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The Anatomy of Interest:

Women in Undergraduate Computer Science

Jane Margolis, Allan Fisher, and Faye Miller

Lily was a first-year undergraduate computer science major who entered one of the top computer science departments in the country with a great deal of enthusiasm for the subject. Her interest was first sparked in high school, when she took an advanced placement computer science course at the suggestion of her guidance counselor. "As soon as I started taking that course in programming, I realized I loved it . . . I absolutely loved it," she tells us in her first interview. Her enjoyment of a summer programming job solidified her decision to major in computer science. She enjoyed "the challenges the programmer faces" and found the problem solving to be fun.

Yet by the end of her second semester, she had decided to transfer to the English department. Her enthusiasm for computer science is now extinguished. She says, "In high school, when I'd go home from class, I would be like, 'Oh, let's program a little.' But, now I am just like, 'Let's not bother.'" Struggling with the course work, perceiving her peers (mostly male) as doing much better with much less effort, feeling that there was a bad fit between herself and a cultural norm that associates success with an all-consuming love of computing, she questions whether she belongs in the department. Several semesters after leaving computer science, Lily describes her disappointment in having transferred out. It is not that she is unhappy in English. She loves the humanities. But she remembers how much she loved programming and how she had wanted to major in computer science, and she feels dismayed about how her interest has been extinguished.

Lily's experience is not unique. Her story highlights a key struggle experienced by many women studying computer science at the college level. Once enthusiastic about the field, they find that their interest dissipates. Departments have witnessed many of these students leaving computer science, often around their sophomore year—the time when many students, male and female, regardless of major, do their "switching." It is then too convenient for all concerned to conclude that Lily, and others like her—those "appropriate switchers"[1]—have found their

intellectual interest and passion elsewhere. The professors may even be thankful that these students made this self-discovery earlier rather than later. In computer science, a higher proportion of students who transfer to other majors are women.[2]

In this paper we focus on the process by which women students who enter with high enthusiasm and interest in computing quickly lose both faith in their ability and interest in the subject. We believe it is critically important to gather carefully rendered accounts of how these women students lose interest in computer science, particularly in light of the commonly held belief that girls and women are not as "intrinsically interested" in technology as are males. We look at the ways that interest in a subject area is influenced by factors beyond an individual's intellectual preference for an abstract body of knowledge. We have found women's departing statements that they are "just not interested" to be a misleading endpoint to a complex process we've seen over time, involving the interplay of gender-biased norms of interest and eroded confidence. We look at the mechanisms that promote a male focus of interest as the standard for success, while casting doubt on women's interest and ability in computing.

At stake in the experience of women as undergraduates is the makeup of the technology-creating population. While girls and women may be using the Internet for communication and the Web for information retrieval, it is predominantly men (the majority, in the United States, being white and Asian American) who are programming the computers, designing and fixing the systems, and inventing the technology that will affect all aspects of our lives (National Science Board 1998). Only 15–20 percent of undergraduate computer science majors at leading U.S. departments and only 17 percent of those taking the high school computer science advanced placement test are female (College Board 1998; Kozen and Zweben 1998). The underrepresentation of men of color and all women among the creators of information technology has serious consequences, not only for those individuals whose potential goes unrealized but also for a society increasingly shaped by that technology.

An Interdisciplinary Collaboration

For the past four years at Carnegie Mellon University, at one of the top computer science departments in the country, we have been interviewing female and male computer science students about their experiences and decisions about studying computer science. The department ranks in the top three in the country, and admission to

the program is a source of pride for many students here. Prospective students apply for admission to the computer science program itself. In 1995 only 8 percent of the first-year class were women; today the 1999 first-year class is 37 percent women.

Our research team is unique in that it is interdisciplinary, made up of researchers from computer science and education/women's studies. The heart of our research is interviews with computer science students themselves. Students are initially interviewed about their prior experience with computing at home and at school; then, once per semester, they are interviewed about their experiences in the program and their feelings and attitudes about studying computer science. Additional data is gathered through surveys, classroom observations, interviews with faculty, a small journal-writing project, and monitoring of electronic communication and forums. Our sample consists of the majority of female computer science majors at Carnegie Mellon and a comparable sample of male majors. We have interviewed 51 female and 46 male computer science majors, most multiple times, for a total of 210 interviews with 97 computer science majors. The majority of the students are European American and Asian.[3] At the conclusion of this year we will have followed samples from three incoming classes through two to four years of study.

Gender and the Initial Interest in Computers

The women who are admitted to the Carnegie Mellon School of Computer Science enter with high enthusiasm and interest. We've interviewed a student who was the president of her school's computer club, another who took great pride in being the "computer genius" in her family. Almost every woman in our sample came to computer science because of an interest and strength in math and science; they also enjoy problem solving, puzzles, and logical-thinking tasks. They take pleasure in programming. As one student tells us: "I have always been a problem-solving person and it just really gives me a rush when you are working and working on a problem and finally it just works!" A number of the women express delight in the sense of mastery of figuring out the program. Women talk about the pleasure in "systematic thinking," as well as the creative aspects of programming.

While the women students enjoy the "rush in having my program run," the context and connections of computing to other arenas often makes the study of computer science meaningful. Forty-four percent of the women students in our study (as compared with 9 percent of the men students) contextualize their interest in computers in other

domains such as medicine, space, or the arts. These women emphasize the importance of integrating computing with people and other arenas. As one student tells us:

> 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, the mysteries.

A first-year student told us how much she enjoyed science fiction when she was young. She remembered reading about a robot that was "more like a tool; it wasn't something that would take over a place, but it was a machine that would help out." She wants to design this type of intelligent machine. Inspired by a lecture about a robot car (in which the lecturer explained the utility of the car by describing the number of accidents and deaths caused by human error), she explained how this people-oriented purpose for computers is what resonated with her desire to connect computer science to real-world problems:

> The idea is that you can save lives, and that's not detaching yourself from society. That's actually being a part of it. That's actually helping. Because I have this thing in me that wants to help. I felt the only problem I had in computer science was that I would be detaching myself from society a lot, that I wouldn't be helping; that there would be people in third world countries that I couldn't do anything about. . . . I would like to find a way that I could help—that's where I would like to go with computer science.

Our finding that women are concerned with the usefulness of computers is concordant with other research from the field (Honey 1994; Martin 1992; Schofield 1995). While women's interest and enjoyment of computing for its own sake is often a primary reason for majoring in computer science, most also tend to have a multitude of practical and related reasons for choosing their major, such as the desire for secure employment, the versatility of computer science, encouragement from others, and the exciting, changing field itself.

Despite the fact that most of the women students educated in the United States had computers in their homes when they were growing up and enjoyed using them, their interest in computing was usually one among several other interests and developed more gradually than it had for the male students. As the women describe their enjoyment of programming, most compare themselves to a male member of their family, and note that he was the one who was "really into computers."

More female students in our sample report watching while a male family member (father or brother) played games, tinkered, or took the computer apart. As one female student tells us: "We got a computer when I was . . . I don't remember how old I was, but my brother just totally took to it and that's when I wondered, 'What is this thing?'" There are no subsequent references to her own self-exploration. Another student, in describing her computer experience, also draws a clear contrast between herself and her brother:

> My basic exposure was learning to type in middle school. My brother, even just a couple of years ago, he started kind of playing on them, pulling them apart; I never did that. I never pulled them apart and said, 'Oh, I wonder what this does.' For whatever reason, I never did. He always did.

Male Attachment to Computing

In response to our opening interview question, "Can you tell me the story of you and computers?" male students describe falling in love with the computer the minute they put their fingers on the keyboard—often at a very early age—and the screen responded. For most of them in our study, love of computing comes early, and becomes part of their identity and the stories they tell about themselves. They describe a magnetic attraction between themselves and the computer, with the computer becoming an object of fascination and allure. From then on their activities, conversations, and waking hours center around the computer. The computer is the ultimate toy. "Intensely fascinated," "play," and "fun" are words they use when they describe their first experiences with computers. One of the male students we talked to said, "My mother bought 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?'" Another student tells us:

> 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 [a] totally self-contained one-unit thing, and I remember just playing with that all the time and trying to figure stuff [out] 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.

This fascination with the computer often leads to self-initiated exploration and learning about various aspects of computing, includ-

ing programming. Computer games are predominately designed with boys' interests in mind, and have much to do with this (Cassell and Jenkins 1998). One student told us how games were a key source of his motivation to learn programming:

> I would see stuff, because I played video games all the time and I really liked the graphics and everything. And I was interested in learning how to do that. So to learn how to do that you've got to go get the books and to understand how to do graphics you have to understand how to do the basics so you have to learn the basics. And then just like a general progression, if you are interested in something and you want to learn how to do it, you have to get from point A to point B and along the way you pick up a lot of stuff that you need and will help you out with some of the other classes.

This description of the pull to "figure out how it works" is something prevalent in the male interviews and very rare in the female interviews. It positions the male students in a very active relationship to the machine. As young boys, males step right into the driver's seat, leaping from the outside to the inside. Many male students report programming to be a source of extracurricular pleasure, having done it since they were young (38 percent of the males, compared with 10 percent of the females in our sample). Computing emerges as an integral part of their lives.

The College Experience: Living among the "Programming Gods"

Students are thrilled to be admitted to the Carnegie Mellon School of Computer Science. Although Carnegie Mellon may have less name recognition than Massachusetts Institute of Technology or Stanford, within computing fields it rivals them. Admission is very competitive. In the entering class of 1997, 28 percent had a perfect math SAT score of 800; nineteen were high school valedictorians; forty were in the top five of their class; and the mean math SAT score was 765. Not all but most of the first-year students have had quite a bit of computing experience and knowledge. A sophomore woman says:

> I was on top of the world when I first came here. Getting into CMU was like, "Wow!" I mean, how many people get into the computer science department at CMU!!? Wonderful, it was something for me. One of my biggest achievements in my life. I have a lot of achievements, but this was one of the better ones and they can't take that away from me no matter what they do. I'm going to stick here whether they like it or not.

The Norm of Knowledge: "Everyone Seems to Know So Much More Than I Do"

While almost every woman at Carnegie Mellon enters the program enthusiastic about being a computer science major, their confidence and interest too frequently erode shortly after they arrive. A woman student who described a computer graphics lecture as "the most exciting lecture I have ever attended" went on to describe how discouraged she had become:

> I'm actually kind of discouraged now. Like I said before, there's so many other people who know so much more than me, and they're not even in computer science. I was talking to this one kid, and . . . oh, my God! He knew more than I do. It was so . . . humiliating kind of, you know? So I get discouraged by things like that—I don't know what I think I need to know. And that inhibits my willingness to continue . . . if you can understand that. It shouldn't. It should like make me want to learn even more. But I feel like I'll always be behind, and it's discouraging.

Many women do enter undergraduate computer science with less computing experience than their male peers (Klawe and Leveson 1995; Teague and Clarke 1996). To assess gender differences in the prior programming experience of our 1995 interviewees, we conducted a survey of incoming students, and found that 40 percent of male respondents from the Carnegie Mellon first-year class passed the advanced placement computer science exam, thereby placing out of the Carnegie Mellon introductory-level programming class, while none of the first-year women placed out. Men were also familiar with more programming languages than females, and were much more likely than women to report having had an "expert" level of knowledge of a programming language prior to Carnegie Mellon. Despite this gender gap in computing experience, it is important to note, we have found no correlation between prior experience and success; some of the most successful students have entered the program with very little computing experience. Yet when women students encounter difficulty with course work, these comparisons between their experience and that of their mostly male peers can become the kiss of death. As one woman said:

> If anything, it's very intimidating because I often think I'm in the lower half of the class, working hard but below many people who still don't have to work at all, and it's frustrating. I'm intelligent, I learn things solidly, and I very much enjoy coding and the computer sci-

> ence stuff in general . . . but I think I pick up ideas slower than other people, and I get mad at myself.

Clearly, a wide range of psychological, pedagogical, and socialization-related factors contribute to women perceiving themselves as "picking up ideas slower" and perceiving their male counterparts as being "so good without even trying." For instance, while males often have more experience, there is also the likelihood that male students are inflating how much they know, or are overly confident, while women have been shown to underestimate their abilities (Sax 1995; Lundeberg, Fox, and Puncochar 1994). Much other research and our own observations point both to the fact that men tend to exaggerate their achievements more than women, and to their being more likely to attribute their successes and failures in a self-affirming way than are women (Eccles 1992; Dweck 1986; Licht and Shapiro 1982). A. Christopher Strenta and colleagues (1994, 543) found that "even with the same grades in science and other courses, women in science were less confident of their abilities and more depressed about their academic performance than men." We see both of these effects clearly in our interviews, and we suspect that a greater knowledge of the prevalence of these trends would help students to insulate themselves. And although prior computing experience is not a criterion for admission to the program, many students find that introductory courses do require a certain amount of technical familiarity that many novices do not have, and seem to expect a background that is far more typical for men than for women in the program. To create gender equity at the undergraduate level, computer science programs must address the question of the unlevel playing field in terms of prior experience. Other research studies of women in the sciences and engineering (Brainard and Carlin 1997; Seymour and Hewitt 1997) have found a similar pattern of the unraveling of undergraduate women's confidence during these students' first year.

The Norm of Interest: "I Don't Dream in Code Like They Do"

In the article "Encountering an Alien Culture," author Lee Sproull and colleagues (1987, 175) describe the college computing culture as an "adolescent one" in which

> there is competition to write the best, fastest and biggest program . . . the status hierarchy is revealed through assigning people to such categories as wizards, wheels, hackers, users, and losers. True members of the culture can be found at the terminal room or computer center at all hours of the night.

An intense focus and love of the computer is part of being "in sync" with the culture (Kidder 1981; Hafner and Lyon 1996; Levy 1984).

A female junior student who was very involved in the Internet before coming to Carnegie Mellon, and who has always regarded herself as a math-science person, after several semesters doesn't think that computer science is for her, because "it's not my passion like everyone else. They're all, like, really into it." In her particular case her boyfriend is "really into robotics," planning on going to graduate school and becoming a professor, but she sees herself differently. When the interviewer asks her to "talk to me a little more about the reasons you are thinking that computer science isn't for you," she says:

> When I have free time I don't spend it reading machine-learning books or robotics books like these other guys here. It's like, "Oh my gosh, this isn't for me." It's like their hobby. They all start reading machine-learning books or robotics books or build a little robot or something and I'm just not like that at all. In my free time I prefer to read a good fiction book or learn how to do photography or something different, whereas that's their hobby, it's their work, it's their one goal. I'm just not like that at all; I don't dream in code like they do.

Comparing herself to peers who "dream in code," she feels that she is not meant to be in computer science. Another woman feels that her male peers "have a motivation that's deeper than I do," and "if they love programming that much" she wonders if she should be in the major. She continues:

> I have friends who will be like, "Well, I am going to teach myself a new language" and they'll go pull an all-nighter. I don't have that motivation, so, "Am I in the right department? Am I in the right thing?"

A woman student who ended up transferring out of computer science to information systems describes how she was not interested when her classmates would talk about the "latest machinery on the market or how much RAM space a computer has and how they have to upgrade it and what new software they want (blah, blah, blah)." She concluded:

> I just didn't feel I was like them or that I could work like them or have an interest in the things they did. Every one of my friends had interest in at least something and whatever they had interest in they were like solely devoted to that thing and I didn't have that kind of devotion.

Twenty percent of the female computer science majors we interviewed have questioned whether they belong in computer science, because they feel they do not share the same intensity of focus and interest they see in their male peers. Women describe wanting to talk about other things besides computers, feeling estranged from those who are myopically focused on a machine.

The Boy Wonder Icon

Sheila Tobias, in her study of women in science, argues that the "boy wonder icon," the association of male traits with success in science, is central to the broad assumptions of who does (and who does not) become a scientist:

> One of the characteristics of the ideology of science is that science is a calling, something that a scientist wants to do, needs to do above all else and at all costs. Another is that both scientific talent and interest come early in life—the boy wonder syndrome. If you don't ask for a chemistry set and master it by the time you are five, you won't be a good scientist. Since far fewer girls and women display these traits than boys and men, you end up with a culture that discriminates by gender. (Alper 1993, 411)

The computing culture, in particular, reflects the history and legacy of actual "boy wonders." The widely held expectation that there is one way (the male way) to come to science shapes the expectations and assumptions of parents, teachers, and students themselves. As women begin their undergraduate computer science education and perceive that men go through the program with more experience, less effort, and more interest, too many women conclude that they do have to look "like him" in order to succeed. Women begin to question their ability and their interest—whether it is "enough."

These male-biased expectations of who will succeed affect teachers as well. A particularly clear illustration of this is captured in an E-mail exchange between two high school computer science teachers who had participated in a Carnegie Mellon summer program for advanced placement computer science teachers (http://www.cs.cmu.edu/6apt). A male teacher began the discussion about the low numbers of female students in his computer science classes:

> I have any number of boys who really really love computers. Several parents have told me their sons would be on the computer programming

> all night if they could. I have yet to run into a girl like that. A couple are Internet nuts but that's social, not programming. Where are the girls that love to program? My girls sit up and take notice when I talk about programming as a good way to make a living, but look at me funny when I talk about it as fun. The boys think money is nice but fun is where it's at. Why is this?

A female teacher responded that many of her students make the same observation, having the idea that "staying up all night programming is a sign of love for computer science, and not doing so is a sign that one doesn't love it." But she disagrees. She talks about taking her first programming course in college and how she "fell in love with it." She said it was "organized, logical and yes, fun." However, she did not stay up all night doing it. She says she "did not even spend a majority of my time programming" and did not program on her own, coming up with games, entertainment, and so on. She said she enjoyed the programming assignments "immensely," enjoyed the challenge, and especially enjoyed the "practical problems." But then she adds:

> My point is that staying up all night doing something is a sign of single-mindedness and possibly immaturity as well as love for the subject. The girls may show their love for computers and computer science very differently. If you are looking for this type of obsessive behavior, then you are looking for a typically young, male behavior. While some girls will exhibit it, most won't. But it doesn't mean that they don't love computer science!

We concur that there are multiple ways of being interested in a subject, and that valuable contributions to the field come from people with different sets of attachment to computers. Students can love computer science without being "like him."

The Nonhacker Male

It is important to note that we have also interviewed a significant number of male students who describe themselves as different from the hacker stereotype. One male student said:

> I am interested in doing computer science but I don't think it's the be-all and end-all of human existence. I think that's a mentality that some of these people have—it's a hacker mentality that I don't really identify with.

Yet despite these feelings of difference, we find that male students report less distress, are less affected by the perceived difference between themselves and their peers, and leave the major in smaller proportions; and notwithstanding the resistance to a total absorption in computing, they do not question their ability to become computer scientists if they choose to do so, and they seldom feel the need to conform or change to match this norm. They do not speak of being discouraged by others who are passionately involved with computers and thereby know more. And from the men with less experience, we do not hear anguish over whether they "have what it takes." They describe themselves as being different from the dominant image, but this does not excessively discourage them or immobilize them with self-doubt.

We believe that the reason why female students feel more distress over this difference from the stereotype than do nonhacker males is that the computer science culture assumes that men will succeed. Success is linked to a stereotype based on a common male pattern of desire for, interest in, and attachment to computing. Such a stereotype can only bolster men's confidence and sense of belonging. This same culture does not assume (often accurately) that women conform; hence they enjoy no default expectation of success, and their interest in and attachment to computing may be regarded as deviating from the norm, and as being less serious than the interest and attachment of the male students. This, combined with a vast array of gender-socialization factors, chips away at women's sense of confidence and of belonging in the field. Men who face difficulties with course work do not struggle under the additional burden of the presumption that they are somehow inferior by virtue of their gender; nor do they have the pressure of feeling they are representative of their gender. One woman student hit the nail on the head:

> They [male students] have the pressure to do well, but they don't have excess pressure from us saying, "You know, you're pathetic, you just got in because you're a guy," or something. We don't give them that . . . their confidence hasn't hit rock bottom because of that. They tell us all the time and it isn't something we like to deal with. We shouldn't have to deal with it.

Nexus of Confidence and Interest

Elaine Seymour and Nancy Hewitt (1997), in their multiuniversity study of students leaving math and science majors, concluded that

"intrinsic interest" in the subject was the number-one factor in helping students persist in the face of various obstacles, including poor teaching, lack of support, and a chilly climate. The importance of intrinsic interest makes intuitive sense. Yet our research identifies a chicken-and-egg problem that affects a female student as she thinks about her interest in computer science: Is difficulty with course work due to lack of experience? Or is lack of experience due to lack of interest? Or is lack of interest due to lack of confidence? Or is lack of confidence due to lack of interest? It is hard to disentangle one influence from the other, to know how they interact. Women's interest (or lack thereof) may not be as intrinsic as it feels, for interest is continuously encouraged or extinguished, and defined, by cultural norms, external factors, and internal responses. This interest or disinterest is far from being a static, immutable given; rather, a combination of gender socialization, cultural artifacts of the field (male-dominated history, culture, educational practices, and peer interactions), and individual psychology all construct and/or undermine many women students' sense of their own intrinsic interest.

The words of one of the women we interviewed, a junior at the time, capture well what we have identified as a nexus of confidence and interest that entangles many of the women computer science undergraduates:

> I enjoy computer science, but it's not my life. Especially not like some other people who can sit and just play with their computers a lot. I don't own a computer, I don't play with my computer. There are other things I'd rather be doing. Part of it is a confidence thing. Which may even stem from that . . . because I sometimes feel like I'm not nearly as good as some many other people. I'm not a whiz. It just feels like everyone around me does. So when you feel like you are not as good at things, you lose a little bit of interest.

A woman student who has been playing with computers since she was four and coding since she was five or six, who was on the high school programming team and has won prizes, tells us how comments from male peers shook her confidence, which then diminished her interest in programming:

> I began to lose interest in coding because really, whenever I sat down to program there would be tons of people around going, "My God, this is so easy, why have you been working on it for two days, when I finished it in five hours," and, "Jeez, you're such a terrible hacker,

> you must have only gotten into SCS [the School of Computer Science] because you're a girl," and so on.

Biased Social Environment: "You Are Only Here Because You Are a Woman"

Research shows that both males and females believe that males are better at computing (Clarke 1992; Spertus 1991). These low expectations for female students become part of a biased social environment, often manifested in the form taken by peer-to-peer interactions. The following comment was posted by a male student on a Carnegie Mellon electronic bulletin board for computer science undergraduates, on why there are so few women in the department:

> In fact, I haven't seen that many girls really interested in computer science. The girls in computer science right now (that I know of at least) just seem to be perfunctorily going through the major. How many girls actually *enjoy* programming? Do it for fun? I'd be very surprised if we even found one (but I am sure there are one or two around).

Comments from male peers, which may appear incidental or random, accumulate to make women feel undervalued and unwelcome (Valian 1998; Spertus 1991). Women report being faced with comments such as "You are a computer science major and you don't know *that*?" if they don't know a technical detail or if they ask a question. The most damaging comment, and perhaps the most telling, is one that one-quarter of the women we have interviewed mention having heard: that they "got in" to the computer science department only because of their gender:

> When I was a freshman, someone made a comment to me like, "Oh, you only got into computer science because you are a girl," and I'm like, "I don't think so!" You know, I'm like, "I had higher SATs than you. Shut up!" or just something like that. But . . . I mean I am not the only one who got that. One of my friends came crying to me when she was a freshman. She said, "Some guy just told me that I only got into computer science because I was a girl!" and I was like, "It's not true. Just say, 'My SATs were better than yours,' and they'll shut up, even if that's not true." I mean, that's one thing you get a lot of.

While most of the women say that the majority of their male peers are nice and helpful (their perception is that just a few are "bad eggs"),

it is clear that a biased belief system affects peer interaction. Research from other universities shows a similar pattern. The MIT Artificial Intelligence Laboratory report "Why Are There So Few Female Computer Scientists?" concludes that comments and behaviors such as those just cited here are "the symptom of a more fundamental problem: lower expectations for females" (Spertus 1991, 14). While there is no way for us to know how much effect this biased social environment has on individual women, research across fields, studying, what matters in college for students, concludes that "the students peer group is the single most potent source of influence on growth and development during the undergraduate years" (Astin 1993).

Psychologist Claude Steele's examination of the experiences of African Americans in higher education and women in traditionally male fields suggests that when one is in a situation in which a negative stereotype about one's group applies, one is fearful of confirming the stereotype. This can lead to poorer performance (as in test scores and work performance); in turn, this turns into disidentification with the field. Disidentification with a field offers "the retreat of not caring about the domain in relation to the self. But, as it protects in this way, it can undermine sustained motivation in the domain" (614). This is one way of understanding students' statements that "computer science just doesn't interest me," as an endpoint of experiencing difficulty with course work and a drop of confidence. Steele (613) believes that "one must perceive good prospects in the domain, that is, that one has the interests, skills, resources, and opportunities to prosper there, as well as that one belongs there, in the sense of being accepted and valued in the domain" in order to persist and maintain one's interest and engagement.

We believe that this social environment, and the biased assumption that females are not as likely as males to be capable computer scientists, is made ever more potent by the following characteristic of the field: the range of student knowledge and skills appears to have no upper limit. Because of adolescent male interest (and energy), which often is directed into investigating everything about computers, and the availability of vast informal learning opportunities, many undergraduate students (mostly male) enter the program with what seems to be a limitless amount of knowledge. In some cases, the "whizzes" and "experts" are the students, rather than the faculty.

Counterpoint: International Women and Other Persisters

A fascinating counterpoint to the stories noted above are those of the international women, many of whom enter the undergraduate major

with the least experience and intrinsic interest in computer science, yet who persist and succeed in the program.[4] Kanitha, from Thailand, told us:

> Actually I came from Thailand and basically I hadn't dealt with any computer at all before I came. And after that I got a scholarship to study computer science, but I didn't know anything about computer science. And then I went to high school here and then I started taking a course about computer programming and it was kind of interesting. But, then I mean, I have no choice, so that is why I am doing computer science.

These students often go on to employment in the computing field or to graduate school in computer science. Furthermore, their persistence often leads to an intellectual pleasure in computer science that they often did not have when they began. A second-semester student from China speaks of how her attitude toward being in computer science has changed:

> I don't think my plans changed, I think it's just my attitude that changed. . . . I mean, I decided to major in computer science because it was practical for me and for other reasons, but it wasn't because I was especially interested in the subject. But this semester it's like for the first time I really want to do this. I just really want to do this because I like it.

With these students having so little computing history, and in some cases even lacking a minimal level of interest, to what do we attribute their persistence and success? A critical factor is their sense of self-efficacy around math (de Verthelyi 1997) and a different motivation. Having done well in math and/or science in their home countries, the students regard computer science as a ticket to economic opportunity. For many of them, their families are depending on them for economic survival. For these women, there is little or no option for failure. Several have chosen computer science because good scholarships are available for students willing to study this subject. The chance to study abroad is important for these students; the subject of their major is of less importance. Therefore, when an interviewer asked Kanitha, "So how did you end up getting a scholarship to study computer science?" she answered, "I just want to study abroad, so anything is fine with me." Our data also suggests that these international students have alternative norms of success and social bonds that protect them. We speculate that the international women do not use the boundless hacker as

their reference group. Other priorities are dominant, and with these come other scales for self-evaluation.

The stories of these women who enter with little intrinsic interest and experience in computers challenge the stereotype of who can do computer science. The international female students enter with the least computing experience and the least intrinsic interest; however, as their hard work takes effect, the mystery of computer science begins to metamorphose into mastery. They then often begin to find intellectual pleasure in the field. It becomes an "acquired taste." A Malaysian student told us of the eventual satisfaction she got from sticking it out:

> It's like an acquired taste for me. . . . At first it was very hard. . . . After a couple of years, I realized it's kind of late to back out. I sort of went through with it, and along the process I'm beginning to think I like it more and more. So, at the end I just went along with it, and it's pretty exciting, now that I learn more about it.

Rather than the women relating epiphanic moments of falling in love with computing the minute they touched the keyboard and the computer responded, as described by male students, the stories from international women present a different trajectory to becoming a computer scientist, in which their interest in computers had evolved over a longer time. But it takes a completely different cultural orientation, and a different set of motivations, to overcome the biases in the program that they also face.

Our data suggest that many of the U.S. women who persist are those who have found a way to get the grades they are satisfied with, who are able to reconcile themselves to a different relationship to computing, and who maintain confidence in the face of more experienced peers. These women also conclude that they don't have to measure themselves against the male norm of interest. For instance, a female student who plans on using computing to improve tutoring programs for children described how she has refused to conform to the image of the myopically focused "computer geek" who "hacks for hacking's sake." And since she is "getting really good grades without changing myself," she is ever more confident that she can remain in the major and be herself. When the interviewer asks her if she feels a need to conform to the stereotype, she answers, "I refuse to." Then she adds:

> I was worried . . . will I need to conform to that? Will I need to read books on computers all of my free time or something to survive here? And I feel like so far I haven't. I'm getting really good grades with-

> out that . . . without changing myself. So I feel much more confident now that I don't have to. It's kind of nice, I can prove them wrong or something.

Engaging and Respecting the Interests of Women Computer Science Students

While there is a large inherited component to the gender gap in higher-education computer science, we believe that there is much that higher education can do to protect and engage the interest of women students in computing. Our understanding of the problem, some initial intervention experiences, and other research suggest key areas for intervention: culture, curriculum, and confidence. An important theme throughout each of these is that women must not be expected to model themselves after the stereotypical male computer science student.

Broadening the Culture and Curriculum: Multiple Ways to Be a Computer Scientist

Computer science departments need to establish the idea that there are multiple valid ways to "be in" and be interested in computer science. This can take the form of faculty initiating discussions of the computer science stereotype, stressing to entering students that achievement in computer science is more multidimensional than the standard "boy hacker" icon, and emphasizing that prior experience is not a critical issue. One can be concerned about people, family, literature, and a good night's sleep and still be successful in computer science. Curriculum must also incorporate this understanding.

Computing in a Social Context

Studying how males and females design technological innovation, researcher Cornelia Brunner (1997) concludes:

> The feminine take on technology looks right through the machine to its social function, while the masculine view is more likely to be focused on the machine itself. As a result, when technology is introduced as an end in itself, as in a programming class, for instance, young women are less likely to be interested than young men.

Some of the elements of a more contextual approach include early experiences that situate the technology in realistic settings, curricula

that build upon the connections between computer science and other disciplines, and diverse problems and teaching methods that appeal to a broad variety of preferences and styles. At Carnegie Mellon, some of the approaches that we have adopted include

- interdisciplinary courses that bring students of diverse backgrounds together to work on multifaceted problems;
- an undergraduate concentration in human-computer interaction;
- a course that engages students with nonprofit groups in the local community, applying their skills to community issues.

All of these efforts provide further paths for students to pursue in addition to the traditional, technically focused route, and more remains to be done. Sue Rosser (1990, 72), in her book *Female-Friendly Science,* argues that "insuring science and technology are considered in their social context may be the most important change that can be made in science teaching for all people, both male and female."

Addressing the Initial Experience Gap

Our findings regarding the disparity between the average levels of computing experience of men and women, and its effect on their confidence, echo observations by Janet Ward Schofield (1995, 163), who concludes in her ethnographic study of computer usage in a midwestern high school that course offerings "must effectively compensate for the likely initial disparity in prior experience between male and female students . . . that tend to reinforce pre-existing differences in interest and expertise by discouraging many girls from seeking out opportunities to use computers." Accordingly, at Carnegie Mellon we have designed multiple points of entry into the computer science curriculum that allow students with widely varying levels of experience to enroll in courses with appropriate prerequisites, and to end up "in the same place" with only small variations in schedule and with ample time to complete graduation requirements. These changes have increased levels of satisfaction among both more and less experienced students of both genders, and indeed seem to result in the smooth integration of the less experienced into the remainder of the curriculum.

Confidence Issues

Although issues of women's confidence have been shown to have a significant impact on women's interest in majoring in computer science, these issues are often regarded as beyond the purview of faculty, who

are focused on curriculum and research. Seymour and Hewitt have found that the relationship between teachers and students is particularly significant for female students. They observe that "more women than men arrived in college with the expectation of establishing a personal relationship with faculty" (Seymour and Hewitt 1997, 267). In their multi-institutional study of students who leave math and science, they found that male and female students had different objections to large classes. Men objected because such classes have a "negative effect on grades," encourage more competition for grades, and are usually taught by less qualified faculty. Women objected because "you don't get to know the professor," faculty are "too impersonal," and "the professor doesn't care about you." They believe that "failure to establish a personal relationship with faculty represents a major loss to women, and indeed, to all student whose high school teachers gave them considerable personal attention and who fostered their potential" (267). They conclude that the lack of faculty relationships and mentoring relationships is one of the most common causes of women's drop in confidence:

> To be faced with the prospect of four years of isolation and male hostility on the one hand, and the abrupt withdrawal of familiar sources of praise, encouragement, and reassurance by faculty on the other is, in our view, the most common reason for the loss of self-confidence that makes women particularly vulnerable to switching. (271)

Steele also emphasizes the importance of positive student-faculty relationships. Steele reasons that the student "must feel valued by the teacher for his or her potential and as a person. Among the more fortunate in society, this relationship is often taken for granted." Building this relationship of respect between teacher and student is "the first order of business—at all levels of school. No tactic of instruction, no matter how ingenious, can succeed without it" (Steele 1992, 77).

From our interviews with female undergraduate computer science students, we concur that faculty relationships and support for women students are extremely important. Women students describe how they got turned on to computer science and began to consider it as a major because of a high school programming class they enjoyed and were good at, and a teacher who worked with them and encouraged them. They also talk about the importance of the support, advice, and guidance they get from the faculty members at Carnegie Mellon who teach and advise first-year students.

Peer support is also vital. We have found that many women students are unaware that other students are struggling, thus permitting an interpretation that their difficulties are due to an individual "bad fit," rather than there being a larger, more institutionally based problem. We need to promote social bonds that protect women from, in Seymour's words, "self-immolation by invidious comparison with the hackers" (personal communication). This can involve bonds among women and between women and supportive male peers.

A more difficult feature of the confidence problem is the role played by students' self-evaluations. A partly intellectual, partly cultural agenda that we have considered pursuing is one that would raise awareness of the issues that affect women students' self-assessment and confidence. One approach would be to provide students with some information on cognitive psychology, in the hopes that this would help dispel some of the myths about effortless learning and innate ability that seem to have a corrosive effect on self-confidence (Dweck 1986). Departments also need to find ways to reduce the occurrences of comments such as "You are only here because you are a girl." Students must be educated about admissions policies to show that such an accusation is not based on fact, and they also must understand that the institution considers taunting such as this to be unfriendly and hostile to students' learning environments.

Summary

In this paper we show that behind the commonplace observation that "women are not interested in computer science" lies a complex of influences. Although some people believe that it is the inherent nature of computing itself that turns women away, we have documented social and cultural expectations within the field that discourage girls and women. Our close-up look at the experiences of women in undergraduate computer science who were once very enthusiastic reveals some of the pernicious ways in which male behavior and interest become the standards for "the right fit" and success. Fast-forwarding the tape from their initial interview where students are excited about learning computer science to the following two to three interviews, we hear too many women students say that they feel as though they are "drowning," believing that they lack the interest to keep afloat. Trying to find their place in a culture that challenges whether they are "really into it" and in a curriculum with an underlying assumption that their learning will occur in the same sequence and timing as that of their male peers, too many women conclude that they "just aren't inter-

ested." Interest is a precious thing to have. We believe that its loss is unnecessary and unjust.

NOTES

1. This is a phrase coined by Seymour and Hewitt (1997) in their study of students' decisions to leave science majors, to show how reasons for students' decisions to leave math and science get obscured.
2. Since we began the study at Carnegie Mellon University, women in the computer science program have transferred to other majors or left the university at more than twice the rate as that of male students. In the classes of 1999 and 2000, 30 percent of women have transferred out or left the program versus 12 percent of men. This gender difference in retention rates is found in other sciences as well (Seymour and Hewitt 1997; Strenta et al. 1994).
3. Among the 51 computer science women in our sample are 24 European Americans, 16 international students, 8 Asian Americans, and 3 African Americans. Among the 46 men are 28 European Americans, 7 international students, 6 African Americans, and 5 Hispanics. We are concerned with the low percentage of underrepresented marginalized groups in the program, which generally tracks the university average of 7–8 percent. African American and Hispanic students together make up less than 7 percent of advanced placement computer science test-takers nationwide. On average, only about half of our African American and Hispanic students persist through graduation.
4. During the course of our study, approximately 30 percent of the undergraduate female computer science majors at Carnegie Mellon have been international women—students raised and educated in countries other than the United States. The majority are from Asia and Eastern Europe.

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