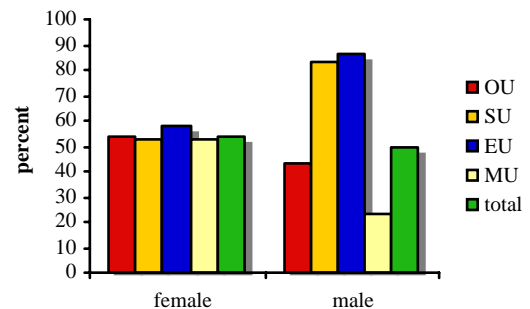


Figure 11
PERCENT OF STUDENT PARTICIPANTS WHO SAID NON-IEs DESCRIBE IE AS IMAGINARY ENGINEERING.

DISCUSSION

It appears that increasing sample size by aggregating across groups can help identify possible patterns. However, our analysis here indicates that detailed information about specific groups (by gender and/or institution) might be lost by aggregating. For these reasons, we reported our data here in aggregate and with details included.

Almost doubling the sample size at OU had two effects that surprised us. First, each of the descriptors for IE identified in our early analysis were mentioned by even higher proportions of participants in the expanded sample. Second, all but one (*status potential*) of the possible gender differences identified in the initial sample were washed out in the expanded sample. It is important to note that, with a smaller sample, the responses of any individual participant have a greater impact on calculated proportions; thus, apparent differences may be the result of only one student in each gender. This observation is relevant when considering the results reported here about SU, EU, and MU.

Another relevant observation from the OU data was the match – and the mismatch – between student and faculty descriptions. To some extent, there was consistency between the two groups, as might be expected. There were differences, however, the strongest of which was the degree to which the faculty emphasized the mathematical or statistical aspects of IE whereas the students hardly mentioned this attribute.

Student participants from all four institutions described IE as being *people-oriented* and about *efficiency*, a finding that is not particularly surprising. From our own experiences and prior work, we did not anticipate the high proportion of students who mentioned *business* and the unexpectedly low proportion of participants who mentioned *systems-oriented*.

Based on the literature, the salience for women of the people-oriented nature of IE was not surprising. It is interesting to note, however, the high proportions of male participants in the prior paper [1] and in this extended sample, both in the gender proportions aggregated across institutions and at each of the four individual institutions. Therefore, the *people-oriented* nature of IE can be interpreted as a positive attribute of the field for both genders. More generally, attributes of a field that are attractive to women are not necessarily unappealing to men.

In our previous paper about IE as a field [1], from a sample of 26 IE majors at OU, we identified possible gender differences in the categories *people-oriented*, *status potential*, *systems-oriented*, and *problem-solving*, all mentioned by a higher proportion of males than females. The only one of these categories that sustained a substantial gender difference with the expanded sample of IE majors at OU was *status potential*, which continued to be mentioned by a higher proportion of males. In fact, this difference was substantial in the gender proportions aggregated across institutions (17% difference), and in gender proportions for three of the four institutions in the expanded sample (differences ranging from 14% at MU to 30% at OU). These results make *status potential* one of the two categories with the most substantial, consistent, and thus

likely to be meaningful, gender difference. There is a noteworthy reversal in which the female participants at EU mentioned this more than the males (by 10%), with the caveat that the sample of males was small ($n = 7$).

The other category that showed a substantial and consistent gender difference was participants' perceptions that non-IEs are unaware of IE as a field, which we labeled *invisible*. Higher proportions of male participants discussed this aspect in the aggregate and at all four institutions.

The literature points to aspects of IE that are likely to be appealing to women (e.g., [4], [5]). Our research indicates that these aspects are also appealing to men. We believe that most disciplines have characteristics that would appeal to diverse populations but for whatever reason only certain aspects get emphasized, limiting the appeal. For example, if IE as a discipline primarily emphasized its *status potential* characteristic, thus hiding aspects that are more appealing to women, the field might be less attractive to women. However, IE has emphasized a variety of characteristics, among them *status potential* but also *people-oriented* and *efficiency*, that accordingly appeal to a diverse population, including men. If other disciplines would similarly identify a variety of salient characteristics, and market those characteristics, then each might be able to be attractive to a wider diversity of students.

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