Industrial Engineering Student Perceptions of Computer Science, Computer Engineering, and Electrical Engineering

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Abstract - **During a NSF funded (HRD-0225228) study of gender parity in the School of Industrial Engineering (IE) at the University of Oklahoma, IE students' responses to questions about courses, experiences with faculty, and computers were noted. Over half of the students (21 out of 41) interviewed commented about Computer Science (CS), Computer Engineering (CE), or Electrical Engineering. Student responses fell into three categories: perceptions of the disciplines (12), perceptions of the departments (7), and perceptions of programming courses (15). IE students perceived these disciplines as intangible, populated by cubicle dwellers, limited, and lucrative. These disciplines need to better communicate their professional context. Perceptions of the departments came mostly from former CE majors who felt unwelcome there. Of the 30 students who had taken the programming course, 4 students enjoyed it and 11 students disliked it. The absence of an accepted pedagogy for beginning programming classes is felt by these students.**

Index Terms – computer science, computer engineering, electrical engineering, and programming.

INTRODUCTION AND RELATED WORK

The University of Oklahoma's School of Industrial Engineering (IE) achieved gender parity during 2001 (58% of enrolled IE majors were female). This achievement occurred organically, not as a result of a deliberate or funded effort. In 2002, a research team was assembled to identify the elements leading to this desirable result that can be replicated at other Schools at OU and in other institutions. In order to make meaningful comparisons, students from a variety of disciplines at OU (Chemical Engineering, Computer Science, Electrical Engineering, Computer Engineering, and Physics) and Industrial Engineering departments at three other institutions are being interviewed during 2004-2005. Some IE students at OU were repeatedly interviewed to gain longitudinal data.

The ethnographic research model, similar to that used by Seymour and Hewitt [1] and Margolis and Fisher [2], focuses on quantitative and qualitative analysis of interviews of research participants. Supporting quantitative data available from Institutional Research and other sources is also used. Leydens surveyed methods for this type of qualitative research [3]. The research is ongoing, and has already produced valuable insights about the IE department's attributes that are attracting and retaining female students, including recognizing the importance of high quality interactions with faculty during office hours [4], recruiting and retention strategies [5], and the student friendly culture of the department [6]. The factors identified to date potentially benefit all students, although they likely have a disproportionate impact on female students.

These interviews open the students' views of their experiences within the College and the University to analysis by the research team. In addition to insights aligned with the original research direction, this analysis has developed other themes for exploration. For example, the research team noted that many students had interesting perceptions and misconceptions of Computer Science (CS), Computer Engineering (CE), and Electrical Engineering (EE). These perceptions provide us with a unique opportunity to see these disciplines from an outsider's view.

METHODOLOGY

During 2003, we interviewed 41 students (23 female, 18 male) majoring in Industrial Engineering at the University of Oklahoma using a semi-structured interview protocol. Interviews were typically between 1 and 2 hours long. The interview protocol included the questions below, among others. Additional probes were selected by the interviewer to solicit information relevant to the original research question.

- What was your favorite (least favorite) course?
- What was your best (worst) experience with a faculty member?
- What are your experiences with computers?

These interviews were recorded, transcribed, and coded into approximately 200 categories using NVivo qualitative analysis software. Both the transcription and the coding were verified to ensure accuracy. NVivo allows researchers to perform searches based on keywords, as well as coded categories.

During the processing of transcripts, the research team noted that many students were discussing CS, CE, and EE. No questions about these fields had been included in the research protocol. A search of the full document set was performed which identified any question/response pairs that used "computer", "programming", or "software" or were coded into the categories: computer, computer programming, computer applications, computer games, computer hardware, or undergraduate classes in the College of Engineering. The

result of this search was culled, analyzed and categorized producing the observations below.

RESULTS

Approximately half of the students (21 out of 41) interviewed during 2003 made comments related to CS, CE, or EE. The results fell into three broad categories: perceptions of the disciplines, perceptions of the individual departments, and perceptions of introductory programming courses. Table I correlates the student's original major with whether or not they spontaneously commented on these disciplines, departments, and the required, introductory programming class. The table shows that 9 of the 21 students making comments started as CS, CE, or EE majors. Also, students who had majored in CS, CE, or EE were more likely to make comments on these categories (9 out of 10) than students who had not majored in these disciplines (12 out of 31).

TABLE I
NUMBER OF PARTICIPANTS COMMENTING ON THESE DISCIPLINES BY ORIGINAL MAJOR

Original Major at OU	CS/CE/EE	IE	Other
Made Comments	9	9	3
No Comments	1	12	7

The following conventions are used in reporting the interview data. **I:** indicates questions asked by the interviewer. **P:** indicates a participant's response. Quotes without a prefix are student responses. Words in square brackets are editorial additions that improve the readability or clarity of the quote. Words are placed in parentheses to indicate that the transcriber and reviewer were uncertain about the accuracy of the transcription. At the end of each quote is the gender and academic year of the student.

I. Perceptions of the Disciplines

Twelve out of 21 students who made comments talked about their perception of CS, CE, or EE as disciplines. Of these twelve students, seven had majored in CS, CE, or EE. Two students were CS minors, including one student who had originally majored in CE.

CS: Comments reveal that students don't have an accurate understanding of a career in CS. Two students reported that CS is intangible.

> *I didn't want to be in physics or you know computer science. I wanted something that was real and that allowed me to produce things, to produce things and you know make money. (male, alumni)*

The student below, a CS minor, referred to CS as "black magic" and added:

> *I want to solve problems, and I did the CS minor [IE with the IT option] because I wanted to have that tool available to me…but I didn't want to be a CS major because all those guys learn about is tweaking algorithms for efficiency and discrete mathematics and it's all very heavy in theory. And what they miss out on is how to actually use computers to solve problems. (male, senior)*

The daily work environment of Computer Scientists was also misunderstood. Four students described CS jobs as programming in an isolated cubicle. While there are some CS jobs in this environment, CS is not the only field where people work on computers all day.

> *Well, I don't think I mind doing designs and everything it's not like sitting in front of the computer and writing a … program code. Because that's what I would be doing if I was a CS major. (female, junior)*
>
> *I enjoyed it [introduction to programming class] and I think it's interesting as far as the logic to follow it and get something done at the end. But I don't think I ever want to be interested in doing that. It's kind of an isolationist kind of thing you know, all day on the computer. (female, junior)*

One student didn't want to spend the rest of her life working on computers.

Two students perceived that CS skills and careers are lucrative.

> *I understand a lot of the problem areas in a production or manufacturing environment and I can program, which a lot of IEs can't. And that makes me able to lead a team of programmers to design a database system or whatever that will solve X production problems. (male, senior)*

CE and EE: Just like CS, students don't have an accurate understanding of the CE discipline or professional context.

One student had never heard of computer engineering, although she did know about computer science. A second student viewed the CE careers as hardware oriented and cubicle work. A third student saw more limited career options with a degree in CE than with a degree from IE. This student thought that CE was too cut and dried:

> *[In IE] you have to be able to look at things in different ways. There is not necessarily one solution for every problem. Like in computer engineering there is pretty much one good way to do things… There is one equation. Use this equation to solve this problem. (female, junior)*

As with computer science, two students reported that computer engineering was intangible.

> *[IE is] very realistic compared to computer engineering, [CE is] totally things that you cannot see. You can't see, I don't know, electrons or something. (female, senior)*

CE was also seen as lucrative by two students. Both students reported strong parental support for their intended CE major, although both subsequently left CE for IE.

One student reported that his father had bragged that:

'My son is going to be a computer engineer', and it [the CE major] has just been hell and I had to go [leave the CE major]. (male, senior)

Another student talks about her mother's reaction to her switch from CE to IE:

> *She was really mad… She's like, 'How much money are you gonna make?' … I was like 'you make, we*

make less than a computer engineer would make'… She was very mad, she was very upset that I switched. (female, senior)

Just as students eschewed CS majors because they don't want to program all day, the connection with programming tainted CE for two students. One thought that CE was a hard major because programming is involved. The other perceived that programming created a gender bias within CE.

CE is basically math and programming and you always hear that guys are better at that kind of thing than girls are. (female, junior)

One student perceived EE and CE to be prestigious, even among engineering majors. Of the 41 students, this was the only comment regarding EE as a discipline.

II. Perceptions of the Departments

At the University of Oklahoma, CS is an independent unit within the College of Engineering. The CE and EE majors reside in the School of Electrical and Computer Engineering.

Seven of the 41 students commented on the CS, CE, and EE departments. It is not surprising that so many IE students discussed issues with the CS, CE, and EE departments. Ten of our participants had once been majors in these departments, as summarized in Table II. In fact, five of the seven students making comments in this category were former majors in CE, or EE. One student commenting on these departments was a CS minor. The other student had always majored in IE. The female students may be more likely to comment on a previous department (2 out of 3) than the male students (3 out of 7), although the small sample size weakens this conclusion.

TABLE II
NUMBER OF PARTICIPANTS WHO PREVIOUSLY MAJORED IN A GIVEN DISCIPLINE, BROKEN DOWN BY GENDER

Discipline	Majored in discipline	Making comments
CS	1 female	0
CE	2 female, 4 male	2 female, 1 male
EE	3 male	2 male

It is important to remember when reading the comments about these departments that many of them are coming from students who were sufficiently dissatisfied with their major to attrite. Some of the attrition from CS, CE, and EE is the result of these Schools having stricter enrollment management policies than the remainder of the College of Engineering. For example, to take upper division courses in CS, CE, and EE students must have a 2.8 GPA when their lower division course work is complete. In IE, the GPA requirement is 2.0.

CS: Only two students commented on the CS department. One perceived that many IE majors have dropped out of CS, although this observation did not prove to be true in our sample of the department. The other student said that he has a "variety of issues with CS faculty", although he is a CS minor. He attributes enjoyment of the classes to his interest in the subject matter, in spite of the faculty.

CE and EE: Five students reported having difficulty relating to faculty in CE and EE. A lack of rapport between faculty and students was reported by four students. One of these students also reported that there was no interaction between faculty and students outside of the classroom.

[The CE faculty] didn't really show interest in the students… When you're just another number in a classroom, you don't feel like you really want to work…. My advisor for IE versus my advisor in CE was day and night. Because, when you walk into the room, first they [IE faculty] know your name, and second they know exactly where you are in your curriculum and with that they can help you out…And in computer engineering you had a different advisor every semester, I was just another student. (female, senior)

A similar observation was made by a second student:

I never really liked most of the electrical engineering professors… a lot of them are kinda cold in a way with you. You know, [students should] just go do your stuff and leave me [the EE faculty member] alone. (male, senior)

The environment within the classroom was also discussed in two different contexts by a student who was a CE major at the time of the experience. In an EE class she didn't like the nature of the interaction between a fellow student and a faculty member. The fellow student was ridiculed by other students in the class and the faculty member for asking questions they judged to be stupid. In a more general complaint about the ECE faculty, she commented:

You ask a question and …they [ECE faculty] are so high up there and on the higher order of thinking and you have someone who is just now taking this class and they don't understand, you know it's like 'Hello! One day before you [the faculty member] were that student and you didn't grasp it that well'. (female, senior)

In addition to problems interacting with the faculty, one female student reported difficulties interacting with the male students in the discipline:

Computer engineering is pretty much all guys… I think that they [male CE students] thought that we weren't as smart as they were because we were girls. Or they thought we would just sit there and be pretty or something (female, junior)

A male student also reported difficulty communicating with other CE majors.

III. Perceptions of Introductory Programming Courses

Fifteen out of 41 students discussed the introductory programming course: CS 1323 Introduction to Computer Programming. This Java programming course is the first course for CS majors, as well as a service course for IE, CE, and EE. The course prerequisite is high school algebra. Students in the course have a wide range of backgrounds. Some students have programmed for years, while others have only rudimentary computer skills.

Of the 15 students who made comments about CS 1323, only four were positive. The remaining 11 students made negative comments. The percentage of students who pass the

course, however, is not radically worse (outside of 2002) than other beginning courses in STEM disciplines taken by IE students. Table III shows the percentage of IE students who get a passing (A, B, or C) grade out of those who received a grade (A, B, C, D, F, W (for withdrew), I (for incomplete)) in four introductory courses taken by IE majors from 2000-2003. The numbers in parentheses are the number of IE students who received a grade in the class. Table IV shows similar data across the College of Engineering.

TABLE III
PERCENT OF IE STUDENTS WITH PASSING GRADES IN I NTRODUCTORY COURSES

Course	2000	2001	2002	2003
CS	100 (5)	80 (31)	51 (36)	65 (38)
Chemistry	64 (25)	77 (22)	85 (21)	88 (17)
Physics	71 (35)	87 (24)	81 (22)	81 (32)
Calculus	60 (15)	57 (21)	61 (21)	63 (22)

TABLE IV
PERCENT OF ENGINEERING STUDENTS WITH PASSING GRADES IN INTRODUCTORY COURSES

Course	2000	2001	2002	2003
CS	72 (312)	66 (296)	58 (291)	59 (259)
Chemistry	77 (546)	76 (559)	81 (436)	81 (502)
Physics	80 (448)	89 (378)	81 (436)	79 (430)
Calculus	55 (518)	55 (510)	48 (566)	53 (539)

Tables III and IV show that the rate of IE students passing these critical introductory courses is approximately equal to the overall pass rate for the College of Engineering. This is important because if IE students failed the introductory programming course more often than other CoE students, their animosity towards the class might be unrepresentative of the population as a whole.

In the introductory CS course, the pass rates between IE students and the CoE are similar (although fluctuating). In 2000, IE students did substantially better than the CoE. In 2000, the School of IE did not require CS 1323 in its curriculum. Therefore the students who chose to take the course were probably both more interested in CS, and more experienced with computers. The disparity in pass rates (72% versus 100%) can also be a small sample anomaly since only 5 IE students took CS 1323 in 2000. Since the requirement for CS 1323 was implemented in 2001, the difference between the number of IE students and the CoE students passing the course has fluctuated (+14%, -7%, +6%), but has not been radically different, on average.

An additional pattern that is visible in Table III and Table IV is that generally more students are failing the introductory CS class than the introductory chemistry and physics classes. The pass rates in calculus are somewhat lower than those in the introductory programming course, both for IE students and for the College of Engineering as a whole.

Out of the 41 students in our sample, 30 students have a grade recorded on their academic transcript for CS 1323. Although CS 1323 is a required class in IE, some students have transferred the class from another institution, and some had not taken this class at the time of their interview. The breakdown of grades for the students who had taken this class at OU is shown in Table V.

TABLE V
GRADE DISTRIBUTION IN CS 1323 FOR OUR PARTICIPANTS

	A	B	C	D	F	AU	W	I
Female	2	6	2	2	0	1	1	0
Male	6	6	2	1	0	1	0	0
Total	8	12	4	3	0	2	1	0

Of the six students who did not pass the class (D, F, AU (for audit), or W (for withdrew)), one made a positive comment, two made negative comments, and three made no comments. The bulk of the negative comments were not made by students who failed the course.

Four students enjoyed the introductory programming course. Two students attributed some of this to the instructor. Two students commented that they would like to continue to take additional CS courses.

I considered taking more [computer science] classes just because I wanted to learn more (female, sophomore)

Another student commented in general that he liked CS courses, although he did not specifically mention the introductory programming course. This student has a minor in CS.

Eleven students discussed their dislike of the beginning programming class specifically. In addition to a general agreement that beginning programming classes are extremely difficult, students observed that (the number of students making the observation is in parentheses):

- prior programming experience should be required (3)
- this course is perceived to be a "weed out" class (3)
- the instructors were difficult to understand (2)
- students generally disliked programming (2)
- the book was difficult to understand (1)
- the instructors were disliked (1)
- the classes were too large (1)
- the class covered an excessive amount of material (1)
- cheating is common place (1)
- CS should not be taught outside of a laboratory setting (1), and
- the tests were too difficult, requiring large curves (1).

The student quotes below indicate how passionately some students dislike the beginning programming class.

I: Any more Java?
P: No, thank god. (male, sophomore)

A second student had a long list of complaints:

[Java I] is not a beginning class really. I think OU is making a big mistake that they don't have introductory computer science classes before they go into Java… Someone who has little or no programming experience prior to that has no clue what's going on. I had no clue what was going on. A lot of the juniors would leave engineering because of that class. …The people who do well [in Java I] are the students who spend most of their lives on computers in the high school… it's not fair to the other people who are good with math and science

and other fields but have to, are held back because of this one course… The rate of academic misconduct in that class is very high. Not because people are [too] lazy to try to do it, they just cannot get it…Not even maybe a fourth of the students know what's going on… A lot of them just get help from their friends…I think they [the College of Engineering] do it to minimize the number of engineering students. I know some students who were 4.0 students in high school, which are bright and getting like As in all their classes, and then they come take Java and they fail it and it's discouraging. …90% of the students who take Java cheat to pass the class. 90% of the projects are either copied or they're given, done by someone they knew or they paid someone [to write their programming projects]. (male, senior)

A third student was more succinct:

But whenever somebody says, 'Hey, I need you to program this, it's just like Java.' I'm like, 'I don't know Java! Don't talk to me about Java.' I think if I tried to learn another programming language, I could be fine. (female, senior)

While three students reported that the course needed a prerequisite, one student who had high school programming experience including object-oriented programming in C++, still disliked Java and thought the class was hard.

Two students reported that they did not learn enough in the first programming course to be successful in the second one, which is required for CS minors and CE majors. An additional student commented that the second Java programming course caused him to attrite from the CE major.

Three students commented that the requirement of CS 1323 for IE majors caused people to attrite from the College of Engineering. One reason for this perception is a college-wide enrollment management rule that students must pass all courses required for their major in their first three attempts. The fact that the Java course was not a prerequisite for other courses in IE may be adding to the students' frustration since it makes the course appear to be unnecessary.

One student thought that IE majors shouldn't be required to learn programming. This student mentioned his disdain for the programming class in response to three separate questions.

ANALYSIS

I. Perceptions of the Disciplines

The fact that so many IE students have misconceptions of the CS, CE, and EE disciplines is an indication that these disciplines and departments are not successfully communicating their professional context to undergraduate students. Since seven of the 12 students expressing misperceptions of these disciplines once majored in one of these fields, the communication problems persist both inside and outside of the major.

The fact that students equate CS with programming has been observed by Long et. al. [7], among others. This would be similar to having students equate mathematics exclusively with algebra. An introductory computer science course which emphasized breadth instead of programming might give students an opportunity to see the discipline more realistically. Improving the perception of computing is a problem of such importance that it was recently listed as one of the grand challenges in computing education [8].

An interesting contrast to the student perceptions of CS, CE, and EE is the student perceptions of IE [9]. Unlike the CS, CE, and EE out-switchers with ill-conceived visions of what it means to be a professional within their original disciplines, students who persist in IE express considerable knowledge of the opportunities available within that discipline. Having a well-conceived, accurate understanding of a discipline may be significant in the retention of students in general and female students in particular [10], and is an area of future investigation.

Recently, the College of Engineering implemented a required introductory course that includes a survey of each major within the College. It is hoped that this course will help our students see these disciplines in a more accurate perspective.

II. Perceptions of the Departments

The chilly climate [11] of the CS, CE, and EE departments reported by students aligns with the description of culture of STEM disciplines given by out-switchers in both Seymour and Hewitt [1] and the culture of CS at Carnegie Mellon University as described by Margolis and Fisher [2]. This culture is radically different than the open and friendly culture of the IE department in which these students currently major [6]. Having a learning environment where they feel invited and welcome has a disproportionate impact on underrepresented groups, females in particular [1, 12].

When reviewing the student comments, it should be remembered that they were made, almost exclusively, by out-switchers from CS, CE, and EE. Some of these students were attrited by enrollment management policies put in place to keep the CS, CE and EE schools from being overrun with students during the dot com boom. The perceptions of attrited students may not be representative, although they also should not be dismissed.

III. Perceptions of the Introductory Programming Courses

The dislike of the introductory programming courses is also not unexpected. Introductory CS classes are reported to have high failure rates [13]. Controversy about the pedagogy of beginning programming is widespread. For example, the ACM 2002 curriculum lists six possible options for teaching a beginning CS class [14]. The passion with which proponents of these options defend their preference can approach religious zealotry, as can be seen in the abstract of Astrachan's recent SIGCSE paper [15] where he informs readers (perhaps in jest) that he will be serving as moderator of the panel discussion to "ensure that the debate remains civil". Introductory classes are one place where CS clearly does not have its house in order. CS pays a price for this disorder. Our data shows that other majors also pay a price.

The litany of problems that these students report shows another example of an issue that our research group first discussed in 2004 [16]: student dissatisfaction with courses that serve both as service courses for non-majors and foundation courses for majors. It is not uncommon to hear CS students complain that the course that IE students and former CE and EE majors find too difficult is too easy. It is not surprising that faculty who must choose between the interests of non-majors and majors would consciously or unconsciously favor their own majors at the expense of the non-majors. The diversity of student backgrounds and interests also makes such courses difficult to teach.

The OU School of Computer Science offers an introductory programming course for non-majors. No prerequisite relationship exists between the non-majors and majors course. IE, and CE require their students take the more challenging course for majors. The programming requirements for EE majors have recently been reduced to the non-majors course. Given the student response to the majors course, IE may want to consider following in EE's footsteps.

In the summer of 2005, OU will be offering a summer bridge program to at-risk students that will focus on calculus and computer programming, instead of the more common combination of calculus and physics. If this program is successful, it may be made available to other student populations in the future.

CONCLUSIONS AND FUTURE WORK

The outsiders' viewpoint revealed in our data shows that CS, CE, and EE are not communicating effectively in two dimensions. First, they are failing to communicate the professional identity within the major. Second, they are failing to communicate caring attitudes to some of their students. In addition, the introductory programming course is not appealing to many non-CS majors.

CS, CE, and EE are disciplines where students can have a bright future solving the concrete problems of a technological society. However, students will only have this opportunity if they are not driven out of the discipline by inadequate initiation into the profession, or by non-encouraging and unsupportive faculty. Socialization into the field needs to be accomplished early in students' academic careers to give them the incentive to endure the rigors of the challenging courses that populate these disciplines.

Introductory courses can carry a heavy weight when they are shared by both majors and non-majors. For majors, these courses need to capture the students' interest (since disinterested students attrite), to help students begin to build a professional identity, and to set the foundation for the curriculum. For non-majors, these courses need to build on realistic expectations for prerequisite knowledge and address the needs of the client disciplines. This is a lot to expect from a single shared class.

Future work in this area includes continuing analysis of IE students' interview transcripts, as well as analysis of transcripts from students in other majors and at other institutions.

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