Viewpoints from the Doorstep:
Pre-major Interest in and Perceptions of Computer Science

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This is to certify that I have examined this copy of a doctoral dissertation by

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and have found that it is complete and satisfactory in all respects,
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Abstract

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The goal of this two-part work is to extend the small but growing body of research on the recent, rapid drop in undergraduate interest in CSE, especially among women. Both the first part, a qualitative study, and the second part, a curricular development effort, draw on a wide variety of disciplines, spanning the social sciences, CSE, and CSE education/pedagogy. The first and main part is an interview-based, descriptive study of pre-major undergraduates. By framing the findings in Eccles *et al.*'s expectancy–value model, an established theoretical model of academic motivation from the educational psychology literature, we describe how a variety of factors affect women and men's interest in the CSE major. As a theoretical contribution, we also propose refinements and extensions to the expectancy–value model for specialized application to research on entry into CSE and gender. The second part of our work is the design and formally evaluated pilot deployment of an educational intervention whose aim is to address some of the issues illuminated by the descriptive study. The "CSE Exploration Workshop," as it was billed, was designed to help pre-major undergraduates make better informed decisions about majoring in CSE and was a qualified success, based on an external evaluation.

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Chapter 1

INTRODUCTION

This work expands understanding of the causes of low enrollment in undergraduate computer science and engineering (CSE), particularly among women, and contributes a research-based approach to addressing these problems. In addition to providing an empirical basis to inform efforts to inform and recruit prospective CSE majors, our research extends current theory about entry into undergraduate CSE.

The first and main piece of this work consists of a qualitative, descriptive research study of a specific population of undergraduates who are a good audience for efforts to encourage majoring in CSE. The second piece is the evaluated pilot deployment of an intervention whose design was directly informed by the study findings. Data analysis in the study and design of the intervention were both guided by a combination of an established theoretical model adapted from educational psychology and expert knowledge of the discipline of CSE.

The study's overall goal is to extend the small but growing body of research on dropping interest and the underrepresentation of women in CSE by illuminating the factors affecting interest in the major among pre-major undergraduates. Specifically, rather than examining reasons why students (especially women) *leave* CSE study, our study focuses on an earlier point in time and seeks to understand what affects entry into the major (or rejection of it, as is more often the case). Most prior research on undergraduate CSE enrollment has primarily focused on a more self-selected population in later stages of their academic career, *i.e.*, students who have already elected to major in CSE and the factors affecting their persistence in the major. Extremely low initial undergraduate interest in majoring in CSE motivates our contrasting focus on a pre-major population.

We propose that a deep understanding of the factors that affect interest in CSE requires investigating related questions about students' beliefs about CSE. These include beliefs about CSE as a discipline, as well as the activities, lifestyle, and culture they associate with

CSE careers. Our study includes these research questions mainly for framing and informing interpretation of our primary question about initial interest in the major. However, particularly given the apparent lack of public understanding of CSE, we also find these questions informative in and of themselves. Research questions are formally stated in Chapter 4.

To ensure an outcome of immediate, practical value, the descriptive study portion of our work was designed to directly inform an intervention targeted toward the same population sampled for the study. Design, deployment, and evaluation of the intervention are also discussed as part of this work.

Section 1.1 motivates our work by providing background on the problems of falling enrollment and the widening gender gap in undergraduate CSE in the U.S. Section 1.2 acknowledges the complexity of research and action on these problems, recognizing not only the challenges intrinsic to these problems, but also hindrances rooted in the academic culture of CSE. The chapter concludes with a brief overview of the remainder of this report.

1.1 Background and Motivation

Although CSE is a relatively young discipline, national data tracking undergraduate interest and degree production are available from a variety of sources, including the Department of Education, the Higher Education Research Institute (HERI), and the Computing Research Association (CRA). These data illustrate the rapidity and magnitude of the recent downturn in undergraduate CSE enrollment and the widening gender gap. Both of these problems have serious consequences that might reach beyond the discipline of CSE. In spite of nationally funded research and intervention efforts, particularly directed toward the gender gap, the CSE community is far from understanding why it has been largely unable to address these problems.

1.1.1 Low CSE Enrollment and its Consequences

Undergraduate enrollment in CSE has dropped rapidly in the U.S. in recent years. Between 2000 and 2005, the fraction of incoming undergraduates planning to major in computer science fell by over 70%, and, historically, this statistic has accurately predicted trends in bachelor's degree production [119, 121] (Figure 1.1). Although the latest undergraduate

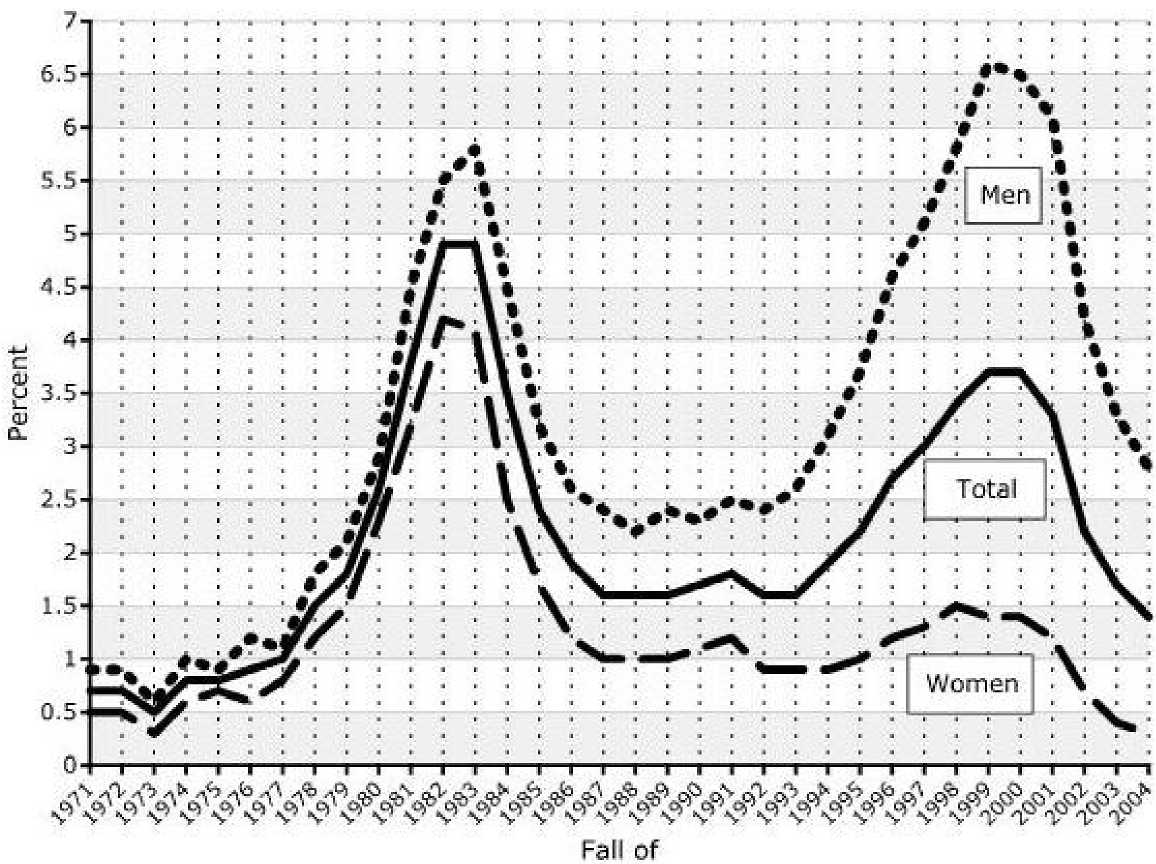

Figure 1.1: Fraction of incoming freshmen listing computer science as probable major, total and by gender (source: HERI via CRA [120])

enrollment statistics suggest that the downward trend might be abating, at least at doctoral-granting departments, enrollments are still 40% lower than four years ago [133, 121].

Possible consequences of the downturn in interest include a shortage of qualified, domestic candidates for computing-related jobs and the downsizing or even elimination of CSE programs and departments. According to current U.S. Department of Labor projections, demand for multiple CSE-related occupations will rise rapidly during the 2006–16 period [41], with multiple occupational categories in software engineering listed among the fastest growing occupations. Academia has reason to be doubly worried. Dwindling enrollments have led to the merging of smaller CSE departments with related departments such as math. In the UK, similar circumstances have even led to the elimination of entire departments [91]. Meanwhile, as industry continues to court CSE degree recipients—recent graduates as well as current faculty—with higher salaries, the discipline risks losing the teaching talent needed to prepare future generations of computer scientists. (By analogy, Roberts discussed the need for "conserving the seed corn" [93].)

1.1.2 The Growing Gender Gap

In the U.S. and most western countries, computer science has always been a male-dominated discipline, and recent trends indicate that the gender gap is growing. Nationally, the percentage of computer science bachelor's degrees granted to women steadily dropped from its 1984 peak of 37% to 21% in the academic year ending in 2006 [84] (Figure 1.2). Among the science, technology, engineering, and mathematics (STEM) disciplines, CSE claims the dubious distinction of being the only one whose undergraduate gender gap has *widened* since the mid-1980s (in the U.S.) [84]. Although there are disciplines (certain areas of engineering) where representation of women is lower than in CSE, they have all achieved steady (if modest) progress toward parity. In fact, women outnumber men in the life sciences, and the gap is basically closed in mathematics. Meanwhile, the physical sciences are climbing past 40% women. The significance of these gendered enrollment statistics is heightened in light of the larger undergraduate enrollment of women in the U.S. Since 1979, women have outnumbered men among undergraduates, with women representing over 57% of undergraduates in 2005 [84].

A closer examination of the recent, falling trend in CSE interest reveals a grim outlook [120, 119]. With interest among women falling more rapidly than among men, the undergraduate gender gap in CSE bachelor's degree awardees will almost surely continue to widen in the coming years. At the high school level, we see a similar gap in Advanced Placement examination statistics, with women representing only 17% of Computer Science A and AB test takers [32].

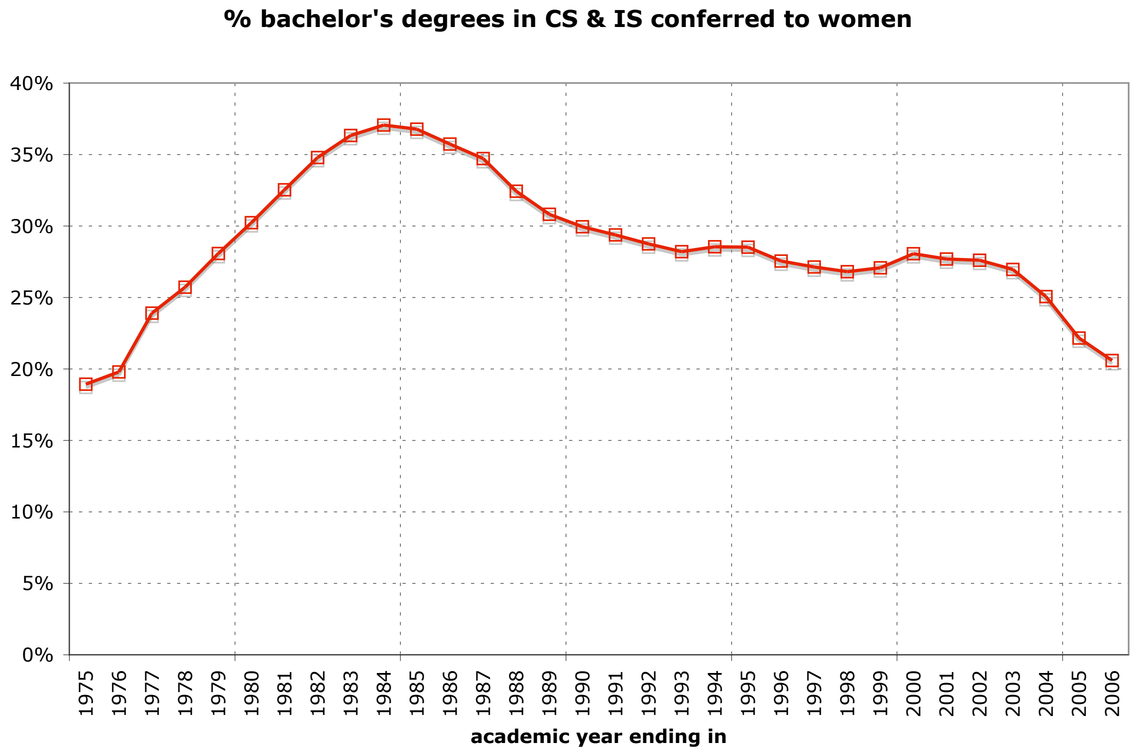

Figure 1.2: Fraction of bachelor's degrees in computer science and information systems conferred to women in the U.S. (source: National Center for Education Statistics [84])

1.1.3 Consequences of the Underrepresentation of Women

This growing gender gap is troubling for a variety of reasons, both practical and ethical. First, there are general, practical arguments in favor of diversity whose implications extend beyond gender and CS. Problem-solving and engineering are core elements of CS, and both of these processes benefit from the wide range of backgrounds and perspectives that a diverse body of computer scientists brings to the table. (Former National Academy of Engineering president William Wulf discusses this at length in a 2002 NAE report on diversity in engineering [34].) With computing playing increasingly prominent roles in so many aspects of our lives, it is especially important that the CSE community more accurately reflect our society.

Another frequently cited practical reason applies to most math/science disciplines but is probably most relevant to CSE, given predictions of a shortage of computing professionals with CSE degrees. Some CSE and STEM gender gap researchers argue that more women degree recipients can help remedy a shortfall of qualified professionals [61]. In this sense, women and other underrepresented groups represent a talent pool that has historically been underutilized.

The above discussion addresses more practical arguments for the best interests of CSE as a discipline. Assuming the goal of equal opportunity for women and men to study CSE, we must consider the likelihood that the CSE gender gap is caused by obstacles to entering and succeeding in the discipline that affect women more than men. Some of these obstacles can be directly addressed by CS programs, *e.g.*, through teaching and curriculum. Others are aspects of students' preparation and experiences before higher education, and while understanding and addressing them can be more difficult, CS programs need to adapt to them as well.

Finally, the gender gap in CS is curious enough in itself as an educational and social phenomenon to warrant further research into its causes and effective remedies. The extent to which CS stands out among the math/science disciplines with respect to gender parity, as discussed above, is particularly puzzling.

1.2 Challenges

With only a small number of in-depth research studies devoted to the topic, explanations for the growing CSE gender gap remain elusive. Indeed, one lesson from the existing literature is that there are no simple explanations and, to date, few generalizable findings. One challenging aspect is the variability of the gender gap, hinting at a complex relationship with cultural factors. Although the problem of underrepresentation of women (and other groups) is hardly new, the CSE community has only recently begun to appreciate the value of research-based approaches in understanding and addressing the problem. We discuss this and other challenges here.

1.2.1 A Widely Varying Problem

The national average statistics discussed in the previous section belie the complexity and variation of the gender gap phenomenon. Gendered enrollment and attrition varies widely across institutions and CSE departments. Cohoon found that, within the state of Virginia, attrition rates among women and men who initially declared the computer science major differed by as much as a factor of four in some departments but were equal in others [27]. In fact, in a small minority of departments, women were less likely to switch out of the major than men. (Although this statistic implies nothing about the gender ratio among degree recipients, women were likely in the minority at most if not all these departments.)

Lopez and Schulte took a closer look of a different sort with the undergraduate CSE degree recipient statistics, focusing on African American students [76]. Surprisingly, they found that, in the 1990s, the gender gap—so pronounced in the national, aggregate statistics—was virtually nonexistent among African American CSE majors. (While it is true that women outnumber men among African American undergraduates by a larger margin than among whites, this difference is insufficient to account for this within-CSE difference [NCES 2007].) Even more interestingly, they reported that, among African American CSE majors at historically black colleges and universities (HBCUs), women outnumbered the men, while the opposite was true among African Americans at non-HBCUs. Eidelman and Hazzan described a similarly intriguing situation in Israel [48]. Women represented only about a quarter of Jewish high school students enrolled in "advanced-level Computer Science," while, at Arab high schools, the figure was closer to one half.

International surveys reveal other exceptions to the typical gender gaps. Charles and Bradley reviewed statistics on undergraduate degree recipients in 21 mostly Western, industrialized, democratic nations [24]. While all studied nations exhibited gender gaps in CSE, the degree to which men outnumbered women varied. Female representation varied between 13% in the Czech Republic to 36% in Turkey. Galpin's comparison of statistics in over thirty nations was broader in that it included computing-related programs of study beyond CSE, but the general results were the same [57], with representation of women mostly ranging between 10% and 40%.

The above findings rule out simple explanations attributing the gender gap to intrinsic differences in interest or ability. It remains unclear what the key variables are, but gender differences in enrollment and attrition vary with department/institution, location (region, nation), and culture. This wide variation also implies that findings from one study do not necessarily apply to other contexts. It also threatens the validity of aggregating or directly comparing findings across departments. Similar validity concerns motivated our focus on a single department with few initial assumptions about factors affecting interest in CSE.

1.2.2 Many Guesses, Few Answers

To date, there are more conjectures than reliable evidence explaining the downturn in interest in CSE among undergraduates (both women and men). High-profile members of the CSE academic community have offered their guesses and policy recommendations with little grounding in empirical research. Peter Denning, former ACM president and NSF Distinguished Education Fellow, claimed that perceptions that CSE is narrowly focused on programming are to blame [40, 39] but did not cite research suggesting as much. David Patterson, as ACM president, more humbly admitted to offering only an "opinion" about the causes of the downturn in interest, pointing the finger at fears of offshoring of IT jobs [91]. Indeed, both of these hypotheses might be correct for certain undergraduate populations, but to what extent and for whom remains unclear.

In part, this lack of research can be attributed to the fact that low enrollment in CSE has only become a problem during the last several years. A short time ago, many departments had the opposite problem; so many undergraduates were clamoring to major in CSE that some departments instituted stringent admissions requirements and challenging prerequisite courses whose effect (not necessarily intentional) was to filter out a large number of prospective majors.

However, for the more specific question of why women in particular are so poorly represented in CSE, the history is different. As observed above, progress toward women's representative participation in computing faltered in the mid-1980s and never recovered since. In spite of a variety of efforts to address the gender gap, successes have been few, and the recent, further widening of the gap suggests how little we understand about this complicated problem.

1.2.3 CSE Education as an Area of Research

There are a variety of potential explanations for the lack of progress with respect to enrollment of students in general and women in particular in CSE. The tendency to make changes in educational policy and practice based on conjecture rather than research is one. Of those efforts that appear to have been successful, fewer still have been evaluated with the degree of rigor required to illuminate the transferability of best practices for recruiting and retaining students in CSE in other departments.

Other disciplines, including mathematics, physics, and, to a lesser degree, engineering, are further along than CSE in terms of recognizing domain-specific teaching and learning as legitimate and important areas of research. CSE education is making progress, however, with a dedicated conference [6], journals (*Computer Science Education*, *Journal on Educational Resources in Computing*), and efforts to build capacity to conduct high-quality, CSE education research [50]. Gradually, the standards and expectations for supporting claims about CSE education are rising, demanding more than personal impressions, anecdotes, and surveys limited by inappropriate design, administration, and/or analysis.

An essential element to any scholarly research is understanding and building on related, past work. In terms of methodology, the CSE community has recently begun to recognize the role of the social sciences in helping us achieve a rigorous, research-based understanding of enrollment and gender in their discipline. At the same time, deep background in CSE and, in particular, the associated teaching and learning challenges are both integral to achieving such an understanding. One practical way of combining CSE and social science background is through collaborative research efforts such as Margolis & Fisher's Carnegie Mellon study [78]. As CSE education continues to gain legitimacy as an interdisciplinary area of scholarly work, we hope that such collaborations will yield more valuable insights.

In addition to adapting proven methodologies from other disciplines, CSE education researchers can also consider the applicability of findings from past work. Analogues to the gender gap and many of the other problems CSE education faces have been the topics of research in other disciplinary contexts. However, given CSE's unusual gender enrollment history, compared with other STEM disciplines, we cannot simply assume that findings from the more substantial body of research on gender and STEM enrollment apply to CSE. That said, research such as Seymour & Hewitt's landmark study [100] and the work of Strenta *et al.* [109] (both STEM-wide) serve as rich sources of hypotheses and methodological insights. Testing hypotheses borrowed from other domains is one way of understanding the CSE gender gap, but this approach has limitations, as discussed more in the next section.

1.3 Organization of this Report

Chapter 2 reviews relevant research literature and illustrates the intricacy of the enrollment and gender gap problems in CSE. Describing a selection of significant studies in this area, we highlight the opportunities for our work to extend the CSE community's understanding of and ability to address these problems.

The next chapters detail our two major contributions: a descriptive study and a curricular intervention based on the study. Chapter 3 introduces the theoretical model applied in both parts. The expectancy–value model is an empirically validated model of achievement and motivation from the educational psychology literature. Researchers have only recently begun applying it in the context of CSE enrollment, as discussed in the chapter. Given the model's generality, the chapter also identifies the parts of the model that are most relevant in our work.

Chapters 4 through 6 are devoted to the descriptive study's methods, findings, and implications. Chapter 4 provides the formal statement of the descriptive study's research questions and an overview of the interview-based methods employed. Chapter 5 presents findings about student beliefs about CSE from the study's core data set: transcripts of individual interviews with pre-major undergraduates. The findings are organized by theme, with each theme being a group of related patterns about student beliefs and attitudes about CSE that emerged during close readings and analysis of the transcripts.

In Chapter 6, we take a broader view of the findings from the thematic analysis. For each factor found to be related to entry into CSE, examining how the findings fit into the expectancy–value model illuminates how and why the factor impacts interest in CSE. The model also makes clearer how the factors affect each other. An outcome of this higher-level, more formally structured analysis is a theoretical contribution to research on gender and CSE. This analysis provides a context-specific understanding of how the general expectancy–value model applies to CSE enrollment and its complex relationship with gender. We identify which parts and causal relationships in the model seem most relevant to this context. We also suggest ways in which the model might benefit from extension to more precisely capture influences on student entry into the major.

This more structured framing of the findings leads into Chapter 7, which focuses on how the findings informed the design of the curricular intervention. The expectancy–value model provides a structured means of directly linking findings to elements of the intervention design. The intervention took the form of a one-time workshop for pre-major undergraduates, and its main goal was to help students make an informed decision about whether to major in CSE. The chapter describes the pilot offering of the workshop, facilitated by the researcher, as well as the outcome of an outside evaluation.

Along with concluding remarks, Chapter 8 discusses three categories of future work: other interventions and changes in practice informed by the descriptive study findings, next steps in research to better understand the local situation at the studied university, and ways in which the methods (if not findings) in this work can be extended or adapted to apply at different institutions.

Chapter 2

RELATED WORK

This chapter discusses selected prior research relevant to undergraduate enrollment and the gender gap in CSE. Reviewing findings about factors influencing entry and persistence in CSE provides context for this study and highlights opportunities to confirm hypotheses and address unanswered questions. We primarily restrict discussion to recent studies that are specific to CSE and focus on student perspectives, particularly those of women. To supplement these CSE-specific studies, this review of related work also includes two studies with broader disciplinary scope—one STEM-wide (science, technology, engineering, and mathematics) and another engineering-wide.

Section 2.1 details selection criteria for the set of studies reviewed here. Section 2.2 provides an overview of each study, highlighting distinguishing aspects of the research approach and study design. Each of the remaining sections discusses a factor found to be related to entry and/or persistence in CSE and related disciplines.

2.1 Selection Criteria

This chapter's coverage of prior research is not intended to be comprehensive. (See Cohoon & Aspray [30] and Singh *et al.* [103] for more complete reviews of the literature.) However, we intentionally sampled the literature based on methodology, population studied, date and method of data collection, and analysis methods. The sample was limited to studies conducted in the U.S., in an effort to limit variation related to cultural differences.

Given recent and substantial shifts in CSE enrollment patterns, as well as the generally fast pace of change in computing in general, our review only covers studies for which data was collected since 2000. The year 2000 roughly marks the start of the most recent downturn in undergraduate interest in CSE [120].

The studies vary methodologically in that some of them test specific hypotheses about factors affecting entry/persistence; other studies make fewer assumptions at the outset and are designed to discover such factors. The approaches have differing strengths and are not mutually exclusive. Hypothesis-testing studies can provide an efficient means of determining the relevance of a set of specific factors for a large population. However, such studies can lead to misleading results if there are other, possibly more influential factors that were not hypothesized and tested for by the study. Hypothesis-generating studies can more easily illuminate factors like this. A common method for "casting a wide net" is by employing open-ended questions in interviews or surveys. Analyzing data collected in this way is considerably more resource-intensive, but the data can provide a more representative, comprehensive, and detailed understanding of phenomena. Another potential advantage is that the responses are in the participants' own words and, in this sense, might provide a more direct or authentic understanding.

Related to these methodological differences are variations in methods for data collection and analysis. The selected studies employ a wide range of qualitative and quantitative methods. Data collection methods include surveying, interviewing, and focus groups. Some studies reduce collected data to numbers for statistical modeling, while interview- and focus group-based studies traditionally involve analytic methods that yield detailed interpretations of patterns and variations in students' first-hand accounts.

All of the selected studies include data collected from students, but some also looked to other sources, including teachers/faculty and institutional data. The student populations sampled by the selected studies cover a range of timepoints in students' educational careers, from high school through completion of an undergraduate degree and beyond. Since this study's primary focus is on pre-major undergraduates and choice or rejection of CSE as a major, all of the surveyed studies investigate factors affecting entry into the major or persistence (*i.e.*, the decision to stay or leave, after having initially chosen to major in CSE).

Gender ratio is another aspect of population that varies across the studies. Most of the studies focus on gender differences in CSE entry/persistence and, as such, collected data from both women and men. Some of the studies oversampled for women to compensate for their underrepresentation in CSE and to ensure sufficient data for drawing conclusions.

Most of the studies focused on populations of students who had at least initially chosen to study CSE. For comparative purposes, some studies sampled students who chose non-CSE majors from the start, while others included students who switched out of CSE. Some of the selected studies focus on current CSE majors, instead of the perspectives of students who did *not* intend to major in CSE at the start of their undergraduate careers. These findings illuminate the experiences of women (and men) who choose to study CSE in the status quo. Interventions that aim to broaden participation in computing should ensure that they do not inadvertently alienate these populations (particularly the women). The findings also have value for being based on retrospective reflection by the participating students. If prospective majors could be helped to recognize the aspects of CSE that graduating majors find attractive, they might have a more extensive and accurate basis for deciding whether to major.

The five recent (*i.e.,* 2000 or later) studies covered in this chapter are supplemented by three older studies—one CSE-specific study and two studies with broader disciplinary scope. The supplementary CSE study is Margolis & Fisher's oft-cited study of majors at Carnegie Mellon [78], where data for this study was collected in the late 1990s. Although not as recent, this study's influence in the CSE education community and similarities between CMU and the department studied for this dissertation motivated its inclusion. The broader studies are Seymour & Hewitt's landmark seven-campus study of STEM (science, technology, engineering, and mathematics) students [100] and Brainard & Carlin's longitudinal study of women in engineering majors [21], conducted at the same institution as in our study. Both of these studies are based on data collected in the 1990s, but influence and relevance warranted relaxing our year-2000 constraint. Notably, Seymour & Hewitt's study served as a source of inspiration (methodological and otherwise) for Margolis & Fisher's CMU study.

2.2 Selected Studies

The six CSE-focused studies and the supplemental STEM- and engineering-wide studies are listed in Table 2.1. For each study, the table shows the years of data collection, sample size, level of education of the sample (*e.g.*, pre-college, year in college), representation of women in sample, and number of campuses studied.

2.2.1 CSE-specific Studies

Our core group of studies focuses on the range of factors affecting student entry and persistence in CSE. These factors include perceptions of CSE and associated careers, academic self-confidence, academic ability, prior computing experience, and parent/teacher/peer influence. The studies are described roughly in order by timepoint in educational career.

Goode et al.*, 2006*

Goode *et al.*'s qualitative study of students enrolled in computing courses at three Los Angeles, CA high schools provides a view of pre-college interest in and perceptions of computer science [59]. Because of the study's focus on pre-college students, it examines entry (*vs.* persistence) and suggests reasons why high schoolers do or do not consider studying CSE in college. In addition to student interviews and focus groups, the researchers collected data from teachers and conducted observations at the schools, with data collection occurring between 2001 and 2003. Although the interviewed samples included both women and men, the study's focus was on underrepresented students, and focus groups were conducted with women and students of color. The three study sites were chosen so that they varied in enrollment demographics, school resources, student access to computing, and computing-related course-taking opportunities.

Beyer et al.*, 2004*

Beyer *et al.* have conducted a series of quantitative, survey-based studies of CS majors and non-CS majors [18, 15], including two of first-year students [17, 16]. The study selected here sampled over 500 first-year undergraduates at the University of Wisconsin at Parkside, and, like Goode *et al.*, focuses more on entry than persistence. The participating students had varying levels of computing-related course experience, but the majority had none at all, with almost all of the remainder having taken computer literacy courses (which did not count toward the CSE major). Women were oversampled and represented about two thirds

Table 2.1: Summary of studies selected for this review. Shaded bars indicate the range of education level represented in each study's sample(s). Numbers in the bars indicate sample size.

			sample size and education level							
study	disciplinary scope	date of data collection	high school	undergrad ...Year 1	...Year 2	...Year 3	...Year 4	post-undergrad	% women	institutions
Goode *et al.*	CSE	2001–2003[1]	**180+**[2]						n/a[3]	3
Beyer *et al.*	CSE	2001–2002[4]		**567**					64%	1
Cohoon *et al.*	CSE	2001		**182**					43%	16
Biggers *et al.*	CSE	2007			**118**[5]				13%	1
								51[5]		
Blum *et al.*	CSE	2002					**33**		52%	1[6]
Margolis & Fisher	CSE	1995–1999		**127**					53%	
Brainard & Carlin	engineering	1991–1997		**672**					100%	1
Seymour & Hewitt	STEM	1990–1993				**460**			~50%	7

[1]The data collection end date for Goode *et al.* was estimated, based on the published study description.

[2,3]Goode *et al.* did not publish precise sample size or demographics.

[4]Dates of data collection for Beyer *et al.* were obtained via personal communication.

[5]Biggers *et al.* sampled 118 switchers (former CSE majors) and 51 CSE majors who had just completed their degrees.

[6]The Blum *et al.* and Margolis & Fisher studies were both conducted at Carnegie Mellon University.

of participants.

In 2001 and 2002, a wide range of data was collected for each participant, including responses to questions about educational interests, computing experience, confidence, perceptions of CSE, and personality characteristics. Most questions were closed-ended, with Likert scale responses. Many additional survey items came from previously validated instruments for assessing career selection criteria, gender roles, and personal relationships. Reported statistical analyses of responses took the form of analyses of variance, comparing across gender.

Tillberg & Cohoon, 2005; Cohoon, 2006

Two publications report on Cohoon *et al.*'s national study of persistence and gender in CSE departments [114, 29], a follow-up to a previous, state-wide effort examining CSE departments in Virginia [27]. Data was collected in 2001 from over 180 CSE majors at 16 departments across the nation using single-gender focus groups with a mean of 6 participants each. Women were oversampled and represented 43% of the sample. Unique among the other studies selected here, this study also collected data from faculty and department chairs at over 150 CSE departments. We primarily focus on the focus group findings here, reported by Tillberg & Cohoon [114], given our interest in student perspectives.

With its qualitative data collection and analysis methods, this study design helps address concerns about the generalizability of the high-profile studies at Carnegie Mellon. Valuable as they are, the CMU studies were based on an unusual population of students in a unique environment, given CMU's reputation in CSE and its resources.

Biggers et al.*, 2008*

The most recent study selected was conducted around 2007 at the Georgia Institute of Technology. The comparative research design focuses on persistence and involved a sample of 51 graduating CSE majors and 118 former CSE majors with varying class standing, ranging from second-year undergraduates to graduate students. Women were apparently not oversampled, given their representation was 10% and 14%, respectively. Recognizing the limitations of closed-ended questions, the researchers collected data using surveys with both open- and closed-ended questions. Question topics included reasons for choosing to major in CSE (at least initially), and perceptions of the discipline and major. Additional questions for only the switchers included reasons for switching and how their new major differs from CSE.

Margolis & Fisher, 2002: Unlocking the Clubhouse

Margolis & Fisher's study, conducted at Carnegie Mellon University in the late 1990s, is among the best known and is notable for its extensive, longitudinal data collection. Findings from this qualitative study were published in the influential 2002 book, *Unlocking the Clubhouse* [78]. The focal participants in this study were 51 women (oversampled) and 46 men who majored in computer science. Accordingly, this was primarily a study of students' accounts about entry and persistence in CSE. The students were interviewed multiple times per year during their undergraduate studies, providing a richly detailed account of their pathways either toward completion of the CSE major or the decision to switch to another major.

Blum & Frieze, 2005; Larsen & Stubbs, 2005

Blum *et al.* conducted a follow-up to Margolis & Fisher's study at Carnegie Mellon in 2002. Using an adapted version of the interview methods in the original study, they collected data from a sample of 33 fourth-year CSE majors, oversampling such that half were women. With the focus on CSE majors close to graduation, this study yielded profiles of persisters. In contrast to the earlier study, this follow-up was not longitudinal.

2.2.2 Supplemental Studies

Seymour & Hewitt, 1997: Talking About Leaving

Possibly the most influential study in our selection, Seymour & Hewitt's extensive study of third- and fourth-year undergraduates at seven varying institutions was published in the 1997 book *Talking About Leaving*. Interviews and focus groups were used to collect data from 460 students, all of whom at least initially chose a STEM major, with roughly half in engineering and the remainder in science/math. (Notably, CSE was *not* included in either group and was not represented in this study.) About half of the sample had switched to a non-STEM major, so many of the findings are based on comparisons between switchers and non-switchers. Oversampling of underrepresented populations resulted in about half being women. The researchers also oversampled for racial/ethnic minority students.

Brainard & Carlin, 1998

In their extensive, longitudinal study of women in engineering at the University of Washington, Brainard & Carlin collected data from over 670 students using survey and structured interview methods. Data was collected over a period of six years (1991–1997) from successive incoming cohorts of women, following samples of about 125 female, prospective engineering/science majors from each cohort. Research was entirely focused on factors related to persistence, which was assessed on an annual basis. Regular, repeated data collection across class standing yielded findings about longitudinal trends in the influence of certain factors on persistence. Most notably, findings showed a sharp loss of confidence during the first year, followed by a late but only partial recovery during the fourth year of study.

2.3 Factors Affecting Entry and Persistence

Entry and persistence in CSE are distinct but obviously related phenomena. Some factors are more influential on one than the other, but research has connected most factors to both entry and persistence, to varying degrees. This section catalogues the factors found to be related to entry and/or persistence in CSE by the selected studies.

For clarity, the section is organized by categories of factors, but the discussion emphasizes the interrelated nature of many of the factors. Confidence, achievement, computing experience, and satisfaction with teaching, for instance, appear to be related in different ways. All of these factors, either directly or indirectly, seem to influence entry and persistence in CSE. The precise nature of these relationships is unclear from the selected studies' findings alone. However, the findings collectively suggest a variety of explanations for why women and men major and persist in CSE.

Some findings appear to be more influential for certain populations and at certain time-points in a student's educational career. Given our research interests, much of our discussion focuses on the differential influence of certain factors for women and men. However, we also touch on differences in findings pertaining to students in CSE *vs.* students in other STEM majors.

2.3.1 Perceived and Actual Preparedness

Perhaps unsurprisingly, one factor affecting major choice and persistence is relevant ability—*i.e.*, abilities in areas that the student perceives to be relevant to CSE. The simplicity of this intuitive notion belies subtleties in measuring ability and interactions with gender in education research. In the context of our study, a critical consideration is the distinction between actual and perceived ability, particularly for women. Ultimately, confidence—*i.e.*, perceptions of one's own ability—is what affects the academic decision-making examined by the studies reviewed here. Actual ability, while relevant, is only one of many other factors influencing confidence. After a discussion of confidence, this subsection touches on the related factors of actual ability and computing experience. Later in this chapter, we discuss other related factors, including influential people such as parents and peers. One interpretation of all of these findings is that confidence and interest are the factors directly impacting decisions to enter and persist in CSE. The effects of experience and achievement on entry and persistence might largely be indirect. (Chapter 3 develops these ideas more formally, through a model borrowed from the educational psychology literature.)

Confidence and Major Choice

Confidence with computers appears related to both decisions to enter and persist in computing-related study. Beyer *et al.*'s [17] findings suggest that students with higher confidence with computing are more likely to enroll in CSE courses. Their gender comparisons confirmed their previous studies' findings on the relationship between gender and confidence [16, 18]. They found that first-year undergraduate women were less confident with using computers than men, as well as differences in prior experience, as discussed below. Women in their sample also regarded computer science as a more difficult major than the men did.

The above findings suggest that lower confidence partly accounts for the underrepresentation of women in CSE. Seymour & Hewitt's STEM-wide study [100] yielded findings consistent with this explanation. Women majoring in STEM areas were half as likely as men to cite math/science proficiency as a reason for their major choices.

Confidence and Persistence

Studies of undergraduates who at least initially elected to major in CSE show that confidence continues to be an influential factor in academic decision-making, particularly for women. Biggers *et al.*'s findings suggest that confidence upon entry into the CSE major predicts persistence. In their retrospective, comparative study, students who completed CSE degrees reported having felt more academically prepared and more confident that they could complete the major when they decided on CSE, compared with students who switched majors [19]. Unlike the men in Seymour & Hewitt's study, many women math/science students questioned whether they belonged in a math/science field [100]. As a result of this self-doubt, they reported having difficulty persevering through setbacks, hesitating to seek help from teaching staff, and depending on external encouragement as a source of self-confidence.

Recognizing the dynamic nature of personal attributes like confidence, some longitudinal and cross-sectional studies have examined how confidence changes during the undergraduate years. Research in CSE [78], engineering [21], and STEM [100] document the same gender gap in academic confidence found by Beyer *et al.* and, worse, a drop in confidence during the first year of study. Women who started in CSE and engineering but switched majors later reported that low confidence was a significant factor in their decisions to switch. In Biggers *et al.*'s Georgia Tech study, as well, 80% of women who left CSE reported being unhappy with their grades, compared with less than a third of the men [19]. Brainard & Carlin found that low science confidence but not math confidence was a factor in decisions to switch out of engineering. (Although the math finding seems curious at first glance, it is consistent with the absence of a gender gap among math majors in the U.S. [84].)

Inaccurate Assessment of Ability

Given confidence's substantial influence on women's decisions to enter and persist in CSE and related disciplines, some research has tried to understand what accounts for the gender gap in confidence. Multiple studies have ruled out the simple explanation of an actual, objective difference in ability (*vs.* in subjective self-assessment) [18, 78]. In other words, women tend to self-rate their ability lower than men, even in cases where external assessments of ability show no gender difference. This phenomenon appears to be more general than just in CSE. Strenta *et al.*'s earlier (*ca.* 1990) study of over 5000 students at highly selective institutions found that women in the sciences were more depressed about their academic progress than men with similar grades. Relative to men, women appear to hold themselves to higher academic standards.

2.3.2 Prior Computing Experience, Achievement, and Confidence

Different kinds of computing experience have the potential to impact entry and persistence in different ways. To the extent that students interpret their academic successes as an indicator of their ability, computing experience might lead to higher confidence through achievement of higher grades. Experience can also lead to interest, as in the case of a student whose interest grows beyond simply using computers into curiosities about their fundamental capabilities, inner workings, and broad applications. Experience, achievement, interest, and confidence all appear to be related, and, directly or indirectly, affect decision-making about majoring in CSE.

Older studies suggest that general computer experience contributes to academic success in CSE [25], possibly by contributing to student confidence or comfort in computing [127]. More specific findings speak to the value of programming experience. Consistent with the emphasis on programming typical of the early part of undergraduate CSE curricula [68], prior programming experience has been found to predict achievement in introductory CSE courses [78, 127, 96]. Notably, at least Margolis & Fisher found that longer-term success in the major was *not* related to programming experience [78]. However, a student suffering an early slump in confidence might abandon CSE after a discouraging experience in introductory courses, well before realizing such longer-term success.

As with confidence, computing experience and opportunities for such experience vary with gender. Given the effects of computing confidence and experience described above, an experience gap might partially explain women's lower enrollment in CSE. Collecting data in the late-1990s, Margolis & Fisher found that undergraduate women had less access to computers before college. Today, the explosive popularity of personal computers and the Internet (at least among higher socioeconomic classes) appears to have closed this gender gap in the U.S. [95], with girls and boys reporting roughly equal computer use.

However, more specific findings suggest differences in how (*vs.* how much) girls and boys spend their time using computers. Crucially, women appear to enter college with less programming experience [78], particularly extracurricular and paid professional programming experience [17]. They also reported less experience tinkering with computer hardware [17]. Other differences include women's greater interest in computers as a medium for creative self-expression, rather than for video games, whose popularity is largely limited to men [114]. A recent Pew Internet & American Life study found girls to be more likely than boys to engage in web content creation and to use instant messaging (IM), especially among 15- to 17-year-olds [95, 72]. Content creation included a variety of forms: blogs, web pages, or profiles on social networking sites like Facebook and MySpace.

Not only do women appear to have different kinds of experience with computing, the relationships between these experiences and interest in CSE appear to be gendered. Tillberg & Cohoon examined what attracted CSE majors to the discipline and found men were more likely to have become interested through computer games [114], consistent with boys being more likely to be regular video/computer game players [88]. Students in their study (both women and men) also described how computing-related work experience increased their interest in studying CSE, as well. In spite of the apparent equalization of computer use among girls and boys, women are probably still less likely to have pre-college work experience with programming, as Margolis & Fisher found. This would clearly contribute to the gender gap in undergraduate CSE.

2.3.3 Influential People

Women and men report varying degrees of influence from parents, teachers/faculty, advisers/counselors, and peers when making decisions about their major. For the most part, research shows that these figures can encourage both entry and persistence in CSE and related majors, particularly for women. However, Seymour & Hewitt's STEM-wide study suggests a complex relationship between this kind of external influence persistence in STEM, finding that women who switched out of a STEM major were twice as likely as male switchers to have been influenced by a parent, teacher, or other external figure [100]. External influence has more consistently been found to promote persistence in more recent and/or CSE-specific studies.

Parents

Two of our selected studies found that entry into CSE, regardless of gender, was positively influenced by parents [78, 114]. Their influence appeared to be related to both confidence and interest, *e.g.*, through simple encouragement or passing on of computing-related interests and knowledge. Having a parent with CSE or engineering background could benefit students through role-modeling and as a source of emotional and intellectual support [78]. In these ways, parental influence appears to contribute to persistence, not just entry, in CSE. These findings are consistent with Brainard & Carlin's finding that maternal support was related to women's persistence in engineering beyond the first year.

Other research contributes to a more nuanced view of these effects, suggesting interactions with gender. Young women might not get the same opportunities to interact with parents around computing. The women in Margolis & Fisher's study were less likely than the men to have had hands-on computing experiences with parents. With respect to persistence, parental encouragement might be more critical for women, possibly to counterbalance lower confidence or other challenges posed by a male-dominated discipline.

Teachers and Counselors

In addition to family members, high school teachers and counselors can also influence students' academic choices [100]. When it comes to steering students toward CSE, teachers and counselors tend to favor men [78]. Once students enter the major, faculty members take the place of these figures, and their influence can promote persistence, particularly for women. Many students at Carnegie Mellon, however, felt they lacked faculty relationships and encouragement after their first year of CSE study. Cohoon's national study underscored the importance of faculty support for women. They found that CSE departments where women and men persisted at comparable rates had faculty who tended to encourage students to persist and mentored with the goal of promoting diversity [29]. Brainard & Carlin reported consistent findings from their study of women studying engineering. The women in the study identified positive faculty influence as a primary factor related to persistence beyond the first year of study, and advisers were cited as a positive influence on persistence in the following year [21].

Peers

External influence is not limited to senior figures such as parents and teachers. Students influence each other's academic choices, as well. Adding yet another layer to the confidence findings discussed above, peers can encourage and support or shun and intimidate, with gender sometimes being a factor. Such peer interactions were documented in Goode *et al.*'s study of high schoolers in computing-related courses. The men, who often had more self-taught programming experience, benefited from an exclusive, informal social network, through which they encouraged and assisted each other. The women reported feeling intimidated by the widening computer experience gap and exclusionary, sometimes scornful attitudes of their male classmates [59].

Studies of undergraduates in CSE document the important, positive role of peers, especially for women. Friends, partners, and coworkers, as well as older students already majoring in CSE, could serve as role models or otherwise inspire women to consider the major [114]. Upon embarking on a CSE major, support from other women studying CSE contributed to persistence. Women majoring in CSE at Carnegie Mellon reported valuing such peer support [78], and this finding was replicated in Cohoon's more recent, national study [29].

One related finding from Blum & Frieze's more recent follow-up study of fourth-year CSE majors at Carnegie Mellon suggests a cautionary note about transparency in implementing efforts to promote diversity. Their finding illustrates the negative impact of the perception that women were afforded advantages solely because of their gender. Some of the interviewed students perceived (inaccurately) that gender was a factor in major admissions. While students acknowledged the value of diversity, some men objected to gender as an admissions criterion and wondered whether the women were less qualified than the men in their cohort [20]. Regardless of the truth, such perceptions potentially damage women's self-confidence by leading them to question their academic qualifications and inhibit a collegial, mutually respectful culture among students.

2.3.4 Culture and Values in CSE

Employing the word "culture" loosely to encompass a specific group of people, their lifestyles, and their values, the next set of findings illuminates the ways in which perceptions of the culture of CSE (both the major and related careers) affect entry and persistence. We discuss the negative and gendered "nerd" stereotype, related expectations of the amount of human interaction associated with study and work in CSE, and the extent to which CSE is seen as a means of serving people and society.

Nerd Image

From high school to first-year undergraduates and beyond, the dominant image of a computer scientist is an unsociable (or socially awkward, at best), computer-obsessed, and typically white or Asian male [59, 17, 78, 80]. Notably, even students enrolled in or majoring in CSE (regardless of their gender) held such unflattering perceptions. In fact, identification of computing as a male domain seems to begin well before high school. Mercier *et al.* used multiple methods to elicit perceptions of "knowledgeable computer users" from sixth- and eighth-graders. The majority of their representations were male, and, particularly among the eighth-graders', some included characteristics consistent with (albeit not exclusive to) the nerd stereotype (*e.g.*, glasses) [83].

Unsurprisingly, given the male aspect of the nerd stereotype, most CSE-focused studies have found this image has a particularly negative effect on women's entry and persistence in CSE, both at the high school level [59] and in college [78]. Goode *et al.* conjectured that some aspects of the nerd stereotype come from depictions of computer users and computer scientists in popular media and are reinforced by high school courses. Chapter 6 extends the latter point with evidence connecting experience in introductory CSE courses and student perceptions of CSE culture.

Human Interaction

Related to the nerd stereotype, the association of CSE with less human interaction (*vs.* in other majors or career areas) may be another factor depressing entry and persistence in the discipline, again, particularly for women. Beyer *et al.* found that first-year undergraduate women were more likely than their male peers to value a career involving working with people, but neither they nor the men in the study associated CSE with such careers [17]. They also found that those first-years who had taken some CSE courses were more likely to feel socially isolated than those who had not. These findings do not conclusively show whether taking the CSE courses resulted in the feelings of isolation or that students who feel isolated tend to be attracted to computing and related courses. Both cases, however, validate associations of CSE with social isolation, as documented by Margolis & Fisher [78].

While the above findings suggest impact on entry into CSE, Biggers *et al.*'s Georgia Tech study suggests a related connection between valuing human interaction and persistence. When students who had switched out of CSE were asked to compare their new majors with CSE, many said they were happier with the quality and amount of interaction with students and faculty with their new majors [19]. Their responses about potential factors affecting their decision to switch majors are consistent and suggest that interaction with students and teaching staff is a more critical factor among women. Women who left CSE more than twice as likely to cite “CS classes were unfriendly” and “Poor teaching by CS faculty or teaching assistants” as reasons for leaving. Dissatisfaction with teaching and its impact on persistence may be a STEM-wide issue, given similar findings in Seymour & Hewitt’s broader study [100].

Other aspects of educational experience, such as workload, are discussed separately, later in this chapter.

Service to Society

Another factor affecting entry (and possibly persistence) that is widely believed to be gendered is student interest in serving society and the extent to which they see majoring in CSE as consistent with this interest. Beyer *et al.*’s study of first-year undergraduates reported that women were more interested than men in careers involving helping others. Neither women nor men in this study, however, perceived CSE careers as involving such service [17]. Similarly, women in CSE at Carnegie Mellon were significantly more likely to be interested in CS’s interdisciplinary applications and contributions to humanity, what the study authors dubbed “computing with a purpose” [78]. Tillberg & Cohoon’s national study corroborated this, reporting that women in CSE more commonly stated desire to help society as a reason for majoring [114]. These CSE-specific findings suggest that the discipline is, in this respect, not so different from other STEM disciplines. Seymour & Hewitt found that students who expressed altruistic reasons for studying in STEM were predominantly female and/or students of color [100]. Although most findings about motivation to serve society are about entry, students who switched out of CSE in Biggers *et al.*’s study reported that their new majors had more relevance to the real world [19].

2.3.5 Motivation

Intrinsic Interest in CSE

As intuitive as it is that interest in a discipline should contribute to entry and persistence, it is reassuring that both CSE-specific [19] and more broadly scoped studies [100, 21] have shown this to be true. In response to Biggers *et al.*’s open-ended question about the most important factor contributing to their decision to switch, former CSE majors overwhelmingly cited a loss of interest in the field and/or associated careers.

These findings quickly lead to practical questions about the nature of interest in CSE, *e.g.*, what aspects of CSE attract prospective majors) and what kinds of experiences and influences nurture interest in CSE. Findings about the latter have been addressed earlier in this chapter. With respect to the former, Tillberg & Cohoon's national study found that math/logic, programming (discussed more below), and hardware were among aspects of CSE that drew majors into the field, but not equally for women and men [114]. Women were more likely to be interested in math/logic and less so in hardware, consistent with women's substantial representation among math majors [84] and their tendency to have less pre-college experience with hardware [17]. In addition to these observations about intrinsic interest in CSE, previous subsections have already discussed motivation to study CSE as a means to achieving other goals (*e.g.*, careers in societal service).

Programming and Interest in CSE

Programming is an aspect of CSE whose role in interesting prospective majors, especially women, has been debated extensively. Subsection 2.3.2 discussed how having less programming experience would disadvantage women taking programming-heavy introductory CSE courses, potentially resulting in lower grades that threaten self-confidence and, ultimately, switching out of the major. After some observations about the emphasis of programming in high school and introductory undergraduate CSE courses, we consider the extent to which programming interests prospective CSE majors.

Both the A- and AB- level Advanced Placement (AP) Computer Science exams put primary emphasis on programming and algorithms and secondary emphasis on the design of computing hardware. There is virtually no coverage of contemporary applications such as graphics and animation, artificial intelligence, data mining, and computational biology. Other high school courses that do not follow the AP model can be even more problematic, in terms of their influence on perceptions of CSE. Computing courses (sometimes even labeled "computer science") covering office productivity software or computer and network maintenance are even less representative of CSE as a discipline than courses that are programming-centric.

By design, the AP exams' emphasis is consistent with the majority of introductory undergraduate CSE courses [68]. In most CSE departments, prospective majors spend two or three terms studying programming and closely related topics before they can take courses that begin to reveal the breadth and variety of subtopics within CSE.

Might the monolithic introductory view of CSE presented by these programming-centric courses be related to the demographically monolithic (*i.e.*, white and male) enrollment? In their 2000 report, the American Association of University Women warned against programming-focused introductions to computing for being less likely to appeal to young women [2]. Research confirms a link between interest in programming and interest in CSE, although the extent to which the effect is gendered remains unclear.

Some evidence shows that high school women are more likely than men to reject CSE due in part to a lack of intrinsic interest in programming and an according misfit with their career ambitions [59]. On the other hand, the Georgia Tech study's findings suggest that both women and men who switched out of CSE lost interest in a discipline and related careers that they perceived to be narrowly focused on programming [19]. Other studies suggest that some students are not repelled by but are in fact drawn into CSE by programming. Blum & Frieze reported that both female and male CSE majors expressed intrinsic interest in programming [20], and a similar, national study corroborated this finding [114].

Taken together, these studies illustrate how programming can affect interest in CSE positively or negatively, depending on the student. Both Blum & Frieze's and Tillberg & Cohoon's findings are based on data collected from "non-switchers," *i.e.*, students intending to complete (and had all but completed, in Blum & Frieze) their CSE studies. As such, the studies were not designed to capture the perspectives of prospective (yet undecided) CSE majors or students who had rejected CSE as a major. These were the very populations sampled in the high school and Georgia Tech studies cited above. One explanation consistent with all of these findings is that current CSE curricula convey a focus on programming that discourages certain students (and more-so women) from majoring. This "filtering" process would preferentially retain students whose interests are more aligned with a focus on programming, regardless of gender.

Finally, foreshadowing a later discussion on the influence of early, CSE-related educational experiences, there is evidence that focusing on programming is not necessarily flawed or disadvantaging to women. *I.e.*, it would be oversimplifying to assume that programming-focused courses are intrinsically bad (or good) for women or other audiences. Teaching methods and quality—*how* programming is introduced, taught, and contextualized in the classroom—are likely to influence student interest in programming, as well as interest in CSE, by association.

Career Prospects

One popular (if not well-substantiated by research) perception is that the IT industry decline in the early 2000s contributed to the sharp drop in undergraduate interest in CSE [119, 91]. Regardless of whether undergraduates themselves are aware of or concerned about employment prospects in CSE, their parents, guidance counselors, undergraduate advisers, and other influential people might dissuade them from majoring in CSE. If this is the case, with research showing that women's academic choices are more likely to be influenced by such figures, such an effect might be magnified among women.

That being said, the research is unclear about how much career prospects influence major choice and persistence, whether in general or for women in particular. In fact, two CSE-specific studies [17, 114] and the STEM-wide study [100] suggest that financial motivation was less important to women studying CSE/STEM.

The extent to which students (and the people who influence their decisions) are accurately informed and concerned about career prospects has become an even more important research direction in recent years. Fears that offshoring is reducing career opportunities in CSE have prompted CSE leaders to respond with attempts to clear the record [7], pointing out that federal projections of demand for CSE professionals are very favorable [41]. It remains to be seen whether these messages are reaching students and their parents, teachers, and counselors/advisers.

2.3.6 Other Factors

Satisfaction with Early CSE Education

Highlighting the critical recruitment role of early CSE coursework, Margolis & Fisher found that women were much more likely than men to identify experience in a high school programming course as a critical factor in choosing to major in CSE [78]. They also found that early undergraduate courses were similarly influential, and negative course experiences appeared to have a more discouraging effect on women. Women who left CSE at Georgia Tech were more likely than men to cite unfriendly classes and poor teaching as reasons [19]. Conversely, Tillberg & Cohoon's national study of found that a positive introductory course experience led some women to choose to major in CSE [114].

The link between early undergraduate coursework and persistence has been observed in other disciplines, as well. Women's persistence in engineering appears to be closely related to experiences in first-year math/science courses [21]. Over 40% of students in a national study who switched out of engineering majors cited poor teaching as a factor in their decision [100]. Brainard & Carlin's findings suggest that satisfaction with teaching affects persistence not only by influencing interest but also confidence. They found that the women who bucked the trend and somehow maintained their confidence through the first year of engineering study tended to enjoy their math/science courses more and and were more satisfied with teaching [21].

Goode *et al.*'s high school study provides more detail, suggesting that *how* programming is taught can affect interest. For instance, the students in their study were dissatisfied with classes where programming work constrained them to following rigid, step-by-step instructions. Women in particular disliked individual (*vs.* group) programming assignments, possibly because they were consistent with negative stereotypes of isolated, antisocial programmers. CSE studies confirm this, showing a relationship between pair programming and persistence, particularly among women [81, 125].

In addition to instructional design, interaction with teachers is another important aspect of early educational experiences. We have already discussed the role that teachers (and advisers) can play in encouraging and mentoring prospective and current CSE majors earlier in this section.

Other characteristics that may be related to persistence include workload and curricular flexibility. Almost half of the students in Seymour & Hewitt's study who switched out of engineering majors cited curricular overload as a reason. Interestingly, they found that concern about curricular overload was shared by students who remained in STEM majors, so overload alone might not be sufficient to cause students to switch. Perhaps other factors mitigate the negative effects of overload, *e.g.*, external encouragement, peer support, strong interest, and recognition of future pay-off. In any case, Biggers *et al.*'s CSE-specific study echoes Seymour & Hewitt's basic finding. The majority of former CSE majors cited excessive workload as a reason for switching—over 70% among the women who switched.

2.4 Situating this Study in the Related Work

Details of the research design for our study are given in Chapter 4, but this chapter concludes with a brief discussion of how the study compares with the reviewed studies above. With respect to data collection and analysis methods, our study is most similar to the 2002 follow-up study at Carnegie Mellon [71, 20]. Both are single-institution, interview-based studies favoring detail and depth over a large sample size. As with most qualitative studies, departmental and institutional context heavily informed both the study design and interpretation of findings.

One important point of contrast with the CMU study is that our study focuses exclusively on entry, rather than persistence. This is reflected by the differences in sampled populations. In this sense, our study is more similar to Beyer *et al.*'s study in that the sample is composed of pre-major undergraduates.

Some of the studies selected for the review above attempt to examine factors effect entry into CSE by having CSE majors reflect on decision-making, beliefs, and attitudes from as many as two or three years before (*e.g.*, Seymour & Hewitt, 2002 CMU follow-up, Biggers *et al.*'s Georgia Tech study). Our study design addresses two important limitations of such retrospective studies by capturing pre-major student perspectives "in the moment." First, by collecting data from students at the time during which they are making decisions to enter CSE, we avoid the potential incompleteness and, worse, inaccuracy of recounting events and state of mind from years ago. Second, we capture a broader range of perspectives by sampling both students who are intending to major in CSE *and* students who are not. Perspectives of the latter group are rarely represented in the research literature. However, they are equally if not more valuable for informing how CSE programs could be improved than findings from students who complete CSE majors, *i.e.*, those for whom the current system is working at least acceptably well.

Unique to our study is the application of a theoretical framework (detailed in the next chapter) that enables a structured interpretation of a complex set of interrelated findings, relates them to past research, and links them to changes in the ways we teach CSE.

Chapter 3

ADOPTING EXPECTANCY–VALUE AS A THEORETICAL FRAMEWORK

Both the interpretation and presentation of findings from our descriptive study are framed by Eccles *et al.*'s expectancy–value model [47, 44]. This chapter discusses the advantages and potential trade-offs of choosing the expectancy–value model, beginning with a general discussion of the value of adopting a theoretical model.

As observed by Cohoon & Aspray [30], few studies on gender and computing apply theories or theoretical models, in spite of numerous advantages of doing so. A well-conceived theoretical model establishes a shared context and structure for the studies that adopt it. This context and structure in turn facilitate connections among separate studies, guiding comparison with and extension of prior research. A model can also inform research design by suggesting how to focus data collection or analysis. Our study benefits from the expectancy–value model in all of these ways.

A potential trade-off of adopting a theoretical model, particularly in the case of exploratory studies, is the risk of overlooking a promising line of inquiry not aligned with the model's focus or assumptions, both explicit and implicit. As discussed more in the next chapter, our study's qualitative character and data collection/analysis methods limited this risk. Interview and survey questions were not designed specifically to confirm specific elements of or hypotheses based on the expectancy–value model. Instead, the questions, most of which were in free-response format, explored interest in CSE and related topics in a more open-ended fashion. This research design resulted in an opportunity both to confirm certain aspects of the chosen model and to generate claims unrestricted by the model. In addition, the expectancy–value model's generality and encompassing nature make it less likely to restrict the research process (in an undesirable fashion).

After an overview of the model, Section 3.2 describes the model's quantitative heritage in educational psychology research and its more recent, less typical applications in studies that are similar to ours in their qualitative methodology and/or disciplinary focus in CSE. The remainder of the chapter is devoted to a detailed description of the aspects of the model that are most relevant to our study.

3.1 The Expectancy–Value Model of Eccles et al.

Many studies of gender and achievement behavior have employed Eccles *et al.*'s expectancy–value model [47, 46, 44]. The model assumes that achievement behaviors such as the decision to enroll in advanced mathematics courses, commitment to a course of study, and academic performance are primarily influenced by specific beliefs held by the student, even if the beliefs sometimes inaccurately reflect reality. In the model, two categories of student beliefs affect achievement behavior. *Expectation of success* is the student's belief that they will be successful in a particular domain. (This construct is similar to but more general than Bandura's self-efficacy [10], which is generally measured in terms of confidence with specific tasks.) The second factor, *subjective task value*, is how much the student values the achievement in question and includes considerations of costs and benefits. Informally speaking, a student's achievement behavior is predicted by their answers to the questions "What are my chances?" and "Is it worth it to me?" The expectancy–value model elaborates on a variety of indirect factors that influence both expectation of success and task value, including socialization, prior experiences with related achievement, and aptitude, as illustrated in Figure 3.1, which diagrams a recent version of the model. This section describes selected prior work related to the expectancy–value model and discusses its appropriateness for the study in this dissertation.

3.2 Methodologically Related Work Using the Expectancy–Value Model

Originally proposed in 1983 [47], the expectancy–value model was first applied in quantitative studies of children and adolescents' achievement in mathematics. Eccles' *et al.* went on to study pre-college students' beliefs and achievement in a variety of academic domains, often with a focus on gender differences. Our work differs from these studies in its qualitative methods, focus on older students (undergraduates), and limiting disciplinary scope to

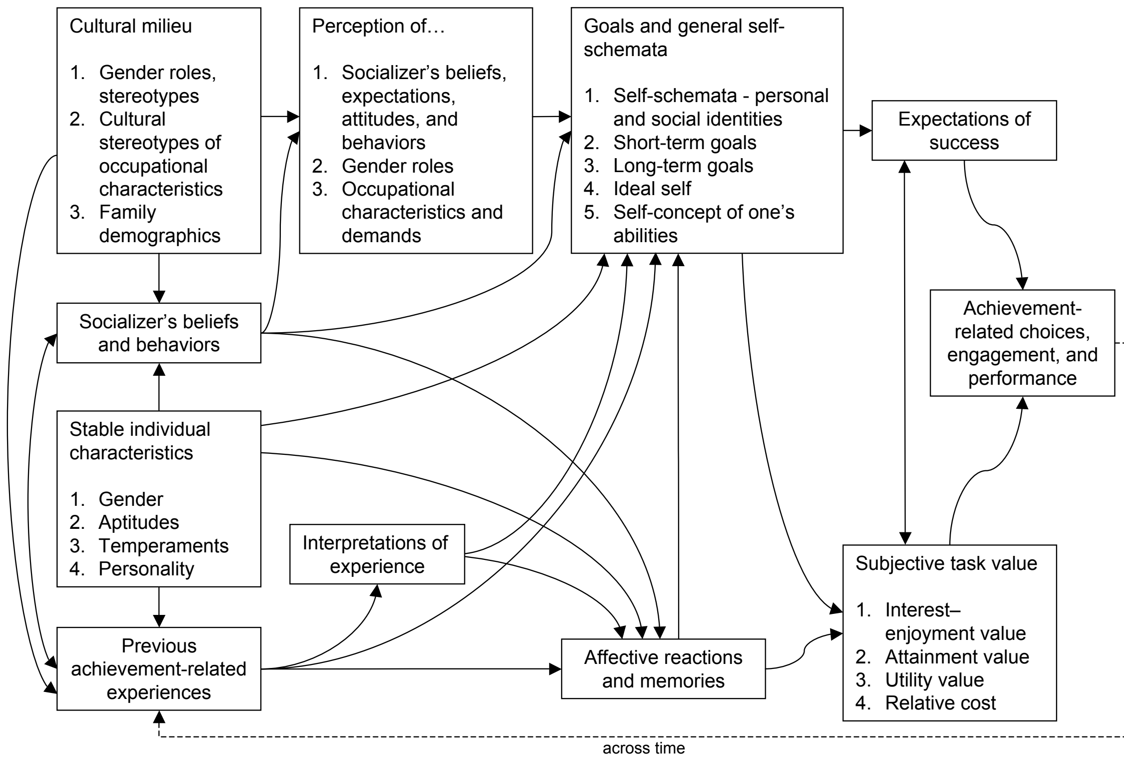

Figure 3.1: Expectancy–value model, based on version published in 2007 [44]

CSE. In spite of these differences, the model is useful for structuring and interpreting our findings, and past expectancy–value research provides a starting point for understanding factors specific to major choice and CSE. The extensive body of work on the expectancy–value model includes examples of its application in qualitative, undergraduate-level, and computing/IT contexts.

Most studies of the model have employed statistical analyses of surveys with a large number of participants. As such, these studies are generally limited to examining correlations between achievement behavior outcomes and specific influences as manifested in a specific academic context. However, the literature includes some examples of qualitative research guided or framed by the expectancy–value model. James's dissertation used Eccles' model to guide an in-depth, qualitative, interview-based study of 12 pre-adolescent and adolescent girls' persistence in the sciences [67]. In another interview-based study, Watt explored the expectancy–value model's fit with adolescent interest in mathematics careers [123]. Drawing on the traditional strengths of qualitative research, the goals of these studies complement those of the survey-based studies more commonly associated with the expectancy–value model. The qualitative studies are opportunities to validate causal links in the model, extend the model by discovering new influences or interactions not adequately expressed in the model, and refine the model for use in specific contexts (*e.g.*, in terms of academic discipline, age level).

As mentioned earlier, early expectancy–value studies were of pre-college populations, usually middle and high school students. However, at least two of Eccles *et al.*'s large-scale, longitudinal studies of academic choices (including undergraduate major) and career aspirations followed students beyond their high school years and through at least two years of undergraduate studies [45, 131]. These studies gave us confidence of the expectancy–value model's applicability to the decision-making of first- and second-year undergraduates in our study.

Finally, with respect to disciplinary scope, while the expectancy–value model has been extensively applied in mathematics and various science disciplines, there are few examples of its application to CSE and related disciplines. Eidelman and Hazzan studied high school-level computer science students in Israel using the model [48]. Zarrett *et al.*'s longitudinal analysis focused on IT career aspirations and examined race as well as gender [132, 131]. (With its focus on gender, undergraduates, and IT, this study is closest to our own, but it differs in its methods and scale.)

In forming the expectancy–value model, Eccles *et al.* set out to unify the numerous psychological and social theories about achievement-related choices. The resulting model was very general, and, as illustrated by the above examples, it has been applied in a wide range of contexts. The importance of the factors and causal relationships in the model, as well as how the factors are manifested, vary with context. Our study focuses on specific parts of the model that appear to be relevant to interest in majoring in CSE for the population of pre-major undergraduates.

3.3 Relevant Elements of the Expectancy–Value Model

According to the expectancy–value model, a student's choice of majoring in CSE is directly influenced by two kinds of beliefs: their expectation of success as a CSE major and how much they value becoming a CSE major. Both kinds of beliefs are subjective. With respect to expectation of success, "success" is defined in terms of the individual student's values and goals, both long- and short-term. The student's expectation of success depends on what the student perceives is required to become a successful CSE major, as well as how well they believe their abilities and preparation match these demands. With respect to task value, this category of beliefs includes interest level in CSE, alignment with personal identity and goals, and considerations of costs (*e.g.*, in time, money).

According to the model, expectancy and value beliefs are affected by a wide range of factors, including prior experiences, the influence of socializing agents (*e.g.*, parents, teachers, peers), and cultural stereotypes. Rather than assuming direct effects, the model makes explicit that many of these factors are mediated through the student's interpretations. For instance, the model includes at least two pathways where a socializing agent's beliefs or behaviors affect how capable the student thinks they are with a given activity. In one pathway, the effect is more direct, *e.g.*, a case where a teacher's compliment about the student's mathematics achievement raises the student's self-concept of their mathematics ability. In another pathway, the student's perception and interpretation of a socializing agent's beliefs or behaviors is what affects their self-concept of ability. Consider, for instance, a case where a teacher invites only boys to try out for a mathematics competition. A girl in that class might interpret this as an expectation (on the teacher's part) that girls are not good at mathematics, thus depressing her self-concept of her mathematics ability. Ultimately, it is the student's *perceptions* of the teacher's expectations that influence the student's expectancy beliefs, regardless of whether the perceptions accurately reflect the teacher's expectations.

This section describes those elements of the model that are especially relevant to our study of the decision to major in CSE: subjective task value, goals and general self-schemata, perceptions of occupational characteristics and demands, and previous achievement-related experiences. Given the nature and timing of the data collection, we focus on the middle part of the model graph. Relatively short, one-time interviews limit inferences about more abstract or distant influences on achievement-related choices such as cultural milieu and socializer's beliefs and behaviors. Most of the participants had not yet made final major choices when they were interviewed, so we cannot be certain that the beliefs they discussed and their influence on major interests did not change by the time they finalized their choices. We do, however, assume that we captured accurate (if not comprehensive) snapshots of beliefs relevant to their initial (*i.e.*, pre-CS 1) interest level in majoring in CSE.

3.3.1 Expectancy and Value

Expectations of success and task value are the direct influences on achievement-related choices in the Eccles model. Expectations of success, in the context of our study, are the student's beliefs about whether they will meet their personal criteria for success as a CSE major. The model assumes that the individual student determines what constitutes success but acknowledges a wide range of external influences. Expectation of success is also a function of confidence and efficacy beliefs in relevant domains. As with success criteria, students have varying (and not necessarily accurate) beliefs about their abilities, as well as which abilities are relevant to the achievement-related choice in question.

The model decomposes beliefs about task value into four different categories: (1) intrinsic value, (2) attainment value, (3) utility value, and (4) cost [46, 43]. Intrinsic value includes enjoyment the student gets from engaging in the task, as well as their subjective intrinsic interest. Attainment value comes from the task's alignment (or lack thereof) with the student's sense of self or identity. Utility value is the extent to which the task brings the student closer to fulfilling other goals. Finally, costs consider the negative consequences of engaging in the task, including opportunity cost.

We present a brief example to clarify each of these aspects of task value and how they could plausibly operate independently. Consider a male student who chooses to study nursing, based partly on his interest in the field (high intrinsic value). He also chose nursing with the goal of working in a senior living facility in mind (high utility value). However, he is sensitive to the fact that, at least in American society, nursing is a very female-dominated profession. As a result, he sometimes feels out of place among his male friends and avoids discussing his professional interests (low attainment value). Although the nursing program he attends is very good, the tuition is high, the commute from his home is quite long, and he wishes he could spend more time with his wife and children (costs).

3.3.2 Goals and General Self-schemata

In the model, subjective task value is closely tied to another group of beliefs labeled, “Goals and general self-schemata.” These beliefs reflect the student’s personal values and sense of self. The model categorizes these beliefs as follows: short- and long-term goals; self-schemata and ideal self; and self-concept of abilities. Goals are simply the things the student wishes to do and achieve in the future. Self-schemata and ideal self deal with the values that the student considers most important. This includes values that distinguish self from others, as well as the values they share with and through which they identify themselves as members of social groups (*e.g.*, defined by gender, culture, age/generation, socioeconomic class, geographic region, *etc.*). Finally, self-concept of abilities is how good a student thinks they are at certain activities or in certain domains that are perceived as relevant to the achievement-related choice in question (in this case, majoring in CSE).

This group of beliefs can affect both expectations of success and task value positively and negatively. Most obviously, a student’s self-concept of those abilities they deem relevant to majoring in CSE are likely to affect their expectations of success. As discussed above, the utility value component of task value is a function of goals. Similarly, attainment value depends on the student’s values, sense of self, and identity. To the extent that cost includes considerations of opportunity cost, goals are again relevant.

3.3.3 Perceptions of Occupational Characteristics and Demands

Although the interviews were very open-ended, we did start with a small number of specific questions, most of which focused on student perceptions of CSE as a discipline and career area. The responses to these questions fit directly in the model under “perceptions of occupational characteristics and demands." As indicated in the graph, the expectancy–value model shows that these and related perceptions influence goals and self-schemata.

3.3.4 Previous Achievement-related Experiences

Toward the end of the interview, students were asked to describe prior experiences with computing and, more specifically, programming. This section of the interview discussed more structured, formal experiences, such as courses taken in school and extracurricular programs, as well as self-guided exploration. Many students described how they were introduced to using computers. In the expectancy–value model, these experiences are captured by the node in the lower left corner labeled "previous achievement-related experiences."

3.3.5 Student Perceptions

In addition to the elements of the model described above, there are some framing assumptions that are associated with the model but are not represented in the model graph diagram. First, factors identified in the model should be interpreted from the perspective of the student; reality as perceived by the student is paramount. In the case of "Previous achievement-related experiences," for example, the experiences that the model shows as potentially affecting achievement are those that the student *perceives* to be related to the achievement in question. Whether or not the researcher or general consensus agrees that the relationship exists is irrelevant. The focus on perceptions is particularly important in the context of our study, due to the prevalence of misconceptions about CSE.

An important consideration related to perceptions pertains to decision-making. The main purpose of the expectancy–value model is to better understand achievement-related choices. In the case of our study, the focus is the choice to major in CSE. Eccles *et al.* acknowledge that people only choose from among options of which they are aware [43, 44] and that incorrect information can also affect the range of options considered. Accordingly, we make no assumption that pre-major undergraduates are necessarily aware of the option of, let alone consider, CSE as a major.

In at least two important respects, however, the model does account for phenomena that are outside of the student's perceptions. First, it acknowledges that the student is not necessarily conscious of all of the factors influencing expectancies of success and task value, nor that expectancies and value are the primary factors influencing achievement-related choices. Indeed, most students are not conscious of factors like gender socialization and their effects. Similarly, Eccles *et al.* make explicit in [43] that the model covers both conscious and non-conscious choices. Students encounter many decision points throughout their academic careers, but many of these decision points go unrecognized.

Chapter 4

SEMI-STRUCTURED INTERVIEWS WITH PRE-MAJOR UNDERGRADUATES

To broaden our understanding of the decline in interest in CSE, we surveyed and interviewed pre-major undergraduates about their perceptions of, interest in, and experiences with CSE. Although the survey and the interview included many similar questions, the data sets serve complementary roles in our study. In both data collections, we asked students about what majors interest them, their perceptions of and interest in CSE, and their prior experiences with CSE and computing.

In this chapter, we describe the site of the study, the data collection plan, and its rationale. Details about the site of the study include information about the institution, department, and course in which the participants were enrolled. We also describe the the studied population and how it was sampled to meet our research goals. This contextual information informed the research design and interpretation of our findings. Later sections describe the design of the survey and interview instruments, as well as how data were analyzed. Before getting into specifics of the research design, however, the first section discusses the overall approach of the descriptive study and how it fits with the research questions and expectancy–value model.

4.1 Overview of Study Design

The descriptive study portion of this work aimed to answer the following research questions: (a) What factors affect interest in the CSE major among pre-major undergraduates, especially women?, (b) To the extent that it is relevant to the main question, what are pre-major undergraduates' beliefs about the CSE major and career paths associated with CSE? Our approach was guided by the expectancy–value model, with the goal of understanding which parts of this general model are relevant to Question (a).

A key aspect of our method is a focus on the student perspective, with minimal imposition of researcher assumptions of explanations of student interest (or lack thereof) in majoring in CSE and of student beliefs about CSE. Survey and interview data, consisting mostly of responses to open-ended questions, were coded using a thematic analysis approach, a process that identified common patterns in the responses.

The primary data set in this study came from the interviews, but the earlier survey stage of the study played an important preparatory role and yielded valuable data to frame the interview findings. In addition to addressing the main research questions given above, the survey was used to collect selected demographic information, including gender, class standing, and amount of prior experience with programming. The survey was also an opportunity to confirm that questions were appropriately worded and that they were interpreted as intended by the researcher.

The interview and survey methods were also complementary, in a sense. Surveys were administered during class, yielding a high response rate and large sample size. However, most participants wrote short responses to the open-ended questions. In contrast, the comparatively small number of interviews provided detailed, contextualized views on student perceptions of and interest in CSE.

4.1.1 Motivating an Exploratory Approach

A variety of reasons motivated this exploratory approach, which relied primarily on open-ended questions and semi-structured interview for data collection. First was our interest in privileging the student perspective. Rather than imposing specific, preformed hypotheses on the participants, we provided opportunities for participants to tell us, in their own words, what factors and beliefs were important to them. Semi-structured interviews gave the interviewer freedom to pursue interesting and relevant topics as they arose.

Another reason was that the body of research done on CSE interest among pre-major undergraduates is still relatively limited. On the basis of such a meager research literature, it would have been difficult to formulate a set of hypotheses that promised the accurate and comprehensive explanations we were seeking. Although the more developed, broader research record on interest in engineering offered some directions, we chose not to assume transferability of those findings to the CSE domain, primarily because CSE has proven unique among the STEM fields with respect to enrollment and gender gap.

Based on the limited literature suggesting that gender differences in undergraduate CSE enrollment vary widely across institutions, this study was designed to be sensitive to local variables. A study limited to testing hypotheses based on findings from other departments risks overlooking factors uniquely relevant to the local population.

4.1.2 Rich, Complex Data for a Rich, Complex Process

One reason for adopting the expectancy–value model in this work was its promise to illuminate how a multitude of factors can influence each other and, ultimately, interest in majoring in CSE. Relatively little research identifies the factors and pathways of influence in this general model that are relevant to interest in majoring in CSE. The model has historically been associated with quantitative studies attempting to statistically confirm relationships between hypothesized factors and achievement-related outcomes. However, the use of in-depth, semi-structured interviews matches the model well, too. Such interviews are ideal for capturing rich accounts of complex phenomena from an individual's perspective. The resulting data, interpreted with the model, yields structured, holistic descriptions of interest in CSE among individual students.

Employing thematic analysis permitted us to not only compare themes across participants but also to examine how various themes were related to each other within an individual participant's transcript. Accordingly, we present our findings both in terms of common themes (and exceptions), as well as through case studies of individual participants that illustrate how different experiences and personal influences relate to beliefs about and interest in CSE.

4.2 Population and Context

4.2.1 CSE at the Studied Institution

All study participants (survey and interview) were pre-major undergraduates enrolled in an introductory computer programming course at a large, public research university. Although the course is listed as a "CSE" course, as with many traditional introductory CSE courses, it focuses almost exclusively on computer programming, rather than providing a broad introduction to CSE. By convention, we refer to the course by its generic name, "CS 1". (See *Computing Curricula 2001* [68] for a taxonomy of introductory courses and model curricula. This course adopts the "imperative-first" style programming-first approach.)

The studied institution offers two CSE bachelor's degrees: Computer Science and Computer Engineering. The former is officially in the College of Arts & Sciences, and the latter is an ABET-accredited program in the College of Engineering. However, the two majors are very similar and are offered by a single department, Computer Science and Engineering. Admission to the programs, detailed later, is through a unified process. Although there are some differences in graduation requirements, computer science and computer engineering majors are often in the same classes together. There are no separate computer science and computer engineering courses; all courses are labeled "CSE". For these reasons, throughout the study, we merge the two majors and refer to them as "CSE".

CS 1 is the first course in a two-course sequence required for all prospective CSE majors. However, CS 1 is also required for a wide range of other majors, including most engineering majors and a newly established informatics major. No separate introductory course exists for prospective CSE majors; CS 1 serves as the combined pre-major introduction and service course for majors requiring computer programming fundamentals. As a result, the majority of CS 1 enrollees go on to choose majors other than CSE, often engineering. (This premise was confirmed in survey results, which indicated that less than 20% of CS 1 enrollees were interested in the CSE major [129].)

Before applying to the CSE department, prospective majors must complete the two introductory CSE courses and a standard set of calculus, physical science, and English composition courses. Given these requirements, most students apply during or shortly after their second year of undergraduate study. (The department offers alternative admissions paths for high-achieving students, but the standard "Upper Division Admission" process is most relevant to the population in our study.) Application materials consist mainly of an academic transcript and a personal statement. Admission criteria include academic background, extracurricular interests, leadership potential, life experience, and writing ability.

Roughly half of applicants are accepted into the program. Almost all accepted students complete their CSE degree, indicating that retention is not a problem once admission is secured. Indeed, this late measure obscures the drop in the number of students intending to major in CSE that takes place well before the application stage.

4.2.2 Rationale for Studying this Population

The students enrolled in CS 1 are unlikely to be representative of the institution's overall undergraduate enrollment. However, there is an important, practical reason for making them the focus of our study. Many CS 1 enrollees are pre-major undergraduates in their first or second year of study. With respect to encouraging broader interest in CSE, we consider pre-major CS 1 students "lower-hanging fruit" than the average undergraduate. Although some students take CS 1 solely because it is required for a prospective major (other than CSE), some choose to take it based on an interest in CSE or at least computer programming. In either case, the CSE department has the duration of the course to pique the interest of prospective majors. In this sense, CS 1 is a unique opportunity, and concentrating recruitment efforts there might be more productive than recruiting from the general undergraduate population.

Another reason for choosing CS 1 is related to the gender ratio in the course's enrollment and in the CSE major. Under 20% of the CSE majors are women in the studied department, which is in line with the national average. However, women are better represented in CS 1 and, to a lesser degree, in the follow-on course, CS 2. The percentage of women starts in CS 1 at above 25%, drops to about 20% in CS 2, then drops again slightly in the applicant pool for the CSE major [130]. Within the subset of CS 1 enrollees who are considering majoring in CSE (under a fifth), women are represented at an even higher level—about 40%. This "early pipeline leakage", to use a popular metaphor, suggests that CS 1 is a key point for intervention in prospective majors' academic careers, especially for women.

Throughout the study, we focus primarily on gender and not on race/ethnicity, but we acknowledge that the latter is an important dimension of diversity. In fact, racial/ethnic minority students are even less represented than women in CSE [84]. The exclusion of race/ethnicity in our study is a practical response to the realities of the studied department and institution's overall enrollment demographics. With so few minority students enrolled in CS 1 and even fewer in the major, however, even a fundamentally different research design (*e.g.*, a case study) would likely be complicated by issues of participant anonymity.

4.2.3 Overview of Introductory Course

CS 1 meets four times a week: three one-hour lectures in a large auditorium-style room and one "quiz section" meeting with an undergraduate or graduate teaching assistant (TA) in a smaller group (25–30 students). Programming projects are assigned roughly weekly, and the TAs grade the homeworks for their respective sections' students.

Strictly speaking, CS 1 has no prerequisites, and the course catalog states that no prior experience with computer programming is assumed. In fact, survey data indicated that about a third of the CS 1 students have prior programming experience, *e.g.*, from high school courses or self-teaching. The department makes some effort to separate students with prior programming experience from the others, offering a small number of specially designated quiz sections for students with substantial prior experience and those with none—"high" and "low prep" sections. Students are expected to self-select into these sections, course schedules permitting. Only quiz sections are tailored to experience level; all students attend the same lectures, regardless of prior experience level.

4.3 Survey- and Interview-based Study Design

As discussed above, the study focused on first- and second-year undergraduates enrolled in CS 1. This group represents about two thirds of the total typical CS 1 enrollment. Although the survey and interview data collection yielded very different kinds of responses, this section discusses aspects of the data collection that were common to both methods. Both the survey instrument and interview script were developed in accordance with accepted social science research design guidelines [8, 111, 99, 108].

4.3.1 Question Topics Common to Both Data Collections

Both the survey and interview cover the following topics in order: (1) CS 1 course enrollment and experience so far, (2) academic interests (major(s) chosen or under consideration), (3) interest in CSE, (4) beliefs about CSE, (5) CSE-related preparation. The main topic of interest was the third (interest in CSE). We included the other topics to facilitate a richer, more accurate interpretation of the respondent's responses about this main topic. For reasons discussed later, the length of the survey was severely restricted, so only one or two questions were allocated to each topic. The interview, however, afforded time enough for multiple questions and follow-ups for each topic. This subsection introduces the five topics, deferring survey- and interview-specific details to later sections and the appendices containing the full survey instruments and interview script.

Table 4.1: Question topics included in survey and/or interview, in order as administered.

survey	*interview*	*question topic*
✓	✓	reason(s) for taking CS 1
✓	✓	academic interests (prospective majors)
	✓	aspects of prospective majors that make it interesting
	✓	current/past interest in majoring in CSE
✓	✓	aspects of CSE major that make it interesting
✓	✓	aspects of CSE major that make it less interesting
	✓	characteristics of a successful computer scientist
✓	✓	past experience with computer programming
✓	✓	class standing

In order to "warm up" the survey/interview respondent, the first questions were specific, concrete, and pertained to the CS 1 course. These questions were intended to prepare the respondent for the rest of the survey/interview by encouraging reflection on the topics covered by the rest of the questions and by helping the respondent feel more comfortable. This first set of questions included one about the student's reasons for enrolling in CS 1. We expected that questions like these would be unambiguous and easy for any respondent to answer. We also hoped that these opening questions would establish the character of survey/interview, with a neutral focus on the understanding the respondent's beliefs and attitudes, rather than judging or evaluating their responses.

Before being explicitly asked to discuss CSE, interviewees were posed a more general question about the majors that interested them. This question was the starting point for discussion of what aspects of certain majors make them more interesting to the respondent. In part, this question provided an opportunity for the respondent to indicate interest in CSE as a major without being asked directly about CSE. We hoped that placing this more open-ended discussion before discussing CSE explicitly would be more likely to yield an unbiased response. Occasionally, students would also discuss majors they had considered in the past but had since ruled out. This discussion provided some idea of what students were looking for in a major, *i.e.*, their choice criteria, influences, and decision-making process. As discussed more in Subsection 4.3.3, in the interview, discussion of this topic was used to frame and refine discussion of CSE.

Discussion of the third topic, interest in CSE, centered on a pair of related questions. The questions ask the respondent for aspects of CSE that make it more interesting to them, as well as those aspects that make it less interesting. We initially considered a more conventional approach, asking whether they were interested in CSE and following up with a "why or why not" question. Instead, we opted for a balanced pair of questions to avoid the potentially oversimplifying assumption that academic interest is a yes/no issue. We hoped that asking both the positive and negative versions of the question would yield a more complete and detailed response.

The fourth topic was included to address concerns about unfamiliarity with CSE and its impact on how we should interpret respondent discussion about CSE. We suspected that our respondents would have different conceptions of CSE as a major and an academic discipline. In fact, we expected some, if not many, to have incomplete or inaccurate conceptions of CSE. A possible, if not likely, result is that respondents interpreted questions about CSE differently and effectively answered different questions, even when presented with the same wording. Instead of imposing researcher assumptions about how respondents interpreted the question, we decided to try to elicit these personal conceptions of CSE.

We chose to order the fourth topic (beliefs about CSE) after questions about interest in CSE to minimize the potential effect of study participation on their level of interest. Given the likelihood that most respondents had not directly reflected on their conceptions of CSE (let alone articulated them), it seemed possible that even a small amount of such reflection might change their responses about interest in CSE. At least one interview participant seemed embarrassed when admitting poor knowledge of CSE only shortly after discussing their interest (albeit tentative) in the major. As was more often the case, however, students who expressed uncertainty about CSE tended toward low interest in majoring.

4.3.2 Timing of Data Collection

For both methods, data collection was scheduled as early as possible in the term, typically within the first two weeks. By collecting data from students before they had substantial experience in the course, we hoped to capture the state of their attitudes and beliefs before they were substantially affected by their experience in CS 1—*i.e.*, capturing their "start state". Ideally, data would have been collected from students registered for CS 1 *before* the start of the term, given the possibility that even a few class meetings might affect their attitudes and beliefs. However, recruiting participants and scheduling interviews during the university break would have been impractical. Waiting until after the course had started simplified both recruitment and data collection. We were able to visit the class to make an in-person call for participation, utilize the course e-mail list to send a written call for participation and associated reminders, and students were back on campus and available for in-person interviews.

Collecting data early in the term also gave us the option of aggregating data collected across multiple terms. Resource limitations restricted the amount of data collection that could be completed within an approximately two-week window at the start of the term. To compensate for this, the study was designed to allow for combining data collected during one term with those collected during a later term.

An important consideration, however, was the variability of the CS 1 offerings from term to term. Two local, departmental factors contribute to CS 1's variability. First, the department's standard practice includes rotating teaching assignments for CS 1. Instructors also enjoy a great deal of freedom to decide how to teach the course (modulo a fixed set of expected outcomes and topics). This combination of policies offers advantages, *e.g.*, allowing faculty to tailor their courses to their interests and teaching strengths. However, it also means that the student experience during one term's offering of CS 1 might be substantially different from another term's, particularly at some point in the middle of the term, if topic order varies with offering.

The second, independent reason for term-by-term differences was related to departmental curricular change efforts. Around the time of this study's data collection, the CSE department was experimenting with substantial changes to their introductory course sequence.

All this variability of the CS 1 experience potentially complicates combined analysis of data collected across multiple terms. Collecting data during the first weeks of each term minimized the potentially differential effects of varying offerings of the course on the students' attitudes and beliefs. Accepting the possibility that even a week or two of being in the course might affect students' attitudes and beliefs about CSE, the researcher observed the first course lectures, ending observations after the last interview of the term was administered.

4.3.3 Question Wording and Ordering

Questions on the survey and in the interview were worded and ordered carefully to minimize biasing responses and to ensure content validity. Most of the wording and ordering decisions described in this subsection were made while creating the survey instrument and interview guidelines. Reviewing (by research colleagues) and piloting helped refine the designs.

One concern was that students, in answering survey or interview questions, would engage in the kind of reflection that would change their attitudes or beliefs about CSE. This risk seemed particularly likely in the interview, where follow-up questions would encourage elaboration. For instance, questions about interest in and attitudes about CSE were placed before those about conceptions of CSE. Questions about prior experience with programming were asked toward the end of the survey/interview. This ordering addressed concerns that extensive discussion of programming before asking for student conceptions of CSE might bias their latter responses toward emphasis on programming.

As discussed above, the survey and interview included a balanced pair of questions about interest in CSE. In addition to avoiding oversimplifying assumptions about students' academic interests, we hoped that asking explicitly about aspects of CSE that students found *less* interesting might counter student hesitation to be forthcoming about reservations about CSE. Such hesitation was a concern, because both the survey and interview were presented as efforts, in part, initiated by the CSE department, rather than an independent third party. Such a perception might result in social desirability bias, but participants' open criticism of CSE department policy suggest that this effect was limited.

Some questions were accompanied by explicit guidelines about how they were intended to be interpreted. Before asking about programming, we reminded students that prior programming experience was *not* required for CS 1, to avoid implying any such expectation. When asking for a definition "computer science", we reminded participants that our interest was in understanding what they think, rather than evaluating their response accuracy with respect to some objective standard.

To minimize subjectivity, we were careful to assess prior programming experience using factually based questions. Rather than ask for self-ratings of experience on a subjective scale (*e.g.*, a Likert scale from "none" to "extensive"), we asked for experience in units of time. Our primary concern was that a self-rating would conflate actual experience and self-confidence. This is especially important, given our study's focus on gender differences and the literature documenting lower academic self-confidence among women.

A subtle wording issue with questions about programming surfaced during piloting, highlighting the danger of assuming that students will interpret questions according to researcher expectations. Responses suggested some variation in what students thought qualified as "programming". Some considered programming to include making web pages by writing HTML. We acknowledge that authoring web pages and programming are conceptually similar in some respects, but the differences are substantial enough to differentiate HTML-only web page authoring from programming in our study. (Consider, for instance, the lack of control flow, mutable state, I/O, *etc.*, all of which are fundamental features of popular programming languages.) We did, however, want to recognize JavaScript, frequently combined with HTML for web page authoring, as a programming language. Our solution was to have students indicate the programming language(s) they have experience with, and our choices included JavaScript but *not* HTML. (In future work, including PHP as a response choice seems sensible, for the same reasons.) Finally, a write-in option helped accommodate unexpected responses.

4.3.4 Protecting Interests of Participants

All data collection, analysis, and reporting procedures were approved by the studied institution's institutional review board (IRB). Participation was voluntary, and students under the age of 18 were not allowed to participate. For the 2006 winter interviews, modest cash compensation was offered for participation. CS 1 instructors were given only aggregate data and anonymized quotes that would neither directly nor indirectly identify the participant. To encourage open and honest responses, prospective participants were assured that participation would not affect their standing in CS 1 in any way.

4.4 Surveys, 2004 Spring

This study's first substantial data collection effort took place at the start of spring term of the 2003–2004 academic year. This survey data was used to confirm key assumptions about the study population and its appropriateness for this study. The survey data also complements the interview data for being focused on the same set of topics but differing in sample size and level of detail, with surveys favoring the former and interviews favoring the latter.

With the cooperation of the instructors, this survey was administered at the start of the second class meeting. The researcher requested a very brief, neutral introduction by the instructors and handled introducing the study and administering the survey personally. The two-page survey was administered on paper and took less than ten minutes. Although both the spoken instructions and survey preface text clearly state that participation was voluntary, the response rate was very high. Of 301 students who completed the survey, 205 were first- or second-year undergraduates and were the focus of our analysis.

4.5 Interviews, 2006 Winter

Approximately one hour-long, semi-structured interviews were conducted at the start of the 2006 Winter quarter. Interviews were conducted according to established social science research practices [99, 108], with the main objective being to obtain an unbiased, detailed picture of the interviewee's beliefs and interests in CSE. Fourteen students were interviewed in 2006 Winter. After earlier, less successful attempts at recruiting interview participants without offering compensation, for the 2006 interviews, we offered $20 to participants, which was met with substantially more interest. Women participants were oversampled by giving them priority for interview scheduling. Otherwise, participants were scheduled on a first-come, first-served basis. Sample demographics and other details are provided in Chapter 5 with findings.

4.6 Analysis

Data collected by the surveys and interviews fell into three categories: (a) nominal or ordinal data from forced-choice survey questions; (b) short, written data from open-ended survey questions; and (c) extensive transcripts data from audio-recordings of open-ended interview questions. Analysis methods were chosen to match the unique characteristics of each of these sets.

Given the large size of the survey sample, Category (a) data was well-suited for conventional statistical analyses. We categorized or *coded* Category (b) data according to independent, question-specific coding schemes before applying statistical analyses.

Category (c) data, from interviews, was both the richest and most challenging to analyze. Interview transcripts were examined thoroughly, and the researcher identified and coded segments related to the core research questions. In contrast to the survey responses, which were analyzed one question at a time, for each emergent theme, interview transcripts were analyzed in their entirety. The main reason for doing so was that many themes were discussed multiple times throughout the interview. The more conversational and less formally structured character of the interview (relative to the survey) facilitated a more freely ranging discussion. The divisions implied by prepared questions were blurred, follow-up questions varied, and topics were revisited throughout the interview. Partitioning interview transcripts by question would also remove them from their context, potentially obscuring relationships among topics and themes.

Details of the analysis process are provided later, where findings are presented.

4.6.1 Trade-offs, Limitations

We acknowledge at least two significant trade-offs inherent in our approach to the study. First, due to the practical resource constraints, our study does not yield "large-N" data suitable for statistical hypothesis testing. Instead, the study's primary goal was to illustrate the range of beliefs about CSE and factors affecting interest in CSE. As such, our claims do not include precise estimates of the prevalence or relative significance of these beliefs and factors. However, given the breadth and open-ended nature of the interviews, we suggest that themes independently raised by multiple participants are likely to represent widely held beliefs within the studied population.

Another limitation follows from the privileging of the student voice discussed above. Since the only source of data is students, our study is inherently limited to discovering those factors and beliefs that students are conscious of and perceive as being relevant to interest in CSE. One consequence of this "filtering" is that we did not expect to cover all or even most of the expectancy–value model with our data, because the model was formulated to also include factors of which students might not be conscious. Given the limited body of research on the student perspective, however, we do not consider this a serious limitation of our study.

Chapter 5

INTERVIEW FINDINGS

5.1 Interview Sample Demographics

The 2006 winter interviewee sample consisted of 14 students. With the exception of oversampling for women, conditions on participation were minimized in the interest of recruiting as many participants as possible. The lack of pre-interview screening precluded intentional sampling with respect to interest in the major, but half of the students included CSE among the majors they were considering pursuing. The earlier survey of the same population (CS 1 students at the studied institution) showed that 17% of first- and second-year undergraduates enrolled in CS 1 were interested in majoring in CSE, so students interested in CSE are overrepresented in our sample, but not overwhelmingly so.

Due to oversampling, 9 of the 14 interviewees were women, but women were not equally represented with respect to interest in CSE. All but one of the subsample not considering majoring in CSE were women. As a consequence, this study's findings are more likely to represent the perspectives of pre-major women not considering CSE. Given the need to concentrate recruitment efforts on this population, this bias is not problematic.

A broad range of programming experience was represented in the sample, with 6 of 14 participants reporting some prior experience (excluding web authoring but including PHP, JavaScript, and other web-related programming). Most participants reported little or no programming experience, with only two reporting more than two years of experience. The survey data showed that about a third first- and second-year undergraduates enrolled in CS 1 have prior programming experience, so the interview population is reasonably representative with respect to this attribute.

Table 5.1 summarizes demographic data collected from the interview participants. The table also provides pseudonyms for each participant. These names are used throughout the chapter and can be used to associate individual participants' quotes with basic demographic

Table 5.1: Interview participants with pseudonyms. For class standing, 1 is for freshman, 2 is for sophomore, *etc.* Programming experience excludes HTML experience but includes PHP, JavaScript and other web-related programming.

pseudonym	*considering majoring in CSE*	*class standing*	*gender*	*programming experience*
Hilary	no	3	female	none
Mei	no	1	female	none
Sarah	no	1	female	none
Young	no	1	female	5–6 years
Liz	no	1	female	none
Amy	no	2	female	none
Steven	no	1	male	2 years
Jennifer	yes	2	female	$< \frac{1}{2}$ year
Claire	yes	1	female	none
Erica	yes	1	female	none
Brad	yes	1	male	1–2 years
Lucas	yes	1	male	$\frac{1}{2}$ year
Tom	yes	1	male	none
Danny	yes	2	male	8 years

information.

Neither the interview nor the survey asked students to report their race/ethnicity. This was partly because the focus of the study was on gender but also due to the studied institution's demographics. Majority students (*i.e.*, Caucasian, Asian, or Asian American) dominate the enrollment at the institution, making it a less practical context for studying race/ethnicity effects without a concerted effort to sample minority students. Among undergraduates enrolled at the institution in 2006 (the year interviews were conducted), only 1.2% were American Indian, 3.1% were African American, and 4.7% were Latino/Latina [117]. Although statistics are unavailable for the studied CSE department, racial/ethnic minority students are similarly underrepresented.

Although socioeconomic status (SES) data was not collected, as with race/ethnicity, our interview sample is likely to be representative of the local CS 1 enrollment with respect to SES. In the context of CSE education, SES is primarily important because of its relationship with access to computing [64]. Interview participants were recruited with minimal assumptions of access to computing—assumptions that were reasonable for the studied population. Study recruitment materials made no reference to prior computing experience, and interview participation involved no computer use. Participants were, however, required to use e-mail and the web to indicate interest and schedule their interviews, but this level of computing access and facility was required and assumed of all CS 1 students anyway (as well as in many other courses on campus.) Even the minority of students who do not own a computer have ample access to campus computing labs. These aspects of the study recruitment process reduced the risk of biasing the sample toward students with greater levels of access to computing. In any case, bias was not evident in the sample's prior programming experience. As noted above, over half of our interview sample reported having none.

5.2 Full-transcript Analysis for Themes

This chapter details several themes that emerged from analysis of the interview transcripts. Most of the themes are directly related to students' beliefs and attitudes about CSE, both as a field of study and a career domain. As described in Section 4.6, themes emerged from analysis of the full interview transcripts, rather than independent analyses of responses to specific questions.

The themes discussed in this chapter are listed in Table 5.2. For each theme, the table gives the total number of participants who discussed the theme, making explicit that several participants independently raised these themes. Tallies are split based on interest in majoring in CSE and gender to identify themes that might be related to these factors. However, due to the small sample size, these numbers are conservatively presented as only suggestive of between-group differences. (We return to this discussion in the concluding chapter.) Sample size also precludes making claims about relative frequency of these themes within the different groups. Accordingly, each theme is presented with only tallies, not normalized by group size, and no statistical comparison tests were employed. This style of presenting findings is intended to discourage inappropriate comparison or interpretation of the data.

Table 5.2: Theme occurrence summary. Number of participants discussing each theme overall, by interest in CSE major, and by gender is shown.

		interest in CSE		*gender*	
theme	*total*	yes	no	female	male
uncertainty	8 of 14	3 of 7	5 of 7	5 of 9	3 of 5
long hours at computer	7	4	3	6	1
confusing CSE and prog.	6	3	3	4	2
nerd image	5	2	3	4	1
human element: missing	3	1	2	2	1
human element: competition	7	5	2	3	4
creativity	8	3	5	5	3
from web authoring to Java	6	4	2	4	2
employment prospects	5	2	3	3	2
benefiting society					
factor in major choice	8	4	4	5	3
associated with CSE	5	3	2	3	2

5.3 Theme: Uncertainty

> "I actually don't know what people do when they major in CSE. I know they earn a lot of money but I don't know what they do." —Young

Before discussing students' beliefs and attitudes about CSE, we discuss an overarching pattern that arose in the interviews. Several interviewees admitted to not being sure what it is that CSE majors study and/or what CSE professionals do. By some students' accounts, this conscious lack of knowledge was in contrast with the confidence they expressed in their understanding of what other majors were like—often majors they were more seriously considering pursuing. The level of uncertainty varied across the interviewed group. When asked about CSE and what computer scientists do, some said they had little or no idea, while others gave guarded or vague responses.

5.3.1 Uncertainty about the discipline and careers

Amy, in discussing pros and cons of majoring in CSE and career prospects in CSE, said, "I don't really understand, like, um, like the different things about computer science." Mei prefaced her remarks about what she thinks computer science is by asking, "What if I know nothing about it? I don't know." Young's quote at the start of this section reflects her uncertainty about what CSE professionals do. She also expressed uncertainty about CSE as a discipline when asked to define computer science:

> "Computer science is like you know, same label as like life science...so, you know, general stuff about computers. I'm pretty sure computer works [*sic*], or, I actually don't know, I feel stupid now but, I'm pretty sure computer works with, all its codings right?"

(She even expressed embarrassment at her lack of knowledge, in spite of the interviewer assuring her that there were no right or wrong answers to this question.)

Given the abstract nature of describing the academic discipline of CSE, interviews also included a question about the attributes of a successful computer scientist. The hope was for this question to be more concrete and accordingly easier to answer, providing an alternative framing of student perceptions of CSE. Interestingly, some students who had little to say when asked to define CSE gave longer, more detailed descriptions of a computer scientist. (Section 5.4 provides examples.) However, just because a student appears to know what a computer scientist is like, it does not mean they have any idea what it is that they *do*. Amy, quoted above admitting that she knew little about CSE, followed an extensive (and unflattering) description of an isolated, overworked, "zombie-like" male with the following remarks:

> "I'm imagining a person in a cubicle with a desktop [computer]...They're constantly typing and typing and typing, and their screens are like Matrix [movie] codes...those weird codes, flying around like—I don't know why they're typing, like, 'What are you typing to?'"

Although able to describe what the computer scientist's activity looks like to an external observer, Amy emphasizes the cryptic nature of his work by invoking the image of the unreadable waterfall of characters depicted on computer screens in the popular *Matrix* movies.

Not all students found the computer scientist question easier to answer. Consistent with her uncertainty about CSE, Mei's description of a successful computer scientist was spare and clearly expressed uncertainty:

> "Smart, and uh, um. I mean he must be like interested in this kind of thing, in computer stuff. Yeah, that's it."

In response to a follow-up asking if she had any ideas about the kinds of work a computer scientist does, she simply answered, "Um, no." A second follow-up rephrased in terms of activities they would do finally elicited a halting response with a few examples:

> "Design something...and they're probably working for Disney to make animations...or need to figure out if the—if it's proper to build a bridge there or something."

As detailed later in this chapter in Subsection 5.4.2, several students, even some who were unable to describe CSE in much detail, did associate being a computer scientist with at least one activity: computer programming. For instance, later in Amy's interview, she used "codes" when describing the programs computer scientists work on.

5.3.2 Uncertainty and Interest

Although a small sample size restricts our ability to infer statistical correlation, the students who expressed little or no interest in majoring CSE were more likely to express uncertainty about CSE. This suggests that unfamiliarity with the discipline and associated career paths hinders development of interest in the major. In the case of a few participants, this relationship was discussed quite directly. In response to the question about aspects of CSE that make it less interesting as a major, Amy, who expressed her uncertainty earlier in the interview in the quote above, said,

> "Also I don't really know much about computer science. Like, um, what people do really. That's another factor."

Also consistent with familiarity being prerequisite to interest, students described their knowledge of non-CSE majors they were considering studying with more confidence (and often enthusiasm). Young, quoted above, is a prospective industrial engineering major. She discussed at length her knowledge of the profession of industrial engineering, mostly gained through her father, who works and teaches in the field. Brad spoke excitedly about why he was planning to major in electrical engineering (EE):

> "Um, because you can do so much with it, 'cause whether it's from the phone over there sitting on the wall or the recorder that's recording this conversation right now, it's—it's—it's everywhere like—you can do pretty much any—like you can go from cars and then you can—you can go to like, down to like motherboards or computers or whatever..."

In contrast, later in the interview, Brad had much less to say when asked whether he had ever considered majoring in computer science:

> "Um, a little bit, but I didn't know like—considering I never took a course in computer programming, I didn't know if I would like that. And—'cause when you break down the word computer science like I'm thinking like well there's like the science of the computer and maybe how it like it works, and like, I'm like—I'm—I don't know...I don't know if I would like it. So I don't know. I just—I don't know enough information about computer science say to dive completely in."

As with Amy, a lack of information appeared to be one of the things restricting Brad's interest in majoring in CSE. Perhaps in response to uncertainty about CSE, Brad turned to other majors with which he was more familiar.

Brad's interview was particularly informative, because he also talked about how he recently found out more about EE, hinting at why he was so excited about the program. He described a recruiting event for prospective EE majors that had helped him see how his existing personal interests fit with majoring in EE. Although it seems likely that Brad already had interest in EE, the department's active recruitment effort might partially account for Brad's enthusiasm and intention to major.

In discussions of other themes, we see other ways in which students deal with this uncertainty about CSE, *e.g.*, by making guesses, by generalizing on the basis of small amounts of information, by appealing to sources they regard as authorities. As with any real-life decision, however, these students must make up their minds about which major(s) to pursue on the basis of incomplete information. Chapter 6 discusses uncertainty's effect on this decision-making process, according to the expectancy–value model.

5.4 Theme: The Nature of Study and Work in CSE

Even with the uncertainty discussed above, students expressed some beliefs about the kinds of things a CSE major or professional does. In some cases, they were unable to identify specific work activities, but they expected that CSE work entailed sitting at a computer all day or working in isolation (*vs.* as part of a team). When interviewees did mention work activities, programming emerged as the dominant (if not exclusive) activity.

We examined the transcripts for counterexamples, *i.e.*, beliefs that study or work in CSE involved more than just sitting at a computer. Participants cited a variety of skills and knowledge as being important in CSE, as well as ideas on what CSE was good for or what it could accomplish. However, with few exceptions, their vision of the everyday activities of CSE were limited to sitting at the computer.

5.4.1 Long Hours at a Computer

Many interviewees associated CSE with long hours working on a computer. Amy's response to the "definition of computer science" question was interesting in that it anticipated the follow-up question about a successful computer scientist. Instead of giving a traditional definition, she described the appearance and activities of a computer scientist:

> "Can I give you my imagination part of it? Like okay, I'm imagining a person in a cubicle with a desktop [computer]...having their um shoes off with coffee mugs and pizza boxes all over the place in the cubicle, with their beard grown

> out, unshaved, um, they're eyes are very weary and their face are like tired and zombie-like. And they're constantly typing and typing and typing..."

Later in the interview, she returned to this theme in her description of a successful computer scientist:

> "...very dedicated to their work, as well as the health of their body. Like actually, you know, not just work but actually go and work out and keep your body healthy for [you] in order to just sit there and type all day."

The emphasis on health represents a change from Amy's earlier impressions, but she mentioned spending all day typing on a computer both times. These impressions are not necessarily contradictory, because the questions she was responding to were different. Both quotes describe things that computer scientists, as perceived by Amy, might do to maximize time spent at the computer: consume caffeinated drinks and fast food at the desk and forgo shaving in the first quote, and physically train to prepare for the demands of sitting all day. Amy might regard the former as ways in which the average or less successful computer scientist copes with the sedentary lifestyle she perceives. A successful (perhaps ideal) computer scientist might make different choices but adopt the same sedentary lifestyle.

Hilary said long hours at the computer was main reason she did not want to major in CSE, directly linking her perceptions with major choice:

> "Um, I think my biggest thing is I don't think I'd want to spend most of my time in front of a computer, and that seems to be what a lot of computer science majors do."

Unlike Hilary, Jennifer was considering majoring in CSE, but she shared Hilary's concern:

> "Um, probably my biggest concern is ending up like working in a cubicle, for the rest of my life. Like, just the stereotype of you know working in front of a computer screen in a little office or something, just, you know until I'm fifty or something. I don't want to end up like that...I mean I think it'd be fun to work with computers but I don't know if I'd be able to look at a computer screen for

> eight hours a day or forty hours a week, that kind of thing, for the rest of my life. So, that's probably the biggest negative aspect of it."

Erica's view of CSE was not quite as one-dimensional as in the above quotes, but, again, spending long hours with computers was a key aspect. She associated computer science with both working on programs and machines:

> "Um, I guess to me uh—to me computer sciences would uh be building different kinds of hardware and software, whether by using code or actually building them using physical materials."

Shortly afterward, her description of a successful computer scientist echoed the two kinds of activities but suggested that they both involved long hours with computers.

> "And, they'd have to be a person that would be willing to sit down for long periods of time to do coding or put together pieces of a computer or whatever it is they're working on."

(Our discussion of external influences returns to this quote, since it appears that Erica's beliefs about CSE are substantially influenced by her experiences in computer-related high school courses.)

Some participants, including Young, Claire, and Lucas, also associated CSE with long hours at a computer but were more specific, describing those hours as devoted to computer programming. We explore the association (or, arguably, conflation) of CSE with programming as a separate subtheme in the next subsection.

The above quotes express more than just a perception but also a personal value judgement. The perception is that computer scientists (at least professionally, if not also earlier, as an undergraduate major) spend almost all of their time sitting at a computer. The value judgement is that such a lifestyle is undesirable or even unacceptable to these students.

Notably, participants associated long hours at the computer with only CSE and not with the other majors or professions they were considering. Multiple participants acknowledged the use of computers in a wide range of work, study, and play. However, they did not call out computer use as the dominant activity (or even a primary one). Two possible explanations are related to uncertainty about what computer scientists do. With so few concrete ideas of activities, students' conceptions of CSE could be based on the limited set of activities that seem obvious (using computers) or that they have been exposed to in association with CSE (programming). These few obvious or observed activities "fill the vacuum" and, unmoderated by other ideas, dominate student conceptions of CSE work. Another explanation might be related to a lack of knowledge of what computer scientists use computers *for*. This explanation speaks to why students seem aware of heavy computer use in other professions but do not call it out as a salient feature of non-CSE work.

5.4.2 Confusing CSE and Computer Programming

Although defining any discipline or profession is difficult and beyond the scope of this work, equating CSE with programming is a substantial misunderstanding. While programming plays a central role in CSE, studying CSE can lead to a wide variety of jobs beyond just programming, and even for many professional programmers, programming is not the sole or central activity in their daily work.

Unfortunately, for many participants, the distinction between studying or working in CSE and computer programming seemed unclear, at best. Not only was programming's dominance evident in their discussions about CSE as a discipline and the daily work of a computer scientist, but their responses and word choice implied conflation of CSE and programming.

Direct References to Programming

Hilary, although uncertain about what the CSE major is about, described programming as the sole activity of the CSE major:

> "Um, and I can't think of anything off the top of my head of what else you would rather than spending a lot of time programming computers..."

Liz's definition of computer science was worded more broadly, but it also centered on issuing instructions to the computer:

> "I guess—I think computer science is—is learning to communicate with computers through—through various computer languages?, such as Java?, I [guess] that would be one language. Um, and if web development falls under that I guess HTML as well would be another language..."

She went on to describe some goals of programming, which we discuss in a later section, but the primacy of code is clear.

Lucas similarly perceived the CSE major as largely focused on programming, as illustrated by this part of his description of a successful computer scientist:

> "Um determined and hard-working, because, when I think of a computer programmer, I think of someone who sits at a computer debugging code for like ten hours or something. You know, staring at their computer screen for a long time, looking through lines and lines of code."

In another part of the interview, he explained how, with his interest in programming, CSE's focus on programming made it an appealing major choice, but the exclusiveness of this focus was too much much for him:

> "Another would be, well this is more about the major but just most of the classes have to do with learning how to program computers and not much else...I don't think I want to have my complete major be just programming. Um, more of a general area of computers or maybe even computer hardware would be more to my interests..."

Later, Lucas contrasted CSE with informatics, his primary academic interest. He saw the latter as a broader discipline, encompassing interactions between computing and society and how people access and use information. We also return to Lucas's views on CSE and programming in our later discussion of external influences on beliefs, since his beliefs appear to have been shaped by a high school teacher's concept of computer science.

If Hilary, Liz, and Lucas's statements seemed to be limited to his beliefs about CSE study, Young's remarks suggests similar beliefs about CSE-related professions. In her extensive description of what a successful computer scientist would be like, she described "a person who could always think [about programming], 24 hour seven days. Maybe, you know, to actually live by coding."

Implicitly Equating CSE and Programming

In addition to direct statements suggesting the programming's domination of perceptions of CSE, there were occasions where participant responses to questions implied a belief that CSE and programming were basically the same. Although the interviewer carefully and consistently phrased questions in terms of "CSE" or "computer science," participant responses were phrased in terms of programming instead.

This happened twice during Claire's interview, first when she discussed aspects of CSE that make it less interesting to her: "People around me describe the life of a computer programmer, and mostly they um um, their life is basically sitting in front of computer." Later, when asked to describe a successful computer scientist, she began her response with the phrase, "successful computer programmer." Brad, quoted earlier discussing his ambivalence about majoring in CSE, began his response by talking about programming courses:

> "Um, a little bit, but I didn't know like—considering I never took a course in computer programming, I didn't know if I would like that."

When asked about aspects of CSE that make it less interesting to Hilary, she cited the sole focus on programming (as quoted at the start of this subsection) and went on to describe friends of hers who enter programming competitions, noting that she had no interest in such activity. These instances where participants were asked about CSE but seemed to answer about programming are insufficient evidence of conflating CSE and programming. However, they are consistent with the more direct evidence in the quotes at the start of this subsection.

The salience of programming among a computer scientists' activities was clear in several participants' interviews. There were, however, exceptions to this pattern, with some participants noting other activities (usually in addition to, rather than instead of, programming). Moreover, even participants who mentioned programming as the sole or primary activity sometimes mentioned other aspects of CSE, *e.g.*, the applications of programming. We discuss some of these remarks later in this chapter.

5.4.3 CSE and the Nerd Life

The terms "nerd" and "geek" are used to indicate a variety of negative personal characteristics stereotypically associated with computer scientists (among other kinds of people). Many papers about enrollment and the gender gap in CSE use the two terms interchangeably, often without defining them. Here, we we use the term "nerd," partly because this term was used by two of our interviewees. As with the choice of the term "nerd," the definition adopted in this study is also grounded in data. The personal characteristics interviewees associated with being a nerd included being asocial or socially inept, unkempt, and overworked (and often underslept). This description matches at least one popular dictionary's definition of the term: "an unstylish, unattractive, or socially inept person; especially: one slavishly devoted to intellectual or academic pursuits" [1].

Although only one participant directly cited the nerd image as reason for rejecting majoring in CSE, multiple other participants similarly described computer scientists in clearly negative terms. The nerd image seems likely to be related to another theme that seemed to be a greater concern among women. The other theme was the belief that CSE involves (or even requires) spending long hours sitting at a computer. This belief seems closely related to the nerd image, to the extent that the image includes being overworked and obsessed with computers. Chapter 6 suggests interpretations of these findings and explanations for the relationship with gender.

Young was the one participant to directly cite the negative image of computer scientists as a reason for her disinterest in majoring. However, four other interviewees made similar associations between nerds and CSE. Interestingly, her association of "nerds" with CSE arose early in the interview, well before she was asked directly about CSE. When asked about majors she was considering or had considered in the past, she mentioned CSE. As a high schooler, she had considered majoring in CSE, but she now describes the idea as "scary" because of her image of CSE majors:

> "Scrubby, just wearing a sweater, hair is all—all over the place, pants are like all the way up here, glasses, and you can tell that they don't wash their face. They just don't care about their outlook, because all that matters [like], you know, what they did in [their] room—whatever—their cave. Coding."

Young's vivid and unflattering description of CSE majors was particularly interesting, because she later admitted to her fear that she was susceptible to becoming a "nerd" herself, based on her experiences with marathon web site development sessions that went through the night.

> "...and like I said, CSE, I like coding, but when it comes to like really sitting at the computer three hours—three days in a row, doing Java, I can't do it. When it came to web sites, though, I could do—I actually did it once or did it several times, like without sleeping, stayed up... I remember I did it more than 24 hours the other day...from morning 'til like the next day night without eating or sleeping or I ate a little bit but [...] sit there and actually work on a computer."

She admitted enjoying web site development but talked about how she had to restrain herself from getting too involved, describing it as "too unhealthy" and "dangerous" to become so "nerdy" and attributing a drop in her high school GPA to it. Later in this chapter, we discuss how Young's image of CSE majors has been influenced by her peers.

Amy's response when asked to define computer science was similarly unflattering, describing the same overworked lifestyle and disregard for grooming:

> "I'm imagining a person in a cubicle with a desktop [computer]...having their um shoes off with coffee mugs and pizza boxes all over the place in the cubicle, with their beard grown out, unshaved, um, they're eyes are very weary and their face are like tired and zombie-like."

In Amy's case, these images were based, in part, on her contact with friends who study or work in CSE. She invokes the "zombie" comparison again in describing how they have changed:

> "I don't know what happened to them. I don't ever see them at school. It seems like they're always stressed out...Yeah, busy and scary-looking. They look like zombies...very tired...They used to be very friendly but now they look very tired."

She also recounted memories of an older student who lived next door and studied CSE.

> "When I was younger, my mom, or no, I would see her come home at like, midnight and her mom would say that um, she always has to go to group study and um her, she has to study really hard...and she got really skinny like she was always sleepy, she was like, 'Oh I wish I could sleep. I can't. I have to study."'

Although Claire's description of a CSE professional was not as detailed or negative as Amy's, her distaste for the overworked lifestyle, which she describes as "pretty busy" and "kind of scary" is evident:

> "...because like uh pretty much your life is dedicated to—to your career and your study, and you don't have life outside this."

Other participants discussed the nerd image, although they did not directly connect it with their lack of interest in CSE. Liz, the prospective drama major, described the community of CSE students she knows in milder but similar terms as Young and Amy's:

> "It's this whole other subculture, right? Kids that—maybe, maybe they're not like the most like popular, maybe they weren't like so social in high school, but when it comes to computers, like that—that's their field, like, 'Get me next to keyboard. This is—this is where I thrive."'

5.4.4 The Human Element: Missing, Negative, or Positive?

Participants varied widely in the extent to which they associated CSE with personal interaction. Some interviewees clearly felt that CSE was missing this human element. Others had both positive and negatives views of the social culture associated with CSE, with a few acknowledging the importance of teamwork and others expressing distaste for the competitive culture. Students described academic competition, in terms of admission to the major, as well as competition in the professional sphere. These perceptions appeared to be related to gender, with all but one of the men but only three of the women discussing it in their interviews. The next chapter discusses potential explanations for this apparent gender difference.

Lack of Human Interaction

Lucas described in general terms how the absence of the "human side" in CSE made informatics a more appealing major to him:

> "One thing that interests me that I've been told about [the informatics major] is the human side of computers, where instead of focusing on just the technical aspect, like I've been told CSE does, informatics is more about helping people find and understand information, and you know inside a computer sort of. It kind of, in my opinion, combines psychology with computers."

Students like Lucas might be surprised to learn about human computer interaction (HCI), the CSE subdiscipline devoted to exactly the sort of work he describes above.

Like Lucas, Young described how a major other than CSE, industrial engineering (IE) in her case, appealed to her for having a human element:

> "I like working with people. That as a lot of—lot to do with IE, I realized, when I saw my dad, because you have to work with people, and then, like—so that also connects with business, and then I like art stuff, making posters, web sites, like creating things that people use to communicate..."

Although she only implies that these are aspects of IE that contrast it from CSE at this point in the interview, Young's later remarks make clearer that she does not associate CSE with working with people.

A culture of individuals working in isolation or, worse, of cutthroat competition was mentioned by several interviewees. Young's image of CSE majors (quoted in Subsection 5.4.3) described programmers emerging from their "caves" after working alone for hours or even days. Later, elaborating on her description of the ideal computer scientist, she mentioned a variety of skills that would be *less* important if you were the ideal, successful computer scientist:

> "They don't need to learn how to communicate or anything, because all they do is sit in front of the computer...nor how to socialize."

She was careful to recognize the possibility of human interaction but quickly qualified her response:

> "Then again like, through working people, I think that person could also improve, you know, but I'm talking about this perfect computer scientist I think I'm thinking of, then you probably don't have to work with people at all...So I'm thinking they don't need to socialize, they don't need a family..."

While Young's perceptions seem exaggerated, the basic themes were echoed in other interviews. Amy's image of the "cubicle zombie" computer scientist was one of a programmer working long hours in isolation, and Hilary and Jennifer both cited this as their main reason for not majoring in CSE.

Competition Admission into CSE

Lucas, Young, Amy, Hilary, and Jennifer all described the absence of the human element in CSE, but they and other interviewees also associated CSE with a specific, negative kind of personal interaction. They perceived the culture of CSE as one of unhealthy competition. (Note that the image of the isolated, lone computer scientist does not necessarily conflict with perceptions of a competitive culture.)

Claire's discussion of aspects of the CSE major that make it less interesting suggests intimidation by the competitive culture:

> "It's really like competitive, because people from the past who really has—like people in this major maybe, in the past they have really, uh high experience

> computer skill and computer programming skill as well, so it makes me kind of um terrified, because it's a competitive major, seems to me."

Lucas heard about the competitiveness of the CSE major from a friend who has his heart set on studying CSE:

> "It's flooded with people, applicants. My friend [Eddie] who I sit next to in class is always talking about like—[laughs] It's kind of funny because he sees it as a war of uh students trying to get into the major, and he told me, half-jokingly, in one uh lecture of [CS 1] he was like, 'Look around you, man. All these guys are uh going to be fighting with me to get in the major. They're all uh competitors, not friends.' I'm like, 'Huh. That's kind of a negative outlook on it."'

Danny had the most to say about the admissions process and its effects. He mostly described how competitiveness affected the classroom climate and inhibited social connections:

> "When you walk into [CS 1] so far, you get this feeling of everybody hates because if you end up getting into CS, that's one less spot for them to get in so you can feel this very bad vibe in the air that everybody's hating each other. It's a really bad uh place to be but it's just there, and you can feel it, ever since the first day."

He directly attributed this "vibe" to two official policies. The first was the CSE department's selective admissions process, and the second was the CS 1 course's policy on collaboration.

More than any other interviewee, Danny was focused on competing for admission to the CSE department. He described the slim odds of admission—80 out of 2500, according to him—and wondered why some people even try. (In reality, close to half of applicants are granted admission.) He described his enrollment in CS 1 in strategic terms, based on his belief that GPA was a primary criterion for admission. Having already had programming experience, he expected to get a good grade in CS 1, which would demonstrate to the admissions committee that he was qualified and committed to major in CSE. At the end of the interview, he even volunteered a number of suggestions on how the department's admissions process and criteria should be changed.

Competition and Collaboration in CS 1

Danny also saw the competitive atmosphere in CS 1 as an outgrowth of the collaboration policy:

> "Because if I get a spot in CS, they don't. And if they get a spot in CS, I may not. So it's very limited. And at the very beginning of class the professor, he said, no sharing, no talking, no this and no that, like tons of rules. We get the idea that it's setting up a little border so that the computer science department can pick out the best students. So when—in terms of that, it makes everybody hate each other..."

In Danny's estimation, most of his CS 1 classmates felt this way, as reflected in an unwillingness to assist each other, body language, eye contact, and other manifestations he described. He tries not to think about his classmates this way himself but admitted to sometimes harboring similar, competitive hostility.

Danny was not the only participant to cite the CS 1 collaboration policy as a constraint on social interaction. When Young was asked about how many CS 1 classmates she knew and whether she expected to get to know more, she said no, her reply echoing some of Danny's concerns:

> "Because it's a class where you sort of—well it tells you to work alone, basically. It doesn't—it tells you strictly, do not work with people, do not work with classmates. [So there's] like, there's no point of getting to know people other than just for complaining reasons."

Young said she wanted to study with other students but understood this to be disallowed by course policy.

Clearly, some students interpreted the course collaboration policy (Figure 5.1) more strictly than was intended by the instructors. The policy allows for discussion of assignments (albeit with some strongly stated qualifications) and makes no specific statements about studying (*e.g.*, for exams). Not everyone we interviewed appeared to be aware of or have interpreted the collaboration policy in the same way. Liz, for instance, seemed reassured at the prospect of being able to turn to a dormitory hallmate for help if she got stuck with CS 1 work. In any case, our data suggests that the policy was commonly (if not uniformly) misinterpreted.

Policy on Collaboration

From the class webpage you will find a link to the department policy on collaboration which will be applied in this course. You should familiarize yourself with this policy.

You are to complete programming assignments individually. You may discuss the assignment in general terms with other students including a discussion of how to approach the problem, but the code you write must be your own. The intent is to allow you to get some help when you are stuck, but this help should be limited and should never involve details of how to code a solution. **You must abide by the following:**

- You may **not** work as a partner with another student on an assignment.
- You may **not** show another student your solution to an assignment.
- You may **not** have another student (current or former) "walk you through" how to solve an assignment

Figure 5.1: CS 1 collaboration policy as published in syllabus on course web site

Competition in the Workplace

Perceptions of competitiveness were not limited to the major. Later in Lucas's interview, he said he expects a successful computer scientist would have to be competitive, extrapolating from his perceptions about the major. Amy recounted her neighbor's experience of having her work sabotaged in the software industry:

> "She told me her job was um bad because people try to wreck her codes. Like um somebody in her company totally erased what she wrote and that was really

> mean. ... That's horrible. [He was] very competitive or something. Is it—is it like a competitive field, computer science?"

Later in the interview, Amy described the role a social network could serve in a successful CSE career. Ideally, a CSE professional would rely on peers and superiors to advocate for them and "protect their codes" from sabotages.

There were notable exceptions to the otherwise negative beliefs the above students had about how people in CSE interact. Danny, for all his exaggerated and even cynical perceptions of CSE's competitiveness, maintained a view of CSE (as a profession, if not the major) where collaboration was crucial:

> "...it's never a one-man army. There's always a team to working in a program."

Being able to work on a team and be open-minded to the ideas of others were important to being a successful computer scientist, in his view.

Similarly, Tom's idea of a successful computer scientist involved working across disciplinary boundaries. He described how computer scientists could apply their programming skills to problems in areas like bioengineering, mechanical engineering, and aeronautics.

5.4.5 Creativity in Various Forms

Several participants discussed the role of creativity in CSE. With one exception, they saw CSE (or at least programming) as an opportunity to exercise creativity. Three distinct conceptualizations of creativity appear in these students comments: one related to problem-solving and two primarily related to programming.

Creative Problem-solving

Sarah and Amy both described creative problem-solving as important to success as a computer scientist. In this context, being creative meant the ability and willingness to consider a wide range of approaches to a problem. According to them, this kind of creativity is what advances CSE, through innovation and improvement on existing work and ideas. To Amy, this is one aspect that CSE shares with other engineering disciplines:

> "Um I think engineering is about creativity, or science—or no. Okay I'm thinking engineering. Computer science to me is somewhat like engineering—engineering the codes, making up the codes, and you need to be creative for that, because if you're going to—if the—the scientist is only going to stick to one thing, to the original like—[hard] probably um—they're not going to make any improvement, and I think that's what um some of the mistakes that people are making these days [in] hiring very experienced um engineers or computer scientists, because they'll just making—they're just doing the same thing, and they don't change."

(Interestingly, Amy also implies that veteran engineers are less likely to be creative in this way, although she did not discuss this further.) Sarah observed the particular value of advancement through innovation and improvement for a young field like CSE, describing this creativity in terms of "different ways of thinking, not just sticking with what people have thought of already":

> "Part of computer science is like developing ideas or it's like, finding new uses for computers or improving them or, I don't know. It's—I think it's important to try out new things and like computer science definitely isn't like finished. I mean there's—I mean there's so many more different things that we can do with them, and the only way to figure them out is for someone to think about them."

In the quotes above, Sarah's conceptualization of creativity in CSE refers to both new applications of computers, as well as improving computers themselves. This conceptualization seems broader in scope than Amy's, which implies the context of programming. The other participants were more similar to Amy, and they more directly defined creativity in CSE in terms of programming. (Their focus on programming is, of course, consistent with a lack of understanding what differentiates CSE and programming, as discussed earlier in this chapter.) As we see in the next part of this chapter, for these students, programming provided opportunities for creativity in two main senses, both associated with creative freedom. Liz, Young, and Jennifer mention the malleability of programming as a creative medium, allowing the programmer to create *whatever* they wished. Others observed that "there's more than one way to do it"—that the programmer can write a program *however* they wish, within certain technical constraints and functional requirements.

Freedom to Program What I Want

Liz sees the opportunity to "design things, to like be the creator of something" through programming. Although she has misgivings about other aspects of CSE, she finds programming's potential as a creative medium appealing:

> "...that idea, that you can make something, just of like words on a computer. Pretty cool."

A prospective drama major, Liz sees some important differences between programming and the arts, but both can be creative and even expressive outlets:

> "There's room for like expression, even if it's through computers, and it's not so much like art, drama...Yeah it's different in the sense that it's like, you're still doing math, there's still structure but like there's definitely room to—to design things, to like be the creator of something."

Young described her early, self-taught experiences with programming with similar enthusiasm for creative freedom:

> "I did that for a very, very long time. Like four to five years, and I thought I enjoyed sitting at my computer, making something out of it, on-line..."

As the same quote continues, however, she draws a sharp contrast with her high school and college experiences learning to program in Java:

> "...but oh I just hate Java...I don't know. If they tell me to make something out of it, after I know all the—like all the coding like expressions, like how to—like how to do actual loops, maybe we'll—I'll get to that later, at the end of the quarter, but it's just not my style where they tell me to do something like this and I'll do exactly the same."

Describing her interest in programming earlier in the interview, she describes the creative element missing in her experiences with Java so far:

> "...When it comes to Java... Because I know when I—when I'm done [with a Java program], I don't feel any like accomplishment...When I make web sites, I make something on my own, but, [with] Java, you like make something that's assigned by the teacher. If it's not the way he wants it to be, then you get points off, and it get—it gets me frustrated.

(For both Liz and Young, making web sites was their introductory experience with the creative potential of computing. Other participants described web pages as a prelude to their programming experiences, and we examine this theme later in this chapter.)

During Jennifer's interview, she described various assignments that she particularly liked for providing the same kind of creative outlet that Liz and Young discussed. She responded enthusiastically to the most recent CS 1 assignment:

> "And like in the homework assignment we just got the other day, uh there's two parts to it. One of them is—they just introduced the graphics on it, so one of them you just kind of get to draw whatever you want and, you know, make a nice little picture...As soon as I got the project I started thinking of like the different things I could make and...how far I can take—or—go within the guidelines and rules kind of thing, to make it as creative as possible."

Her descriptions of similarly appealing assignments from non-CSE classes clarify the common, creative element:

> "...just a lot of creativity involved in that [introductory engineering] class, where they just kind of give you a project and give you some guidelines, but you have the freedom to do whatever you want within those guidelines with that project. So that—that's a lot of fun, just kind of being able to, you know, put your—your own style into a project...It's hard when [really] you have to do exactly—you know regurgitate exactly what they want you to do kind of thing. It's—it's nice when you get a little freedom like that. You can have fun with it."

She also described a writing assignment for an English class that she found considerably more interesting than the more traditional literary analyses she has had to write to date.

> "It's a creative writing assignment. So we get to take a point of view from one guy that we've read about and another guy that we've read about and kind of like imagine a scenario if they sat down coffee...It's probably the most—one of the more interesting English assignments that I've had to do in a while."

Freedom to Program How I Want

Typical CS 1 programming assignments specify what the program should do, *i.e.*, in terms of behavior or output, but they rarely fully restrict the student in terms of how the program should fulfill those functional requirements. In this sense, there is no one right answer to most programming assignments. Multiple students described this aspect of programming, most often in relation to creative freedom.

For Danny, this aspect of programming was the main creative element of CSE. The first characteristic he mentioned in his description of a successful computer scientist was creativity:

> "Um someone who's creative, because there's more than one way to write a program. And if you can make it simple, using very simple functions, even better than making a ten-page program."

While potentially related to the problem-solving notion of creativity discussed first in this subsection, Danny's notion is firmly contextualized in programming. Note the contrast with the broader sense of creativity that Liz, Young, and Jennifer describe above. The creativity Danny describes here is exercised after determining what the program should do.

Jennifer's own words clarify the latter distinction. She describes room for creative freedom, albeit limited, in assignments restricting her say in what the program does:

> "Even on the other [assignments], where they say, this is what your output has to be, there's still kind of—you get to have your own say in what the program looks like, to a certain extent. I mean, there's not much freedom but...There're

> so many different ways you can write a program...It's more of an organizational thing, I guess...There's still a little bit of freedom, because they—they—you know, they don't tell you exactly how it's going to accomplish that, you know. That's for you to figure out."

Even Young, whose distaste for her Java programming experiences is partly due to a lack of creative freedom, acknowledged multiple ways of approaching Java programming. Although the following quote was part of Young's discussion of the CS 1 course's collaboration policy and her perception that study groups were prohibited, her description of Java programming is markedly similar to Danny's quote above:

> "Well, I guess, you know, [when] you code Java, there's different [ways] of thinking, like which method to put first and what to call first, how to name them, how to make it more efficient or how to make it shorter, that sort of pattern of thought—if we could share with each other, maybe that would give us some kind of insights."

Creativity with Constraints

Overall, these participants seem to describe creativity in CSE as being in balance with a variety of constraints, some inherent and others arbitrary. For Liz, the constraints are mathematics and structure. Young is frustrated by constraints imposed by her instructors in the form of programming assignments, but she also seems to suspect that other constraints are designed into the Java programming language.

5.5 Theme: Benefiting Society

A variety of previous research and recommendations on interventions to promote the participation of women in computing highlight the value of placing CSE in the context of socially relevant applications [78, 28, 114]. The research literature specific to women in CSE, however, appears mixed in terms of evidence that societal benefit is a factor that particularly strongly influences women's academic choices [31]. Our study suggests that its influence is equally substantial for women and men, at least in our sample of CS 1 enrollees, but that relatively few students see studying CSE as a means of achieving societal benefit.

5.5.1 Academic Choices and Societal Benefit

When discussing their academic interests (regardless of whether this included CSE), just over half of the interviewees related their choices to a desire to contribute to society. For some students, this was implied by the nature of the challenges that motivated their interest in a major. Others made more explicit that they sought a major associated with benefiting society.

Perhaps unsurprisingly, the prospective bioengineers in the sample (three women) were some of the clearer examples of students selecting majors based on societal benefit. All three were motivated by scientific and medical challenges related to prosthetics and implants. Amy describes her attraction to bioengineering as follows:

> "I see how it can improve other people's lives, who are less unfortunate [*sic*] than, like, you know, people who have um lost an arm or a leg as a war veteran or whatever and like they could, have it um, a fake one for them to live a normal life. And old people who um can have their heart or their hip or—it just—it helps improve other people's lives."

Amy also described having previously aspired to medical school, also a path that would have been consistent with her interest in societal benefit.

Among the three prospective bioengineers, Amy was the one for whom societal benefit appeared to be the most important. Later in the interview, she described how she had difficulty reconciling her intellectual curiosity about philosophy with her desire for societal benefit. In spite of interest and talent in the subject, she was wavering on her initial intention to minor in philosophy:

> "You can reason as much as you want, but then, if it doesn't benefit the rest of the world, in a way, then it's not going to happen—or, it'll take a lot of willpower for it to happen, so... Yeah, that's a problem for me. I'm trying to figure that out."

Although their major choices differed from the women's, some of the men in our sample also exhibited interest in societal benefit. Tom's interest in CSE was related to medical research applications of computing. In Danny's case, benefiting society did not seem as important a factor as for Tom, but it did play a role in his interest in CSE. Both Tom and Danny's cases are described further in the next subsection. Lucas's first-choice major was informatics for its combination of technical and human elements. Although he admitted being somewhat unsure of what the informatics major was about, he did describe it in terms of societal benefit:

> "One thing that interests me that I've been told about [the informatics major] is the human side of computers, where, instead of focusing on just the technical aspect, like I've been told CSE does, informatics is more about helping people find and understand information...It kind of, in my opinion, combines psychology with computers."

The next subsection discusses the contrast that Lucas draws between informatics and CSE.

5.5.2 Benefiting Society through CSE

Participants varied in the degree to which they recognized CSE as a discipline with potential to benefit society. As a factor affecting choice of CSE as a major, however, benefiting society influenced at most three students: Tom, Danny, and possibly Claire. Tom wanted to study CSE in part to move beyond everyday applications of computing like the web and e-mail, to

> "...see what makes [computers] actually useful for something besides games. I think it'd be interesting to find some use for computers other than just moving information across a wire."

When asked for examples of more interesting applications, he enthusiastically described computing's increasing role in solving problems in cancer research, genetics, and bioengineering.

Multiple times during Danny's interview, he mentioned computing's potential to do work for people, freeing up their time to do other things:

> "[Computing is] like um being lazy. You just sit there and you let the computer do things. It's great...It's an awesome idea. It's exactly what the [CS 1] professor said...He said um, 'Computer scientists are lazy. They program computers to do things for them, and they just sit there and watch."'

It was not until very late in the interview that he explicitly linked this particular kind of "laziness" with societal benefit. Danny was one of a few students who extended the interview beyond the prepared script by taking the opportunity to ask the interviewer questions. During this extended conversation, most of which focused on departmental admissions, he expressed the opinion that the admissions committee should take into account the "intentions" of an applicant:

> "It's not all about um making money, because I know computer scientists do make a good amount, but it's also about what you're um trying to give to society...We want people who have the intentions of actually making mankind better, from computers."

Finally, Claire did not mention societal benefit when describing aspects of CSE that made it interesting to her. (This was in contrast to her remarks about cancer research motivating interest in biochemistry and prosthetics motivating interest in bioengineering.) However, she did refer to societal benefit when defining CSE and describing a successful computer scientist:

> "Computer [*sic*] um may contribute in other different industrial [*sic*] as well like health industrial and um maybe government industrial, and so forth that benefits the society."

For Claire, it was important for a successful computer scientist to understand people and their needs:

> "...really care about uh what people needed in this society and what can be improved and can really see the problems that need to be solved in the world."

Claire's remarks suggest that she saw CSE's potential for societal benefit but did not associate CSE with societal benefit the way she did with her top major choice of biochemistry and a secondary interest in bioengineering.

Even with a small sample, there is a striking suggestion of gender difference in association of CSE with societal benefit. Although we observed both women and men considering societal benefit in their academic choices, only men seemed to see majoring in CSE as consistent with this goal. In contrast, societal benefit led women to choose life science-related majors.

5.6 Theme: From Web Authoring to Java

Although every student was asked a broad, open-ended question about their prior experiences with computing, no question explicitly asked students how their computing background related to their experiences in CS 1. Interestingly, three students described important connections between web authoring and programming in Java. After a comparison of web authoring and programming as background, we discuss the connections between web authoring and programming that the participants described. Later, Chapter 8 discusses the apparent popularity of web authoring among young people and expands on other reasons for including this theme in this chapter.

It was less surprising that students related JavaScript or PHP to Java, since all three are programming languages. HTML, on the other hand, differs fundamentally from these languages in that its purpose is describing a web page's content, structure, and organization (and sometimes visual presentation). As such, most computer scientists consider web authoring and writing computer programs to be distinct activities, although they often go hand-in-hand, *e.g.*, dynamic web pages composed of HTML augmented with scripting languages. To the extent that HTML is much more limited than programming languages, it is arguably easier to learn, a point our discussion returns to later. These distinctions between web authoring and programming, while valid and useful, might obscure the connections observed by some of our participants. In fact, some participants' remarks indicate uncertainty about whether HTML qualifies as a programming language. Later, we consider whether blurring this distinction might allow some students to see how working with HTML can prepare them for the additional complexity of working with a programming language like Java.

Of nine participants with web authoring experience prior to enrolling in CS 1, six related their experience to learning programming in some way. Some described how working with HTML naturally led to an interest in programming, often using languages commonly associated with web development like PHP and JavaScript. Some students with experience with such web-related programming languages recognized general concepts that apply in the Java context. Most intriguingly, one student with HTML (but not programming) experience observed a number of ways in which working with HTML prepared her for learning Java.

Our data suggest web authoring's great popularity, at least among the generation of students sampled in our study. Many of our participants got started with web authoring as early as in their pre-teen years, often on a self-taught basis. Eight of our participants reported having taught themselves HTML (with some also learning PHP and other web programming languages on their own). Some mentioned learning HTML with a friend. Participants were motivated enough not only to learn HTML using on-line tutorials but also to reverse-engineer parts or features of web pages they wanted to imitate. Participants who described web authoring's appeal described it as a fun opportunity for free, creative expression and communication.

Web authoring experience was most frequently discussed as an entry path to programming, *e.g.*, with interest in web authoring naturally motivating students to learn programming. This motivating effect was described in general comments like Erica's, when she was asked whether she expected background in web authoring would prepare her for CS 1:

> "Um well it's been helpful in keeping my interest in computers up. I don't know how much I'll be able to use HTML when I'm working in a class that is focused on Java..."

Erica was unsure how familiarity with HTML would be help her learn Java, but other participants described connections with more confidence. When asked why he found programming interesting, Lucas described how he arrived at programming via HTML:

> "I consider uh web design, like HTML, uh somewhat of a programming language, even though I think most people think it's not strictly a programming language, and I've always had a lot of fun programming in HTML and XHTML and CSS...so that's kind of given me uh more of an open mind towards other programming languages."

Other participants described how their work with HTML eventually led them to trying some programming, even if not in Java. Young tried some PHP as part of her extensive web authoring work, and Jennifer was introduced to UNIX and some programming (language unspecified) by a friend who helped her with a web project.

Brad and Lucas were two students who had taken a relatively new introductory course on fluency with information technology (FITness) [35] before enrolling in CS 1. A substantial portion of this course was devoted to web authoring using HTML and JavaScript, with an introduction to some fundamental concepts in programming. The FITness course is not intended to be an introduction to CSE, nor is it a prerequisite for CS 1. However, both Brad and Lucas said their FITness experience gave them a conceptual head start in CS 1. Brad described the FITness course as a gentle introduction to foundational programming concepts:

> "[Material in the FITness course] did relate a lot to Java, and it helped—I think it helps. Like I can pretty much follow pretty quickly in Java...It as a pretty good intro."

Lucas described the value of the FITness course similarly:

> "Oh most definitely [helpful]. Um, the JavaScript correlates almost directly with what we're learning now...Basically everything I learned so far in [CS 1], I already knew how to do it on a web page with JavaScript from my [FITness] class."

For him, the value came from the FITness course covering the same programming concepts as in the first weeks of CS 1, but spending more time on them and having lab activities to apply and learn the concepts. Both Brad and Lucas said that CS 1 would be harder if they had not taken the FITness course earlier.

Brad and Lucas provided more details about how web authoring with JavaScript helped prepare them for learning Java. They recognized specific, syntactic features common to the two languages (*e.g.*, `System.out.println` and calling parametrized methods). Brad's describes how Java satisfies expectations formed during his experience with JavaScript:

> "Function calls—it's like—it's pretty similar. Like semicolons are there, you got, you know, your squiggly lines [curly braces] or whatever, and like, variables are—are pretty similar. So I—I—I don't know. Like, the way Java works is like, it's the way I think it should work."

In addition, Brad recognized stylistic standards like variable naming and indentation, as well as the value of writing code with a human audience in mind, not just the computer:

> "You indent your lines, and like, the proper format of like—more than just computer syntax, like visual syntax, I guess. So it gets you thinking at that right mindset."

The parallels between web scripting languages such as JavaScript and Java would be obvious to any computer scientist. These parallels are discussed here primarily to emphasize that even beginning programming students independently noticed their value in facilitating learning Java. This subsection closes by focusing on the case of Liz, who observed less obvious connections between HTML (typically not considered a programming language) and Java. Although she was the only participant to provide detailed examples of connections between working with HTML and programming in Java, as noted at the start of this subsection, other participants found some preparatory value in HTML.

Liz first described web authoring's preparatory value in terms of comfort with working on the computer. Although she was not asked to relate her web authoring background with her experience in CS 1, she volunteered the following while describing her prior experience with computing:

> "Yeah [web authoring] was definitely fun. Definitely fun. I wasn't making—I wasn't working for like—like an Internet company or something, making a web site. This was just for—it was just for fun, but um it got me really comfortable with—with working on a computer, in regards to like a different language and getting used to um like basic stuff that even can relate to Java...There's concepts that are definitely applicable from HTML to Java. It's—it's—a lot of it's different, but some stuff isn't."

She continued with specific examples of how working with HTML helped her with learning Java. Here, she describes how both languages have rigid, structural rules:

> "Like in Java, if you are—if you're telling the computer, this is a quote, and you only put one quotation mark, then the rest of your code, the computer thinks it's all part of the quote, because you didn't close it. In HTML, if you tell the computer, this is—I want this sentence to be green, and you put the formatting for green, and you don't close it at the end of that sentence, you're not specific about, this is the only thing I want it to do, then your whole page is going to be green. So that—that's a really basic one."

The fact that computers interpret languages with unforgiving strictness demands a level of care and precision in communicating instructions that many computing novices find challenging. Liz's remarks suggest she had an easier time adjusting to these demands in the relatively simpler (and possibly more interesting) context of web authoring.

For Liz, the similarities went beyond attributes of the HTML and Java languages. She described how the "system of thinking" she developed for working with HTML transfer to the programming context:

> "Um, there's definitely troubleshooting that goes on with those codes. If you—if you put part of your HTML code incorrectly, and you're looking at the result,

> and it doesn't match what you thought you were doing at all, then you go back to your code, and you scan it, and you try to remember everything you know about, you know, a certain code you used, and if you did it incorrectly, you fix it, and you look at the result again. Well, what changed? Okay, it changed a little, but not the way I wanted it to, so that's—that whole—that whole system of thinking—that you have to tinker with it until it's just right is definitely something that is probably even more so important in Java than it was in HTML."

Consistent with Liz's expectations, elements of the approach that she describes are integral to debugging programs: comparing actual program behavior with expected or intended behavior, double-checking key code elements, and an iterative process of making changes and examining their impact on program behavior.

Among the interview participants, Liz was exceptional in the breadth and specificity of her observations about connections between web authoring and programming. She noted analogous concepts and syntactical parallels (*e.g.*, scope and paired symbols), as well as aspects of process that apply to both web authoring and programming (*e.g.*, troubleshooting, debugging). Section 6.4 in the next chapter discusses the significance of the connections Liz observed and other ways in which previous computing experiences and major choice might be related.

5.7 Theme: Employment Prospects

Given the continuing concern about CSE job shortages [40], we noted with interest that few students had negative perceptions about finding a well-paying job in CSE. Among the five participants who discussed employment issues, poor job prospects discouraged only one from majoring in CSE. (A later chapter discusses the possibility that such negative perceptions might be more prevalent in the general undergraduate population.)

Steven is the exception in the group and had ruled out majoring in CSE for fear of not being able to compete with the highly qualified candidates seeking jobs at top software companies. He described hearing about these candidates from a family member and a friend, both of whom work for a large software corporation. Steven's concerns about competition were accompanied by perceptions of a job shortage in CSE:

> "Computer science, like, was really hot and like everybody like—at least like I don't know like in general, but in like just people I know, from my family like and our friends, like a ton of people went into it and...it just seems like there are so many people that are qualified in that field that there's way too much supply, and it's really hard to find a nice job."

Amy's case differs in an important way. She had also heard, from a peer, that the job market for computer scientists was bad. Unlike Steven, Amy regarded her friend's advice against majoring in CSE with skepticism:

> "My friend told me that's stupid because um most computer engineers are just um jobless right now like his friend who has a B.S. in computer science is unemployed so. But that's not part of why I don't want to [major in CSE]...I'm not that gullible."

As described earlier in this chapter, Amy's concerns about professional life in CSE were different—about the competitive culture and excessive workload, rather than job prospects.

The remaining three participants who mentioned employment issues held positive expectations about employment and income. While Young admitted to not knowing much about CSE, she did say she knew that they are very well paid. Similarly, although Jennifer expressed concerns about a sedentary career life stuck in a cubicle, she did describe the good pay as a "plus."

Lucas's case differed slightly from Young's and Jennifer's. He said that financial gain seemed to motivate students to study CSE:

> "From the people I've talked to in my [first-year, special interest cohort] and also some friends of mine that are interested in the [CSE] major, a lot of them want to go into it purely for the money, because they've been told that if they become a computer science major, there'll be a lot of high-paying jobs for them when they get out of college."

Lucas did not express any doubt that these students' employment expectations were reasonable. However, he made clear that his priorities for undergraduate education differed sharply from these students'—enough that he felt he would not fit in:

> "And my view right now—I can't say about later on—but uh right now, I'm not trying to learn things because I want to get a job or to earn money...So I'm—I think if I go into CSE I might be surrounded by a lot of people that have just kind of this narrow outlook on—uh go to college, major in whatever gives them the most money, get a job, and that's not a philosophy I agree with."

5.8 Summary of Findings

The findings presented in this chapter primarily address our second research question, "What are pre-major undergraduates' beliefs about the CSE major and career paths associated with CSE." Students in our sample expressed a wide range of perceptions and concerns related to interest in majoring in CSE. Overall, all participants expressed beliefs about CSE, but many admitted being uncertain or lacking information about the discipline or what professional computer scientists do. What perceptions they did have commonly referred to isolated or competitive nerds spending long days at the computer. Programming dominated their characterizations of CSE work, although some recognized additional dimensions, such as creativity, problem-solving, and computing's applications. Students who had web authoring experience found it helpful as preparation for learning programming in CS 1. Those students who considered employment prospects in CSE mostly had positive expectations.

Most of the themes seemed unassociated with gender or intention to major in CSE. Exceptions included uncertainty about CSE (and what computer scientists do), the nerd stereotype, and desire to benefit society. Uncertainty about CSE was more commonly cited by participants who did not intend to major in CSE. Women were more likely to discuss the nerd stereotype. Finally, while both women and men expressed interest in majors that would lead to opportunities to benefit society, women were less likely to recognize this potential in CSE.

This chapter's discussion of student perceptions of CSE began to address our first research question, "What factors affect interest in the CSE major among pre-major undergraduates, especially women?" The next chapter employs the expectancy–value model to propose more specific and detailed relationships between student perceptions of CSE and interest in majoring in CSE.

5.8.1 Comparison with Related Work

In general, the fact that so many concerns were shared by students interested and uninterested in CSE parallels findings from Seymour & Hewitt's study [100], which found that STEM switchers and non-switchers were more similar than expected, with respect to reported factors affecting persistence. This suggests that some students enter and persist in CSE because they recognize positive aspects of the major that balance the negative aspects.

Our findings on the prevalence, intensity, and influence of the "nerd" stereotype corroborated numerous earlier studies' findings [59, 17, 78, 80]. Suggestions of gender difference were consistent with earlier findings [59, 78], with women more likely to express concern about the nerd image.

Our findings about the gender and the role of service to society in motivating majoring in CSE suggest a more complex relationship than claimed in previous studies. In our sample, both women and men considered societal benefit in their academic choices, but only men found ways for CSE to fulfill this goal. The women's major choices, in contrast, suggested that other majors (often in the life sciences) were a better fit.

Many students associated CSE culture with competition, but most were men. As discussed more in the next chapter, this result is consistent with Seymour & Hewitt's claim that women are less likely to have been socialized to recognize and respond to a "weed-out" system, where success is linked to independence and survival of individuals competing with each other. This might be why so few women mentioned (let alone expressed concern about) competition, *e.g.*, for grades or admission to the CSE major.

In contrast with much of the research reviewed in Chapter 2, participants in this study offered little discussion of confidence, regardless of gender. In fact, the one participant to relate their confidence to the decision *not* to major in CSE was a man (Steven). This suggests that women who self-select by enrolling in CS 1 might have higher-than-average intellectual and/or computing confidence. At least for these CS 1 enrollees, pre-college self-confidence might not be a major factor explaining women's low entry rates into CSE. However, it seems more likely that confidence does indeed play a role, but in ways less likely to be observed by our data collection methods. Students might not be conscious of confidence's effects or, even if they are, they might feel less comfortable discussing these effects. (Note that students were not directly asked about confidence or its effects on major choice.)

Chapter 6

THEMES AND PATHWAYS IN THE EXPECTANCY–VALUE MODEL

The previous chapter described a selection of the more common CSE-related beliefs expressed by our study participants. Our interest in many of these beliefs stems from their likely connection with interest in the CSE. This chapter employs the expectancy–value model of Eccles *et al.* (introduced in Chapter 3) as an organizing framework for contextualizing and interpreting selected themes (or groups of common beliefs) that emerged from the inductive analysis of our interviews. In the course of the interviews, participants often discussed or implied the relationships between these beliefs and their (dis-)interest in CSE. To a great extent, these accounts are consistent with the causal relationships proposed in the expectancy–value model, and the model guides our understanding of how the beliefs/themes are related to the outcome of interest in this study: the decision to major in CSE.

In the graph representation of the expectancy–value model (shown again in Figure 6.1), rectangular nodes denote related groups of hypothesized factors influencing achievement-related choices. Some factors take the form of student beliefs, *e.g.*, "Perceptions of occupational characteristics and demands." Others are people and experiences that influence beliefs, *e.g.*, "Socializer's beliefs and behaviors." Directed edges indicate how these factors influence each other, with arrows indicating direction of influence. The direct influences of expectations of success (expectancy) and subjective task value (value) are visible in the rightmost nodes. According to the model, all other factors influence achievement-related choices through one or both of these two direct influences.

Practically speaking, gathering empirical data to validate the model is easier for certain parts than for others. This is partly because the model includes influences that people are unlikely to be conscious of, *e.g.*, the items in the node "Cultural milieu." (Eccles *et al.* make no claims about how aware the individual is of the influences mapped out by the

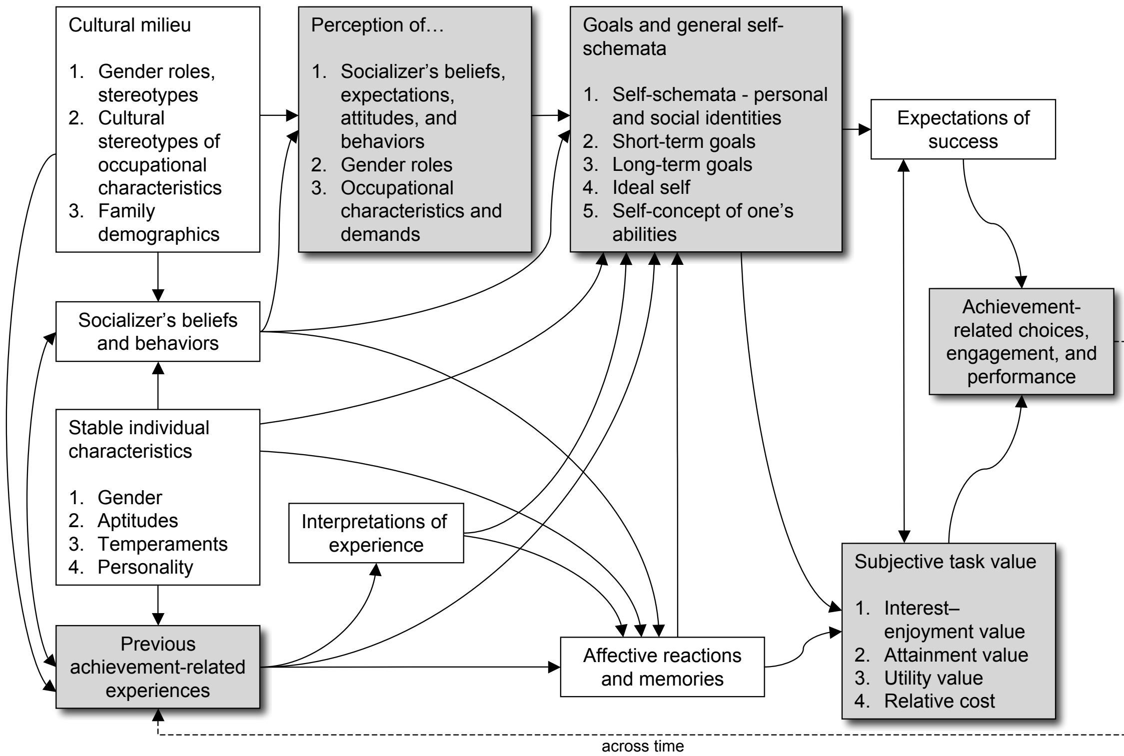

Figure 6.1: Expectancy–value model with shading showing those nodes for which data was collected during interviews

model—only that the influences exist.) In this sense, certain parts of the model are more observable or facilitate collection of direct evidence.

Based on this study's one-time interviews with students, our data represents a primary source for the specific parts of the model highlighted in Figure 6.1. As described in Chapter 4, interview questions were designed to elicit certain kinds of beliefs and accounts. Responses to these questions map most directly to the parts of the model labeled, "Perceptions of...", "Goals and general self-schemata", "Previous achievement-related experiences", "Subjective task value", and, of course, "Achievement-related choices, engagement, and performance". Because of the semi-structured format, interviews frequently led to discussion of other, related beliefs or factors influencing beliefs, even when questions did not directly ask about them. The resulting, broad-ranging, rich data set provided an opportunity to validate and extend the expectancy–value model as a whole, rather than examine only isolated parts.

To the extent allowed by the data, this chapter maps themes described in the previous chapter to *pathways* of influence in the graph. Pathways are paths in the graph theoretic sense—sequences of connected nodes in the model graph. Each pathway represents how external influences affect specific student beliefs, and how those beliefs in turn affect the decision to major. The model's structure places the beliefs in the larger context of a complex network of causal relationships. As discussed more later, fitting interview findings into this causal model also guides the design of intervention efforts. Variations of Figure 6.1 appear throughout this chapter to illustrate specific, causal relationships.

As observed above, our interview data provides a broad but incomplete picture of student beliefs and their influence on the decision to major. This chapter supplements interview data with evidence from past research. The expectancy–value model provides the structure for combining evidence from these sources, resulting in more detailed hypotheses about factors affecting beliefs about CSE and, ultimately, major choice.

The next section consists of general observations about how the themes fit into the model. Subsequent sections focus on specific themes selected for their relevance to the underrepresentation of women in computing or to level of interest in the CSE major. For each theme, we begin by identifying the node in the model graph that corresponds to the student beliefs that constitute the theme. From there, to the extent supportable by evidence from interviews and the literature, we trace edges backward to nodes representing influences on the beliefs and forward to nodes representing the effects the beliefs influence. Participants' discussions of their beliefs about and interest in CSE (as summarized by the themes) suggest that the beliefs affect interest in majoring in CSE through multiple pathways in the model. As detailed later, most factors appear to influence interest in CSE by affecting task value, rather than expectancy.

Finally, other themes have no obvious mapping to the graph and are discussed separately at the end of this chapter. As we detail later, however, these themes also fit well with the prior work of Eccles *et al.* The concluding section of this chapter presents the theoretical contribution of our work, discussing how the expectancy–value model can be refined and extended to facilitate research in the specific context of CSE enrollment and gender.

6.1 Perceived Occupational Characteristics and Demands

The previous chapter detailed a wide range of negative and positive perceptions students have about study and work in CSE. As a group, these perceptions fit in the expectancy–value model best under the "Perceptions" node in the top row. More specifically, in the context of this study, the third category of perceptions, those of "occupational characteristics and demands," is most relevant. As the graph indicates, the model suggests that these perceptions interact with the student's goals and self-schemata, potentially affecting expectations of success and task value.

Based on interview data, the most common reported or implied effect of perceptions about study and work in CSE was on task value, rather than expectations of success. Figure 6.2 illustrates this pathway. Participants reported or at least implied that long hours, the dominance of programming, the human element, and the role of creativity in CSE all affected their interest in majoring in CSE. The interview script did not include questions designed to discover the origins of these perceptions or the specific ways in which these perceptions affected decisions to major in CSE. However, in the course of the interviews, many participants discussed these topics without prompting.

In some cases, participants appeared to be considering these perceived aspects of CSE in the context of their goals. Jennifer rejected the future career that she envisioned majoring CSE would lead to. She describes how whatever interest–enjoyment value CSE offered was outweighed by the mismatch between her expectations of a future career and her perceptions of CSE career life:

> "Um, probably my biggest concern is ending up like working in a cubicle, for the rest of my life [laughs]...I mean I think it'd be fun to work with computers but I don't know if I'd be able to look at a computer screen for eight hours a day or forty hours a week, that kind of thing, for the rest of my life [laughs]."

Hilary's similar concern about long hours at the computer seems similarly framed, except

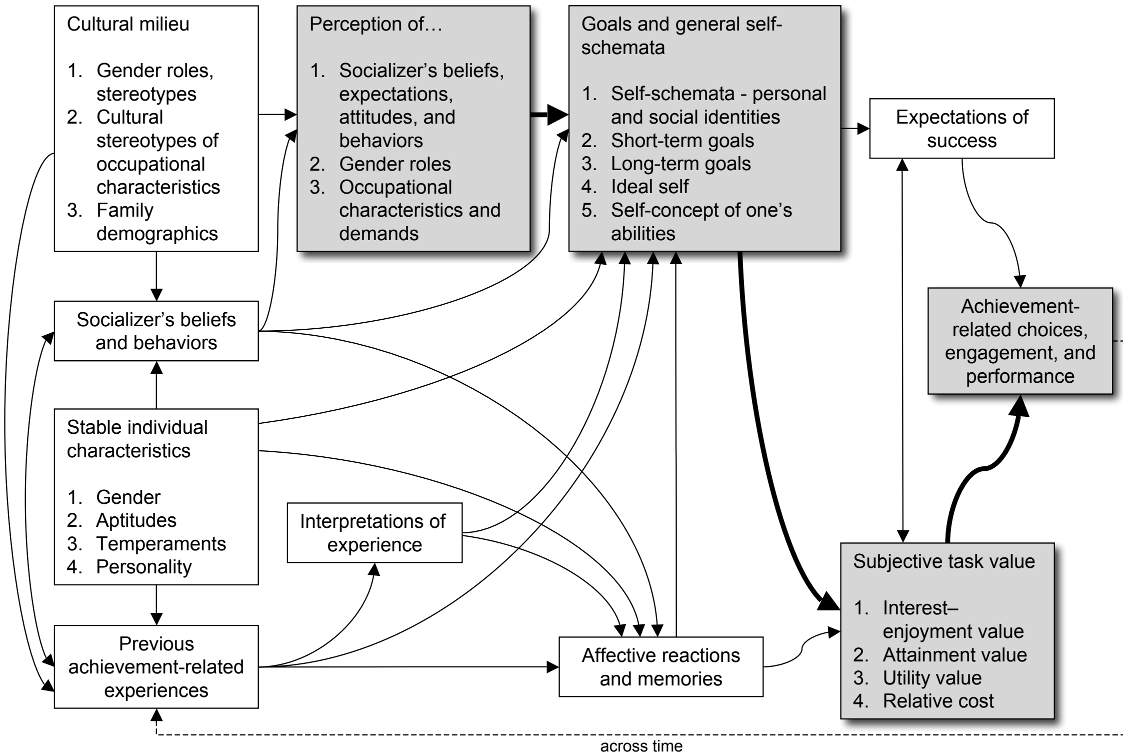

Figure 6.2: Pathway (bold edges and shaded nodes) showing influence of perceptions of occupational characteristics and/or demands

with the shorter time horizon, looking ahead only to the major, rather than careers.

> "Um, I think my biggest thing [about majoring in CSE] is I don't think I'd want to spend most of my time in front of a computer, and that seems to be what a lot of computer science majors do."

For participants like Lucas, the question was whether their intrinsic interests aligned well with perceptions of CSE's subject matter, essentially a question of interest–enjoyment value. Lucas favored the informatics major over CSE, the latter of which he perceived as being about "learning how to program computers and not much else." In contrast, he described informatics as the combination of two of his academic interests: psychology and computers. Similarly, Young described how she enjoyed working with people, one aspect of industrial engineering that attracted her interest.

There were also positive statements about interest–enjoyment value in CSE. In the previous chapter, Liz and Young described enjoying the creative freedom in programming. With other participants, the interest–enjoyment value was implicit. Jennifer's account about starting on her programming assignment as soon as it was assigned expressed a similar enthusiasm for programming and creativity.

Other student perceptions seemed to be more about CSE students and professionals, rather than the discipline or profession itself. As described in Section 5.4, many interviewees were turned off by images of asocial, competitive, and/or work-obsessed computer scientists. These perceptions, while also falling under the category of occupational characteristics and demands, appear to affect interest in majoring in CSE in different ways, compared with perceptions of the discipline/profession. The next section elaborates on this, focusing on perceptions related to the "nerd" stereotype, including how cultural and social context might lead to these perceptions.

6.2 Women, Men, and "License to Nerd"

Although our sample size is limited, the perception that people who study or work in CSE are "nerds" appears to be gendered, with women being more concerned about this in their considerations of majoring in CSE. In our sample, four of nine women and one of five men described the nerd stereotype and its negative effect on their interest in majoring in CSE, with the women tending towards lengthier, detailed descriptions and negative judgement. (Not all of them used words like "nerd," "geek," or "dork," but the negative images of CSE students or professionals were similar.) The expectancy–value model suggests causal chains relating gender socialization, identity, and major choice. Using the model to integrate evidence from our interviews and research literature, this section focuses on specific aspects of the nerd stereotype and proposes that the greater concern among women is partly a reflection of gender socialization.

6.2.1 *The Asocial, Unkempt Nerd*

The nerd stereotype is related to a variety of negative perceptions about CSE, including expectations of a stressful, sedentary lifestyle dominated by working alone at the computer, often late into the night. We chose to focus on two personal attributes associated with the nerd stereotype: asocial nature and disregard for physical appearance.

Multiple participants described computer scientists as socially inept or disinclined, whether by choice or because they were overworked or overstressed. Amy described friends of hers who "used to be friendly" before they became CSE majors and became stressed-out "zombies" whom she rarely saw any more. Young described students who seldom emerged from their "caves," spending hours working alone in their dormitory rooms. Liz described a "subculture" of computer science that catered to students who were less popular and not very social in high school. Lucas acknowledged the stereotype that CSE majors have "no social life."

Not as many participants described computer scientists as unkempt or otherwise unconcerned about their physical appearance, but this description seems to go hand-in-hand with the stereotype of an asocial nature. Young's description was among the most detailed and least flattering, complete with messy hair, glasses, and unwashed face. However, other participants described the look of a computer scientist similarly. Amy's archetypical computer scientist neglected to shave. Liz described being initially scared by her teaching assistant's joke on the first day of section, when he role-played a stereotypical nerd, wearing "a crazy sweater" and talking in a funny voice.

The remainder of this section supplements interview data with evidence from gender-related research, fitting both into a variety of pathways in the expectancy–value model that suggest not only how the nerd stereotype affects interest in majoring in CSE but also why this effect might be gendered. The pathways of influence discussed in this section are illustrated in Figure 6.3.

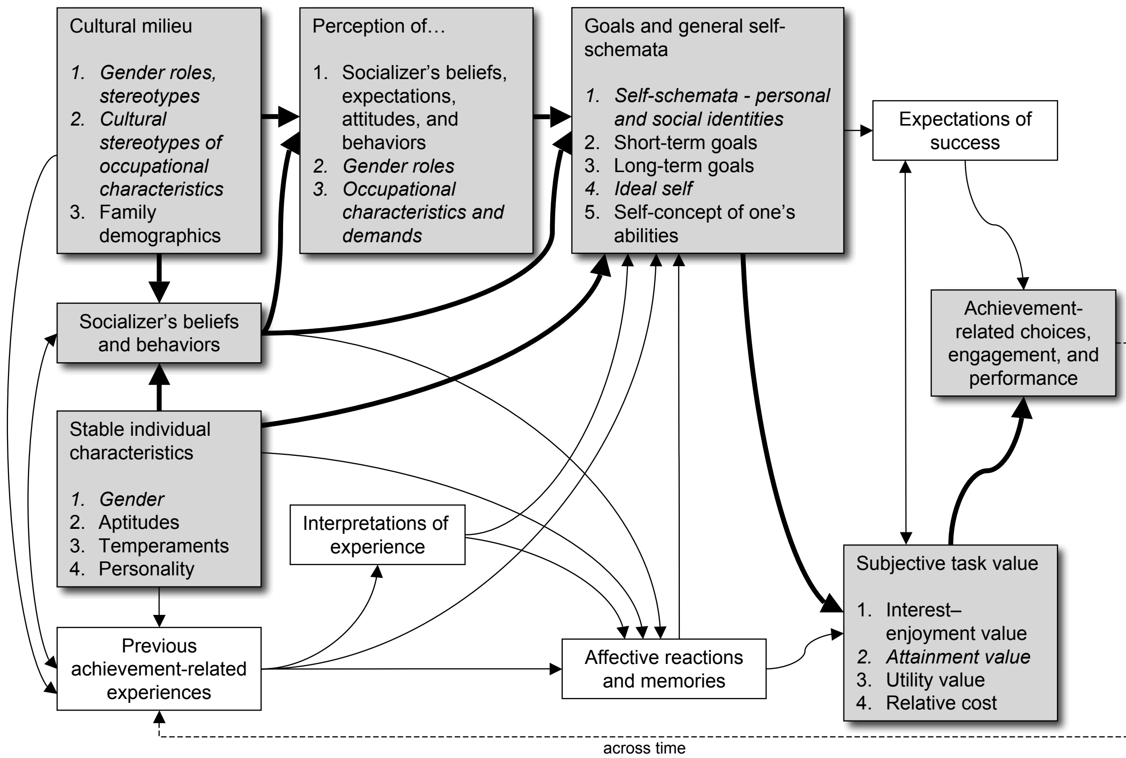

Figure 6.3: Pathways showing the variety of interacting factors affecting the nerd stereotype's impact on task value, with italics indicating specific factors that were found to be relevant in our study

6.2.2 Framing the Nerd Stereotype's Impact with the Model

In the expectancy–value model, these perceptions fit best under the category of perceptions of occupational characteristics and demands. One pathway of influence suggested by the interview transcripts begins with these perceptions interacting with self-schemata. Figure 6.4 shows this partial pathway in the model. In this pathway, rejection of CSE as a major is rooted in a mismatch between these participants' personal and social identities or ideal self (self-schemata) and the kind of person they perceive as common in CSE. All participants who discussed the nerd stereotype at least implied that they rejected this image for themselves. Young's rejection of the nerd stereotype was unequivocal; she talked about how it

Perception of...Occupational characteristics and demands
⟶ Goals and general self-schemata
⟶ Subjective task value: Attainment value
⟶ Achievement-related choices, engagement and performance

Figure 6.4: How the nerd stereotype affects attainment value, when students reject the stereotyped characteristics that they strongly associate with CSE

was "too unhealthy" and "dangerous" to become so "nerdy."

Our interviews suggest some ways in which a mismatch between self-schemata and the nerd stereotype can lead to disinterest in the CSE major. The model predicts that such a mismatch would depress attainment value, the aspect of task value related to the individual's values, sense of self, and identity. This is consistent with participants' negative judgements of the nerd stereotype, which they closely associate with CSE. To describe the effect of lower attainment value informally, these students did not see themselves fitting or wanting to fit the nerd stereotype, and, as a result, they were less interested in CSE as a major. Later in this section, we extend this explanatory account by considering how gender socialization might lead to the mismatch between self-schemata and the nerd stereotype.

Amy's disappointment with former friends who became CSE majors suggests another way in which the nerd stereotype might depress another aspect of task value, in a way less directly related to self and identity. Students might simply dislike the prospect of having to spend time within a peer group that has unappealing characteristics. This effect of lowering interest–enjoyment value, diagrammed in terms of the model in Figure 6.5, is likely to be related to the effect on attainment value described above, in the sense that students who do not want to be nerds probably also do not want to be in a community of them. In any case, it illustrates how the nerd stereotype (and indeed any negative perception of the people or culture in CSE) might turn away prospective majors in more ways than one.

Looking upstream from the model node for "Perceptions of occupational characteristics and demands," we see that the category of influences labeled "Cultural milieu" influences these perceptions. The model shows both a direct influence, as well as an influence mediated

Perception of...Occupational characteristics and demands
⟶ Goals and general self-schemata
⟶ Subjective task value: Interest–enjoyment value
⟶ Achievement-related choices, engagement and performance

Figure 6.5: How the nerd stereotype can make studying CSE less appealing to a student by influencing interest–enjoyment value, independent of the effects of reconciling their identity with the nerd stereotype (*i.e.*, attainment value, as illustrated in previous figure)

by "Socializer's beliefs and behaviors." This naturally leads to hypotheses about how gender socialization might cause concern about the nerd stereotype to be more influential for women than for men.

6.2.3 Gendered Permission to be Nerdy

Drawing on past research on gendered stereotypes and gender socialization, we propose two, related explanatory accounts for the particularly negative effect of the nerd image on women. An explanation for the gendered effect on attainment value discussed above can be stated informally in terms of "permission to be nerdy." Women's gender-socialized notions of identity and self might be more likely to conflict with perceptions of occupational characteristics and demands in CSE. Specifically, with respect to the nerd stereotype, gender socialization research suggests that it might be less acceptable for a woman than for a man to be asocial and to disregard her physical appearance. Even acknowledging that society generally disparages nerds, regardless of their gender, it seems that the nerd stereotype is relatively more accepted (or less unaccepted) for men.

In terms of the expectancy–value model, this is a situation where gender roles, as perceived by the student, influence their self-schemata and interact with perceptions of students and professionals in CSE, leading to lower attainment value. Figure 6.6 expands on the pathway introduced in Figure 6.4 and illustrates the pathway proposed in this subsection.

Prior research on gender roles and socialization in the U.S. suggests reasons why women would be more likely to reject the aspects of the nerd stereotype we focus on here: asocial

Perception of...Gender roles, ...Occupational characteristics and demands
⟶ Goals and general self-schemata
⟶ Subjective task value: Attainment value
⟶ Achievement-related choices, engagement, and performance

Figure 6.6: How socialized gender expectations can affect how women and men respond to and reconcile their identities with the nerd stereotype

nature and disregard for physical appearance. A study of adolescent notions of attractiveness found that girls were more likely than boys to mention popularity as an aspect of female attractiveness [69]. Another study found that the self-esteem of high school girls appears to be correlated with their assessments of their friendships, whereas no similar correlation was found among boys [113]. In addition to the research cited above, a variety of common gender stereotypes are consistent a greater emphasis on popularity and socializing, *e.g.*, girls talking on the phone more, women valuing personal relationships more.

Similarly, there appears to be a gendered emphasis on physical appearance, with advertising and popular media being prolific sources. Examples include the targeted marketing of cosmetics, cosmetic surgery, and dieting; the popular media's depiction of women as sex objects; and other manifestations of American culture's general preoccupation with feminine beauty.

The construction of the nerd image as male is another likely socialization factor. Media depictions of nerds are predominantly male, and almost all of them are less than flattering. Both asocial nature and disregard for physical appearances are hallmark characteristics. In spite of the negative character of many of these depictions, their presence (perhaps as precedents) might signal a degree of acceptability, however marginal, for males to be nerds.

If socialization does indeed lead to this gendered effect on interest in CSE as suggested by our findings and the expectancy–value model, there are a variety of different responses to consider. The interventions section of Chapter 8 discusses these responses.

6.3 Gender and Competition

Most of the men and a couple of the women interviewed associated CSE with competition in some form. Claire, Brad, Lucas, and Danny were concerned about competitive admissions into the major. Others were looking further ahead and perceived competition in CSE professions. Amy recounted her neighbor's stories of cutthroat competition in the software industry. Steven did not feel as though he could compete in the job market with candidates whom he expected would be more qualified than him to fill programming positions. In either case, perceptions of a competitive culture appeared to have a negative effect on interest in majoring.

6.3.1 How Women Respond to Competition

Two gender-related issues regarding competition motivate our treatment of this perception of CSE. First is the well-documented gender gap in self-confidence in CSE, which seems likely to interact with perceptions of competition. The expectancy–value model suggests that women, who tend toward lower academic self-confidence in CS [78, 127] and other STEM fields [100, 109], might be less likely to attempt a major that they perceive to be highly competitive, based on lower expectations of success. Indeed, Margolis & Fisher's qualitative study attributed the large number of women switching majors from CS in part to low academic self-confidence [78].

Notably, these same studies also show that, in actuality, there is no achievement gap between women and men in CS/STEM. One possible explanation for the gender gap is that women tend to hold themselves to a higher academic standard of success. Ultimately, it appears that, regardless of accuracy, perceptions prevail, and the confidence gap somehow leads to a participation gap.

The second, more subtle finding comes from Seymour & Hewitt's landmark study of undergraduate enrollment in STEM fields, including computer science [100]. In a chapter devoted to gendered issues in persistence, the authors propose that gender socialization prepares young men to respond positively to competition and personal challenge in ways that women do not. Women are ill-prepared to even recognize (let alone thrive) in this cultural model of growth through individual, independent struggle. This model manifests itself in the adversarial atmosphere of "gatekeeper" or "weed-out" courses, as well as in the competitive admissions process for the CSE major at the studied institution.

6.3.2 Competition's Effects as Accounted for by the Expectancy–Value Model

In terms of the expectancy–value model, perceptions of competitiveness fall squarely under the category of "Perceptions of occupational characteristics and demands." Precisely how these perceptions interact with goals, general self-schemata, expectations of success, and/or task values is unclear, based on interview data alone. Based on the model and supported by interview data, we speculate that there are at least three ways in which perceptions of competitive culture can turn students away from CSE. Two involve task value, and the third involves expectations of success. The relevant pathways in the model are illustrated in Figure 6.7.

6.3.3 Competitive Culture's Impact on Attainment Value

Our data and the expectancy–value model suggests relationships between perceptions of competition and major choice via attainment value. These relationships were implied by students who contrasted their self-identity with their images of competitive students or professionals in CSE. As in the case of the nerd stereotype, these students did not see themselves fitting or wanting to fit the mold of a typical computer scientist or the culture of computing as they perceived it.

For instance, Amy expressed this misfit in terms of her study preferences, which were not accommodated by her interpretation of the course's (using her words) "cheating policy." She expressed interest in forming study groups and working with a partner, but she thought neither was permitted by course policy.

> "Um yeah I would consider working with someone else. Like doing partner work I guess is probably better because two heads always better than one. The other person can catch your errors...But I guess that's not what um the university wants us to do."

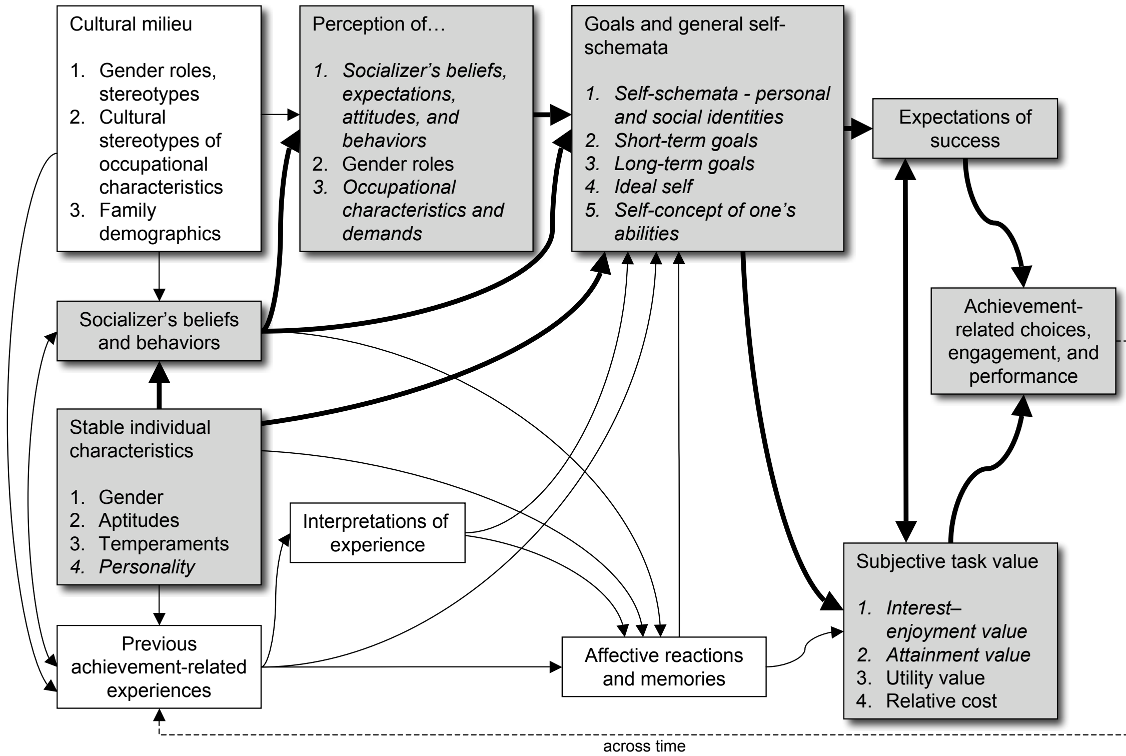

Figure 6.7: Types of factors that affect perceptions of competition in CSE and the other factors that they in turn influence or interact with, with italics indicating specific factors that were found to be relevant in our study

In her view, the university (or at least the CSE department—unclear from her words) wanted students to work individually. The individual working in isolation and in competition was a recurring theme in Amy's interview. Young was similarly unhappy about being prohibited from studying or working with other students. When asked whether she planned on forming study groups, she replied, "I wish I could but I can't right?"

Some of the men, too, described the culture of competition and how well or poorly it fit with their self-image. Danny used the words "negative" and "hate" multiple times in his detailed description of how CSE admissions impacted prospective majors' attitudes towards one another. Wishing the worst for a classmate was common, according to him:

Perception of...Occupational characteristics and demands ⟶ Goals and general self-schemata ⟶ Subjective task value: Attainment value ⟶ Achievement-related choices, engagement and performance

Figure 6.8: How perceptions of competitive culture in CSE can conflict with student identity and dissuade students from majoring

> "You just tend not to help the other person. You want the other person to fail so it's just very negative...You want that person to fail so that he can't get a spot and you might be able to get a spot."

However, when asked whether he personally felt the same way about his classmates, he was careful to distance himself from the cutthroat crowd:

> "It's how I feel they think about everything, about everybody else in class. It's not necessarily how I think, because I think if they are really truly skilled in programming, they should get a spot, because that's—that's what it is, it's selective, like, yeah, I would like a spot, but if they're really good at it, they should get a spot..."

Similarly, Lucas expressed displeasure at his friend's description of competitive pre-majors "fighting" and "competing" for admission, consistent with Danny's impressions. Lucas described his friend's way of looking at things as "negative" and explained that he rejected this attitude: "I don't really feel like uh school should be a competition."

Not everyone who mentioned competition in CSE expressed concern about fitting in, however. Brad made brief mention of the competitive admissions process for CSE but expressed little concern of any kind about it. Steven expressed concerns about competition in the CSE job market, but his concerns did not appear to be about identity, as we discuss further toward the end of this subsection. In any case, no participants described relishing or otherwise favoring the competitive aspect of CSE.

Perception of...Occupational characteristics and demands
⟶ Goals and general self-schemata: Self-concept of one's abilities
⟶ Expectations of success
⟶ Achievement-related choices, engagement and performance

Figure 6.9: How perceptions of competitive culture in CSE can interact with self-concept of abilities and lower expectations of success

6.3.4 Competition and Lower Interest–Enjoyment Value

Some students' remarks suggested that perceptions of competition also had an effect on task value related to but distinct from impact on attainment value. Regardless of how they saw themselves fitting in among other CSE students/professionals, some students indicated their general distaste for the kinds of people they associated with CSE.

Amy described her neighbor's experiences with attempts of sabotage as "horrible" and was concerned enough about these stories that she asked the interviewer whether CSE was a competitive field. In this case, Amy's disinterest in CSE might be in part because she does not want to have a career where her colleagues are likely to be as cutthroat as the would-be software saboteur. Independent of whether Amy feels as though competitiveness is congruent with her own identity, her account illustrates how a negative perception of CSE can depress interest–enjoyment value, not just attainment value.

6.3.5 Competition and Lower Expectations of Success

Finally, we also observed perceptions of competitiveness interacting with self-concept of abilities and, in turn, expectations of success. This represents the pathway in the expectancy–value model that provides an explanatory account of the relationship between low self-confidence and low interest in CSE that Margolis & Fisher observed. Figure 6.9 illustrates this pathway.

Claire is an example of a student for whom perceptions of competition seem to result in lower expectations of success. Recall how she described feeling "terrified" about admission to the CSE program, facing the prospect of competing with students who have extensive previous experience with computing and programming.

Expressing similar concerns, Danny described his grim perceptions of the competitive admissions process in extensive detail. Although he, unlike Claire, was certain that he would apply for admission, he did admit feeling discouraged by the slim odds of success and uncertainty about his chances. In fact, he identified the level of competition for admission to be the only significant negative influence on his interest in CSE.

> "It's a very selective major. Very, very selective. So 80 out of 2500 people a year, that's very not appealing [laughs]. That's like almost saying, oh why bother to try and get in?...I don't know what my chances of getting in is but to now it doesn't matter, as long as I try, then I'll never regret it in my life."

Although Steven did not put it in terms of fear, as Claire did, he was more explicit about not expecting to be able to compete among the large number of highly qualified applicants seeking CSE jobs.

> "After seeing the qualifications on these [applicants], it's like, wow. It's like, you need to be that amazing to get in, and it's like people with like anything less than that can't even like compete...I honestly don't think I would be the best, you know?"

In spite of enjoying programming and earning a top grade in a computing course, Steven did not plan to major in CSE, because he did not expect to be able to secure employment with an undergraduate degree in CSE.

6.3.6 Effects on *Perceptions of Competitive Culture*

The above discussion focuses on the effects of perceived occupational characteristics by examining nodes "downstream" of the perceptions node (rightwards in the figures illustrating the expectancy–value model). We next turn our attention to those nodes in the model that are shown to have an effect on perceptions of occupational characteristics and demands, *i.e.*, nodes "upstream" of the perceptions node. These nodes suggest categories of factors that impact how students perceive CSE: “Cultural milieu”, “Socializer’s beliefs and behaviors”, and “Previous achievement-related experiences.” Indeed, interviewees who associated CSE with competitiveness mentioned or at least implied the effects popular stereotypes, interactions with people who play the role of a socializer, and previous experiences.

References to the influence of socializers were the most common. Amy described numerous stories she heard about her neighbor’s experience as a CSE major and a CSE professional. As illustrated in earlier quotes, her neighbor’s experience left her with concerns about coworkers who were competitive to the point of sabotaging each others’ work. These accounts hint at real problems in CSE culture that have perhaps become amplified as stereotypes.

Related to Steven’s concerns about competitiveness in the job market, Amy also described friends who believed that a glut of qualified candidates for CSE jobs meant that majoring in CSE would be a mistake. Steven’s similar concerns were not from peers but from adult socializers—his father and his father’s colleague, both of whom work for a large, international software company. In Steven’s case, his perception of a highly competitive job market came, in part, from hearing about the outstanding qualifications of new hires at the company. (It also seems likely that news coverage of the collapse of the “dot com” bubble influenced his perceptions, based on his references to CSE’s former glory.)

As with Amy, Lucas’s perceptions of competitiveness in CSE appeared to be stem from the influence of peers. His friend, also interested in CSE, described his view of admissions with the metaphor of a war, in which they were fighting classmates for admission into the CSE program. Brad also said he had been told that CSE major admissions was very selective, although he did not say by whom. Notably, unlike Amy, Brad indicated neither discouragement nor disapproval about the admissions process; it did not appear to affect his interest in CSE.

As discussed earlier, Danny pinpointed two specific departmental policies as major influences on the competitive culture: the selective admissions process itself and CS 1’s collaboration rules, which he felt were overly restrictive and isolating. In this sense, one influential socializer in Danny’s case is the department itself. However, the inaccuracy of his perceptions about both the admissions process and the collaboration rules strongly suggest that his understanding of these policies was filtered through unofficial sources—likely peers.

Our concluding chapter builds on these observations, identifying influential socializers and the messages they could be sending to prospective CSE majors in order to foster more accurate perceptions of study and work in CSE.

6.4 Previous Achievement-related Experiences

Interviewees who related previous computing experiences with their interest in majoring in CSE indicated that the experiences influenced both task value and expectations of success with CSE-related activities to varying degrees. As discussed in Section 5.6, much of the previous experience came in the form of web authoring, sometimes including programming experience with languages like PHP and JavaScript (*vs.* working only with HTML). We will see that only a handful of students described or implied connections between this type of previous computing experience and task value or expectations of success. However, we regard the potential influence of web authoring experience as significant for two reasons. First is the observed prevalence of web authoring experience in our sample, with nine of the fourteen reporting at least some. More remarkably, many of these students reported a high degree of motivation for doing web authoring, *e.g.*, being self-taught or otherwise doing web authoring on an extracurricular basis. Even though only a fraction of these students seemed conscious of and decided to mention in interviews the effects of web authoring experience on their interest in CSE-related activities, these effects are consistent with pathways in the expectancy–value model and suggest ways in which CSE educators can connect their discipline with preexisting interests.

6.4.1 Experience and Interest–Enjoyment Value

Lucas and Erica both talked about how their long-standing interest in web authoring translated into interest in computing and, more specifically, programming. Interestingly, Lucas recognized the fundamental difference between mark-up languages like HTML and programming languages like Java. In spite of this distinction, his interest in web authoring fed his enthusiasm for learning programming and majoring in either CSE or a related program in the School of Information:

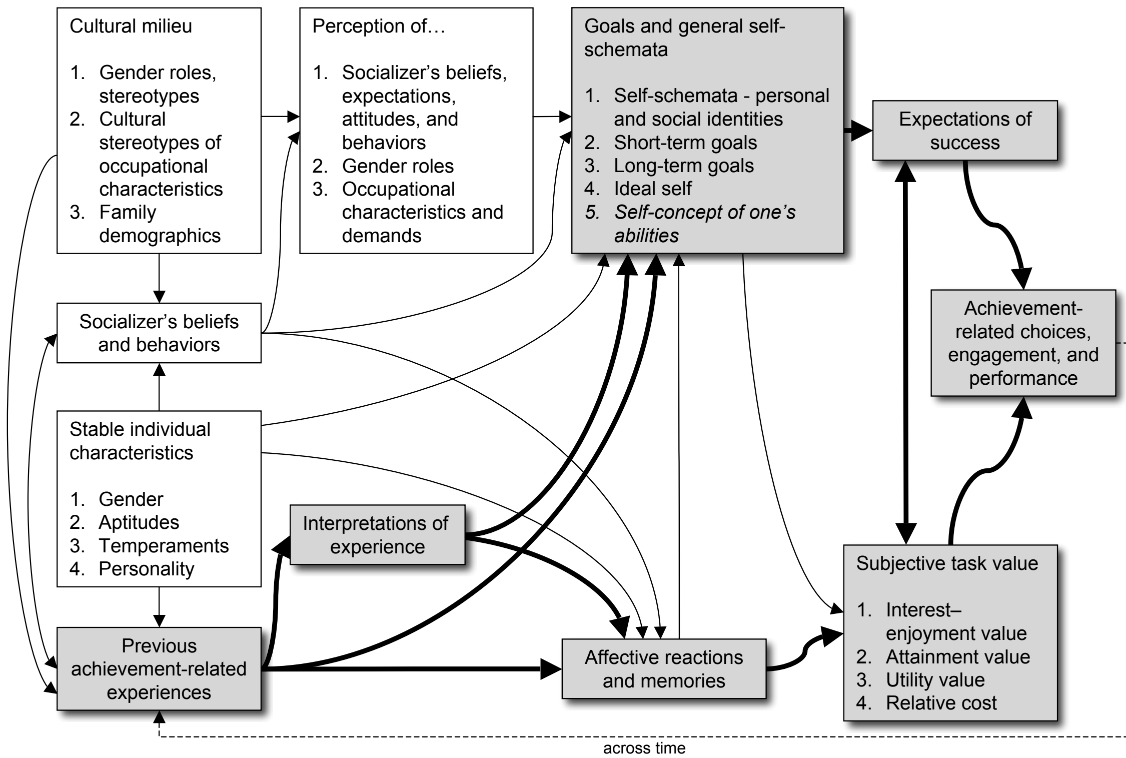

Figure 6.10: How interpretations of experiences perceived to be related to CSE can interact with personal attributes such as goals and self-concept of ability, ultimately affecting task value and, in some cases, expectations of success

> "I consider uh web design, like HTML, uh somewhat of a programming language, even though I think most people think it's not strictly a programming language, and I've always had a lot of fun programming in HTML and XHTML and CSS...so that's kind of given me uh more of an open mind towards other programming languages."

Erica described a similar but more general connection, explaining that web authoring had been "helpful in keeping my interest in computers up." Unlike Lucas and some other participants, however, she had trouble seeing how her background in web authoring might make it easier to learn programming in Java in CS 1. She continued, "I don't know how much I'll be able to use HTML when I'm working in a class that is focused on Java." In this way, Erica's previous experience affected not only task value, but potentially also expectations of success.

Previous experience with programming and related computing activities did not always positively impact task value. When asked at the start of her interview about her reasons for enrolling in CS 1, Young was very frank about her reluctance to take the course. She enrolled solely because it was required for her intended major, industrial engineering. She explained how her high school course experience with Java left a bad impression:

> "I tried taking Java classes back in high school, and it never worked out."

Later in her interview, she provided more details about her negative experience:

> "Well like I mentioned like in high school I tried taking this course twice, and I had to drop it, because—well I also had a problem with teachers but I didn't have enough like all energetic and like all this excitement to spend like more than five hours in front of the computer. And I get really frustrated when all the math comes in and it doesn't work out..."

Young's case reminds us of how previous experiences and interest interact in complex ways. Offering a stark contrast to her high school experience with Java, she described her almost obsessive interest in and extensive experience with web authoring, including programming in PHP. In spite of her enjoyment of the creative work of web authoring and programming, it seems that her negative high school course experiences and perceptions of the culture of CSE were enough to outweigh them and dissuade her from considering the major.

6.4.2 From Web Authoring to Expectations of Success

Instead or in addition to affecting interest in CSE-related activities, previous computing experience appeared to affect expectations of success with the specific activity of learning programming. The pathway of influence suggested by interviewee accounts of this effect seems to be through effects on self-concept one's abilities, which in turn influence expectations of success. Here, we discuss the impact of two specific types of computing experience on expectations of success: JavaScript programming in a non-major computing course and web authoring in HTML (without programming).

Brad was one of six interviewed students who had taken a course on web authoring, including some with background on the JavaScript programming language, prior to enrolling in CS 1. After listing the topics covered in the course he took on IT FITness, he linked the experience to his new learning in CS 1:

> "It [material in the FITness course] did relate a lot to Java, and it helped—I think it helps. Like I can pretty much follow pretty quickly in Java...It was a pretty good intro."

Lucas, who had enrolled in an offering of the same course that Brad took, was more emphatic. When asked about the course's preparatory value, he responded,

> "Oh most definitely [helpful]. Um, the JavaScript correlates almost directly with what we're learning now...Basically everything I learned so far in [CS 1], I already knew how to do it on a web page with JavaScript from my [FITness] class."

Notably, Brad and Lucas's observations about the IT FITness course are somewhat at odds with the way the CSE department positions the course. The IT FITness course, offered jointly by the School of Information and the CSE department, is advertised on the CSE department's web site as a course for students *not* majoring in CSE. Accordingly, it is not a prerequisite for CS 1, and most FITness students do not go on to take CS 1. In this sense, FITness should not be considered a "CS 0" course. (Within the computer science education community, the "CS 0" designation is traditionally reserved for courses that introduce students to CSE and serve as a prelude to CS 1.)

As detailed more toward the end of Subsection 5.6, Liz stands out in that she was able to make conceptual connections between web authoring using HTML (again, not regarded as a programming language) and programming Java. The parallels she drew included aspects of work process (debugging, predicting and evaluating the effects of a change) and expectations of computing (requirements of precision and clarity, conformance with rigid languages rules).

Liz described these commonalities as part of a "whole system of thinking" applied in web authoring and, by implication, programming. Informally, both students and educators in CSE describe the need to adopt a fundamentally new way of thinking when learning to program computers [94]. Perhaps CSE educators, as highly experienced programmers, forget the challenging nature of some of the fundamentals of this new way of thinking.

We acknowledge that CSE is a much more complex and broad-ranging discipline than web authoring is an activity. Ultimately, Liz's longstanding passion for drama seems likely to prevail over CSE; interest in web authoring will not always lead to interest in the CSE major. However, her case clearly illustrates the potential for web authoring (even without exposure to programming) to serve as an entry path to exploring CSE.

As far as the interview data suggests, Liz was unassisted in her recognition of the transferability of certain concepts and structures from the HTML context to the Java programming context. We expect that most students will be more like Erica, who had similarly extensive web-authoring experience but for whom the connections to programming were less apparent:

> "I don't know how much I'll be able to use HTML when I'm working in a class that is focused on Java."

Instruction could guide students like Erica toward discovering these relationships. This would presumably follow a period of HTML instruction, during which students could familiarize themselves with the "system of thinking" common to web authoring and programming in the relatively simpler context of HTML.

6.4.3 Extrapolating from Limited, Previous Experiences

In the absence of formal or official sources of information about the discipline, some students in our study seemed to be extrapolating from their limited, computing-related experiences in forming conceptions of what CSE majors study and do. Later in this chapter, we discuss implications on the expectancy–value model's structure. Here, we consider the four cases of Young, Liz, Erica, and Lucas, whose definitions of CSE and/or notions of a successful computer scientist appear related to their previous computing experiences, often centering on the centrality of programming.

Liz and Erica's perceptions of CSE included elements that appeared directly related to previous experiences with computing. Liz defined CSE as

> "...learning to communicate with computers through various computer languages...just being able to convey ideas and offer solutions to—I mean that's what programs do."

Continuing, she associated it with three main features: programming, puzzle-solving, and creative expression. Later in her interview, she described her extensive experience with web authoring and her admiration for friends who had programmed their own games for computers or even their graphing calculators. She was impressed "that you can make something, just of like words on a computer." Creative expression realized through issuing instructions to computers was a common thread in her accounts of these experiences and exposure. Instructions could be given in HTML, to describe the content and presentation of a web page or in a programming language like Java.

References to the physical machinery of computing are absent in Liz's perceptions of CSE; for Liz, the computer is primarily a medium for creative expression. In contrast, Erica's conceptualized CSE more broadly, as illustrated in her definition of CSE, which she gave after pausing to think about her answer for about one minute:

> "To me computer sciences would uh be building different kinds of hardware and software, whether by using code or actually building them using physical materials."

She referenced the two activities of emphasis, programming and computer assembly—again in her description of a successful computer scientist.

Later in her interview, Erica described her extensive experiences with computing, primarily in the form of web authoring, including using HTML. Notably, Erica's remarks implied that she at least tentatively believed that HTML qualified as programming. (When asked whether CS 1 was her first exposure to programming, she responded, "Yeah, besides

HTML.") One unusual feature among her prior, otherwise web-focused experience was a Microsoft A+ certification course. She briefly mentioned this during her description of the typical work of a computer scientist, whom she said would have to "be willing to sit down for long periods of time to do coding or put together pieces of a computer." Moments later, stopping short of explicitly relating this belief to her experience, she described computer assembly as one of the A+ certification course's prominent activities:

> "I actually took some Microsoft A+ computer stuff last year and spent actually most of my time standing up in front of a desk, trying to piece together bits of computer and make them work, so...um, so I suppose that'd be one of the activities someone in computer sciences would be doing."

Forming and Challenging the CSE–Programming Connection

In Subsection 5.4.2, we discussed the tendency for students to assume that CSE is primarily (if not exclusively) about computer programming. One potential source of this group of perceptions is previous experience. To close this subsection, we examine differences in the previous computing experiences of two groups of students: Young, Lucas, and Danny, whose notions of CSE were largely limited to programming; and Brad and Tom, who conceptualized CSE as encompassing more than just programming.

We first consider the case of Young, whose limited (by her own admission) understanding of CSE was almost exclusively programming-centric. This perception of CSE appears to be rooted in her own and her friends' experiences with computing, most of which featured programming prominently. Although we cannot simply assume that Young associated all of her computing experiences with CSE as a major, a variety of signs point to this association.

Young perceived computer scientists as people who could program around the clock, their lives dominated by programming to the point that they neglected to wash or dress neatly. The theme of long hours spent programming appeared in accounts of both her own and her friends' experiences. Earlier in her interview, before discussing her definition CSE and perceptions of computer scientists, she described her own experiences with web authoring in similar terms. She recounted how she had recently worked on a web project for over 24 straight hours, barely eating and sleeping. She explained that this was not an isolated incident, but that her interest in web authoring had probably even resulted in lower grades in high school.

If the above was just an indirect association between her marathon web authoring sessions and CSE, Young's friends' accounts of CS 1 likely cemented the association. They warned her of programming homework taking "ten hours a day" or having to work three days straight to complete the assignments. According to them, whether she enjoyed the class or not depended on her ability to sit at the computer programming for long hours. Naturally, Young would associate experiences in a course offered by the CSE department with the CSE major.

Lucas's description of a successful computer scientist was consistent Young's in that programming was the primary activity they would engage in. Although Lucas also described other attributes, including diligence, being "logically minded," and having math background, the main activity he described was programming. In fact, although the question asked about computer scientists, in the middle of his response, his choice of words implied that he equated computer scientists and computer programmers:

> "When I think of a computer programmer, I think of someone who sits at a computer, debugging code for like ten hours or something. You know. Staring at the computer screen for a long time, looking through lines and lines of code."

This reinforced the clear emphasis on programming in his definition of CSE, which went as far as explicitly excluding hardware:

> "From what I've heard, computer science is more about the operating system and the software—not the hardware."

Unlike Young, however, Lucas had a broader range of computing experiences, including some work with hardware. With broader computing experiences than Young, Lucas would be expected to have analogously broader notions of CSE, but he did not. The following quote offers an explanation:

> "I don't remember any exact words but I believe he [my high school tech support teacher] expressed the general opinion that computer science was about software and, specifically, programming."

Peers and authoritative sources appear to have caused Lucas to interpret his computing experiences in such a way that he viewed his hardware-focused experiences as being unrelated to CSE. The contrast between Lucas and Young illustrates the importance of considering previous experiences from the student's perspective, instead of making the oversimplifying assumption that the experiences are objective phenomena, unaffected by framing and interpretation.

Finally, for further contrast, we consider the case of Brad, who considered CSE to encompass more than just programming. When asked to define CSE, his response started with programming but went on to include processor design, memory chips, and even interactions between hardware and software. His description of a successful computer scientist was accordingly more varied:

> "...a deep understanding in like more than just—more than just computers. You have to have an understanding of like and sense of chemistry, and you have to—because uh gold conducts better than silver. Depending on what you're going to be doing, for the computer, I mean, you may want something specific regarding materials."

Brad went on to express how he thought computer science and computer engineering differed, with the latter focusing more on hardware. Very few of the interviewed students discussed a distinction between computer science and computer engineering. Although the distinctions Brad perceives are mostly inaccurate, the level of detail exhibited in his response is a point of interest. (At least at the studied institution, both the computer science and computer engineering degree programs afford students opportunities to focus on hardware or software.)

The breadth and level of detail (accuracy aside) in Brad's perceptions likely reflect his high school and extracurricular experiences learning about computing. He had early programming experience in the form of a Visual Basic course taken at a community center when he was in middle school. Later experiences covered a wider range of computing-related topics, including an A+ certification computer technician training, popular applications (*e.g.*, Photoshop), and IT fluency. Brad also described several computer hardware and electronics projects that he did on his own, tinkering with computers, video game consoles, and stereos.

6.5 Expectancy–Value in the CSE Context

Previous sections discussed the benefit of situating interview findings in the expectancy–value model is a deeper understanding of how certain factors affect entry into CSE. In this section, we discuss how the model can be refined and extended for specific application to research on CSE enrollment and gender. Given the generality of the expectancy–value model, we propose that a customized version of the model will better focus research on the parts of the model that are most relevant to undergraduate decisions to study CSE. In addition to ways in which the model could be extended, we highlight aspects of the model whose interpretation requires special consideration in our research context.

Among the factors in the model, perceptions related to CSE and relevant previous experience were found to be especially influential, at least for the studied population. We begin this section by characterizing the different kinds of perceptions our study participants described. Subsection 6.5.2 discusses the significance of previous experiences and its apparent link with perceptions of CSE. Finally, in Subsection 6.5.3 we consider how the model could be adapted to more directly and precisely capture the influence of the high degree of uncertainty about CSE that we observed in our study.

6.5.1 Decomposing "Perceptions of occupational characteristics and demands"

Study participants' perceptions of CSE were wide-ranging, covering not only CSE as a major but also as a career area. In our analysis, we noted the following categories of perceptions of occupational characteristics and demands:

- topic areas in or related to CSE

- activities that CSE work involves
- skills important to being successful in CSE
- personal attributes associated with people who work/study in CSE
- values associated with CSE

Many participants' free responses to questions about aspects of the CSE major that they find appealing or unappealing discussed topics and activities associated with CSE. There was also ample discussion of a more personal nature, describing the kinds of people and culture students associate with doing CSE.

All participants were asked to describe both appealing and unappealing aspects of CSE. Interestingly, responses about appealing aspects of CSE tended to focus on topics and activities but seldom made reference to the people and culture of CSE. In contrast, responses about unappealing aspects of CSE referenced personality, the nerd stereotype, stress, and competition. This apparent difference and the general range of perceptions represented in our interviews indicate the complex, multi-faceted nature of student perceptions of CSE and their relationship with interest.

6.5.2 Breadth and Influence of "Previous achievement-related experiences"

Our study participants identified a wide variety of previous experiences that they associated with CSE. Some were formal, educational experiences, like computing-related courses in high school, but many were less formal, including general computer use and self-teaching in web authoring. A key observation is that the model's wording, "Previous achievement-related experiences," must be interpreted from the student perspective. A more accurate, if unwieldy, description of these factors would be "Previous experiences perceived to be achievement-related."

Few participants reported being taught or told directly about what CSE is. As discussed in Subsection 6.4.3, in the absence of specific, authoritative sources of information about CSE, participants appeared to be inferring a great deal from previous experiences

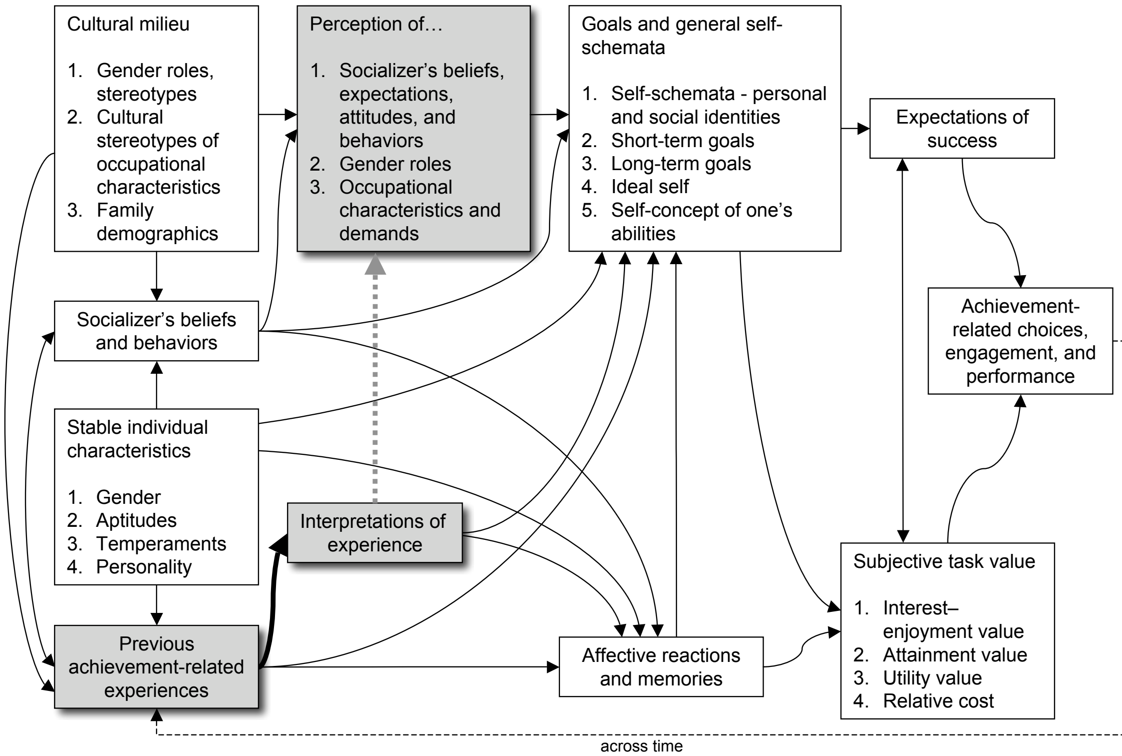

Figure 6.11: Proposed addition of edge (dotted arrow) for influence of prior experiences on perceptions of occupational characteristics and demands

they associated with CSE. More specifically, when we consider the more specific list of characteristics and demands presented in the previous subsection, we found that many of these perceptions of CSE could be traced back to previous experiences. In terms of the expectancy–value model, students are interpreting "Previous achievement-related experiences" as indicative of "Occupational characteristics and demands" in CSE. This apparent interaction between prior experiences and perceptions of CSE suggests a extension to the model, illustrated by the addition of the dotted, gray arrow in Figure 6.11.

6.5.3 *Highlighting the Role of Uncertainty*

Uncertainty or lack of information about CSE was a common theme in our interviews. For some students, uncertainty appeared to be at least partially responsible for their lack of interest in the major. However, interviews provided few details about why or how uncertainty affected interest. In some cases, this was due to the ambiguity or generality of the statements about uncertainty. When asked to try to define "computer science," Mei's first response was, "What if I know nothing about it? I don't know." Data from other students, however, identify the parts of the expectancy–value model where uncertainty can play a significant role, at least in our research context. These observations clarify how uncertainty can affect interest in CSE.

Most of the uncertainty described by interviewees concerned what CSE majors and professionals do. In the model, these beliefs fall in the category of "Perceptions of occupational characteristics and demands." This kind of uncertainty can influence entry into the major in multiple ways, at least one of which was corroborated by interview data. Given the relative lack of discussion about expectations of success in our data, we focus on task value in our discussion.

At least three aspects of task value are likely to be impacted by this kind of uncertainty. Interest–enjoyment value results, in part, from a good match between the student's interests and the activities involved in CSE study or work. Attainment value results from a match between the student's sense of self and the potential for CSE study or work to affirm that identity. Finally, utility value results from a match between the student's goals and the opportunities associated with CSE study or work. With all three aspects of task value, the student cannot confidently determine the task value of majoring in CSE without some basic understanding of what CSE study or work entails.

In our interviews, we found evidence of uncertainty affecting interest–enjoyment value and attainment value. In Brad's case, uncertainty appeared to interact with the former. He admitted that he had only considered majoring CSE "a little bit," mostly due to having not taken any programming classes. Without the basis of such an experience, he was unable to determine his interest level:

> "I didn't know like—considering I never took a course in computer programming, I didn't know if I would like that [CSE]...I don't know enough information about computer science say to dive completely in."

Lucas was similarly unsure about whether his interdisciplinary interests, spanning human psychology and technology, would fit well with the CSE major. Although skeptical, based on what he had heard about CSE, he was postponing final judgement until he had completed some more courses in CSE.

> "I don't think I want to have my complete major be just programming...I'm interested in taking CSE classes to see if they're all, you know, learning C++ and Java and Visual Basic or it's other stuff as well."

During Amy's interview, while recounting stories she heard from her computer scientist neighbor, she asked the interviewer a question to the interviewer, indicating uncertainty about an aspect of the culture of CSE:

> "She told me her job was um bad because people try to wreck her codes. Like um somebody in her company totally erased what she wrote and that was really mean. ... That's horrible. [He was] very competitive or something. Is it—is it like a competitive field, computer science?"

In contrast with Brad and Lucas's reservations above, Amy's concerns were not about interest but about the possibility of having to work in an industry whose culture was adversarial and competitive.

6.6 Summary

In this chapter, the expectancy–value model was used to combine themes from our interview analysis and related literature to extend individual findings into pathways in the model. One set of pathways suggests mechanisms for the negative effects of the nerd stereotype on the task value of majoring in CSE. By extending backwards in the model to factors affecting the nerd stereotype and its gendered interpretation, we also proposed explanations for the apparently greater effect the stereotype has on women. A similar analysis of perceptions of a competitive culture in CSE identified both sources of these perceptions and their effects on task value and expectations of success. Finally, a third set of pathways describes the effects of the previous experiences that students associate with CSE.

These pathways showed how the expectancy–value model extended our findings. In the last section, we considering how the findings could conversely contribute to the specialization of the model to fit the details and context specific to CSE enrollment and gender. Calling out "Perceptions of occupational characteristics and demands" as an especially critical part of the model, we subdivided perceptions of occupational characteristics and demands into more specific categories. In particular, the categories make explicit the importance of the people, values, and culture that prospective CSE majors associate with the discipline. We also propose an expansion of a different sort through the addition of an edge acknowledging the influence of previous experiences on the categories of perceptions mentioned above. Finally, we expressly acknowledge the high degree of uncertainty of many students in their perceptions of CSE and the numerous ways in which this can affect entry into the major.

Chapter 7

DESIGN AND EVALUATION OF A PILOT INTERVENTION

A key finding from our interview-based study is that many CS 1 students have little knowledge about study and work in CSE, and what knowledge they have is often inaccurate. This finding motivated the design of a pilot intervention to help these students make more informed decisions about majoring in CSE. Section 7.1 of this chapter describes how the the expectancy–value model and study findings informed the design of the activities comprising the intervention. Section 7.2 discusses practical considerations and details of the intervention's implementation. Finally, Section 7.3 describes the method and results of an evaluation of the intervention.

7.1 Intervention Design

7.1.1 Targeting Interventions with the Expectancy–Value Model

So far, our use of the expectancy–value model has been limited to framing, organizing, and, to some extent, suggesting explanations for the CSE-related student perceptions and interests catalogued by the interview-based study. The model can also serve as an empirically validated basis for identifying the kinds of interventions that are feasible and most likely to impact student interest in CSE.

Among the interacting factors that the expectancy–value model suggests can affect the decision to major in CSE, many are well outside educators' reasonable sphere of influence, at least in the short term. For example, it is hard to imagine how an intervention could have much impact on family demographics or other aspects of "cultural milieu." The model also includes students' individual characteristics that are similarly difficult to influence at the undergraduate level, *e.g.*, personality, or are essentially constant, such as student gender. While interventions cannot be expected to impact these factors, they must be designed to take the factors' effects into account.

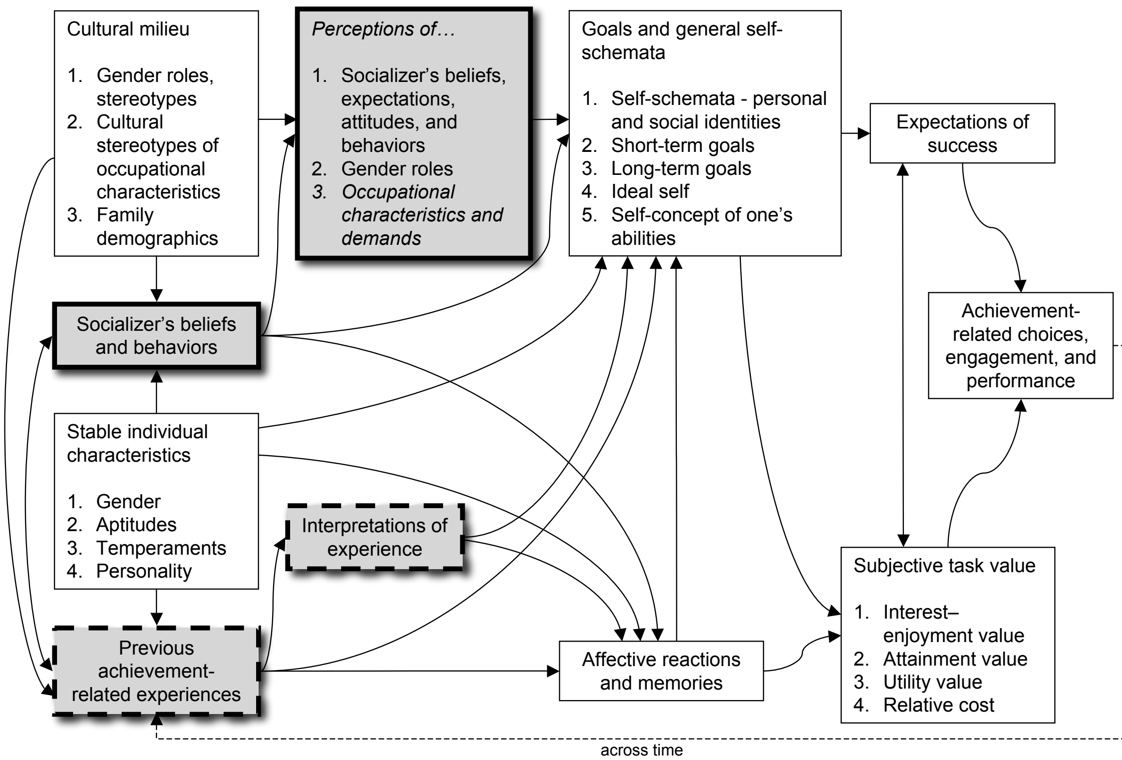

Figure 7.1: Expectancy–value model, with highlights showing the kinds of factors that an intervention could feasibly impact in order to change how students make decisions about majoring in CSE

In contrast, a limited subset of factors seem like they could be influenced by a systematic, designed intervention. In this sense, the expectancy–value model can help focus intervention efforts on the factors that have more potential to lead to real impact. These factors are highlighted in Figure 7.1.

Our intervention, with its emphasis on perceptions of CSE, is largely focused on "Perceptions of occupational characteristics and demands." Advertised as a "CSE Exploration Session," most of the session activities were designed to influence perceptions of study and work in CSE. Additionally, to a limited extent, the intervention was intended to have a socializing effect. These kinds of factors are highlighted with heavy, solid outlines in Figure 7.1. The model shows that socializers can affect a wide range of perceptions, goals, and emotions, but we conservatively expected that a one-time intervention's influence would be limited to perceptions of CSE (*vs.* other factors shown downstream of "Socializer's beliefs and behaviors" in the model, such as "Goals and general self-schemata" and "Affective reactions and memories").

Two other kinds of factors that could be influenced by interventions are related to previous experiences and highlighted with heavy, dashed outlines in Figure 7.1: previous achievement-related experiences and interpretations of experience. Interventions could provide students with positive, achievement-related experiences, *i.e.*, experiences related to CSE. Alternatively, given sufficient knowledge of students' previous experiences, an intervention could help students revisit and reinterpret those experiences, *e.g.*, recognizing how some could be related to CSE. Intervention approaches that focus on providing and reframing experiences so that they are recognized as being CSE-related are discussed further in Chapter 8.

Situating the intervention in the expectancy–value model focused our efforts and provided some assurance of the feasibility of certain goals. However, this was not the only way in which the model was helpful during the design of the intervention. Just as the model helped contextualize the study findings, reminding us of the complex relationships among factors affecting interest in CSE, it also placed the intervention in a larger, complex context. Having identified perceptions of CSE as the intervention's focal point, we were able to see the potentially conflicting influences on such perceptions by examining the model. The model shows that aspects of cultural milieu (*e.g.,* popular stereotypes) and socializers (*e.g.,* peers, parents, teachers) can both directly influence perceptions of CSE. Corroborating evidence from our study indicates that these influences result in incomplete or even incorrect perceptions. As observed at the beginning of this section, many of these influences are beyond our control, so the best we can do is to be aware of them and design interventions accordingly. Put informally, the model helps reminder intervention designers of "what they are up against."

7.1.2 Intervention Goals

Our intervention took the form of a one-time "CSE Exploration Session" for pre-major undergraduates, held at the same institution where the study was conducted. The session's overall goal was to help students make more informed decisions about majoring in CSE. As such, success did not necessarily entail convincing more students choosing the major. Recruitment of an interested, academically prepared student would certainly be considered a success. However, helping an underinformed (or worse, misinformed) prospective major determine that CSE would not be a good fit would also be a favorable outcome. This workshop was also intended to fit into a larger program of efforts to encourage a broader audience to consider majoring in CSE.

In service of the overall goal of more informed decision-making about majoring in CSE, most of the session activities were geared toward expanding or, in some cases, challenging student perceptions about CSE. We focused on perceptions represented in selected themes introduced in Chapter 5. CS 1 students appeared to have difficulty seeing how much more CSE encompassed than just programming (Subsection 5.4.2), so the session was designed to give students a glimpse of the kinds of ideas and activities (beyond programming) that they could look forward to as CSE majors. This included exposure to a variety of non-obvious applications of computing. Discussion of the variety of professional and interpersonal skills CSE requires was motivated in part by negative perceptions of isolation or competition in CSE (Subsection 5.4.4). Other topics included career paths available to CSE majors and admission to the CSE department. These session elements and their relationship with study findings are detailed in the next section.

A number of topics were intentionally given minimal treatment. CS 1's almost exclusive focus is on programming, so there was no need to further emphasize that aspect of CSE. If anything, based on the study findings, counterbalancing this emphasis with other aspects seemed necessary. The CSE department offers web resources and regularly conducts information sessions for prospective majors. These official information sources cover administrative details such as course requirements, prerequisites, and admissions, as well as specifics about the department. The Exploration Session was intended to complement these sources, and attendees were encouraged to seek them out outside of the session.

7.1.3 Unifying Study Findings, Session Design, and Session Evaluation

As discussed in the previous chapter, the expectancy–value model integrated findings from our study and from related research, yielding a more structured, complex view of entry into CSE than would have been possible from the study findings alone. To some extent, it also helped contextualize the Exploration Session and focus its overall goal. However, being a model intended to frame research, the expectancy–value model was less useful for guiding the process of designing the session and planning its evaluation.

For these more practical goals, we adapted a technique called the *logic model* that is commonly used for planning interventions in a way that facilitates evaluation of concrete outcomes [122]. The logic model approach has been used in a wide range of domains, including public health. We chose this approach for its strength in highlighting the relationships between goals, program elements (*i.e.*, activities included in the session), and measurable, intended outcomes.

In a sense, the expectancy–value and logic models played complementary roles in our work, with the latter providing a structured way of bridging research and practice. Figure 7.2 illustrate the models' complementary roles and how they connect the study findings and intervention efforts.

Figure 7.3 shows the logic model developed for this session and provides an overview of the workshop design, rationale, and evaluation, each of which is detailed further in this chapter. The first two columns represent study findings that informed the session design. The first column ("interview excerpt") consists of quotes from study participants that are representative the corresponding general interpretations, phrased in the first person in the second column ("concerns"). Actual participant quotes are shown for concreteness and to help ensure that activities are grounded directly and faithfully in the study findings. The participant concerns are mapped to session objectives in the third column. With one exception, these objectives are essentially subgoals of the overall goal of more informed decision-making about majoring in CSE. Finally, the rightmost column shows the activities

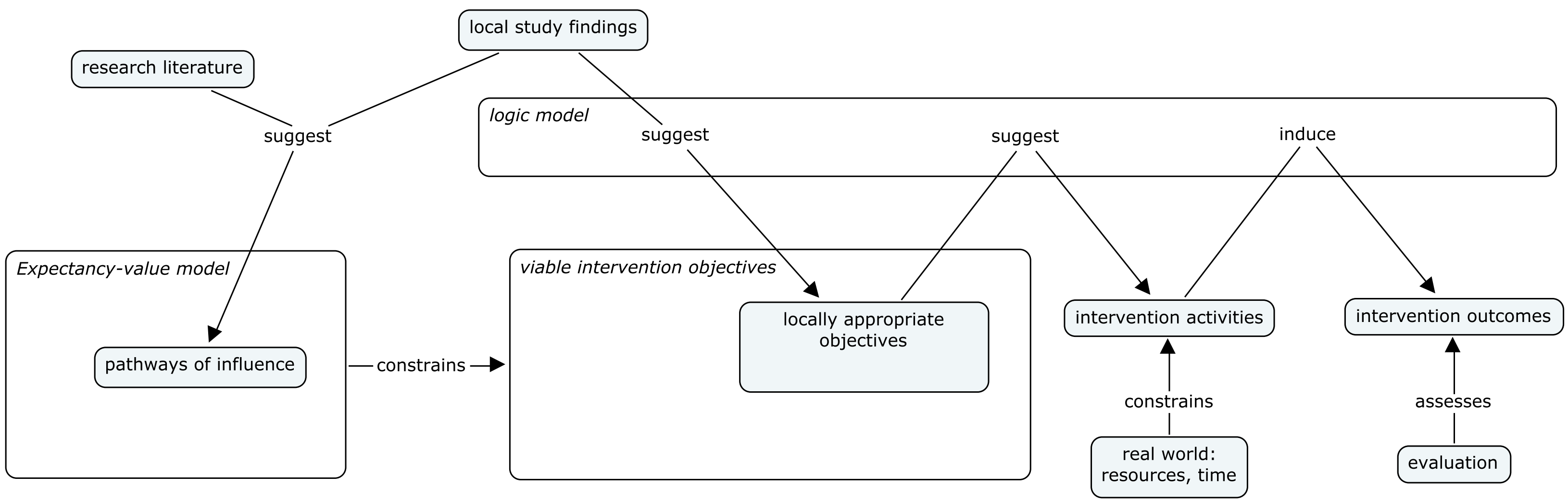

Figure 7.2: Concept map-style diagram showing relationships among our descriptive study and intervention-related activities, showing complementary roles of the expectancy–value model and logic model.

included in the Exploration Session, with each activity linked to the objective(s) it was intended to meet. Activities could have been mapped directly to concerns, but relating them to explicit objectives facilitated evaluation, discussed in Section 7.3.

The rest of this section describes each of the main activities in the order in which they were conducted during the Exploration Session.

7.1.4 Exploration Session Activities

Much of the workshop's design was based on the premise that many of the student perceptions listed in the "concerns" column of Figure 7.3 are incomplete, if not inaccurate. In this sense, most of the workshop activities were designed to encourage students to reconsider these incomplete or inaccurate perceptions.

Overall, the session was designed to be interactive and informal. Interaction and active engagement with ideas and information promotes learning, but we also hoped that contact with CS 1 classmates might counteract the negative, competitive atmosphere that some study participants associated with the course and, by extension, with CSE (Subsection 5.4.4). Keeping the session informal and friendly also seemed consistent with this goal. This had implications not only on how the session was designed and run but also on how it was advertised, as discussed more in Subsection 7.2.1.

Identifying with Study Participants

The first activity of the session was a "reality check" assessment of the attendees' initial perceptions, attitudes, and interests. Diagnostic assessments are a generally good educational practice, but for the Exploration Session, two additional considerations motivated opening with such an activity. As described above, most of the session activities were directly linked with study findings. Although the Exploration Session was advertised to the same population from which study participants were recruited, session attendees and participants likely differed in self-selection. (Neither group was necessarily assumed to have been representative of the CS 1 enrollment.) As a result, there was a danger that activities directly based on study participants' concerns and interests would be less relevant to the session attendees.

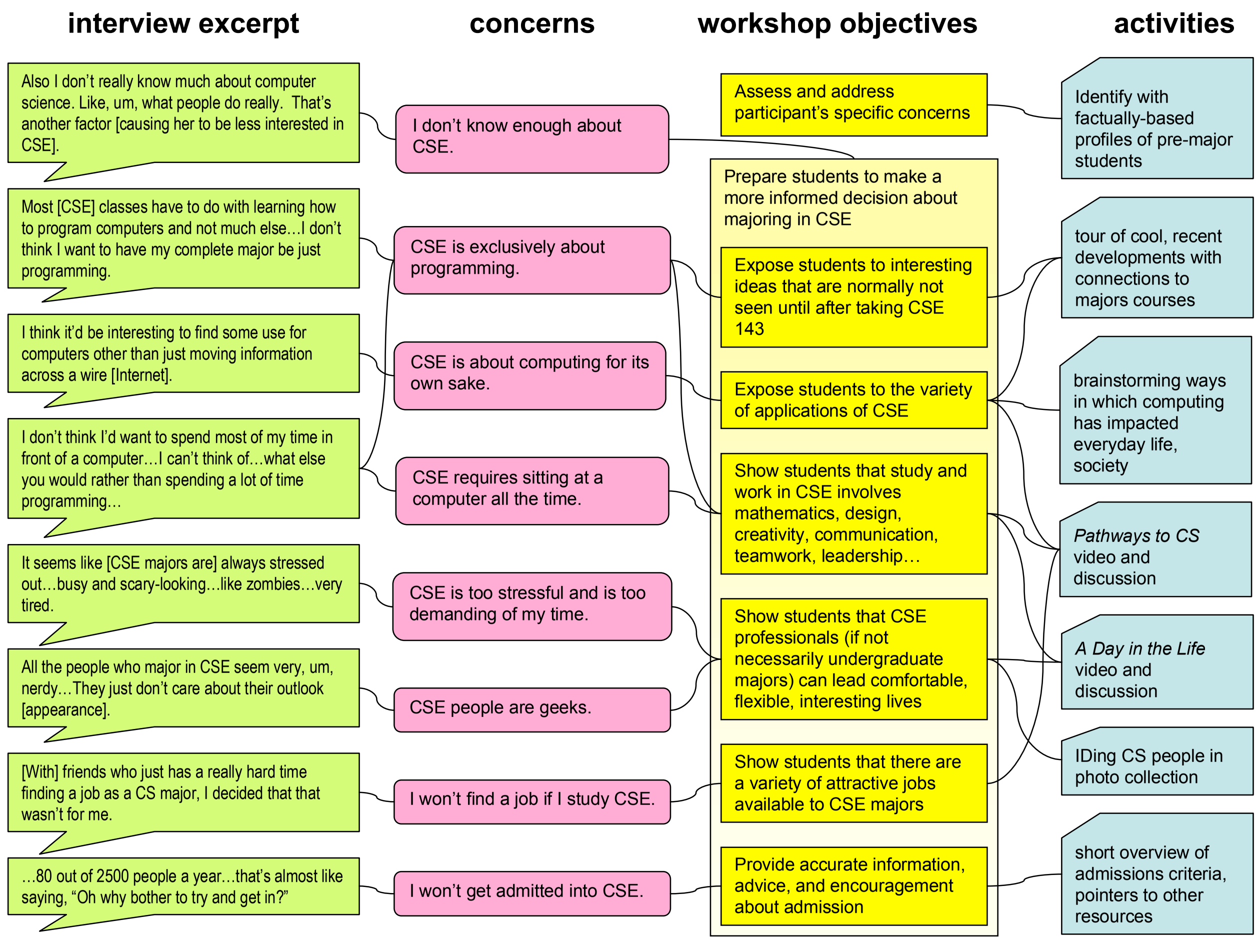

Figure 7.3: Concerns that the workshop was designed to address, with concerns linked (to the left) to representative quotes from the interview study and (to the right) to workshop objectives and (at the far right) the workshop activities intended to meet those objectives.

“What’s neat about CSE is that you get to create your own program...whatever you want to do with the computer.”

“I’m interested in CSE because I like messing around with computers, figuring out problems with hardware and software. It’s fun surfing the web, keeping up with the latest tech gadgets...”

“I don’t really know much about CSE. I don’t know what people do when they major in CSE.”

“Programming is interesting, but I don’t want to get too wrapped up in the technical side. I’m also interested in psychology, so I want to look at the human side to CSE, too.”

“I’m into making computers useful beyond just games or surfing the web. I like the idea of working on real problems.”

“Will I find a good job? I don’t know if I’m good enough to compete with all the qualified CSE people out there looking for work.”

“I don’t want to work in a cubicle for the rest of my life. I don’t know if I’d be able to look at a computer screen for eight hours a day, forty hours a week.”

“CSE majors don’t seem to care what they look like...hair all over the place, scrubby clothes. That’s not really my style.”

Figure 7.4: First-person statements about CSE used at the start of the Exploration Session. Statements were the result of editing actual quotes from study interview participants.

Additionally, regardless of how session attendees self-selected, the diagnostic activity was an opportunity to informally validate the study findings by providing some indication of how common the reported perceptions were in another sample of pre-major CS 1 students.

Several first-person statements representing positive or negative, CSE-related perceptions were printed and taped to the walls in the session room (Figure 7.4). The statements were based on actual quotes from participants in the interview-based study. They were minimally edited for conciseness or, in some cases, to synthesize quotes from multiple participants who expressed similar views.

Attendees were asked to read the statements and mark the ones they agreed with (*i.e.*, the statements that they felt expressed their perceptions or opinions). Marks were anonymous to encourage full disclosure of agreement, and it was unnecessary to map agreement with individual attendees. Attendees were also invited to add "write-in" statements, in case they had any particularly strong interests or concerns that were not represented among the pre-selected statements. To close the activity, the session facilitator tallied the per-statement agreement markers and briefly opened the floor to discussion of agreement (or disagreement) with the statements. The facilitator focused the subsequent session activities according to the attending group's CSE-related perceptions and attitudes, as reflected in the tallies.

Wide-ranging Applications of Computing

The second activity was designed to expose students to a varied set of computing applications. To highlight the relationships between the discipline of CSE and the applications, the facilitator briefly discussed CSE ideas involved in or enabling each application. To make these relationships still more concrete and immediate, attendees were also told about the CSE major courses in which they could expect to learn about these ideas. This helped meet another session objective: to make students aware of the interesting ideas and work (in addition to more programming) that later undergraduate CSE courses include.

The activity began with a brief exercise to engage students with the idea of computing applications. Students were asked to imagine a day without computing and consider what they would have to do differently or not be able to do at all. The intention was to elicit computing applications with immediate relevance to students' daily lives.

After discussing these "everyday" applications, the facilitator presented a set of photo-illustrations and movie clips of other computing applications. These examples were chosen to cover a broad range of areas (*e.g.*, from the fine arts to medicine to developing nations). The applications were also ones that students were expected not to have thought of in the preceding exercise. Some of the applications also highlighted CSE's potential for interdisciplinary collaboration.

To focus attention on the impact of computing on people and the world, each application was framed in terms of the person (or other entity) benefiting from the application. The intention was for each application to be presented with a human dimension, not simply as the solution to an abstract, computational problem. Connections between the applications and undergraduate study in CSE were made explicit by identifying the topic areas covered by third- and fourth-year CSE courses that were relevant to the applications.

One example application was a neurological research study of brain signals associated with body movement [51]. Piggybacking on an existing study of an epilepsy patient with implanted brain sensors, a team spanning the disciplines of neurosurgery, neurology, biomedical engineering, and CSE implemented a way for a patient to control a simple video game with only brain signals associated with movement but no actual physical movement. This application was presented as illustrative of the potential for CSE to contribute to a deeper understanding of the human brain and to new systems for control of artificial limbs. Sensors, hardware design, and artificial intelligence were identified as CSE topics that are potentially related to the project and could be studied as an undergraduate. Additional examples, all based on ongoing projects, are summarized in Table 7.1.

Video and Discussion on CSE Professionals

The next activity was partly motivated by the uncertainty and narrowness expressed by study interviewees about the attributes of a successful computer scientist. A short video excerpt served as the center of the activity. The video features interviews with CSE alumni describing the work they do and the problems they work on [116]. The video, which was produced independently of the session, was also selected for its potential to provide further exposure to applications of computing, as well as career paths available to CSE degree recipients.

To help attendees to focus on the video, the viewing was preceded by a brief exercise where students noted their ideas about attributes of successful computer scientists. After viewing the video excerpt, attendees revised their lists of attributes, and the facilitator led a group discussion of the skills, background, and interests of computer scientists.

Table 7.1: Summary of example CSE applications presented during the Exploration Session, each introduced by identifying the kind of people (or other party) who could benefit from the technology.

beneficiary	*application*	*related CSE topics*
neurologist	3D brain imaging	graphics, computer vision, algorithms
cancer researcher	molecular modeling	graphics, databases, algorithms
car driver	automatic collision avoidance, lane detection	artificial intelligence, computer vision, ubicomp
rural farmer in developing world	rural access to commodity market prices	networks, databases, ubicomp, HCI
person with sight impairment	Braille conversion of charts, diagrams, *etc.*	AI, computer vision
person with hearing impairment	optimized video compression for sign language over mobile phones	computer vision, algorithms, HCI
person with motor impairment	brain–computer interfaces	sensors, artificial intelligence, hardware
earthquake researcher	models, early detection, GIS	sensors, databases, algorithms, graphics
animal behavior researcher	tracking zebras in the wild	sensors, networks, architecture, databases, ubicomp
pet owner, pet	subcutaneous RFID tags for identification	databases, ubicomp
art historian	3D scanning of sculptures	graphics, databases
firefighter, trees	tracking forest fires	networks, sensors, hardware, ubicomp

Video and Discussion on Daily Work in CSE

A second video, also produced independently of the session, was included for its depictions of daily work and lifestyle as a software engineer, a common career path for graduates with CSE degrees [115]. The activity format was similar to that of the previous video activity, with pre- and post-viewing discussions. Attendees discussed what software engineers do during a typical workday. Excerpts of the video were shown to expose students to the wide range of tasks that a professional computer scientist engages in, including many that do not involve working at a computer. The video potentially played a secondary role in rebutting negative stereotypes of computer scientists being asocial, unkempt, and male, since the featured professionals were women who did not fit the "nerd" mold.

CSE Major Admissions

The final component of the session was a brief discussion of admission to the CSE department, led by one of the department's undergraduate advisors. This part of the session was intended provide accurate information about admissions, motivated by study evidence of student misunderstandings about admissions criteria and acceptance rates. An advising staff member was asked to lead discussion to serve as an authoritative source, since the session facilitator was not familiar with the policy details.

For a variety of reasons, we intentionally placed the admissions discussion last in the session. First, we recognized that it is a complicated topic with many important details. Second, based on our study findings, we suspected that many students might become concerned or even anxious about competitive admissions when the topic was introduced, potentially distracting them or, worse, sidetracking the session. Finally, we wanted to avoid duplicating the effort of existing, department-run information sessions that gave the admissions topic ample treatment. Acknowledging the session's limited treatment, attendees were encouraged to attend one of these official departmental information sessions and consult web resources to learn more about the requirements and process.

7.2 Session Implementation and Evaluation

Having laid out the Exploration Session's content, we now discuss logistical details its deployment and evaluation, which took place in spring of 2007.

7.2.1 Audience and Recruitment

Since the design of the Exploration Session was based largely on the interview-based study, the intended audience was CS 1 students who had not finalized their choice of major, *i.e.*, mostly first- and second-year undergraduates. (The Exploration Session also differed from the official, departmental information sessions in that the latter were targeted for a broader audience, albeit also pre-majors.) We hoped (but did not assume, as discussed later) that a close match between the study population and Exploration Session audience would help ensure that the session would be relevant, compelling, and timely for the audience.

The session was designed to be especially useful to students who had not previously considered majoring in CSE, but we expected that most students who already had some interest would also gain substantially from attending. We initially expected that this would be another difference between the Exploration Session and the CSE department's information sessions. The assumption was that the information sessions would attract students who were more confident of their intention to major in CSE. Later in this chapter, we discuss the extent to which the Exploration Session was successful at reaching an audience of students who were not already seriously considering majoring in CSE.

As previously described in Subsection 4.2.2, we chose to focus our limited resources on the audience of pre-major CS 1 enrollees for two practical reasons. With CS 1 being a prerequisite for majoring in CSE, the course represents an opportunity to interest students in CSE, whether through the course's traditional content of computer programming and/or through exposure to a broader view of CSE. CS 1 is also a critical timepoint with respect to goals of gender diversity, with departmental statistics suggesting disproportionate attrition of women as they progress from CS 1 to CS 2 and admission to the major. Even with a particular interest in reaching the women in CS 1, the session was advertised to and open to all students. Study findings indicated some gender-related patterns, but none so distinct to suggest that a mixed-gender session would be unsuccessful. We return to the topic of the session's effectiveness with respect to the goal of reaching women later in this chapter.

Design of and recruitment for the Exploration Session were also informed by experience teaching and working with CS 1 students at the university. Focusing on an audience of current CS 1 enrollees meant that we could safely assume certain things about all prospective attendees. We assumed that they were all very busy and limited the intervention to a one-time event, 90 minutes long, in spite of the limitations of this format. Session announcements prominently featured the inclusion of a free pizza-and-salad dinner. Food was provided to make the session easier to fit into a busy schedule, as well as to attract attention and interest in general. Coordinating with CS 1 teaching staff, the session date and time were carefully chosen so that they did not conflict with lectures, exam review sessions, or other course-related occasions.

The Exploration Session was advertised as an informal, one-time event via electronic and in-person announcements. Focusing on a CS 1 audience simplified targeted recruitment of attendees. CS 1 students were expected to read e-mail regularly, and many students were active participants on the class's on-line discussion forum. The instructor kindly forwarded and posted the announcement shown in Figure 7.5. (We expect that having the announcement appear in inboxes and on the forum as coming from the instructor encouraged more students to actually read the announcement.) The instructor also allowed the facilitator to make a brief, in-person announcements at the start of lecture shortly before the session date.

The electronic announcement requested RSVP via a short web form (Appendix ???), in part to estimate how much food to order but also in the hopes that confirmation responses would indicate more commitment to actually attend. The RSVP web form requested an contact e-mail address, which provided a means of contacting prospective attendees to remind them about the event shortly before the date and confirm attendance. The web form also asked for class standing, which proved useful in screening prospective attendees who did not read the announcement carefully and were not pre-majors and/or undergraduates.

```
Subject:  CSE Exploration Session next Thursday (FREE dinner included)

---> Wondering what CSE is all about?
---> Curious about what computer scientists do *besides* programming?
---> Interested in what kinds of jobs CSE majors get?
---> Like the idea of free dinner on Thursday?

If you answered YES to any of these questions, join us for a fun,
interactive *CSE Exploration Session* next Thursday afternoon (details
below).  RSVP required for *FREE* pizza and salad dinner.

*IMPORTANT*: To reserve a spot, send your RSVP via the web:
https://catalysttools.washington.edu/survey/yasuhara/36946
We don't want to run out of pizza or salad before you get to eat! :(

This event is open to all *pre-major* undergraduates, so go ahead and
forward this announcement to your friends.  *** Space and free food
are limited, so RSVP early! ***


CSE Exploration Session for pre-major undergraduates
*** RSVP required to attend ***
Thursday, May 10, 5:00-6:30 pm*
Allen Center for CSE, Room 403
RSVP:  https://catalysttools.washington.edu/survey/yasuhara/36946

*Estimated time, including dinner.  Dinner will include vegetarian
 options.  We will try our best to accommodate other dietary
 restrictions, so let us know when you RSVP.  Other questions?  Send
 Ken Yasuhara e-mail at <yasuhara@cs.washington.edu>.
```

Figure 7.5: Full text of electronic announcement as distributed to CS 1 students via e-mail and on-line forum.

7.2.2 Exportability of the Intervention

Although the session was specifically designed for a local audience, based on a study of the same population, the general approach and some elements of the session are likely to be transferable to other contexts. Production of some of the session materials required knowledge of the underlying research study and a comprehensive understanding of CSE (curricula, pedagogy, and associated professions). However, facilitating the session, as designed, would not require the same expertise and could likely be done by someone other than a CSE faculty member or graduate student, assuming experience or ability engaging undergraduates in interactive activities (*e.g.*, advising staff, advanced undergraduate).

In terms of resources required, the session was designed to have few requirements beyond what an average CSE department would likely already have or be able to afford. Equipment was limited to a laptop and digital projector, and any normal classroom or meeting room would suffice as a setting. Other supplies were minimal, including paper, tape, sticky notes, and name tags. In our pilot deployment, the most substantial monetary expenditure was for food, which the local department kindly offered to cover. Although a professional evaluation was also conducted (next section) in this case, more lightweight evaluation (*e.g.*, simple paper surveys) would likely suffice for a more typical deployment.

7.3 Evaluation

With funding from the CSE department, a professional evaluator from the campus educational assessment office was contracted to conduct a formal evaluation of the Exploration Session's pilot offering. We avoided directly involving the facilitator in evaluation to reduce risk of bias. In any case, professional evaluation ensured more valid, accurate assessment, given the researcher's relative lack of evaluation background and experience. Contracting also had the practical benefit of allowing the facilitator to concentrate fully on running the session.

Based on discussions with the researcher about the session plans and intended outcomes, the evaluator chose to administer pre- and post-session surveys and supplement that data with in-session observation notes. The evaluator consulted with the researcher in designing the surveys to ensure coverage of outcomes. Evaluation methods and instruments were approved by the campus institutional review board.

To summarize the findings detailed in the evaluation report (Appendix D), the session pilot was a qualified success. Although attendance, at twelve students, was lower than hoped for, evaluation data suggest that the session met its overall goal of helping students make more informed decisions about majoring in CSE. In survey responses, attendees indicated that the session made them more informed about the CSE major and careers in CSE. They valued learning more about both topics and were generally satisfied with the session experience.

Evaluation data confirmed facilitator concerns that the attending students were mostly already committed to pursuing a CSE major. In particular, both of the women who attended fell into this category, showing that the session had not met its secondary goal of introducing CSE to a broader (at least with respect to gender) audience.

Overall, it was encouraging that the session had its intended impact, in spite of a partial mismatch between the attending audience and the sample of students whose perceptions informed the session's design. Chapter 8 discusses how the Exploration Session approach might be improved and adapted to more directly address the goal of attracting a broader audience to the CSE major.

Chapter 8

CONCLUSIONS AND FUTURE WORK

This dissertation described two main research activities: an interview-based descriptive study and a piloted intervention. These activities yielded contributions with immediate, local value, as well as contributions of more general, theoretical or methodological significance. The first section of this chapter summarizes these contributions. The next section discusses selected directions for future work, both in terms of research and interventions. A final section makes some closing observations about CSE enrollment and the gender gap.

8.1 Summary of Contributions

The descriptive study part of this work yielded two main contributions, described in Chapters 5 and 6. The direct contribution was a detailed understanding of a set of factors affecting women and men's entry into CSE at the studied institution. Framing the findings in the expectancy–value model provided details on how these factors interact and affect entry. The theoretical contribution consisted of a refined and extended version of the expectancy–value model, specialized for application in research on CSE enrollment and gender. Building directly on study findings, the second part of this work resulted in our third contribution: an intervention to help students make more informed decisions about entry into CSE.

8.1.1 Local Factors Affecting Entry into CSE

Preliminary survey research confirmed that introductory CSE students at the studied institution vary widely with respect to interest level in majoring in CSE, with women being less likely than men to intend to major. CS 1 was identified as a critical opportunity to recruit women into CSE, because they represented about 40% of CS 1 enrollees who were considering majoring in CSE. In comparison, only about 20% of majors were women, indicating a disproportionate loss of women (or "pipeline leakage") between CS 1 and entry into the major.

Interviews with fourteen pre-major undergraduates newly enrolled in CS 1 (nine women, five men) revealed a wide range of concerns related to interest in CSE. Uncertainty about CSE as a major and/or a professional area made it difficult for many students to decide about the major, with some simply ruling it out on account of lack of information. A variety of negative perceptions also dissuaded prospective majors, including having to work alone at a computer all day (and more), a narrow focus on programming, the nerd stereotype, and an adversarial and competitive culture. On the positive side, several students were attracted by CSE's creative potential (often in the context of programming) and promising career prospects. Previous experience with computing, especially web authoring, appeared to feed into confidence with or interest in CSE.

Our findings suggest some gender differences, with women more likely to be dissuaded by the nerd stereotype and apparently less likely to see CSE as contributing to goals of benefiting society. At the same time, we expect computing- and programming-related confidence to be substantially affected by the CS 1 course experience. Overall, the gender-related findings are consistent with other studies that have found that academically qualified women are rejecting CSE partly because of its perceived culture and values.

Placing these findings in the expectancy–value model related them to past research on academic decision-making and gender. The model's structure provided a way of organizing the range of factors that affect entry into CSE. In addition to structure, the model represents a wide range of previously validated causal relationships among factors affecting academic decision-making. As such, placing the factors in the model's context also showed how they interact with elements of the student's social context, *e.g.*, teachers, peers, cultural stereotypes, and gender socialization.

The level of detail and complexity of the findings are illustrative of the strengths of a qualitative study appropriately framed by theory. Rather than being limited to claims about whether or not certain factors affect entry into CSE, our study has begun to address questions of why and how, as noted above. Both social science and CSE background were critical in informing the design of the study and interpretation of the data.

8.1.2 A CSE-specific View of Expectancy–Value

As expected with such a broad and generalized model, certain parts of the expectancy–value model were more important than others in the specific context of our study. Based their prominence in our findings, we expanded or extended certain parts of the model to capture certain factors and apparent causal relationships in more detail. With students discussing the people, values, and culture of CSE as much as the topics and activities they associated with the discipline, we proposed expanding the model's treatment of perceptions of occupational characteristics and demands to expressly include all of these aspects. We also noted the high degree of uncertainty expressed about occupational characteristics and demands—uncertainty which appeared to affect task value in multiple ways. Finally, we proposed extending the model to capture the apparent relationship between previous experiences and perceptions of occupational characteristics and demands.

Certain factors and relationships represented in the model were less frequently invoked in our analysis. This does not mean, however, that they are uninvolved in the decisions about entry into CSE. Instead, this might partially be an artifact of our research design, which was limited to collecting data about factors that students are conscious of. For instance, there was relatively little discussion of expectations of success (compared with task value), which was somewhat unexpected, given the prominence of low confidence in past studies of factors affecting women's entry and persistence in CSE. While this might be because of the self-selected nature of the studied population (*i.e.*, already enrolled in CS 1), it could also be because students were not conscious of confidence's relevance or, even if so, hesitated to bring it up during interviews. We return to this point in our discussion of future work, later in this chapter.

We began our study with a model that was originally conceived for a younger population and whose application was mostly limited to quantitative studies. By applying and extending it through a qualitative study, we were not only able to independently validate many of the model's theoretical claims but also refine and extend the model for future study.

8.1.3 Intervention Approaches to Recruit CSE Majors

The third main contribution of our work was the systematic design of an intervention whose objective was to address some of the problematic findings from the descriptive study. Guided by both the expectancy–value model and the logic model approach, our CSE Exploration Session was linked directly to study findings. A pilot deployment of the intervention was evaluated to be a qualified success, validating a research-based approach to interventions. While the intervention was designed for the local population of CS 1 students, we expect that elements of the session (if not its entirety) can be used in other departments. However, as was done in our pilot deployment, pre-session diagnostic surveying of or discussion with the attending students will help ensure that the session addresses local issues and student concerns.

8.2 Future Work

Because our descriptive study was broad and exploratory, it naturally leads to a wide range of research questions for further examination. On the practice side, our findings suggest more intervention approaches than could be practically incorporated into the CSE Exploration Session. Example directions for both future research and practice are briefly discussed in this section.

8.2.1 Further Research

As discussed in Chapter 4, one conscious compromise in our study was the small sample size—too small to serve as the basis of strong, statistical claims about the relatively frequency of specific student perceptions and attitudes about CSE. A natural way to complement this study would be a survey of a large sample of CS 1 enrollees. Carefully designed, closed-ended questions could provide a more detailed accounting of how common the perceptions and attitudes we observed in our study are. This would also provide a more precise gender comparison of the significance of certain factors affecting entry into CSE.

In Subsection 4.2.2's discussion of reasons for studying newly enrolled CS 1 students, we observed that CS 1 represents an important recruitment opportunity. Indeed, this was supported by multiple participants describing CS 1 as a basis for determining their interest in the CSE major. For practical reasons, our study was limited to studying these students' "start state," *i.e.*, their perceptions and attitudes at the start of their CSE studies. A natural companion study would entail pre- and post-course data collection for a longitudinal examination of CS 1's effects on interest in CSE and relevant perceptions and attitudes. An analogous study could be conducted in the non-majors fluency with information technology course that multiple participants described as having a positive effect on their preparedness for and/or interest in CS 1.

Looking beyond the local institutional context, replicating this study at other institutions would be one way to examine the generalizability of our findings. In particular, an interesting, contrasting reference point would be a department whose gender ratio is unusually closer to parity. If replicating the study in its full, qualitative form proved too resource-intensive, conducting a survey-based version (as described above) might be a reasonable compromise.

Stepping back further still, research on gender and entry into CSE would greatly benefit from a careful and comprehensive synthesis of past studies that is sensitive to differences in population, departmental and institutional context, and data collection and analysis methods. Such a synthesis might look like an extension to our review of selected literature in Chapter 2 and could be framed with a theoretical model, just as our study findings were. Although we chose expectancy–value, a variety of other established models might be applicable, including Lent *et al.*'s Social Cognitive Career Theory [74], which Lopez *et al.* are applying in their ongoing study of women and underrepresented minorities in CSE [77].

8.2.2 Interventions

Our findings highlighted a variety of perceptions and attitudes about CSE that dissuade students from majoring. The workshop-style intervention such as the one piloted in this work is just one of many approaches to addressing these negative perceptions and attitudes. Due to practical constraints, the piloted workshop was a relatively short, one-time, optional event. Although impact was accordingly limited, measurable changes in student perceptions and attitudes were observed. More design and evaluation of a variety of workshop and other intervention formats is necessary to better understand their relative strengths and impact, both in the short and long term.

For instance, a series of shorter presentations to the entire CS 1 enrollment (*e.g.*, five minutes at the start of selected lectures) would be likely to achieve greater impact. Such an approach would reach a broader audience, including students who are not already considering majoring in CSE. Most of the content in the piloted intervention is simple enough to parcel out into five-minute segments, and shorter presentations would avoid problems with attention span.

Looking beyond workshops, the study findings suggest that some student perceptions and attitudes about CSE could be affected by changes in course practices and policies. For example, multiple students related their concerns about the competitive culture in CSE to the CS 1 collaboration policy. They interpreted the policy as considerably more restrictive than stated, with some concluding that collaboration of any kind was prohibited. Course staff might consider making more explicit what kinds of collaboration are not only allowed but encouraged. Designing positive collaboration experiences into the course (*e.g.*, pair programming) might also help.

Other students attributed the competitive atmosphere in CS 1 to the competitive admissions process for entry into CSE. Although this admissions policy will not (and arguably should not) be fundamentally changed, some clarifications might again moderate the negative effects students described. Transparent, criterion-based, rather than curved, grading could lessen perceptions that one student's academic success comes at the expense of others'. Although undergraduate advising staff have made great efforts to make accurate, complete information about admissions criteria available via the web and (optional) information sessions, more actively "pushing" it to the CS 1 enrollment might also be helpful.

In addition to moderating negative perceptions about a culture of competition, the changes described above might also combat some aspects of the negative stereotypes applied to CSE students. Collaboration could counter perceptions of isolation and asociality, for instance.

Our findings about web authoring experience suggest one way of boosting confidence and interest in CSE. Assuming that positive web authoring experience is indeed as common as we found (which would be consistent with the Pew social media study [72]), relating CS 1 course content and activities more directly with web authoring could translate into higher motivation and better learning. Relationships could be as simple as contextualization of examples and motivation for problems or more involved, as in a homework assignment where programming is embedded in a web authoring context. We mention another successful attempt at linking CSE with commonly existing student interests in the next section.

Beyond the university walls, ensuring that high school teachers and other influential figures in students' lives are more accurately informed about CSE could partially address the uncertainty that our study participants expressed. We touch on relevant efforts in closing observations in the next section.

8.3 Looking Forward

With national statistics and labor projections showing that a shortfall of qualified computer scientists will inevitably follow from the recent downturn in degree production, CSE must take recruitment and retention in introductory courses more seriously—for all students, but especially women and other underrepresented groups.

Metaphorically speaking, treating CSE like a product, our work suggests that the CSE community must be engaged in three coordinated activities: advertising, product development, and, most importantly, consumer research. "Advertising" refers to efforts to inform and attract prospective majors, as well as the general public. Amidst these efforts, the "product" should not be considered unchangeable. Indeed, CSE educators are innovating on many fronts, gradually changing not only the ways in which CSE is taught but also the content of the field. Finally, consumer research—a strong basis in rigorous, theoretically informed, empirical research—must guide both the advertising and product development efforts.

Promising efforts are in progress with all three activities. Substantive collaborations across disciplinary lines suggest that CSE educators are beginning to appreciate the necessity of expertise beyond their traditional, technical backgrounds. Anecdotes and personal intuition are slowly being displaced by research, theory, and principles. On the advertising front, the cross-institutional CS4HS effort to help prepare high school teachers provide students with engaging, accurate first experiences with CSE. CS4HS shares its heritage with the CMU *Unlocking the Clubhouse* study. On the product development front, Guzdial *et al.* have been developing and evaluating new approaches to introducing CSE concepts that connect them to student interests in digital sound and images and creativity. Finally, the publication of key research resources such as Cohoon & Aspray's 2006 volume on women's underrepresentation in computing [31] indicates the growing acceptance of CSE education research, both in general and on the topics treated in this dissertation.

Returning to the product metaphor, we close by encouraging the CSE to advertise in good faith. Efforts to recruit majors that present CSE as broad, exciting, socially valuable, collaborative, and welcoming to a diverse audience must be matched by any necessary and according curricular and cultural changes (particularly at the critical introductory level). If educational experiences in CSE do not deliver on recruitment promises, we cannot expect any real change. Advertising, as challenging as it is, is relatively simpler than changing how and what we teach, the values we validate (consciously or otherwise), and cultures we cultivate. To the extent that negative perceptions and stereotypes often contain grains of (uncomfortable) truths, we must be open-minded to examining them carefully and honestly. Coordinating recruitment and change efforts, basing them on sound research, and evaluating these efforts carefully promise an efficient path to an expanded, more vibrant disciplinary community.

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Appendix A
SURVEY INSTRUMENT

The following survey was approved by the University of Washington's Human Subjects Division and was administered on paper as described in Section 4.4.

CSE 142 STUDENT QUESTIONNAIRE (2004 April)

The Department of Computer Science & Engineering is conducting this questionnaire to better understand your goals, interests, and background as students in CSE 142.

Your responses are completely anonymous and will NOT affect your grade in any course in any way.

Although we greatly appreciate your participation, this questionnaire is optional. You may skip any question that you do not wish to answer.

IMPORTANT NOTE: You must be 18 or older to be eligible to participate.

If you have any questions or comments, please feel free to contact the questionnaire administrator, Ken Yasuhara, at `yasuhara@cs.washington.edu`.

Why did you decide to take CSE 142? Please list your most important reasons.

What major(s) are you interested in pursuing here at UW?

What aspects (if any) of the computer science or computer engineering major make it a MORE INTERESTING major to you?

What aspects (if any) of the computer science or computer engineering major make it a LESS INTERESTING major to you?

For the following item, we are interested in what you think, so there are no right or wrong answers: Please try your best to briefly define "computer science" in your own words.

(Questionnaire continues on back...)

Although CSE 142 does NOT require any previous experience with computer programming, some students in CSE 142 do have some programming experience.

Did you take any HIGH SCHOOL computer programming courses? Please mark one:
◯ yes
◯ no
If yes, what programming language(s) did you use? Please mark all that apply:
◯ C ◯ C++ ◯ Java ◯ JavaScript ◯ Visual Basic ◯ other(s): ____________

Did you take any COLLEGE computer programming courses before this one? Please mark one:
◯ yes
◯ no
If yes, what programming language(s) did you use? Please mark all that apply:
◯ C ◯ C++ ◯ Java ◯ JavaScript ◯ Visual Basic ◯ other(s): ____________

Do you have any out-of-class/self-taught experience with computer programming? Please mark one:
◯ yes
◯ no
If yes, what programming language(s) did you use? Please mark all that apply:
◯ C ◯ C++ ◯ Java ◯ JavaScript ◯ Visual Basic ◯ other(s): ____________

How many years of computer programming experience do you have, including both experience in courses and any out-of-class/self-taught experience? Please mark one:
◯ 1 year ◯ 2 years ◯ 3 years ◯ 4 years ◯ 5 years ◯ more than 5 years

---

What is your gender? Please mark one:
◯ female
◯ male

What is your class standing? Please mark one:
◯ freshman
◯ sophomore
◯ junior
◯ senior
◯ other (Please specify: ____)

Thank you for your time and participation. Please use the space below if you have any additional comments.

Appendix B

INTERVIEW PARTICIPANT CONSENT FORM

The following participant consent form was approved by the University of Washington's Human Subjects Division. The form was completed by each participant before interviewing.

UNIVERSITY OF WASHINGTON
CONSENT FORM
Undergraduate perceptions of the computer science and engineering majors

Investigators:

Name: Ken Yasuhara	Computer Science & Engineering University of Washington	UW College of Engineering
Telephone: (206) 616-7046	E-mail: yasuhara@u.washington.edu *Please note, we cannot ensure the confidentiality of information sent via e-mail.*	

<u>Researchers' statement</u>

We are asking you to be in a research study. The purpose of this consent form is to give you the information you will need to help you decide whether to be in the study or not. Please read the form carefully. You may ask questions about the purpose of the research, what we would ask you to do, the possible risks and benefits, your rights as a volunteer, and anything else about the research or this form that is not clear. When we have answered all your questions, you can decide if you want to be in the study or not. This process is called "informed consent." We will give you a copy of this form for your records.

PURPOSE OF THE STUDY

We are interviewing undergraduate students in introductory computer science (CSE 142) to better understand what makes the computer science and engineering majors more interesting and less interesting to different students. We would like to interview you about your opinions on and perceptions of computer science and the computer science and engineering major programs at the University of Washington.

STUDY PROCEDURES

If you choose to be in this study, I would like to interview you about your perceptions of and past experience with computer science. The interview will last about one hour and will focus on your perceptions and experiences. For example, I will ask you, "What major(s) are you interested in studying?", "Before CSE 142, did you have any experience with computer programming?", and "What aspects of computer science and engineering make it more or less interesting to you?" You may refuse to answer any question in the interview.

I would like to audiorecord your interview so that I can have an accurate record. Only I will have access to the audiorecordings, which will be kept in a locked file cabinet and on a computer with restricted, password-protected access. I will transcribe your interview audiorecording within eight weeks of your interview, assign a study code to the transcript, and destroy the audiorecording.

RISKS, STRESS, OR DISCOMFORT

Some people feel that providing information for research is an invasion of privacy. I have addressed concerns for your privacy in the section below. Some people feel self-conscious when they are audiorecorded.

BENEFITS OF THE STUDY

We hope the results of this study will help computer science educators better understand their students and might be useful for improvements in computer science education. You might not directly benefit from taking part in this research study.

OTHER INFORMATION

All of the information you provide in this interview will be confidential. However, if we learn that you intend to harm yourself or others, we must report that to the authorities. To help ensure confidentiality, I will assign a code to your data and keep the link between your data and identity in a location separate from your data until 28 February 2006. On that date, the linking information will be destroyed.

Government or university staff sometimes review studies such as this one to make sure they are being done safely and legally. If a review of this study takes place, your records may be examined. The reviewers will protect your privacy. The study records will not be used to put you at legal risk of harm.

Your participation in this study is voluntary. You may refuse to participate or may withdraw from the study at any time without penalty or loss of benefits to which you are otherwise entitled.

If you complete the interview, we will give you $20 in cash to partially compensate you for your time and thank you for your participation.

I may want to re-contact you to clarify information from your interview. In that case, I will e-mail you and ask you for a convenient time to ask you additional questions closely related to your interview. Please indicate below whether or not you give your permission for me to re-contact you for that purpose. Giving your permission for me to re-contact you does not obligate you in any way.

Printed name of study staff obtaining consent | Signature | Date

Subject's statement

This study has been explained to me. I volunteer to take part in this research. I have had a chance to ask questions. If I have questions later about the research, I can ask one of the researchers listed above. If I have questions about my rights as a research subject, I can call the Human Subjects Division at (206) 543-0098. I will receive a copy of this consent form.

I give my permission for the researcher to audiorecord my interview:

- ☐ yes
- ☐ no

I give my permission for the researcher to re-contact me to clarify information:

- ☐ yes
- ☐ no

Printed name of subject | Signature of subject | Date

Copies to: Researcher
Subject

Appendix C
INTERVIEW SCRIPT

The following interview script was approved by the University of Washington's Human Subjects Division. In semi-structured interviewing, the interviewer is free to pursue follow-up questions or even omit questions from the script. In the case of this study, while the researcher did freely ask follow-up and clarification questions, all participants were asked all questions in the order given in the script.

INTERVIEW SCRIPT

Study: Undergraduate perceptions of the computer science and engineering majors
Researcher: Ken Yasuhara, Graduate Student, Computer Science & Engineering
206-616-7046, yasuhara@u.washington.edu

1. Introduction

The interviewer begins by introducing himself and setting the interviewee at ease. The interview begins with an overview:

"Thanks for volunteering to be interviewed. Before we talk about the computer science and engineering majors, we'll begin with a few questions about CSE 142 and any pre-college experience you might have with computer science. I also want to assure you that I will respect your confidentiality and the confidentiality of anyone else we discuss. No names, e-mail addresses or other directly identifying information will be used in the study. Some of these questions will be similar to those on the paper survey you completed. The purpose of this interview is to gain a deeper, more detailed understanding of your perspective."

2. Warm-up: CSE 142 enrollment

"I'd like to start by talking about the course you're taking now, CSE 142. Could you tell me why you decided to take CSE 142?"

3. Warm-up: Academic interests

"Next, for some background, I'd like to get an idea of your academic interests. Could you tell me what major(s) you're considering?"

For each major other than computer science/engineering (if mentioned), "What aspects of this major make it interesting to you?" (Computer science/engineering will be discussed in depth in the next section.)

4. Core question: Interest in CSE majors

"Let's focus on computer science now. Have you ever thought about majoring in computer science or computer engineering?" (This question might be rephrased as a confirmation if computer science/engineering was cited as a major of interest in a prior response.)

follow-up: "Are there particular aspects of the computer science/engineering major that make it interesting or appealing to you? If so, could you describe them?" and analogous question with "less interesting or appealing"

E.g., if the interviewee expressed interest in computer science/engineering, "Are there particular aspects of the computer science/engineering major that make it interesting or appealing to you? If so, could you describe them?" "You've told me you're interested in the computer science/engineering major, but are there any aspects of the major that make it *less* interesting or appealing to you? If so, could you describe them?"

For clarification on these responses, the interviewer might refer back to responses from Part 3 and ask the interviewee to compare/contrast computer science/engineering and other majors they are interested in.

5. Core question: Preconceptions of CSE

"So far, we've been talking about your personal academic interests. Let's step back and talk more generally about computer science/engineering."

"Take a moment to imagine someone who would make a successful computer scientist. I'd like you to tell me some of the important characteristics of such a person."

possible follow-up: "For instance, consider what kinds of skills they have, what kind of job they have, what kind of work they like, or what kind of person they are. Try to focus on the characteristics that you think help make them a successful computer scientist."

6. Wrap-up: Background information

"To finish up, I'd like to ask you about any past experience with computer programming you might have."

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“Did you take any high school computer programming courses? If so, what programming language(s) did you use?”

(The interviewer will ask the same pair questions about college level programming courses and extracurricular programming experience.)

“In total, how many years of computer programming experience would you say you have, including both experience in courses and out-of-class or self-taught experience?”

“Finally, what is your class standing?”

“Thanks for taking the time to participate in this study. Do you have any questions for me?”

Appendix D

CSE EXPLORATION SESSION EVALUATION REPORT

The following evaluation report [79] was prepared by Dr. Bayta L. Maring at the University of Washington's Office of Educational Assessment and is included here with the author's permission.

OFFICE OF EDUCATIONAL ASSESSMENT
Improving Learning Through Assessment

CSE Exploration Workshop
Brief Evaluation Report

Bayta L. Maring
July 2007

BACKGROUND

This report summarizes an evaluation of a two-hour workshop for students enrolled in introductory computer science classes at the University of Washington. The purpose of the "Computer Science Discovery Workshop" was to inform students about careers in computer science and about the computer science and computer science engineering majors at the UW. The design of the workshop was based upon an already completed set of interviews with another sample of introductory computer science majors and the themes that emerged from the data about computer science majors and careers. The interviews and workshop are both part of a larger project about why students do or do not decide to enter the field of computer science.

The workshop involved discussions, activities, a film, and a presentation by an advisor from the computer science department. During the workshop, the following general topics were covered:

- The breadth of applications of computer science in everyday life
- Students' incoming knowledge about the field
- Positive and negative aspects of the field/major
- Interesting and unique careers in computer science
- Information about CS and CSE majors, with a focus on application and admission to the majors

The UW Office of Educational Assessment (OEA) was contracted to conduct a brief evaluation of the workshop to gauge the impact of the experience and to gather data about students' satisfaction with it. This report presents a brief summary of pre- and post-surveys conducted at the workshop as well as selected observational notes collected by the OEA evaluator during the workshop itself.

METHODS

Participants were given a brief survey at the beginning of the workshop and a similar survey once the workshop had been completed. Questions on both the pre- and post-surveys focused on level of interest in computer science, attitudes about of the field of computer science, and perceptions of CS/CSE majors at the UW. The pre-survey also contained several demographic items and questions about students' previous experience with the field and any readily available sources of information about computer science. The post-survey included several evaluative questions about the workshop.

A representative from OEA distributed the surveys and also observed the workshop, taking detailed field notes.

There were a total of twelve participants in the workshop. All twelve participants completed a pre-survey and only 10 completed a post-survey. Based on their responses to several demographic questions on the pre-survey, the workshop participants fell into the following categories:

- **Ethnicity:** Eleven participants indicated they were not Hispanic or Latino; one individual did not respond to this question.
- **Race:** Seven participants selected “White” for this question, and four selected “Asian.” One participant did not answer this question.
- **Gender:** Ten participants were male and two were female.
- **Class standing:** There were seven freshmen, three sophomores, and two juniors attending the workshop

RESULTS

This section contains a brief summary of results from the pre- and post-surveys separated into three sections. The first section contains comparative descriptive statistics from the items that appeared on both the pre- and post-surveys. The second section presents results from informational items that were only included on the pre-survey and the final section shows results from evaluative items that were only included on the post-survey.

After each section, the evaluator has provided comments about the data along with selected supplemental insight provided from workshop observation. These comments are relatively interpretive and reflect the evaluator’s perspective on the workshop.

Pre- Post-Comparisons

There were four sets of questions that were included on both the pre- and post-surveys. The first focused on students’ knowledge about computer science as a field and the computer science/engineering majors at the University of Washington (pre- to post- results are shown in Table 1). Second, participants were asked more specifically about attitudes about computer science/engineering majors based on themes that emerged from interviews with introductory computer science students (Table 2). The third set of pre- and post-items were based on similar themes about computer science careers that emerged in the interviews (Table 3). Finally, on both the pre- and post- surveys, participants were asked how confident they were that they would apply to a computer science or computer science engineering major (Figure 4).

The results presented here include only data from pre- and post-surveys that could be matched by participant. Two participants did not complete a post-survey and one did not provide information so that the pre- and post-surveys could be linked. Hence, the total sample for pre- and post-comparisons n = 9.

Table 1. Descriptive statistics for pre- and post- responses to items about students' knowledge and attitudes about computer science majors and careers.

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	SD
		1	2	3	4	5		
I know what being a computer science/ engineering major at the UW would be like.	Pre	1 (11.1%)	4 (44.4%)	3 (33.3%)	1 (11.1%)	0 (0.0%)	2.44	0.88
	Post	0 (0.0)	0 (0.0)	3 (33.3)	5 (55.6)	1 (11.1)	3.78	0.67
Being a computer science/engineering major is a good fit with my skills.	Pre	0 (0.0)	0 (0.0)	3 (33.3)	5 (55.6)	1 (11.1)	3.78	0.67
	Post	0 (0.0)	0 (0.0)	1 (11.1)	6 (66.7)	2 (22.2)	4.11	0.60
Being a computer science/engineering major is a good fit with my personality.	Pre	0 (0.0)	2 (22.2)	1 (11.1)	3 (33.3)	2 (22.2)	3.63	1.19
	Post	0 (0.0)	0 (0.0)	3 (33.3)	4 (44.4)	2 (22.2)	3.89	0.78
I know what having a career in computer science would be like.	Pre	1 (11.1)	2 (22.2)	3 (33.3)	3 (33.3)	0 (0.0)	2.89	1.05
	Post	0 (0.0)	0 (0.0)	2 (22.2)	6 (66.7)	1 (11.1)	3.89	0.60

Table 2. Descriptive statistics for pre- and post- responses to items about students' knowledge and attitudes about the UW computer science/engineering major

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	SD
		1	2	3	4	5		
In general, people who are computer science/engineering majors lack social skills	Pre	1 (11.1%)	2 (22.2%)	2 (22.2%)	2 (22.2%)	2 (22.2%)	3.22	1.39
	Post	2 (22.2)	3 (33.3)	2 (22.2)	2 (22.2)	0 (0.0)	2.44	1.13
People who are in a computer science/ engineering major have no time for extra-curricular activities.	Pre	0 (0.0)	5 (55.6)	2 (22.2)	2 (22.2)	0 (0.0)	2.67	0.87
	Post	1 (11.1)	3 (33.3)	1 (11.1)	4 (44.4)	0 (0.0)	2.89	1.17
Being a computer science/engineering major is more stressful than most other majors.	Pre	2 (22.2)	1 (11.1)	1 (11.1)	5 (55.6)	0 (0.0)	3.00	1.32
	Post	1 (11.1)	1 (11.1)	0 (0.0)	7 (77.8)	0 (0.0)	3.44	1.13
A computer science/ engineering major is almost entirely about learning how to program.	Pre	3 (33.3)	2 (22.2)	3 (33.3)	1 (11.1)	0 (0.0)	2.22	1.09
	Post	3 (33.3)	5 (55.6)	0 (0.0)	1 (11.1)	0 (0.0)	1.89	0.93

Table 3. Descriptive statistics for pre- and post- responses to items about students knowledge and attitudes about careers in computer science

		Strongly Disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly Agree 5	Mean	SD
People with careers in computer science almost always work alone and rarely in teams.	Pre	7 (77.8%)	1 (11.1%)	1 (11.1%)	0 (0.0%)	0 (0.0%)	1.33	0.71
	Post	9 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1.00	0.00
If you graduate with a computer science/ engineering major, it is relatively easy to get a good job.	Pre	0 (0.0)	1 (11.1)	1 (11.1)	7 (77.8)	0 (0.0)	3.67	0.71
	Post	0 (0.0)	0 (0.0)	2 (22.2)	6 (66.7)	1 (11.1)	3.89	0.60
Having a career in computer science involves creativity.	Pre	0 (0.0)	1 (11.1)	0 (0.0)	4 (44.4)	4 (44.4)	4.22	0.97
	Post	0 (0.0)	0 (0.0)	0 (0.0)	5 (55.6)	4 (44.4)	4.44	0.53
Having a career in computer science requires good communication skills.	Pre	0 (0.0)	0 (0.0)	2 (22.2)	4 (44.4)	3 (33.3)	4.11	0.78
	Post	0 (0.0)	0 (0.0)	0 (0.0)	4 (44.4)	5 (55.6)	4.56	0.53

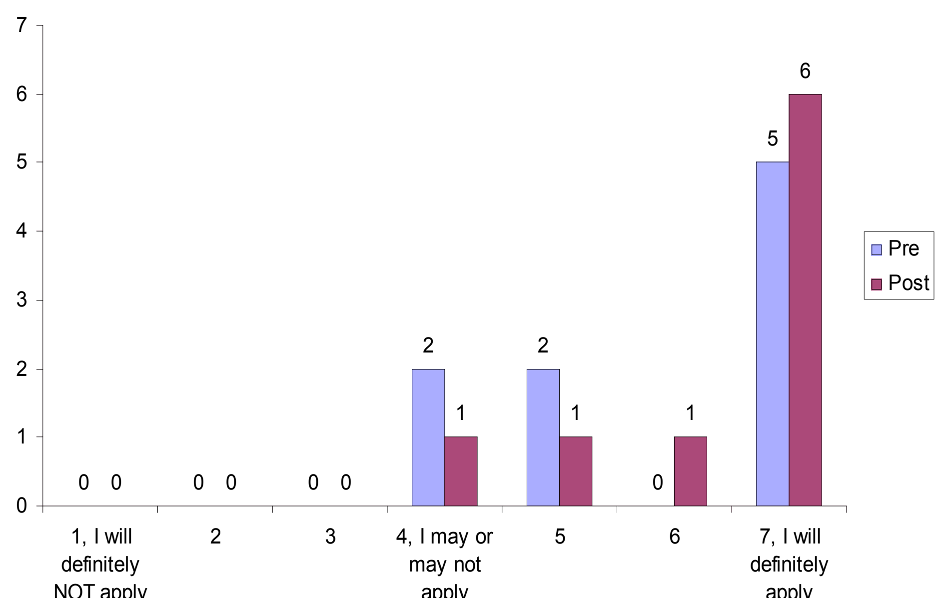

Figure 1. Pre- and post responses to question about how likely it was that students would apply to a composer science or computer engineering major

Evaluator comments on pre- post- comparisons

In examining these pre- and post- comparisons, it is somewhat difficult to determine whether the observed changes are significant, as the sample size was extremely small. However, there are a few notable findings.

First, students' ratings for the item, "I know what having a career in computer science would be like," were very different pre- and post. On the pre-survey, five participants (one third of the total sample) disagreed or strongly disagreed with this statement; whereas no students disagreed with the statement on the post-survey. This finding suggests that the workshop was successful in exposing students to possible computer science careers.

Another goal for the workshop was to provide accurate information about computer science/engineering majors at the University of Washington. Student ratings indicate that this goal was met to some degree, with five students (over one half of the sample) indicating on the pre-survey that they disagreed or strongly disagreed with the statement, "I know what being a computer science/engineering major at the UW would be like," and no students disagreeing with the statement on the post-survey. This change is particularly notable because there was relatively little time devoted to discussing the CS/E major during the workshop.

The remaining pre-/post- comparisons are not quite as remarkable. There was not a considerable amount of change in students' attitudes about the major and careers. Several of the items were based on "myths" about computer science that emerged from participant interviews and it seems as if these students did not necessarily maintain those myths. For example, even on the pre-survey, only one participant agreed with the statement, "A computer science/engineering major is almost entirely about learning how to program." Similarly, on the pre-survey, almost all students agreed with the statement, "Having a career in computer science requires good communication skills," and disagreed with the statement, "People with careers in computer science almost always work alone and rarely in teams."

There was also minimal change pre- to post- in students' ratings on a scale of 1 "I will definitely NOT apply," to 7 "I will definitely apply," about their intentions to apply to a CS/E major. Three students showed an increase in their ratings pre- to post-. Notably, both female workshop participants gave ratings of "7" for this item on the pre-survey. In observing the workshop, it seemed clear that the self-selected group of students who attended the session were already fairly committed to the field and serious about continuing their computer science studies.

Items from pre-survey

The pre-survey included a number of different questions about participants that would not change because of the workshop. Participants were first asked what interested them in the workshop. There were also a variety of questions about these students in relation to their studies in computer science: previous experience with computer programming, plans for applying for majors, and what potential sources of information these students might have about computer science as a field and the computer science/engineering major.

Results from both the numerical and open-ended questions are presented below in the order they appeared on the survey.

Open-ended question: What made you decide to attend this workshop?

- Have interest or skills in the area, interested in learning more about career paths/field (3)
  - I'm taking CSE 142 and decided that I could do this as a living! The homework is fun and challenging to me, and doesn't feel like homework at all! Also don't know much about CSE career possibilities
  - I was surprised by the ease and speed with which I understood java programming. I'm curious to see what options could be in the path.
  - I enjoy programming want to learn more about it
- Interest in major or department (3)
  - I'm intending to major in CSE but it seems like I don't know much about it so that made me attend here
  - I was interested in learning more about computer science and the course of study it entails.
  - My CSE 142 prof emailed me the link . . . I was curious to know more about the department and there was free food!
- General curiosity (2)
  - Curious about CSE
  - curiosity

Table 4. Participants' CSE course status as of the workshop*

Course Status	Number of participants
Currently enrolled in CSE 142, planning on taking CSE 143	7 (58.3%)
Currently enrolled in CSE 142, NOT planning on taking CSE 143	3 (25.0)
Taken CSE 142, currently enrolled in CSE 143	1 (8.3
Taken both CSE 142 and CSE 143	1 (8.3)

Of the 12 participants

- 10 had not applied for a CS or CE major
- 1 had applied for a CS or CE major
- 1 did not respond to the question about applying for a CS or CE major

Open-ended question: If you did apply to be a computer science or computer engineering major, when would you do so?

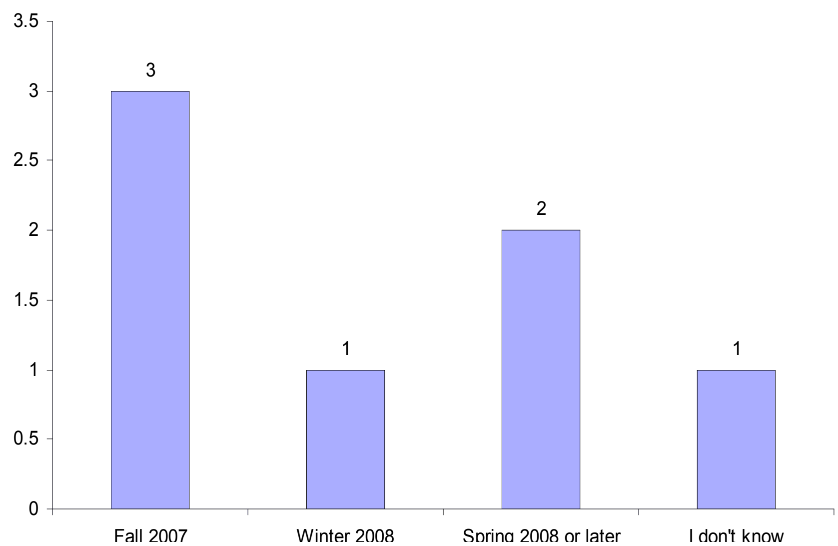

Figure 2. Participants' plans for applying to a CS/E major

Open-ended question: What other majors, if any, are you considering?

Note that participants provided multiple answers to this question. The list below represents all the majors mentioned with the number of participants (if more than one) who mentioned the major (or type of major).

- Other engineering (3)
  - Electrical engineering (2)
  - Mechanical engineering
- Other science (3)
  - Biology
  - Biochem.
  - Microbiology
  - Oceanography
- Arts, humanities, or social science (3)
  - Creative writing (with a double major)
  - Music theory and composition
  - International studies
  - Southeast Asian studies
- Informatics (2)
- Not sure (2)

Table 5. Participants' responses to question about whom they have spoken to about their academic major

People	Number of participants
Parents	9 (75.0%)
Friends	7 (58.3)
Sibling	6 (50.0)
Current or previous CS/E majors	5 (41.7)
Undergraduate adviser (in Mary Gates)	4 (33.3)
Advisor in EOP counseling center (in Schmitz Hall)	1 (8.3)
Faculty member	1 (8.3)
Graduate student	1 (8.3)
Adviser in engineering department (in Loew Hall)	0 (0.0)
Adviser in engineering advising and diversity center (in Loew Hall)	0 (0.0)
Other	0 (0.0)

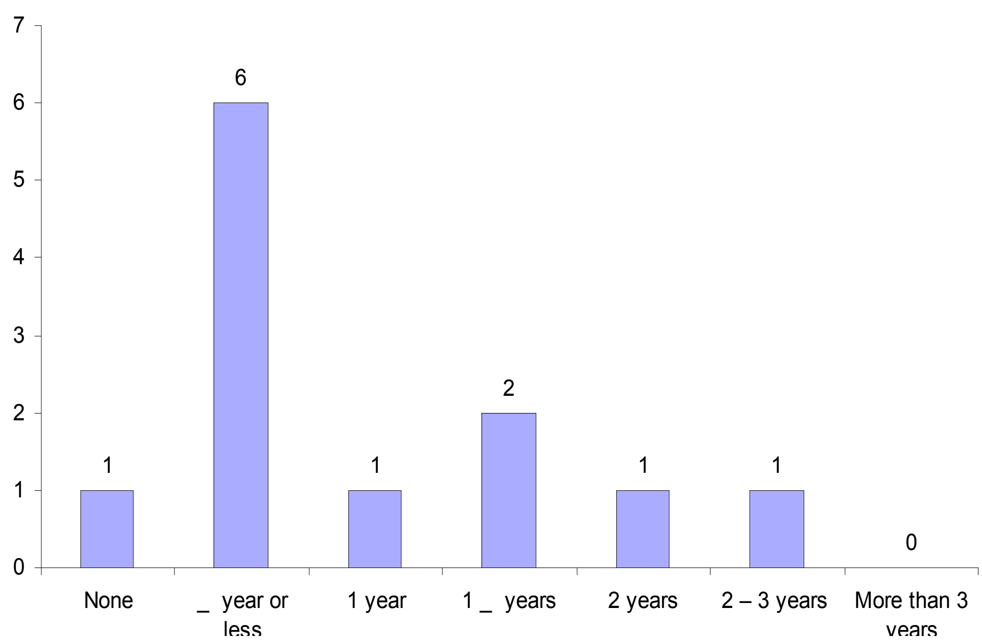

Figure 3. Responses to question about the number of years of programming experience participants had, including in- and out-of-class work

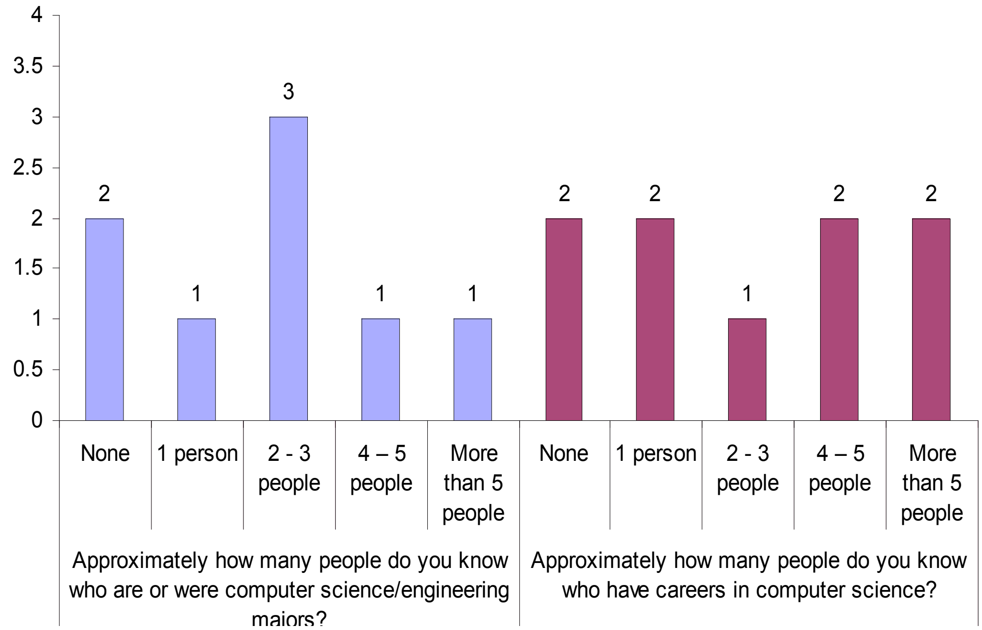

Figure 4. Participants' connections to people in the computer science field or computer science/engineering major.

Table 6. Participants' responses to question about who they know who have careers in computer science

People	Number of participants
Friend (peer)	5 (41.7%)
Parent	4 (33.3)
Family friend	4 (33.3)
Sibling	0 (0.0)
Grand-parent	0 (0.0)
Uncle or Aunt	0 (0.0)
Cousin or other relative	0 (0.0)
Other (*Mentor)*	1 (8.3)

Evaluator comments on items from pre-survey

Coming into the workshop, most participants had minimal programming experience, although four indicated they had been programming for more than one year. However, there was considerably more variance in participants' responses to the question about how many people they knew in computer science, the same number of participants indicating they knew zero or one person in the field as the number who knew four or more such individuals (see Figure 4)

During the workshop, there was some indication of this variance among participants. When the discussion turned to careers in computer science, there were several participants who repeatedly referred to knowledge they had gained from people close to them who they knew in the field. Other participants were less vocal during this part of the conversation than they were during other times of the workshop, which might indicate that they belonged to the group of participants who did not know as many people in the field of computer science.

When asked about possible sources of information about the CS/E majors at the University of Washington, most students who came into the workshop indicated they had discussed this topic with friends or parents. Only five students had talked to any advisor about the major and none had spoken with an advisor within the CS/E department. This lack of contact with CS advisor might explain why there seemed to be such a strong impact (pre- to post-) in students' reported knowledge of the major from a relatively brief presentation from a CS advisor.

Items from post-survey

Items that were included only on the post-survey focused on students' evaluation of the experience, both their satisfaction with it and their ideas about any impact of the workshop. Results from three ratings and four open-ended questions are presented below. Note that participants' responses to the open-ended questions are presented in their entirety, with additional categorization by the evaluator.

Table 7. Descriptive statistics for pre- and post- responses to items about students' evaluation of the workshop

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	SD
	1	2	3	4	5		
As a whole, I enjoyed my experience in this workshop.	0 (0.0%)	0 (0.0%)	0 (0.0%)	8 (88.9%)	1 (11.1%)	4.11	0.33
This workshop was a good use of my time.	0 (0.0)	0 (0.0)	3 (33.3)	5 (55.6)	1 (11.1)	3.78	0.67
I would recommend this workshop to my friends.	0 (0.0)	0 (0.0)	3 (33.3)	5 (55.6)	1 (11.1)	3.78	0.67

Open-ended question: How, if at all, did the workshop change the way you think about computer science?

- Expanded ideas of computer science (3)
    - There are a lot of opportunities to succeed in this area with many different options open.
    - Not change, just expand.
    - It's interesting to learn about the breadth of opportunities
- Insight into major (3)
    - I caught a glimpse of what it would be like to have a career in computer science
    - Made me more aware of the opportunities regarding a major in computer science
    - Admissions
- Insight into careers (2)
    - I understand better what would be required of me in a CS major
    - It opened my eyes to more of what CS majors do
- Did not change (1)

Open-ended question: What was the most valuable aspect of the workshop for you?

- Learning about careers (4)
    - The career paths/possibilities
    - Talking about career paths & real life work experience
    - Talking about the various aspects of the careers
    - Seeing what career options are in computer science.
- Learning about major (3)
    - the diff. between CS/CE
    - When I could ask about the UW program admission.
    - Aspects of CSE

Open-ended question: How, if at all, could this workshop be improved?

- Show more examples of career possibilities & what it would be like to work w/different types of software/hardware companies
- A little too long.
- Less intro/myths/student input
- Talk more about the UW program.
- be more interesting about CSE, different aspects of it.
- I like it.

Open-ended question: Additional comments.

- There was no intermission for bathroom break.
- thanks!
- Thumbs-up on the pizza.
- nicely done. :)
- nice guy.

Evaluator comments on items from post-survey

For the most part, participants were satisfied with their experience, with no one disagreeing nor strongly disagreeing with positive statements about the workshop. In terms of their comments about impact of the workshop, comments paralleled findings from the pre- and post-comparisons, with participants indicating that they had learned more about careers (particularly the breadth of opportunities) and the computer science/engineering majors. Participants also cited these "take-aways" as the most valuable parts of the workshop.

CONCLUSIONS AND ADDITIONAL COMMENTS

In general, student data indicate that this workshop met, at least in the immediate and short-term, its goals of increasing students' knowledge of computer science careers and the computer science/engineering major at the University of Washington. Students also seemed to be generally satisfied with the experience and found it valuable.

None of the students in this workshop had previously spoken with an advisor in the computer science department; and it is notable that although the presentation from the computer science advisor was relatively brief (approximately 15 minutes), data indicated that the discussion had impact. Students said they learned more about the computer science/engineering majors and that it was valuable to hear about them. With such minimal intervention, it might be worthwhile considering the potentially significant benefit to having a similar, brief presentation to all students enrolled in introductory computer science courses.

Given that the workshop is still in the pilot stage and that there was such a small number of students who participated in the pre- and post-surveys, it is still unclear what exactly the potential benefits of the workshop might be. Specifically, it is impossible to tell whether this workshop would have more impact for some students (i.e., those traditionally under-represented in the field) than others. It is interesting to note that before the workshop began, one female student indicated that she had seen the video from the computer science department through a society for women in engineering to which she belonged.

It is also important to note that the interview data from which this workshop was designed was generated from a non-representative sample of students. In particular, the interview sample included many more female participants than the group of workshop participants. Hence, the data indicating that some of the workshop participants might not have maintained certain "myths" about computer science coming into the workshop might simply indicate a difference in the samples of computer science students that participated in the interviews versus the workshop.

VITA

Ken Yasuhara received his A.B. in Computer Science from Dartmouth College in 1998. Attending the University of Washington for his graduate studies, he earned his M.S. in Computer Science and Engineering in 2000, advised by Larry Ruzzo and doing research in computational biology. Experience and interest in undergraduate teaching led Ken to refocus his graduate research on computer science education. Supported in large part by the Center for the Advancement for Engineering Education, he received his Ph.D. in Computer Science and Engineering in 2008, co-advised by Richard Anderson and Denise Wilson.