Undergraduate Women in Computer Science: Experience, Motivation and Culture

Allan Fisher, Jane Margolis and Faye Miller
School of Computer Science, Carnegie Mellon University
5000 Forbes Avenue, Pittsburgh, Pennsylvania 15213

Abstract

For the past year, we have been studying the experiences of undergraduate women studying computer science at Carnegie Mellon University, with a specific eye toward understanding the influences and processes whereby they attach themselves to or detach themselves from the field. This report, midway through the two-year project, recaps the goals and methods of the study, reports on our progress and preliminary conclusions, and sketches our plans for the final year and the future beyond this particular project.

1. Background

The goal of our project has been to understand women's attachment and detachment from computer science, and to find ways for CMU to intervene at the undergraduate level in favor of gender equity in computer science. Women are underrepresented in computer science at CMU and in other higher education institutions across the nation: for example, they receive 18% of the bachelor's degrees in CS at the top 12 research departments [1]. Since computers and information technology play an increasingly pervasive role in education and careers, this underrepresentation is critical, not only for the women whose potential may go unrealized, but also for a society increasing dependent on the technology.

Clearly part of the low representation of women in CS at the undergraduate level is inherited from the secondary school level, where girls do not participate in computer science courses and related activities as much as boys [7]. There is a gap between male and female enrollment in high school computer science courses that increases as students progress from introductory to more advanced CS courses [8]. Females have been only about 12% of AP computer science AB exam takers over the past five years (College Board, private communication). As we learn more about the different ways that students attach to and detach from computer science, we will apply the lessons learned to the design of pedagogical, administrative, and social methods aimed at both attracting and retaining women students.

This paper reports our findings in the initial phase of our research. This part of the research is based on gathering students' accounts of their histories and thoughts about computer science. We have been studying students' perceptions of attachment and detachment from the discipline. In order to conceive of the most effective interventions, we are working to understand the relative importance of the factors that have the greatest bearing on the low numbers of women in the field.

To appear in ACM SIGCSE Technical Symposium, February, 1997.

2. Ethnographic Methodology

We have been using ethnographic methods [4,5], with interviews being the primary source of our data. We regard the students as expert witnesses in their own world, and try to ask the questions that will enable them to best elucidate their thoughts about computer science. It is then up to us to note significant themes and patterns. We are not testing hypotheses, but rather are generating testable hypotheses about students' attachment and detachment.

Participants

The participants of our study are:

1. CMU Computer Science male (29) and female (20) students (first-year to senior);
2. Two selected samples of female non-CS majors: 9 students doing well (receiving an A at midterm) in a non-majors' programming class.

Analyzing the Data

Every interview is tape recorded. The interviews are transcribed and the transcripts are entered into HyperResearch, a commercial computer program developed to assist in qualitative data analysis. After coding the interviews for events and themes, the coder writes what we call a "narrative summary." This is our attempt to keep the participants story as whole as possible, to avoid "context stripping." We have worked very hard negotiating the tension between presenting our data as full portraits and the almost necessary "fracturing" of the data into discrete elements so that we can detect patterns across groups and categories (see [4, p. 63]).

Reliability

We are aware of the risk of compromised data analysis and we are continually asking ourselves how can we get the most accurate and detailed picture of the situation. We have three main defenses against drawing biased or unwarranted conclusions. First, we are refining the coding scheme to a fine level of detail, which tends to decrease the subjectivity of the classification of elements of students' accounts. Second, the cross-disciplinary makeup of our research team helps to expose implicit preconceptions. Finally, we will be holding regular focus groups this year to continually return to the participants, and other groups of CS students, to double-check what we are hearing and hypothesizing.

3. Initial Findings

In this section we briefly discuss our "working hypotheses" from the first year of interviews.

Gender Gap in Previous Experience

During the interviews with first-year CS students, many of the women speak of feeling less prepared than the other students in the department. To obtain more insight into this issue, we distributed a survey questionnaire to all first-year CS students regarding their experience and knowledge of computers prior to attending CMU. Our study confirms a significant gap between male and female prior experience, noted in other studies as well [2,3]. It is notable that 40% of the male respondents from the CMU first-year class passed the AP exam, thereby placing out of the CMU introductory level computing class. None of the first-year women placed out. Also, we found a correlation between females students' sense of feeling less prepared and their actual experience with computers prior to CMU.

Gap Between Perceived and Actual Ability

Despite this difference in how students evaluate themselves, there is a gap between women's perceived ability and their actual performance. Despite their modest estimates of their own standing in the class, three out of the seven first-year students made the Dean's List (which turned out to be about the top third of the class) in the first semester, and six of the seven women made a B or A average for the first year.

Hacking Not a Prerequisite for Success

Many of the female students have entered the department with very little computer experience, yet they do well. Their stories counter the suggestion that prior computing experience is necessary to do well in undergraduate computer science. Their stories of success raise some challenges to widely-held beliefs of who does computer science. Their success is not without costs, though -- they often go through a very difficult period of adjustment, facing tremendous self-doubt and feelings of isolation and inadequacy. Nonetheless, it is clear that one need not have been a high school hacker to major in CS. Our findings have become an important talking point for prospective students, and may have contributed to the improved recruitment of women students for the coming year.

Confidence Gap Narrows

Based on the gender gap in previous computing experience, it is not surprising to find a difference in the confidence levels of male and female first-year students. Female first year students report themselves as being significantly lower in computing experience, preparedness for their computer science courses, and ability to master the course material than the males. In contrast, in response to a first semester survey, the males' stated confidence is quite high. For example, 53% of the men rated themselves as highly prepared for their classes, whereas none of the women rated themselves as highly prepared. 50% of the men reported themselves as having an expert level of at least one programming language prior to CMU, whereas none of the women reported themselves as having an expert level of knowledge of a language. We have heard in the interviews how this gender gap in confidence affects the women students' experiences in the program. In our first-year interviews female students commonly refer to how much more other students (males) know, and question whether they belong.

What we were surprised to hear from the upperclass women was that confidence seems to rise, rather than fall, as women progress through their junior and senior years. This is contrary to the findings of studies from other disciplines. Junior and senior women talked to us about a leveling process, which occurs as the course material gets more difficult for everyone by the junior year, and as women's hard work and discipline has paid off. We asked first-year students and upperclass students to rate their feeling of preparedness for their CS classes compared to classmates, and their ability to master the course material, for their first semester and their current semester. For both groups, those students who felt least prepared at the beginning experienced the greatest increase in feelings of preparedness over time. Women rate themselves lowest in initial feelings of preparedness, and show the most increase (1.1 rise in preparedness for first-year women on a scale of 1-5, versus a .3 rise for men.) If we continue to hear this, as we interview more students, this finding could be very important for increasing women's confidence about themselves in this field.

Attachment Begins at Home

Research on women in the sciences has highlighted the importance of family influence on students' exposure to and interest in majoring in the sciences [9]. Our interviews certainly confirm this. Most of the students, male and female, were first introduced to computing by a parent who either works on computers themselves or brings one home for the child. School is almost incidental, except in a few cases. Male students, with only a few exceptions, reported owning their own computer, or having the family computer in their room, by an early age. Only one of the seven first-year women reported having her own computer prior to CMU.

While females are also influenced by a parent at home, we hear a difference between the females and males that we believe to be important and deserving of further inquiry. Females' stories are filled with descriptions of *watching* their dad work at the computer, or having their older brother *show* them how he programs the machine. From there, their interest is sparked, and some do become active in computing activities in high school, but their participation is much more qualified than the males'. There seems to be less tinkering, less unguided exploration and less obsession. Indeed, even the female who was president of her high school computer club, says in reference to computing, "I never really got totally into it."

Males: Computers as the Ultimate Toy

Several males describe epiphany moments from their earliest (before 10) computing experiences, sometimes receiving the sense that this is what they wanted to do for the rest of their lives. They become consumed early on and their computer activities become a consistent part of their identity. One student answers the question "Can you tell me how you got interested in computers?" this way:

> *Well, I think it was sometime in middle school, sixth grade about then, my dad borrowed a computer from a friend, it was an old black and white Macintosh, just totally self contained one unit thing, and I remember just playing with that all the time and trying to figure stuff on it. And that got me really hooked ... I was really getting into figuring things out on computers and I just knew that that was going to be something for me.*

Other male students respond likewise:

> *I started playing around with computers before I can remember...I think I supposedly knew how to type on a machine before I could write....*
>
> *I liked to play games a lot when I was growing up on them. They just seemed to be really integral to how I like to express my creativity....*
>
> *But I like just what a computer can do. I don't know why it interests me so much...They say kids like to take things apart and see what makes them go and I do that a lot....*
>
> *My mother brought me a computer back in Alabama when I was four years old and I guess ever since it has*

been me playing video games, thinking "WOW, how did they do that"?

The male narratives are filled with descriptions of the *computer itself as an alluring object*. The computer is the ultimate toy and they get "hooked."

Females: Computing with a Purpose

The female stories have a very different sound: When the first-year females talk about their personal history with computers, their narratives are not filled with long and detailed accounts of all the different activities they have done at the computer. They do not describe years of unguided exploration. They contextualize their interest in computer science, instead, within a larger purpose: what *they can do in the world*. One female student who talks about her "lust" for technology, continues to explain that she is "not interested in the nitty-gritty of computers", but sees herself as "exploiting" the department --- getting all the computer knowledge she can, to then be able to apply it to puppetry and art. The women we are interviewing describe computers as a *tool to use within a broader context* of education, medicine, communication, art and music.

> *What I would really like to do is teach...would like to minor in education and how computers affect education and what is the most efficient way to use them in education.*

> *I really wanted to get people together...how can this change the world as we see it today. You can get people together. You can provide information.*

> *I think with all this newest technology there is so much we can do with it to connect it with the science field, and that's kind of what I want to do(study diseases). Like use all this technology and use it to solve the problems of science we have, the mysteries."*

> *You tend to think of computer scientists as people that sit in front of computers all day...doing netscaping, that sort of thing. I can't stand doing that. I have to be actually making something, something productive, or I get depressed.*

This is not to say that women totally lack interest in the computing process itself. Female students describe computing as enjoyable, interesting and "hard but fun." Two of the women who had previous work experience in computing lab environments describe the experience as "awesome." But, most of the women talk more about the uses of computing. We have also heard older males, as they progress in the program, articulate more interest in the larger context of computing.

Computer Science: An Acquired Taste

Rather than epiphany moments as described by the males, females stories seem to reflect a process over time, in which their interest in computers evolves. Due to the variety of obstacles girls/women find in their computing path, it may take women more time to be drawn to computers (Sheila Tobias, personal communication). Developing an interest over time was expressed by one of the first year female students:

> *My dad's always been into computers... We always had a computer in the house. It's always been like, we always like tinker around with them, play games, stuff like that. I never really got totally, like totally into it. I never started programming. But, I don't know, I just kind of found that I really enjoyed working with computers over time... So now I am here and I get it more than I would have. And I'm pretty good at like fooling around with something and just kind of getting it to work, I guess you can say.*

Similarly, an international woman senior student, who had no computing experience at all prior to coming to CMU, described her experience with computing as "an acquired taste." As she progressed in the program she became more comfortable in the department and with the course work and actually developed a new-found interest in the field. This certainly speaks *against* the notion that women are cognitively ill-equipped to do CS. Rather, it bolsters the notion of cultural artifacts that stand in between women and computing.

Decision to Major in CS: Love and Pragmatism

Reasons for becoming interested in computer science and selecting it as a major differ among the men, American women, and international women in our sample. We asked the students both why they became involved in computing, and why they chose CS as a major; the most salient reasons cited are plotted below as percentage citing a reason for majoring vs. percentage citing it as a reason for attachment.

As Figure 1 shows, all of the men interviewed cited an intrinsic interest in computers and computing as a reason for becoming involved in the field. While they cited a number of other factors (notably games, classes and the influence of peers) for their initial attachment, interest alone was the primary driver of their decisions to major in CS.

Figure 1: Majoring vs. Attachment (Men)

American women, while also citing intrinsic interest as a motivator, rank class experiences and their sense of the promise of the field and its future high among reasons for majoring. It is interesting to note that while they reported encouragement from family and teachers as reasons for attachment, these do not rank high in terms of reasons for majoring. Also notable is that few cite games or peer interactions as reasons for attachment.

Perhaps the most interesting finding in our interviews concerns the international women. Among this group, pragmatic factors (employability, the image of CS as a pragmatic choice among math, science and engineering-related fields) dominate both attachment and choice of major. While all of the US students cited interest as a reason for attachment, fewer than 60% of the international students did so. This stands in sharp contrast to Seymour's findings that interest above any other factor is critically important in retaining women in the sciences [9]. Whether this contrast is due to cultural differences and/or to the circumstances under which international women find themselves studying in the US bears closer study.

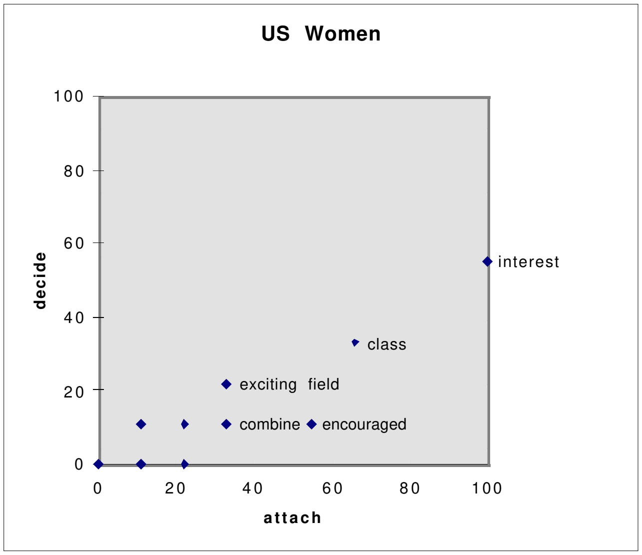

Figure 2: Majoring vs. Attachment (US Women)

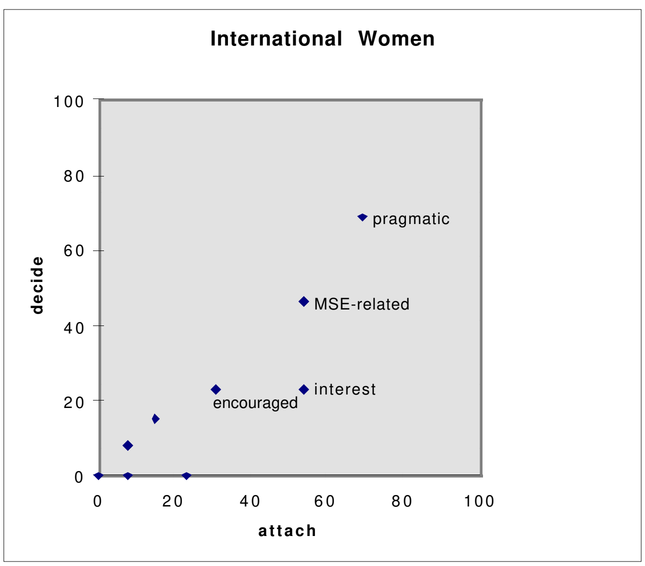

Figure 3: Majoring vs. Attachment (International Women)

Perceptions of the Field

A large fraction of the CS experience in the first year is programming. Upper class students comment on how they realized in their Junior and Senior years that Computer Science is more than programming, and they often express relief at that. First- year students who have had the benefit of hearing from upper class students, and who have regular contact with faculty first-year advisors, also seem to know that programming is not the be-all and end-all. But, outside of the School of CS, we hear students' beliefs that computer science *is* programming.

Students from the Information Science major, who share much interest in computers and computing, state their disinterest in Computer Science largely based on the emphasis on programming in the CS curriculum. Women students whom we interviewed in the non-major introductory programming course (from a variety of fields) describe their fear, dislike, intense anxiety, disinterest in programming when they began the class. Most of these students express an awakening in the course to the fact that programming can actually be interesting and satisfying to understand. But most are not motivated to continue to a deeper level, and they associate the CS major with programming.

Geek Mythology: Lore about Being in CS

Interviews with all students are filled with local lore and impressions about CS and about the CMU department in particular. The beliefs we hear over and over again are that:

• computer science students have a single-minded focus and talk incessantly about computing

• CS is the department with the really smart students

• the work load is extremely heavy (with special emphasis on the amount of time that it takes to complete programming assignments)

The stereotype is clearly the myopic, narrowly focused, young male who sits at his computer all day. This is how one of the female CS students describes this type of student and how they affect her:

> *I ask them, "How can you sit in front of a computer for eight straight hours and then when you go home you start to play on computer games again?" And then they say, "oh, because it's fun." I say, "don't you spend time with your friends?", and they say, "no, I just like sitting in my room and just play these games." So I just felt really different because, I don't know, I don't know... if you want to major in computer science, what you are supposed to do? Like just play on the computer all day? I don't, so I felt different.*

It is important to note that most of the CS students (both male and female) we interviewed feel they do not match the stereotype: their interests are varied (including sports, theater, poetry) and not isolated to computer science. The gap between reality and stereotype of the qualities needed to be a successful CS major and who CS majors are is important to analyze, because the stereotypes work against gender equity. If we can dispel the perceptions of most CS students being immature males who burrow into their computers for all forms of satisfaction, there is hope for progress.

Climate Issues

From our interviews we hear a tension between some women who believe gender to be a non-issue, and other women who feel disrespected in the department because of their gender. The former group feel experienced at handling male environments, feel at ease, and believe attention to gender is unnecessary. The latter group of women describe concerns and/or unhappiness about the male environment and/or the way they are treated. For instance, one first-year woman describes unwanted romantic attention when she is trying to complete her assignments in the computer lab; another describes her alienation from the culture of CS, which she attributes to testosterone run amok.

Peers

It is not unusual for a woman student, within one semester, to report differing impressions: that most of her male peers are willing to help, and that male students make her feel so stupid when she asks them a question. Several of the women talk about the male students knowing so much more than they do.

We asked every student for their views on why there are so few women in computer science. As we understand their comments at this point, we have found some of the male interviews to be particularly provocative. Many of them have concluded, from their school and family experience, that women just aren't interested in the subject the way males are. Most of the males describe school classes with only a very few women, and families where mothers are "unable to plug in the machine" etc. One male student added that he doesn't think he has had a computer conversation with a girl in his life. We wonder how this socializing history may influence male students' attitudes towards women students and faculty in the program.

Faculty and Teaching

While one upperclass student who had transferred out of the department reported negative experiences with an unsupportive and unhelpful professor, most of the female students either have felt supported by the faculty, or have not voiced any complaints. It is not clear to us whether the disparity between this finding and the commonplace occurrence of behavior discouraging to female students in other studies is due to a favorable environment at CMU, failure of the students to notice those behaviors, or the peculiar effects of especially low ratios of women in classes. We will need to carry out more classroom observations and focus group discussions to clarify this point.

4. Conclusions and Next Steps

As we work forward from these observations toward a program of interventions, the three sets of issues we will be working to elucidate are those surrounding individual and cultural conceptions of computer science, those involving pedagogy, and those involving institutional culture. In all cases, we will be working to sort the essential features of computer science from the accidental (and perhaps harmful), and to understand how perceptions and misperceptions are formed and influence students' decisions. We will be asking how we can improve both the reality of the computer science program and its culture, and the accuracy with which they are perceived by computer science students, other students and prospective students.

A key question that pervades students' accounts of their relationships with computing is their understanding of the nature of the field, in both its intellectual and social aspects. Considering that a wide range of conceptions of computer science exists among faculty, what about the nature of the field gets translated to existing and potential female and male students? Among the issues that seem to deter women from pursuing computer science is the conception that it is narrowly focused on programming and other technical issues, and that people who enter CS are forced (or choose) to be narrowly focused themselves. Even students within CS carry this stereotype of others, while denying it applies to them. In our ongoing study, we will work to elucidate these issues, and to develop ways of communicating the "big picture" earlier and more accurately to first-year and prospective students.

Part of this effort will be to sharpen our picture of the CS education process and ways in which it could be improved. If women prefer to learn about the computer in a purposeful context (i.e. "programming for a purpose, not just to program"), does the curriculum respond? Are assignments more in line with what seems to be young male desires, such as focusing predominantly on the machine? Although the department has made improvements, it is arguably still true that the early curriculum (here and nationwide) fails to paint a complete picture of the field's possibilities [3,6]. We are also aware of the possibilities of different pedagogical approaches to programming [10]. One question we are analyzing is whether females and males differ in their cognitive preferences in programming.

Another issue we plan to address is the prevailing conception of gender in CS among the student body. The only significant "chilly climate" issue raised in our interviews concerns the attitudes of fellow students. This is a delicate issue, posing substantial risk of backlash against clumsy consciousness-raising efforts. In seeking effective means of shifting the prevailing culture, we will be asking students about the roots of their assumptions about women and computer science, and about experiences that have changed or might change them.

Acknowledgment

We gratefully acknowledge the support of the Alfred P. Sloan Foundation.

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