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Living among the Programming Gods: The Nexus of Confidence and Interest

Several people who heard about our research project felt that there are few women in computer science because "computer science is boring for women." Interest in a subject, though, is influenced by factors beyond an individual's intellectual preference for an abstract body of knowledge. In this chapter, we look at the ways that interest in computing is extinguished in many college women and how their exit statements that they are "just not interested" are a misleading summary of a complex process. Many once-enthusiastic female college students find themselves in a descending spiral of eroding interest through the corrosive effects of lack of confidence, negative comparisons to peers, poor pedagogy, and biased environments.

Lily is a first-year undergraduate computer science major who entered Carnegie Mellon with a great deal of enthusiasm. 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." 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." By the end of her second college semester, though, Lily's enthusiasm for computer science plummeted. 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.'" All around her, she experiences her peers (mostly male) as doing much better with much less effort. She talks about her loss of confidence. Since her interest in computing doesn't seem to measure up to the all-consuming love of computing that many of her peers have, she begins to question whether she is really interested in computing after all.

Several semesters later, Lily transfers out of computer science into English. She describes her disappointment in having transferred out. She is not unhappy in English; she loves the humanities. But she remembers how much she loved programming and had wanted to major in computer science and feels dismayed with how her interest has waned. Lily's experience is not unique.

"Everyone Knows So Much More"

Sara, a first-year student, entered Carnegie Mellon excited about majoring in computer science. Sara had been computing since she was young; computing was her hobby. Her family thought of her as the "computer genius." In high school, she loved programming and advanced placement computer science. She thought it was easy and that "computer science people are cool!" At Carnegie Mellon, Sara placed out of the introductory course. With all this, Sara still found it "scary" how much computing her peers already knew. She says, "The problem is the friends that I have in computer science know so much about it—more than is expected."

Sara is right. Students at Carnegie Mellon know a lot about computing. Throughout the campus—from fine arts to engineering—many students are extraordinarily knowledgeable about computing. The history of Carnegie Mellon as one of the birthplaces of modern computing, as well as the computing-related orientation of many of the disciplines, attract students who are intensely interested in and knowledgeable about computing. In a study of the introduction of computing into the academic instruction at Carnegie Mellon during the early to mid-1980s, researchers L. Sproull, S. Kiesler, and D. Zubrow (1987) caught an irony of the place:

> CMU clearly values computing quite highly. But in their enthusiasm for computing, its managers and experts have created situations in which it is hard for novices to be enthusiastic. Like the overzealous tour guide who forces his charges to climb endless sets of steps for the perfect view, to eat sheep's eyeballs for the perfect culinary experience, and to sit through a five-hour native poetry reading, this organization can produce more cultural dropouts than recruits. (p. 194)

Scattered throughout the university are students who wanted computer science as their first choice of major but who were not accepted because of the competitive admissions. Every seat in the department is highly coveted.

This leads to campuswide envy (mixed in with some contempt on the part of students who still see computer science majors as asocial geeks) and high expectations of how much a computer science student should know. As a result, the bar of what one should know, if one is a computer science major at Carnegie Mellon, is raised astronomically high. For students, including most women, who have not spent their tender years in front of a computer, these high expectations can be discouraging. This phenomenon is especially difficult for first-year students, who often were at the top of their high school classes and the computer whizzes of their schools or families. Suddenly they are surrounded by new faces, many of who were also at the tops of *their* schools, and they begin to recalibrate themselves in relation to their new classmates.

Carmela, a sophomore who began playing with computers when she was four, started programming when she was five or six, and competed on her high school programming team, tells us how the computing knowledge of her classmates overwhelmed her. Men's comments about how easy assignments were, when she had been working so hard on them, shook her confidence and then diminished her interest in programming:

> Then I got here and just felt so incredibly overwhelmed by the other people in the program (mostly guys, yes) that 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?"

Could this be a case of male boasting? Norma, a first-year student, talks about her assumption that the male students know more. She says that she thinks "it is the way they carry themselves." She has met some guys who "don't know anything" but who appeared at first that they did. She says that she is learning that "if I meet a guy who is a computer science male student, I shouldn't assume that they know everything":

> I mean they're obviously here because they're very bright and they think a certain way, but when it comes to programming . . . some of them haven't had the formal training, and that leads me to believe that they just [exude] confidence, I guess. It is not so much of what they know.

While male posturing and boasting may lead women to feel they know little compared to their male peers, most women college students have had less computing experience in high school and, especially, in informal, extracurricular computing activities. Of 136 incoming computer science

students surveyed in 1998 to 1999, men averaged 3.24 on a 1 to 5 scale of programming experience level, and women averaged 2.14; 38 percent of women and 7 percent of men ranked themselves as beginners; and 12 percent of women and 45 percent of males ranked themselves at 4 or 5. These self-assessments, which could include some estimation bias, are consistent with the percentages of students who reported having paid professional programming experience: 25 percent of men reported such experience, whereas just 4 percent of women did so. Also, more males start programming early "for fun," pursue it as an interest on their own, and take it further.

Repeatedly in our interviews, male students refer to personal programming projects outside of class or work. Most females, by contrast, gained most of their experience in high school classes and seldom programmed outside of school. Although 38 percent of first-year men in our study report significant out-of-school, self-initiated programming experience before coming to college, just 10 percent of first-year women had similar experiences prior to college.

While men do have more experience, prior computing experience level turns out not to be a predictor of eventual success in the program. Prior computing experience can have a significant impact on confidence and comfort in the program and might give some truth to the impression of many women that "others catch on so much more quickly." It also can lead to grade disparities in early courses. However, self-ratings of programming experience are lower for female persisters than for women who transfer out—3.0 to 3.4, on a 1 to 5 scale with 5 being most experienced (see chapter 6). Still, the experience gap contributes to women's unease with what they don't know.

One student, Jeanne, reports standing next to a male computer science major as both were admiring a black wine bottle. Her conversation partner said, "It looks like a NEXT box." She said, "What's that?" and he said, "I can't believe you are a computer science major and do not know what a NEXT box is." She says, "This is what you get a lot of when you are a computer science major."

Not only do women perceive male students as knowing more computer science, but many experience men as doing it with greater ease and more "naturally." When an interviewer asks Penny, a second-semester student, whether her interest in computer science has increased since being at

Carnegie Mellon, she replies by describing a computer graphics lecture as "the most exciting lecture I have ever attended." But then she adds:

> 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?

Penny says that she doesn't know what she thinks she needs to know and that "inhibits my willingness to continue." She knows that this should propel her drive to learn more, but it doesn't. In addition to being humiliated, she feels "like I'll always be behind, and it's discouraging."

The Erosion of Confidence

Researchers on gender and math and science have found that self-confidence, not ability, is the significant difference between male and female science students. In their seven-university study, E. Seymour and N. Hewitt (1997) observed that most women they encountered had entered college at a peak of self-confidence, based on good high school performances, good SAT scores, and a great deal of encouragement and praise from high school teachers, family, and friends. Then, "within a relatively short time of their entry to college, women who felt intelligent, confident in their abilities and prior performance level, and who took their sense of identity for granted, began to feel isolated, insecure, intimidated, to question whether they belonged in the sciences at all and whether they were good enough to continue" (pp. 255–256). In her article "Math Self-Concept: How College Reinforces the Gender Gap," Linda Sax (1994) analyzed a survey of over 27,000 college freshman students and a follow-up four years later. She found that self-concept declines for both men and women in college math classes but that the "magnitude of the decline is greater in more selective schools" and that "the decline in math self-confidence in selective colleges is more pronounced for women than for men" (p. 149). A student's self-perception is formed by self-assessments of her abilities in comparison with those of her peers.

Women's loss of confidence is especially severe in historically male-dominated fields. According to S. Brainard and L. Carlin's (1997) six-year study of women in science and engineering classes at the University of

Washington, many women suffered a steep drop of confidence following their freshman year and never fully recovered. A study of North Carolina State engineering students found that the women in the first-year cohort began the semester less confident, on average, than the men about their ability to succeed in engineering (Fuller et al., 1997). And even though they performed about the same as the men, with an average GPA of 2.89 compared to 2.83, they lost more confidence in ability than did their male counterparts. Indeed, the difference in the level of confidence between men and women is so pronounced that the men who did not matriculate were significantly more sure of their ability to succeed in engineering than were the women who did matriculate. In a 1988 study of premedical students (Fiorentine, 1988), women rated themselves lower than the men rated themselves on every scale—including overall academic ability, mathematical ability, writing, popularity, and expectations of how well they thought they would perform as a physician. While the attrition rate for the students who received good grades was the same for males and females, the attrition rate among the students who received a poor grade was higher for women.

While women in our study expressed more doubts about their ability than most men, course grades for most computer science classes were comparable between the women and the men students. Average grades for men and women were nearly identical in the first programming course most students take, with most students doing well. And computer science grades for the second year and beyond are fairly similar, with women averaging 2.99, and men, 3.08. The only significant exception has been in the data structures course, typically taken in the second semester, where women did not do as well as men, on average.

Small Injuries Hurt Women More

While the confidence of many women hangs on a razor's edge, our tracking of students has shown that problems with curriculum and teaching hurt all students, but they hurt women and minorities even more. For instance, all students in the Carnegie Mellon program take a data structures course (15–211, Fundamental Structures of Computer Science) during the second or third semester. The preceding introductory courses are small, typically twenty-five students, and the first-year advising staff members

are devoted to teaching and make themselves available to students many hours a day. Course 15-211, though, has historically been a large class with a rotating teaching staff. It is a lecture course where computer science majors of all experience levels are students together in a course for the first time. Almost all students complain that this class tries to teach too broad a range of students. Students who are less experienced feel that the professors assume students know more than they do.

In academic year 1997 to 1998, for example, this class became a downhill turning point for many women students. Female students with less experience felt vulnerable in unfamiliar territory. In our sample, women's grades in 211 averaged 2.71, while men's grades averaged 3.21. Women students voiced more criticisms of the teaching, large class size, and assignments and frequently concluded that having trouble in 211 meant that things would get worse in subsequent courses. Many of the women felt lost, unsupported, unconnected, and unable to bolster their own sense of belonging in the field. On top of this, despite a substantial staff of teaching assistants, they felt they had little contact with faculty who could give them much-needed encouragement and support.

While the women report feeling like they were "drowning," most men in our sample describe 211 as "easy," "boring," and "repetitive." This, then, adds an extra layer of discouragement on top of women's frustration. As one woman student said:

> It is annoying to pick up a 15–211 assignment (which all my friends say is easy) and spend several hours trying to figure out what to do, then have to constantly get help from a smarter friend because I don't understand it. Then I overhear comments about how easy it was and how this person loved it and did it in four hours or something, and it seems like I can't do anything on my own.

Much prior research shows that female students in technical disciplines, perhaps partly because of their "outsider-ness," are especially vulnerable to poor teaching, inhospitable teaching environments (such as large classes), and unhelpful faculty. Even a small proportion of such occurrences against an otherwise welcoming and supportive background can have severe negative effects. One woman who transferred out discussed how a perception of poor teaching contributed to her leaving computer science:

> I get the impression that the computer science department here doesn't actually "teach." They just hand out assignments, and they say, "Do them." And they figure if you can do the assignment, then you know what's going on. I guess they

figure if you can handle four years of just doing that constantly, then you're really good at it.

"You Are Here Only Because You Are a Girl"

When we asked a student how she experienced being one of a minority of women, she said: "The guys rub it in. . . . You know, they come in and say, 'Just because you're a girl, you got accepted.'" She goes on: "I guess they're just pulling your leg or something, but it still doesn't feel good when they come back and say things like that." Another woman told us about a male peer who said something like, "Girls . . . they just bring you girls here to make our computer science department look better. . . . They don't really expect you to be able to code, but if you need help, you got the goods to get help from any guy you want." A quarter of the women we interviewed reported hearing comments implying that the only reason they were admitted was because of their gender.

Research from other universities reveals similar environments for women in computer science, in which comments from male peers, seemingly incidental or random, accumulate to make women feel undervalued and ultimately unwelcome. Ellen Spertus's (1991) report on MIT women in computer science, "Why Are There So Few Female Computer Scientists?," concludes that these comments and behaviors are "the symptom of a more fundamental problem: lower expectations for females" (p. 14). Women then internalize these low expectations with the air they breathe.

Virginia Valian (1998), professor of psychology and linguistics at Hunter College, in *Why So Slow? The Advancement of Women,* writes about perceptions of gender differences—gender schemas—and how they accumulate in professional life so that men tend to be overrated and women underrated. She writes that "people's expectations of us lead us to perform in a way that meets those expectations" and that "even when no one is approving or disapproving of us at the moment, our conceptions of ourselves are based in part on a history of other people's views" (p. 145).

When we asked a student in her second interview how it felt being a woman in the program, she said, "It's very disheartening. If you are continually told that you're hopeless, eventually you will start believing it. How long can you put up with that?"

A second-year student, Stephanie, tells us that when a male student said to her "Oh, you only got into computer science because you are a girl," she

retorted: "I don't think so! You know, I had higher SATs than you. Shut up!" She tells us that she was "not the only one who got that." One of her friends came to her when she was a first-year student and told Stephanie that that some guy said she got into computer science only because she was a girl. Stephanie said, "It's not true. Just say, 'My SATs were better than yours,' and they'll shut up, even if that's not true." At the end of this story, Stephanie tells us, "I mean, that's one thing you get a lot of."

While most of the women say that all but a few of their male peers are nice and helpful, 22 percent of the women we interviewed mention having heard that they got in only because of their gender, and an additional 11 percent wonder if this may be true. Some women, although a minority, say that they are completely comfortable in the program and that the small number of women is irrelevant to their experiences. Some even enjoy feeling unique and take pride in being one of a special few. Other women struggle with their doubts but emerge stronger, their self-confidence resistant to such concerns. Even a woman student who feels that being a woman has no effect on her, however, reveals the sting of the admission barbs: "You know, I just hope sometimes that I didn't get into computer science because I am a girl. . . . Other than that, it [being a woman] doesn't affect me very much, you know? In fact, I think maybe some people think I am even cooler."

The irony in these accusations is that until recently admissions standards for the computer science program at Carnegie Mellon arguably carried a small bias against women. Men and women were judged by identical numerical formulae, including a heavy reliance on the SAT math score, which many studies have shown to systematically underpredict women's college performance. Although final admissions decisions were subject to human judgment and review, nonetheless women tended to earn slightly higher grades than men once enrolled at the university. In the past few years, the university has adopted a more holistic approach, which we discuss in chapter 8.

"A Threat in the Air"

Professor Claude Steele (1997) of Stanford University studies what happens to minority and women students when they find themselves in academic situations in which negative stereotypes and expectations are active. In his article "A Threat in the Air: How Stereotypes Shape Intellectual Identity and Performance," he argues that stereotypes and low expectations for

women in math and science play a major role in women's loss of interest in these fields. In situations in which negative group stereotypes apply, there is a "threat in the air" that leads group members to be fearful of confirming the stereotype. This fear creates "stereotype vulnerability," which can lead to poorer performance and "disidentification" with, or detachment from, the field.

One example of Steele's research on stereotype vulnerability involves giving high-achieving men and women a difficult math test. He has found that when women are told that the test results show a gender difference, their test scores drop. When they are told that there is no gender difference, their test scores rise. His research has been replicated in many different settings and shows how the stereotype that women are less able than men in math negatively affects women's test performance. A similar experiment tested the effect of stereotype threat on African Americans students. When they were given a test, asked to note their race on the test, and told that it would test their analytical ability (which is poor according to the stereotype of blacks), their scores dropped relative to a situation where they were not asked to note their race.

Steele believes that stereotype vulnerability explains the drop of interest and disidentification with a field—especially among woman in male-dominated fields and African Americans in academic settings in general. He concludes that these students disidentify with a field in a "retreat of not caring about the domain in relation to the self. As [disidentification] protects in this way, it can undermine sustained motivation in the domain" (1997, 614). This is one way of understanding the nexus of confidence and interest and provides a deeper understanding of women students' sense of vulnerability and the conclusion of some that "computer science just doesn't interest me."

A Vicious Circle

Julie, a junior at the time, describes how interwoven confidence and interest are for her:

> I enjoy computer science, but it's not my life. . . . Part of it is a confidence thing . . . because I sometimes feel like I'm not nearly as good as so many other people. I'm not a whiz. I'm not someone who gets things instantaneously. 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.

Julie puts her finger on a pattern we hear from many students. The pattern begins when, feeling overwhelmed by coursework and outclassed by peers, a woman begins to doubt her own abilities. At this stage, our interviews often find women expressing doubt about their "fit" in computer science but still feeling keen interest. Eventually, though, if a woman's confidence does not return, a process similar to Steele's concept of disidentification ensues, and her interest also declines.

In the peculiar setting of computer science, this pattern can reinforce itself, in that a lessening of interest can cause a woman to doubt herself even more. If the archetypal computer science student is consumed with passion for the field, the thinking goes, perhaps a student with less interest simply does not belong in computing. Thus women can find themselves in a downward spiral of interest and confidence.

What About the Inexperienced Men?

What about the novice men, those with little precollege computing experience? How do they do in the program? The males with less experience are somewhat more likely to transfer out than those with more experience. Of the five males in our sample who transferred to other departments, four had relatively little programming experience. Of nineteen males with the least experience, four transferred out and four left Carnegie Mellon. Among the four who left the university, three were African American and one was Hispanic. There could not be a clearer signal that the experiences of racial minorities in computer science must be more fully understood and addressed.

Males with the least experience are more likely than other men to voice the concerns women speak of: they express doubts about their ability, and some feel like they don't quite fit and don't know what others are talking about. Even so, the self-doubt is not nearly as intense and consuming as it is for many of the female students. We believe this is because the men's abilities are not continuously under suspicion because of their gender.

While some males' confidence drops, those who face difficulties with coursework 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. To examine this further, we selectively sampled male students with little

programming experience. We found that these "novice males" did not express the same level of distress as female peers with similar or even more programming experience. While the absence of these types of feelings in the men's interviews could be due partly to a difference in communication style between men and women, causing men to be less likely to show vulnerability, none of the male students we interviewed mention pointed barbs or snide remarks directed their way. None of the men report having his existence in the department questioned because of his gender. And none reported a fear of being thought of as a "stupid male" if he asked a question in class.

An atmosphere of negative expectations about their gender's abilities places women at double risk in computer science. A female student describes the difference between the women's and men's learning environment this way:

> They [male students] have the pressure to do well, but they don't have excess pressure from us [women] 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.

Lori tells us that "there are classes where I am really afraid to speak or to ask a question because I am afraid that it's a stupid question." She feels "if I, as a girl, ask the question, they would always think 'Oh, the stupid girl.'" Therefore, she usually waits after class and talks to the teaching assistant or the lecturer. She adds: "I know that sounds horrible, but I'm really scared, and that's bad." She also observes that "there's so many guys in the computer science classes that ask the dumbest questions. It's always OK for them."

Another woman comments that "It is a testosterone thing that you can't ask for help with computers. You can't admit that you don't understand something." For instance, whenever Lori asks a question of a male with another major, he retorts, "What's your major again?" She describes reading an assignment and feeling she didn't even know where to begin and "not having any urge to ask my peers." She said, "I would go to my TA, but even that wouldn't be the greatest feeling . . . because it would be like a 'Well, what are you doing here?' feeling." So she sits alone with her questions.

When we ask one female student how statements like "you got in just because you are a woman" affect her, she shows the spirit of resistance that pulls some of these women through: "Well, we just say 'Don't say that!' It does hurt to hear that, but we don't really pay any attention to them. . . . They are not worth paying attention to."

The Need for Respect and Support

In his article "Race and the Schooling of Black Americans," Steele argues that a critical component of reducing the vulnerability of women students in traditionally male fields and of African American students overall is for the student to feel "valued by the teacher for his or her potential and as a person." He considers building a relationship of respect between teacher and student for women and minority students to be "the first order of business—at all levels of school. No tactic of instruction, no matter how ingenious, can succeed without it" (p. 77).

Unfortunately, this quality of relationship between faculty and undergraduate students is far from universal. We found at Carnegie Mellon that a few exceptional faculty, serving both as instructors and as advisors, served as valuable anchors for students during the first year and especially the first semester. Beyond that, though, many students felt they were "pushed out of the nest" and left to fly on their own. While many students formed bonds with other classroom teachers, research advisors, and departmental advisors, for many others no other relationships with faculty took the place of these first-year ties. Women students, especially, noted the absence.

Seymour and Hewitt's (1977) cross-institutional study underlines the importance of faculty mentorship relationships for women students. They stress that "failure to establish a personal relationship with faculty represents a major loss to women, and indeed, to all students whose high school teachers gave them considerable personal attention and who fostered their potential" (p. 267). They found that the relationship between teachers and students is particularly significant for female students, for "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 particularly discouraging

(p. 271). They found that "more women than men arrived in college with the expectation of establishing a personal relationship with faculty" (p. 267).

Seymour and Hewitt (1997) also found that women objected to large classes because "you don't get to know the professor," faculty are "too impersonal," and "the professor doesn't care about you" (p. 267). Men, in contrast, objected to large classes because they have "negative effect on grades," encourage more competition for grades, and are usually taught by less qualified faculty.

Researchers Amy Zeldin and Frank Pajares (2000) found that

> the most important factor in the enhancement of self-efficacy beliefs of women in mathematics-related careers was the confidence that significant others expressed in the women's capabilities. . . . Women seemed to rely extensively on the accompanying confidence development from the relationships in their lives while they were honing their mathematics-related skills. Relational episodes gave birth to relational confidence developed from others, and this relational efficacy informed their judgments of their own abilities profoundly. (p. 239)

Considering the peer dynamics, the computing experience gap, and the technology-focused curriculum that is all too common in computer science programs, it is not surprising that faculty mentoring and social relationships can play key roles in women's persistence.

The Decision to Leave

In our study, we had the privilege and pleasure of talking with women students who overflowed with interest in computing as they began their college careers. Cecily, a bohemian type, dreamed of making computerized gizmos and gadgets, "techie Jim Henson puppets." Maura's interest was in biogenetics and computing. For those of us on the research team who were social scientists, who admittedly held our own preconceived notions of who is or isn't thrilled by computers, it was an eye-opening experience to sit with woman after woman and have her relay her enchantment with majoring in computer science.

Our initial conversations with these women, who were just beginning their studies, were filled with exclamations about learning computer science. By the second or third semester, it seemed as if we were talking with different people. No longer buzzing, too many of these women students now were questioning whether they were still interested. The spark in their

eyes had faded; their flame of interest was dull. It happened so very quickly. And it happened time and time again. It was very disheartening.

During the first year of our research, six of the seven first-year women made the dean's list. The picture became more complicated and less rosy in the second year. Of the seven female students of the 1995 first-year class, four had left computer science by the second year. (One has since returned.) Of those four, two were top students. Among the 1996 cohort of fourteen first-year female students, three students had transferred out of CS within the first year. In the second year, seven began to question seriously whether they would remain in computer science. From our sample of twenty-nine males, three have transferred to other departments, and three (two African American and one Hispanic) have left Carnegie Mellon. Of the female CS majors who have transferred out, multiple factors were involved, the two predominant ones being lack of interest in the course material and self-questioning of their ability, often in relation to their peers.

Attrition of women from computer science has been a significant problem both at Carnegie Mellon and nationwide. Women in the computer science program have transferred to other majors or left Carnegie Mellon at more than twice the rate of male students over the past several years. While it may be tempting to assume that the difficulties expressed by women who leave the program are somehow unique to them, in fact the majority of women in the program, both those who leave and those who stay, express similar dissatisfaction with their peers, the culture of the discipline, and the teaching. The persisters go through the same processes of self-doubt, fear, and anxiety as the leavers. Seymour and Hewitt's (1997) study also found that the experiences and attitudes of those who stay are not very different from those who leave:

> Perhaps the most important single generalization arising from our analysis is that we did not find switchers and non-switchers to be two different kinds of people. That is to say, we did not find them to differ by individual attributes of performance, attitude, or behavior to any degree sufficient to explain why one group left, and the other group stayed. (p. 30)

Conclusion: The Responsibility to Change

Our analysis of the nexus of confidence and interest leads to an emphasis on institutional responsibility. We do not blame the student or expect her to toughen up, turn a blind eye, or adjust. We believe that educational

institutions and their culture, curriculum, faculty-student relations, norms, and standards must change. The problems of teaching, faculty and peer relationships, models of success, curricular focus, and the experience gap all work to the detriment of women's interest in computing. We believe that the decline in women's confidence must be acknowledged as an institutional problem. It is all too common for these psychological concerns to be regarded as beyond the purview of developing a strong computer science curriculum.

It is also too easy for faculty and administrators to take at face value the reports of many students who leave a major due to "loss of interest" and to view this as a natural course of events. If they are unaware of the complex relationship between interest and confidence, they may simply conclude that those who leave are (in Seymour and Hewitt's term) "appropriate switchers" (p. 392): they have found their intellectual interest and passion elsewhere. It is only through understanding the processes by which many women experience an unwarranted loss of confidence, leading to a corresponding loss of interest, that institutions can prepare to intervene.

Seymour and Hewitt also found that in the absence of institutional intervention to actively support women students, what distinguished the persisters from those who left was "the development of particular attitudes or coping strategies" (p. 30). In the following chapter we look at the qualities, experiences, and personal strategies that allow women to stay (and sometimes thrive) in the face of alienation, doubt, and uncertainty. We focus on what the women students who persist as a small minority in the computer science major over the four years reveal about how they sustain confidence in themselves and interest in the subject.

6

Persistence and Resistance: Staying in Computer Science

The Persistence Roller Coaster

During our research we were often surprised by which students stayed in the program and which left. Especially in the first two years, many women ride an emotional roller coaster of certainty and doubt from term to term, indeed from week to week, and whether they decide to finish the ride or get off before it ends is unpredictable. Although we interviewed students each semester, students' decisions to leave the program or to stay surprised us more than once.

Paula, for example, began the program excited, enthusiastic, and confident. She had completed a summer internship at one of the local computing labs and was enthusiastic about majoring in computer science. But not long after her arrival, she began to have doubts about her interest and abilities and started talking about leaving. The following semester she told us she had decided to stay, was happy in the program, and was sure she would continue. In her third semester, she told us she had decided to transfer out because "it just isn't worth it" any more.

As often as we were unprepared when women who seemed happy left, we were also sometimes surprised to find them staying. In *Talking About Leaving: Why Undergraduated Leave the Sciences*, E. Seymour and N. Hewitt also refer to this back-and-forth dynamic of students' decision-making process. The one thing that did become predictable was timing: students would most likely leave in the sophomore year, the time when most students, across all majors, do their switching.

What determines whether a woman chooses to stay in or leave computer science? In this chapter we look at what we call the pillars of persistence—the qualities, experiences, and strengths that allowed the women we

interviewed to persist despite doubt and uncertainty. We are particularly intrigued with the counterintuitive stories of some of the women students. While a segment of the female persisters resembles the majority of men in certain ways, the portraits of many successful majors run contrary to expectations and assumptions about who can and will succeed.

The Expected: "I Have Always Been Around Computers"

One may intuit that women who persist are likely to come from backgrounds similar to many of the males: computer-intensive families, lots of parental support, a fair share of hands-on experience, fascination with computers. But one of the most surprising findings of our research is that the backgrounds of the women persisters varied wildly. Brenda is someone whose background is similar to what we've described, except that her family includes female role models. She describes her family as "basically a whole family of nerds." Brenda has had computers in her house since she was in kindergarten. The whole family used them, and they often had several going at once. As a result, she says computers and her interest in them are "natural" to her. Brenda's dad is an engineer, her mom is a librarian, and her sister is studying computer science at MIT:

> So I've always been around computers, and it's just . . . natural to me. Even when we first had an Apple, they'd [parents] encourage me to just pick up stuff and try around. . . . We'd do it cold—do it without a disk—and I started programming in Apple Basic, just very simple stuff, and it got me interested in it. So everything else later just came naturally that I wanted to learn about.

Brenda's family didn't watch TV much, and computer games were her entertainment. She "dabbled a bit in Apple Basic to see what fun stuff I could do," learned word processing, and did her science projects on the computer. Her parents have lots of computer-literate friends, and when they visited, they would all play computer games together. In junior high, Brenda started getting involved in the Internet through her sister and mother. She helped run bulletin boards. She also had friends who used computers, though not as much as she.

Brenda's "family of nerds" helped her sense of fit and belonging in computer science. Computers were part of her furniture; they became "natural" to her. Perhaps unsurprisingly, Brenda describes her decision to major in CS as a "kind of a default." She had a wide variety of interests,

from music to math to writing, "so it was kind of a toss-up of what I really wanted to do." But she decided that she was "probably the most comfortable around computers in general." She adds, "I'm not sure exactly what area I want to go into. I only know . . . I like computers. So that's a good place to start." Even though she found many of her classes very challenging, Brenda is satisfied with how she did in all of them. She enjoys learning to write code. She says, "I know how to think like a programmer." But she adds, "I'm also not a super-genius or anything."

Family make-up emerged in our study as worthy of further investigation. As in Brenda's case, we repeatedly heard women with no brothers attribute their interest in computer science to this fact. While we do not have enough data to draw a firm conclusion, we heard many reports of boys claiming the title of "family computer wizard," with this spot seemingly opening up for a girl in families with no brothers.

The careers and interests of a student's parents also have a major influence on whether a woman pursues an interest in science or engineering. Not only do women with parents in technical occupations pick up language and concepts around the dinner table, but the intimidation factor decreases, and parental mentoring and encouragement increase. The impact of parents is documented by Paula Rayman and Belle Brett's (1993) Pathways Project, a longitudinal research effort at Wellesley College that investigated the experiences of young women in science and mathematics during their undergraduate, graduate, and early career years. Rayman, Brett, and their colleagues found that parental support is one of the pivotal factors that distinguish women who go on to science careers from those who do not.

Coming from a computing or engineering family certainly provides important emotional and intellectual stepping stones for majoring in computer science, but our research shows that it is not required. Forty-eight percent of the persisters we interviewed did *not* come from "computing families." These students' stories provide us with an opportunity to find other stars in the constellation of persistence.

The Counterintuitive Persisters

Some of the most fascinating stories of persistence were told to us by women students who had absolutely no computing experience in their

family background. These were mostly international students, raised and educated primarily in countries other than the United States. (Approximately 30 percent of the female computer science majors at Carnegie Mellon during the course of our study have been international women—primarily from Asia and Eastern Europe.) Their motivations for choosing computer science, along with their lack of computer experience, make them the antithesis of the "computer-obsessed since childhood" stereotype. In fact, many of these women were only marginally interested in the field when they began the program.

From their experiences, we learned that despite the tremendous range of computing experience among students, women who are complete novices are no less likely to persist than the most experienced women. Their stories show us that prior computer experience does not make the critical difference. The portraits of these students fly in the face of expectations and assumptions about who can and will succeed in a competitive computer science program.

Little Experience and "No Choice"

Kanitha was a junior from Thailand. As one of ten children, her parents could not afford for her to attend university in Thailand. She came to the United States for high school, where she took her first computing class. Her decision to major in computer science was not based on prior experience or love of computing. She told us about her completely pragmatic, and in some ways very uninformed, decision to major in computer science:

> 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.

Kanitha came to Carnegie Mellon on a corporate scholarship, which requires her to return to Thailand after graduation and work for her scholarship sponsor. She is very clear that the chance to study abroad is most important to her; what she studies is secondary. She eventually decided to choose computer science as a major over electrical engineering because the best scholarship offered was from the Bank of Thailand, which wanted

computer science majors. We asked her why she chose computer science over electrical engineering:

> Why? I don't know. . . . Actually, like the scholarship itself, you know, for this different scholarship I have a different sponsor for it, so after I graduate, I have to work for a different person. So now I am thinking about which one I want to work for. And then I finally ended up, "OK, I think I want to work for this sponsor." So that is why I picked computer science. It's not because of the difference between those two. I don't even know what the difference is. Because I have to go back and work, so I just like consider the workplace and like the sponsor.

When asked, "How did you end up getting a scholarship to study computer science with no computer background?" she answers, "I just want to study abroad, so anything is fine with me." Kanitha has been an extremely successful student at Carnegie Mellon and is considering graduate school in computer science.

"You Have This Bridge You Have to Walk Over, and You Just Don't Look Down"

In another set of accounts, we hear how the pressing need of many international students to become breadwinners for their families leads them to pursue economic opportunity over personal interest. Concern for their families motivates them to stick it out and work hard despite doubt and lack of confidence.

Larissa, for example, moved to the United States with her family from Russia two years prior to attending Carnegie Mellon. She learned English while attending an American high school for two years. While Larissa had more prior computing experience than did Kanitha (she used to play computer games with her dad), she had little experience in comparison to either men and women from the United States. Throughout her four years at Carnegie Mellon, Larissa consistently ranked at the top of her class. She was thoughtful in reflecting on her experiences learning to live with the computer culture, accepting how little she knew compared to the peers around her.

Larissa described her first two years as walking over an "abyss." It was very difficult for her, and she frequently doubted herself:

> You have this bridge you have to walk over, and you just don't look down. . . . There were cases when I started looking down, and it was really scary. I'd think,

"WHY am I putting myself through this?" . . . But I have to do this, anyway, because I have to.

Larissa felt there was no option for failure, since her entire family was counting on her for financial support. Her father had been a research scientist in Russia, but in the United States has been managing a small restaurant. Her brother's ability to go to college depends on the money she will make after graduation. She has no financial safety net beneath her and feels she must persist. She believes that "you cannot have everyone doing what they want to do," that there is "supply and demand with jobs and what needs to be done," and that "basically, we have to do good to stay here." And she adds, "It's just a matter that if I'm doing something, I have to be good at it, so . . . you just work hard."

Degrees of Freedom

Motivations like these can boost persistence of students, even in less than ideal circumstances. Seymour and Hewitt (1997), in *Talking About Leaving*, speculate that "gender differences in perceived degrees of freedom to choose and to change direction" lead more women than men to leave the sciences (p. 278). They suggest that especially among students from socially and economically advantaged backgrounds, women choose disciplines "largely by the degree of personal satisfaction they offer" and "pay less regard to their economic viability" (p. 279). The result is that when the math-science tightrope becomes culturally or academically uncomfortable, women with safety nets may jump: "Reports of relatively easy release from initial commitment to a science, math, or engineering major were most common among women from economically advantaged families" (p. 278). On the other hand, Seymour and Hewitt found that black women, older women returning to school, and women from working-class families did not feel the same degree of freedom. We found this also to be the case with many of the international women students.

We do not advocate that women forgo personal happiness and sacrifice academic pleasure in the interest of expediency or financial incentives; rather, we are pointing to ways that motivations can affect persistence. But what also is required is a strong sense of self-efficacy. From interviews with these counterintuitive persisters we were able to identify several "pillars of persistence" that help boost students' sense of self-efficacy.

Attributional Beliefs about Intelligence and Talent

Research on learning motivation based on U.S. students has found that students generally hold one of two opposing views on intelligence. One view is that intelligence is a fixed trait—as in "you are born with the talents that you have, and nothing you do can change them." Students who hold this view tend to focus on performance issues such as grades and other forms of external approval. The other view holds that intelligence is a malleable quality—as in "if you work hard and practice, you will improve." These students tend to orient toward learning goals such as improvement and developing mastery.

Which of these dueling views a woman in computer science holds can make a difference in her sense of self-efficacy and persistence. The research of psychologist Carol Dweck (1986), who studies learning motivation, shows that "a focus on ability judgments can result in a tendency to avoid and withdraw from challenge, whereas a focus on progress through effort creates a tendency to seek and be energized by challenge" (p. 1041).

Believing in the link between effort, hard work, and success seems to be the mantra for many of the international women students. A woman from Thailand, in describing her first-year experiences, credits hard work for her success:

> I know it's hard, it's really hard, because I remember my freshman year. I want to give it up because it's hard. But then I thought, "That's a loser's talk." So then I should try it and work hard. I think I can do it.

An Indian student attributes her persistence to "lagan," a Hindi term akin to "putting your nose to the grindstone." Using an example from Indian math education and its routine disciplined drills, she connects her cultural and educational training to her success in computer science:

> But that routineness, I think, is something that isn't taught enough here. . . . And so people here have, from my experience with my classmates, I see they have a lot of insight, a lot of intelligence. . . . You know, they [snaps finger] pick things up as quickly, but they don't have the grit to sit down with something for, say, six hours and say, "All right, I'm going to get this done no matter what."

When we ask Larissa what factor she feels contributed most to her success, she tells us, in no uncertain terms, that it was "hard work." She believes that despite knowing less than other students, she will catch up and succeed by working hard.

Culturally Inscribed Attributions of Success

Psychology professors Harold Stevenson and James Stigler (1992) have conducted a cross-cultural examination of beliefs about achievement. Their research aimed to figure out why American children seem to be forever losing educational ground compared to children in some Asian countries. In their book *The Learning Gap: Why Our Schools Are Failing and What We Can Learn from Japanese and Chinese Education,* they examine the organization of schooling and the practice and profession of teaching. They also look at attributions of success and show how these beliefs are culturally inscribed.

Stevenson and Stigler (1992) consider the prevailing philosophies in Asian cultures and note that Confucian philosophy promotes the belief that lack of achievement is due to insufficient effort rather than to a lack of ability or to personal or environmental obstacles. In other words, a person who works hard will master a task. Many Asian students grow up hearing adages like those of Chinese philosopher Hsun Tzu: "Achievement consists of never giving up. . . . If there is no dark and dogged will, there will be no shining accomplishment; if there is no dull and determined effort, there will be no brilliant achievement" (p. 97).

In elementary schools throughout China, young children hear parables instructing them to work hard, put in the effort, and learn. One such tale is about Li Po, a poet who walks by a small stream and sees a white-haired old woman who has made a needle from a rock. The woman advises Po: "All you need is perseverance. If you have a strong will and do not fear hardship, a piece of iron can be ground into a needle." Other sayings and mottos convey the belief in hard work and effort, such as "The rock can be transformed into a gem only through daily polishing," and "the slow bird must start out early" (Stevenson and Stiegler 1992, p. 98).

Suzuki, the early childhood educator who introduced a now world-famous method of teaching the violin to very young children, had a similar philosophy about children's learning. Teaching violin to young children is not a question of seeking out the naturally talented. Suzuki (1978) believed that all children, with daily practice and hard work, could learn to play the violin. A boy or girl does not have to be a child prodigy to learn to play very young. Suzuki's teaching model compares violin playing to language acquisition: it happens through regular practice and repetition at a very young age.

Jane has read her daughter the story of Lilia, the 1996 Olympic gymnastic gold medalist from the Ukraine. In the official version of the Ukrainian gymnastic federation, Lilia is not a "natural" gymnast. Her hands are too small for the bars, and her back is weak. But Lilia's coaches recognize her determination—"a will to win and work exceptionally hard." Almost every section of the book repeats this refrain. The book also describes how it takes a team effort of Lilia, her coach, and her choreographer to win the medal. None of them could do it alone. Rather than the single famous star, the book is about a team that works hard until it wins.

Hard Work Versus the "Computer Gene" Theory

When faced with difficult course work, American women also work hard—very hard. Yet too quickly they hit bottom, concluding that they lack the "natural and innate talent" with which the men seem to be born. Lily, a U.S. student who was full of enthusiasm when she began a year ago, in her last interview questions whether she should be in the program:

> I don't really feel like I should be in the department. What am I doing here? So many other people know so much more than me, and this just comes so easy to some people. . . . It's just like there are so many people that are so good at this, without even trying. Why am I here? Do I want to work my butt off for four years, when there are so many people that it comes naturally to? Should I be here for the sake of the field even? You know, someone who doesn't really know what she is doing?

Lily ultimately despairs, concluding that no amount of practice or time spent on a task could improve her mastery of the material. As another female student says:

> There are people who are born to do this, and I am not one of them. And it's definitely not one of those things that, like, "Oh, with practice, you will become one who is born to do it." . . . I think a lot of people are just born with it. You just gotta be like, "Computers! Yeah! they are awesome!! They are my life!" You know, a lot of computer scientists, that's all they do.

We continued to hear this refrain, as women looked around and experienced their male peers knowing more and doing the work with greater ease. We have found too many American women fall victim to the "computer gene theory," even if unconsciously.

Gender and the Entity View of Intelligence

In her article "Motivational Processes Affecting Learning," Carol Dweck (1986) suggests girls may be more likely than boys to subscribe to an "entity" view of intelligence—seeing ability as a fixed, static trait—and therefore exhibit a tendency toward low expectations, challenge avoidance, and debilitation under failure. She describes a series of studies by Leggett who assigned a novel "concept formation task" to bright junior high school students (Leggett 1985). Researchers observed a greater tendency of those girls who subscribed to the "entity" view to avoid challenge.

The entity view of intelligence can take its toll even on a student who works extremely hard. We witnessed how a student who attributes her math success to hard work rather than ability can have low expectations for future success precisely because she thinks her future courses will be even more difficult and demanding than the ones in which she is currently enrolled. A top student in her class reasoned that her As were the result of hard work, not ability; in her view, others got As without working so hard. Despite her 4.0 average, she ended up leaving the major, convinced that she was ill-suited for the field because she put in so much effort.

Cultural Resistance

In chapter 4, we discussed how the male hacker has become the cultural norm in computer science, the standard to which women students begin to compare themselves. We have found that women who persist are those who find a way to get grades they are satisfied with and who can develop a personalized view of computing and their place in it. Women who accept the prevailing culture as the norm and who continuously compare themselves to this norm and find themselves coming up short are the ones who suffer the most.

The majority of women struggle to find a place where they can feel comfortable in the prevailing culture. One female student told us how she has refused to conform to the image of the myopically focused "computer geek." 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 any need to conform to the culture around her, she answers:

> I refuse to. I was worried what if I don't. 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 so far I haven't. I'm getting really good grades without 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.

Ironically, it is in this area of relationship to the culture that the international women may have an edge. The international women do not as readily use the U.S. male hacker as their reference group. Since they are not fully part of this culture, their reference group is elsewhere. Many international students have alternative success norms and social bonds that protect them. Other priorities are dominant, and with these come other scales for self-evaluation.

It is important to note that some women students do feel the prevailing culture is a relatively good fit for their interests and personality. They take pleasure learning to walk the walk and talk the talk; becoming part of this culture helps them persist. An American female student talks of a sense of mastery when she became familiar with computer science (CS) jargon: "It kind of feels like becoming part of a club—CS club." She observes that her new adopted lingo may not be required but that "it is what you grow into:"

> I've had several friends who are walking along the sidewalk and make a joke and say it in code. It's something that non-CS people or maybe an arts person would just think is totally stupid, but we think it's funny. It comes naturally.

Another woman reports, *à la* Star Trek, that "resistance is futile" and takes pleasure in the thought.

Breaking the Isolation and Building Support

"Surround yourself with supportive people!" is the mantra of a current American graduate student who attended Carnegie Mellon as an undergraduate. She attributes her undergraduate survival to the support she received from her family and friends. She recently tells of being the only woman in her lab in graduate school. She didn't mind that except that there was a "guy in the lab who was a sexist pig, to put it nicely." She describes the support she got from the other students in the lab:

> But the best part of it all was that any remarks he made would be stifled by the other men in the lab. I had good friends! They were shocked at this guy, and he shut up (and thankfully left school) eventually.

Rebecca, a junior, tells us that her boyfriend, "can't really help me with my assignments, but he's good moral support." She describes him as "one of those people who, when I am saying 'I can't do this assignment anymore!' he's like, 'Yes, you can. I know you can. I've seen you do these things before!' "

Vera, a junior, talks about the support she received from a computer science women's dinner. She begins by describing her earlier social isolation, being one of a minority of women in the midst of male bonding:

> Being female is scary in this program. First you feel alone, and you don't know who to go to, and you don't know who to talk to. You just feel weird because you see the immediate bonding between other people, just male bonding . . . just showing off and talking. . . . I can still get intimidated easily. And you just feel like you're in a minority. It's just a weird feeling.

She then describes how her self-doubt turned around when she attended her first dinner for computer science women students. She realized that others shared similar feelings and she was not alone:

> I had all those feelings, and I didn't think that anyone shared those. I remember we had a CS dinner with the women in grad school. And it helped me a lot because I wasn't talking, but I was listening, and I thought everybody was saying the exact same things that I was feeling . . . like everybody was talking about them. And it was a big relief for me to realize that actually other people, other females were feeling the same way. And I just felt so much better. I remember after feeling . . . it was such a big relief.

Chirudee, a Thai student, also notes the importance of having a support network of friends. It was the presence of many Thai students on campus that convinced Chirudee to come to Carnegie Mellon in the first place. And indeed the Thai social circle turned into her support network. She says she pulled through one of her difficult programming classes and even enjoyed it because her friends were also taking the course:

> I kind of enjoyed it. But not many people enjoyed this class. But I did because there were many of my friends taking it and we would kind of like suggest with one another. And then I felt like fun doing it, so I mean I enjoyed it. The instructor . . . I felt he was OK. . . . I mean he wasn't that great. But my friends didn't like it, but . . . because of my friends I kind of enjoyed it.

Supportive Learning Communities

Salina grew up in Malaysia and has ten brothers and sisters. Both her father, a forester, and her mother, a housewife, were computer illiterate. She attended a boarding school and was in the "science track." When she arrived at Carnegie Mellon, she "knew a bit about Basic, and I had never really done any hard programming work at the time." She rated her preparedness at the time of beginning Carnegie Mellon as two on a scale of five and had low confidence. By her junior year, she rated her preparedness as a four and her ability as a three.

Salina describes her first year as a "really hard year for me." Her confidence was low, and "I see all these other students just grasping the concept in less time that I could." She sat in class, feeling lost and "in shock," feeling that maybe she couldn't make it. She says, "I was just totally scared at the time." But she says, "just by working harder I eventually caught up with the whole class, and I ended up getting an A in the class."

Salina attributes her success partly to the support she received from friends. She said that everybody was just helping each other out. In her second semester she took 15–211, the course with a reputation of being a major hurdle:

> I was really just baffled in that class because I just couldn't understand anything, so my confidence went down again at that point, plus I didn't know anybody in that class. So I dropped the class because I didn't have any confidence in doing that. . . . I took the course again in sophomore year, and things started to get clearer for me. Understand things better, plus at the time I made a lot of friends in the major. And you know, it is just the feeling that you have people going through the same thing with you. So it makes it better.

Former University of California calculus professor Uri Treisman (1992) believes that a supportive learning community is critically important for the success of minority students in math and science. Seeking answers to the high failure rate of African American students studying calculus at the University of California at Berkeley, Treisman observed that Asian American students formed social communities in which they helped each other with math, competed at mastering the material, and generally supported each others' learning, similar to what was described by Chirudee above.

He also found that most African American math students he studied were highly motivated, worked hard, and studied long hours but that even the best-prepared among them were failing. What stood out between the Asian and African American students was not a difference in motivation, preparation, or family support but in integrating studying and learning into social lives. African Americans were academically isolated and did not congregate into learning social communities the way the Asian students

did. Instead, their academic interests and social interests were separate while they worked hard (and somewhat unproductively) on their own.

Observing the extra boost that comes from living and engaging with the material, Treisman has formed communities for African Americans similar to those created by Asian American students. These communities are built around intellectual interests (in this case calculus), provide well chosen problem sets that drive group interaction, and foster a supportive learning environment. Currently, Treisman-inspired Emerging Scholars programs operate in numerous colleges and universities and achieve high rates of retention in calculus courses among African American and Hispanic students.

Computer Science as an Acquired Taste

Studying the life arcs of women students in computer science over a four-year period has revealed to us some patterns of persistence. If students are able to stick it out through the second year, get grades they are pleased with, and reconcile their relationship to the culture, then their initial level of confidence often returns, accompanied by an increase in interest.

Interviews with persisters often reveal a key moment of success or achievement that keeps them going. For one senior, this moment was in her third semester, when she got over the hump of the data structures course (211) and began taking more advanced classes. She says that she had no confidence after 15–211 and "thought I would flunk out or get kicked out of CS." But then she ended up getting an A in the course that immediately follows in sequence (15–212). She is in awe that she mastered the more advanced material. And the fact that she did it on her own became very important for her. In 211 she frequently needed to consult her teaching assistant, but in 212 she "was able to go right through the course without help." That was her confidence builder:

> In 211 I was constantly going to the TA, and I was like, "I don't know how to do this!" And I felt like he was practically writing my programs for me because every time I'd have a bug or something, I'd be going to my TA two or three times for each program, at least. Then in 212 I was able to go right through the course without help or anything. It was just a great feeling for me, and I feel I learned a lot. And it was just a big transition for me. It was a lot of big "Ah-hah! So that's what we were learning before!" All of a sudden things started clicking. It was just like a really big transition for me.

While this feeling of self-sufficiency may seem contradictory to the confidence gained from working with a supportive group, one way or another students have to internalize a sense that they can do it. If students persist for a sufficient amount of time (at least through the sophomore year), the odds are that they will regain confidence in themselves. Brenda, a sophomore student, talks of this confidence:

> But it's kind of like if you're running, and you get to this big hill, and you're like, "Oh man, I'll never be able to run up that." And you do, and then you get to the next big hill. So it's like you're not exactly dreading it because once you get to the top, you feel really good about yourself. I guess I used to be afraid of a lot of things, but as I keep getting over and over these courses that I never thought I could pass, I think I'm ready to do the next step. And I don't know how I'm ever going to do senior-year courses, but I'll know when I get there.

We have found that if students get through the first two years, that a sense of mystery about computing turns into a sense of mastery. Asked if her interest in CS had increased or decreased, one junior provides an example of an upward spiral of confidence and interest:

> I think partly it's increased just because I put so much work into it. It's like when you invest this much time in something, you want to do good in it. And also, I think the more I learn the more I think, "I can do this thing!" I just need to work really hard at it. But yeah, I think I've gotten more interested in it.

A Malaysian woman describes the satisfaction she felt in 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.

Conclusion

Despite doubts and uncertainties, women tend to persist in computer science when they reject and find alternatives to the dominant culture of the field. A larger question, though, is what institutions can and should do to eliminate the negative factors that lead students to leave computing programs. We touch on several ideas for high schools in chapter 7 and for universities in chapter 8.