A Cultural Perspective on Gender Diversity in Computing[1]

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ABSTRACT

This paper presents a cultural perspective towards thinking about, and acting on, issues concerning gender and computer science and related fields. We posit and demonstrate that the notion of a gender divide in how men and women relate to computing, traditionally attributed to gender differences, is largely a result of cultural and environmental conditions. Indeed, the reasons for women entering – or not entering – the field of computer science have *little* to do with *gender* and a *lot* to do with *environment* and *culture* as well as the *perception* of the field. Appropriate outreach, education and interventions in the micro-culture can have broad impact, increasing participation in computing and creating environments where both men and women can flourish. Thus, we refute the popular notion that focusing on gender differences will enhance greater participation in computing, and propose an alternative, more constructive approach which focuses on culture. We illustrate the cultural perspective using specific case studies based in different geographical and cultural regions.

Keywords: computer science, culture, gender, environment, “Women-CS fit,” gender divide, “female-friendly,” myths, western culture, eastern culture, software engineering, software development method, agile software development.

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1. INTRODUCTION

For some time now there has been rising concern in the US and in many of the "developed" nations over the declining numbers of women entering and succeeding in computing related fields. More recently, young men have also been turning away from these fields. Indeed, we are somehow failing to attract, educate and encourage the next generations of computer scientists, men and women,[2] particularly at a time when computing technology is becoming even more integral to our scientific, economic and social infrastructure. Increased attention to declining numbers has brought a much needed re-examination of these fields and how they are perceived in the public consciousness. At the same time it has highlighted common grounds of concern [Morris and Lee, 2004]. The situation presents an ideal opportunity for broadening the scope of how we account for determinants of participation—or lack of participation—in computing related fields.

This paper presents a cultural perspective towards thinking about, and acting on, issues concerning women and computer science (CS) and related fields. We posit and demonstrate that the notion of a gender divide in how men and women relate to computing, traditionally attributed to gender differences, is largely a result of cultural and environmental conditions. We illustrate that under specific cultural and environmental situations, women fit very well into CS. Indeed, where cultural conditions *allow for* diversity, and where women are perceived as capable of doing computer science (or any science), the "Women-CS fit" is visible and active [Adams et. al., 2003; Schinzel 2002; Vashti, 2002; Eidelman, 2005]. The implications are that women do not need handholding or a "female friendly" curriculum in order for them to enter and be successful in CS or related fields, nor is there need to change the fields to suit women. To the contrary, curricular changes, for example, based on presumed gender differences can be misguided, particularly if they do not provide the skills and depth needed to succeed and lead in the field. Such changes will only serve to reinforce, even perpetuate,

[2] The 2004-2005 CRA Taulbee Survey reports that the number of new undergraduate CS majors in the US dropped by more than 30% since 2001-2002 [Zweben, 2006]. Even more alarming, according to the UCLA/HERI survey, the percentage of incoming undergraduates among all degree-granting institutions who indicated they would major in CS declined by 70% between fall 2000 and 2005 [Vegso, 2005].

stereotypes and promote further marginalization.[3]

Here we share findings (in Sections 3 and 4) from specific case studies that illustrate culture and environment as determinants in participation in CS and ask: a) How can such knowledge best be used? and b) Can such discussions lead us away from the gender differences debates (which seem to be going round in circles), and open the way for more productive directions?

We argue that our understanding and experience with successful interventions that promote micro-cultural change have broad implications for increasing participation in computing and for creating environments where both men and women can flourish.

At the same time, it is also important to recognize the crucial role played by the public's perception and misconception of CS in attracting (or not) students to the field. For the most part, CS has been equated with programming, particularly in the US. This is largely due to the dearth of pre or entry level college/university curricula that present the depth and breadth of computer science and computational thinking. While curricula and perception are not the focus of this paper, we have also been working to develop curricular materials, teacher training programs and outreach efforts to broaden and correct the image of what computer science is and who computer scientists are [Blum and Frieze, 2005b; Frieze and Treat, 2005].

In discussions about participation in CS and related fields, there is often ambiguity about what fields we are actually talking about. This is not surprising, because of the newness and interdisciplinary nature of the fields and the changing and expanding boundaries.[4] But it can lead to confusion, particularly when data and findings about (and programs to increase) participation in "computer science" is sometimes used interchangeably with like data about "information technology" (IT). While many of the issues are similar, not all

[3] We note that recent conferences on gender and IT have also brought culture to the foreground, indicating a timely momentum for our perspective. Examples of such conferences include "Women and ICT: Creating Global Transformation," Baltimore, USA, June 2005 and "Crossing Cultures, Changing Lives: Integrating Research on Girls' Choices in IT Careers" Oxford, England, July/August 2005.

[4] For example, the Carnegie Mellon School of Computer Science (SCS) is comprised of seven interrelated departments. In addition to "core" CS, these departments include robotics, software engineering, human computer interaction, language technologies, machine learning and entertainment technology.

are and the fields they refer to are not the same. The National Center for Women and IT (NCWIT) defines[5] IT broadly as: "1) all forms of technology used to create, store, exchange and use information in its various forms; and 2) the design and use of computers and communications to improve the way we live, learn, work and play." Computer scientists might or might not agree that this includes "computer science."[6] For example, computer scientists who work in the more theoretical and foundational aspects of computer science—such as complexity theory or the theory of computation—might not agree that their work is included in the definition of IT. Other computer scientists might think that areas often considered as IT, such as managing information in large corporations, are far removed from core CS. We do not attempt to resolve this debate, but instead, we clarify that the case studies presented here (in Sections 3 and 4) would mostly be considered within the realm of what might be called *traditional* computer science.

Our first case study looks at *undergraduates majoring in computer science at Carnegie Mellon University in the USA.* We show that as the environment has become more balanced, the culture of computing has changed in such a way that both men and women can thrive. Thus, under specific changes in the micro-culture, the gender divide is shown to dissolve with students presenting a spectrum of relationships to computing [Blum and Frieze, 2005a,b]. Our second case study shows how *the agile approach for software development* [Cockburn, 2001], which is becoming more and more predominant in the software industry, allows for a situation in which both men and women are equally communicative and more effective [Hazzan and Dubinsky, 2006]. Finally, we illustrate how certain Eastern micro-cultures highlight the "Women-CS fit." We hope these illustrations suggest both new perspectives and avenues for further exploration.

[5] See: http://www.ncwit.org/Prospectus.pdf.

[6] Herbert Simon defined computer science as "the theory and design of computers, as well as the phenomena arising from them." The Wikipedia is a source of various views of the fields (http://en.wikipedia.org/wiki/Computer_science): "Computer science rarely refers to the study of computers themselves. The renowned computer scientist Edsger Dijkstra is often quoted as saying, 'Computer science is no more about computers than astronomy is about telescopes.' The study of computer hardware is usually called computer engineering, and the study of commercial computer systems and their deployment is often called information technology or information systems."

2. CULTURE AND GENDER: THE DYNAMICS AND DISTINCTIONS

With respect to all our case studies, we explore *cultural factors*, acknowledging that *culture* is a very complex concept and the term is open to various interpretations. Here we are using the term *culture* to refer to the complex and broad set of relationships, values, attitudes and behaviors (along with the micro-cultures and counter-cultures that also may exist) that bind a specific community consciously and unconsciously. Our definition posits that culture is bound by context and history and that we are born into specific cultures with prevailing values and structures of opportunity.

But culture, like history, *allows for change.* Culture is dynamic, *shaping and being shaped by those who occupy it*, in a synergistic diffusive process. Indeed, while a dominant culture may embrace and influence a community, counter or micro-cultures may exhibit unexpected features. As individuals, and/or as groups, we contribute to culture(s) in different ways to different degrees, and are impacted by culture(s) in different ways to different degrees. In this sense we view culture, and cultural occupants, as agents of change, and environments as appropriate sites for interventions and opportunities.

In this paper, therefore, we propose moving away from discussing gender issues towards talking about *cultural issues*. This raises an obvious but interesting point: *Isn't gender a cultural issue?* Here we try to explain the distinction and why our suggestion to focus on culture is a more pragmatic and positive move.

First, we should explain that we are using the term *gender* to refer, in addition to biology, to the roles, behaviors, attitudes, etc., attributed to men and women as they are born into specific cultures and moments in history. Thus, our working definition of gender embraces the complex dynamics of both natural and cultural factors and influences. At the same time we suggest that the gender differences arguments, like the nature/nurture debates, serve to perpetuate a model of oppositional thinking, a model which begins and ends with dividing men and women, rather than looking at the dynamics of diversity and the common ground they may reveal. Even more, programs designed to "accommodate" presumed gender differences can promote further marginalization.

We suggest a need to escape self-limiting categories and convey the message that gender issues are really cultural issues that concern us all. The discourse of culture tends to be more inclusive, not only for examining gender issues but also issues of race and class. In terms of gender issues, "thinking culturally" means thinking that embraces gender similarities and intra-gender differences. We suggest that "thinking culturally" *broadens* the scope for examining inequities in the light of other models of possibilities while also serving to *focus* our attention on the factors at work in specific environments. In this way, gender issues are not reduced to a simplistic oppositional model which pits men against women and vice versa. Examining gender within the larger, or even localized, parameters of culture can help re-invigorate our research as we learn from other cultures, and share approaches and models of effective practices.

A particularly significant way in which gender issues have become self-limiting lies in the popularity and dominance of theories of gender "differences" which are used indiscriminately to account for our behaviors and attitudes. We have observed that research on gender and CS tends to be driven by the search for gender *differences*. Indeed, a crucial component of NSF funding criteria for gender studies has been to find such differences.[7] Barrie Thorne long ago pointed out the potential for flawed findings inherent in this model when "the strategy of contrast is often built into the research" [Thorne, 1993]. She explains how many studies begin by separating boys and girls into single sex groups and proceed by working with each group separately to find differences, differences which then are attributed to gender. This is just one of the many ways in which gender issues, driven by the search for gender differences, can become self-limiting, self-sustaining and self-fulfilling.

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[7] The synopsis of the NSF program, "EHR: Research on Gender in Science and Engineering" illustrates this point: "Typical projects will contribute to the knowledge base addressing gender-related differences in learning and in the educational experiences" (http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5475). The goals of the program include: "To discover and describe gender-based differences and preferences in learning science and mathematics" (http://www.nsf.gov/pubs/2005/nsf05614/nsf05614.htm).

We need to pay close attention and be wary of attributing differences to gender when they are the outcome of cultural and environmental factors. The significance of this is illustrated in the section of this paper on CS undergraduates (Section 3.1) where we note that most studies on gender and CS have been conducted in situations where, by default, there are *very few* girls and women. Findings from such studies have often revealed strong gender differences. In contrast, we show that such "differences" tend to dissolve and gender similarities emerge when the environment becomes "more balanced." Our findings illustrate Rosabeth Kanter's argument that "(w)hen men and women are in similar situations, operating under similar expectations, they tend to behave in similar ways" [Kanter, 1977, p.312]. Echoing this perspective, Cynthia Fuchs Epstein advocates the "structural approach [which] looks at the ways in which factors external to the individual explain even those attributes ordinarily regarded as wholly internal, such as motivation and aspiration" [Epstein, 1990, p.100]. As she points out, the structural approach is critical to counter a trend in social science research "to find support and justification for gender distinctions and inequality rather than locate the sources of these distinctions and understand the dynamics. In this sense, scientists have also been active agents in perpetuating distinctions based on mainstream viewpoints" [Epstein, 1990, p.4].

A related concern for keeping culture in the foreground of our discussions, and our thinking, is to raise awareness of how easily we buy into *myths* about gender differences. In the book, *Same Difference: How Gender Myths Are Hurting Our Relationships, Our Children, and Our Jobs* [Barnett and Rivers, 2004], the title of the first chapter, "The Seduction of Difference," caught our attention. Gender differences are indeed seductive in that they form so much of the exciting, fun and attractive dynamics of relationships, as well as fueling our fires as we argue for fairness and against inequity. Yet, as authors Barnett and Rivers point out, *so many of these "differences" turn out to be myths.* Boys and girls (and men and women) may well act differently because of the *cultural messages* they have received and taken on board. The danger of the seduction of difference lies in closing our eyes to gender similarities, to cross-gender dynamics, and to recognizing "that people's behavior today is determined more by situation than by gender" [Barnett and Rivers, 2004]. Gender myths based on differences are also easy to buy into since they feed on stereotypes; in addition, based on limited experiences, they seem to ring true on many levels.

Like Barnett and Rivers, other researchers have questioned the dominance of theories of gender differences by "going back to the data" and noting that much of it is misinterpreted, amplifying differences and ignoring gender similarities. Diane Halpern's review of math and cognitive tests led her to conclude that any differences in boys' and girls' cognitive skills are so small as to be insignificant [Halpern, 2000]. Janet Shibley Hyde's extensive meta-analysis of psychological gender differences led her to write "The Gender Similarities Hypothesis" in which she affirms "men and women, as well as boys and girls, are more alike than they are different" [Hyde, 2005, p.581]. Hyde also reminds us of the important effects of timing and context. Test results can "fluctuate with age" and vary "creating or erasing gender differences in math performance" when test takers have preconceived views on the outcome of their performance [Hyde, 2005, p.588-9].

Clearly, as our approach suggests, we need to look beyond gender to account for differences in the experiences and perspectives of men and women. "It is time to consider the costs of over-inflated claims of gender differences. Arguably, they cause harm in numerous realms, including women's opportunities in the workplace. ... Most important, these claims are not consistent with the scientific data" [Hyde, 2005, p. 590].

We illustrate gender myths further in our section on software engineering and the practice of *collaboration* (Section 3.2). It has been suggested that collaboration fits "women's style" because women are more communicative. However, the agile approach for software engineering, which promotes communication and gives rise to collaboration, was designed to improve software development in general, not to suit "women's style." The agile approach provides us with an example of work practices which allow for both men and women to be successful. The example also serves to show that the "style" attributed to women is actually a style developed within the culture of the software development industry which is currently male dominated.

With regards to the larger cultural picture illustrated in our section on Eastern cultures, there is ample evidence to show that "gender distribution (in CS) is culturally diversified" [Schinzel, 2002]. The work of Adams, *et al.*, showed that on the tiny island of Mauritius, women were entering and graduating in computing related fields at rates comparable to their proportion in the general population [Adams *et al.*, 2003]. The same appears to be the case in Malaysia [Othman and Latih, 2006]. Britta Schinzel has looked at female enrollment in CS around the world and notes a multiplicity of reasons that account for higher and lower rates of female participation. She describes how in countries with good gender distribution in computing like India, Brazil, and Argentina, "there seems to be no conviction like in the Northwest stereotyping women as less capable of pursuing education in science and technology." In the North African and Arabic countries where there is an "extremely high participation of women in CS," she highlights the fact that there is "no coeducation at any level of education in these countries" [Schinzel, 2002, p. 10].

In the US, a study by Antonio Lopez and Lisa Schultz looked at African American students of CS in Historically Black Colleges and Universities (HBCUs) and in non-HCBUs during the period 1989-97. They found that at HBCUs, consistently more African American females were awarded bachelor's degrees in CS than their male counterparts, while the opposite was true for African Americans (as well as for non African Americans) at non-HBCUs. They concluded: "For African American females, this might suggest that being awarded a bachelor's degree in computer science has less to do with gender differences and more to do with cultural factors" [Lopez and Schultze, 2002].

There seems to be no single theory that covers all cases, nor should we expect to find one when the variables are so numerous, but what these studies reveal is a multitude of complex cultural factors—some specific and some more general—playing a significant role. "While the problem is wide-spread, the under-representation of women in computer science is not a universal problem. It is a problem confined to specific countries and cultures" [Adams *et al.*, 2003, p. 59].

Thus we argue that *yes – gender is a cultural issue* – but gender should be approached through culture. The arguments we make cannot be contained within the umbrella of "gender" or the framework of gender differences. Barrie Thorne points out the need "to develop concepts that will help us grasp the diversity, overlap, contradictions, and ambiguities in the larger cultural fields in which gender relations, and the dynamics of power, are constructed" [Thorne, 1993, p. 108]. We propose that thinking about culture, whether of geographical magnitude or a localized micro-culture, can embrace such concepts, and remind us of the wealth of evidence relating to culture as determinants of how we perceive and experience the world around us. Ultimately we suggest that the reasons for women entering – or not entering – the field of computer science have *little* to do with *gender* and a *lot* to do with *culture*.

3. CASE STUDIES: WESTERN CULTURES

In this section we examine how a micro-culture within an academic CS department in the USA has evolved. We also look at the agile sub-culture within the software development industry. In each case we discuss the cultural factors that allow for the "Women-CS fit" to present itself. In the next section (Section 4) we discuss two cases within Eastern cultures.

3.1. Case Study 1: Undergraduate CS at Carnegie Mellon University

This case study is based on the work of Blum and Frieze [2005a,b] at Carnegie Mellon University in Pittsburgh and illustrates how women's (and men's) relationship to computing is shaped by the ambient micro-culture. Specifically, this case study illustrates the evolvement of a computing culture—and its synergistic impact—as the environment shifted from an *unbalanced* to a more *balanced environment* in three critical domains: 1) gender, 2) the range of student personalities and interests, and 3) professional support afforded to all students.

Prior to 1999, the undergraduate CS environment at Carnegie Mellon was *unbalanced* in these domains. Indeed, in the mid-1990's less than 10% of the undergraduate CS students were women. The admissions policies, as well as the culture of computing at that time, supported a specific type of (male) student, in particular those who had exhibited great programming proclivity. And women students, being in the minority, did not have access to the various informal professional support systems available to the majority male students.

Early research, conducted by Margolis and Fisher during 1995-1999, which examined the perspectives of this specific student body, found a gender divide in the way men and women related to computer science [Margolis and Fisher, 2002]. The core of the divide, in particular their findings that women wanted to do useful things with computing while men liked to focus on programming and the machine itself, was summarized by Margolis and Fisher as "computing with a purpose" and "dreaming in code," respectively.[8] They also found that women's confidence was extremely low (even "extinguished"). Not surprisingly, women *in their cohort* felt they did not fit into the computing culture. Not surprisingly, given that most undergraduate computing environments were similar to that of Carnegie Mellon's in the 1990's, these findings rang true with many in the CS community.

By the fall of 1999 new admissions criteria were in place at Carnegie Mellon that de-emphasized prior programming experience[9] while at the same time placed more emphasis on breadth and leadership promise[10] (without reducing the high academic criteria). This allowed for diversity in the student body, in particular an increase in the numbers of women[11] and an increase in the numbers of students with broad interests, both men and

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[8] These findings led Margolis and Fisher to recommend a female friendly/contextual approach to revamping the CS curriculum [Margolis and Fisher, 2002]. Our findings lead us to question such a recommendation. Whether or not it is a good idea to incorporate applications into a particular course should depend on whether it makes sense for the subject matter, for the intellectual and technical skills to be developed, and/or for pedagogical purposes, not as a presumed means to promote gender equity [Blum and Frieze, 2005a,b].

[9] This was an important pragmatic consequence of the Margolis and Fisher finding that the amount of prior programming experience did not affect graduation rates.

[10] Raj Reddy, then Dean of the School of Computer Science, asked the undergraduate Admissions Office to develop criteria that would select for future leaders and visionaries in the field. One subsequent criterion gave value to "evidence of giving back to the community."

[11] See [Blum, 2004], [Margolis and Fisher, 2002] and [Blum and Frieze, 2005a,b] for fuller details on the key factors that resulted in the change in the undergraduate CS population at Carnegie Mellon. A particularly key factor was a series of workshops held on the university campus for high school teachers of Advanced Placement CS, funded by the National Science Foundation. These workshops ran for three summers during the late 1990's and integrated discussions about women and CS along with technical CS

women. It is important to note that the Carnegie Mellon CS academic curriculum *was not adapted* to become “female-friendly,” and in fact continues to be one of the most rigorous CS programs in the USA.

Subsequently, the student body became more balanced in terms of gender and in terms of students with a broader range of interests. In 1999, the organization Women@SCS[12] was established to formalize a program of professional, networking, and mentoring opportunities for women. In this way female students were formally provided with those opportunities that had been available naturally for the majority (male) students [Frieze and Blum, 2002]. Thus, the environment became more balanced in the three critical domains.

A primary reason to establish Women@SCS was to provide a structure that would help ensure the retention and success of our new undergraduate student body. At the same time, impetus came from our women graduate students’ perceived need for community; already they had initiated “pot-luck” dinners and get togethers with women faculty.

It is important to emphasize that Women@SCS has evolved *not* as a “handholding” support group*, but rather as an action oriented organization in which women have taken leadership roles that have enhanced the entire CS community.* We emphasize further:

Women@SCS explicitly provides crucial educational and professional experiences generally taken for granted by the majority in the community, but typically not available

training. Indeed, without such focused outreach, it would be hard to buck downward national trends of dramatic declines in computer science enrollments [Camp, 1997; Vegso, 2005; Zweben, 2006]. Support (including funds) for teachers to participate in such programs is crucial. Unfortunately, for a number of years, government support for these important “hands-on” workshops has not been as forthcoming.

Based on our belief that the reasons for under-representation in CS are very much the same as the reasons for the huge decline in interest in the field generally, in the summer of 2006 with support from Google, Carnegie Mellon sponsored a pilot workshop for high school CS teachers (CS4HS) that focused on computational thinking [Wing, 2006] and changing the image of what computer science is, and who computer scientists are [Frieze and Treat, 2006]. Currently, we are working to expand this program nationally and internationally. (See: http://www.cs.cmu.edu/cs4hs.)

[12] Women@SCS is an organization of undergraduate and graduate students, and faculty, in Carnegie Mellon’s School of Computer Science (SCS), working on-campus and off-campus to create, encourage, and support women’s academic, social and professional opportunities in the computer sciences and to promote the breadth of the field and its diverse community. The Women@SCS program of activities is designed and implemented by an informal Advisory Council made up of core Women@SCS members. Women@SCS also runs an informative website: http://women.cs.cmu.edu/.

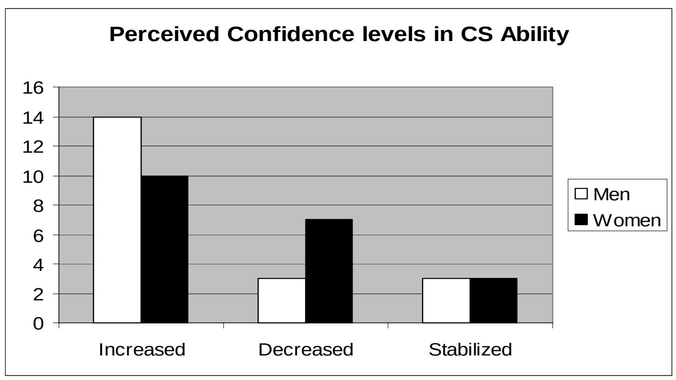
for the minority participants. Many of these experiences are casual and often happen in social settings. For example, in an undergraduate CS program, male students often have the opportunity to discuss homework with roommates and friends late at night or over meals. Course and job information and recommendations are passed down from upperclassmen, from fraternity files and from friends. Women students being in the minority, do not have access to, in fact are often excluded from, these implicit and important advantages. As one proceeds into the professional world, similar phenomena occur [Blum and Frieze, 2005a,b].

These changes in the “local environment” in a few short years have provided us an opportunity to examine how men and women relate to CS in a more balanced situation and to compare with earlier studies.

Here we illustrate this shift with our most recent data collected from interviews with the senior class of 2004, a class which consisted of 156 students, 104 men and 52 women. The methodology for interviewing the seniors began by generating randomized lists of men and of women using a computer program. The first 25 male students and the first 25 women students were invited to interview. When students did not respond (after two or three invitations) the next group from the random list was invited. Eventually 55 seniors, 23 men and 32 women (including all 12 senior active members of Women@SCS) were interviewed. We took a random group of 20 men and a random group of 20 women (which included 5 of the active 12 Women@SCS members) to arrive at our cohort for the data presented in Figures 1, 2 and 3. These figures point to some post-1999 specific changes with regard to *confidence levels* and *perspectives on programming*. Figure 4 uses data from a general student survey to illustrate the post-1999 change in students’ *sense of fitting in*.

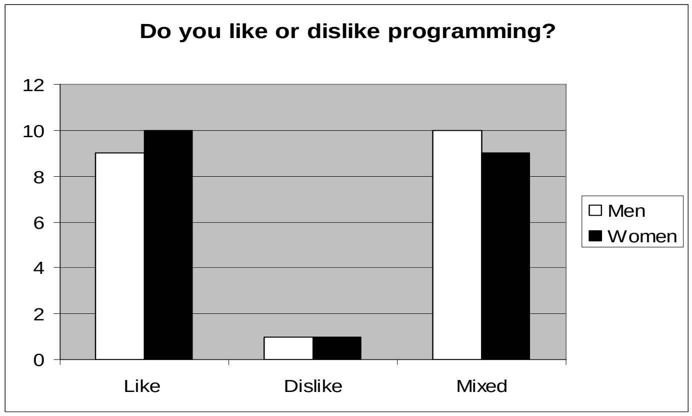
Confidence Levels: In our 2004 studies we found that while men were still reporting higher confidence levels than women, most women in our cohort reported an increase in their confidence levels. The confidence gap had narrowed significantly (see Figure 1). Students, men and women, stated that although their confidence increased overall, levels varied greatly over the years, depending on the classes they were taking. Several students, 3 men and 3 women, said their confidence had fluctuated or remained stable, or as this woman says, it can do both: “It’s probably remained about the same actually. I was pretty confident coming in and I’m pretty confident now, in between it has gone up and down.” We categorized this group under “stabilized.” One woman in the class of 2004 acknowledges “bumps along the road, but overall I think I’m pretty happy with the way it went.” Another woman in that class gives a roadmap for her increased confidence: “Once you start working on different projects or having more projects under your belt you just feel a little better. ... Public speaking and having a more professional front is all part of it. And joining a group like Women@SCS really helps because there are plenty of chances to speak, talk and I think just growing more as an individual” [Blum and Frieze, 2005a,b].

Figure 1. Increase/Decrease in Confidence Levels



Attitudes to Programming: Perhaps one of the strongest illustrations of emerging similarities and the Women-CS fit is found in the data relating to programming. Our randomly selected cohort of 20 men and 20 women were specifically asked about their attitudes towards programming. In answer to the question, “Do you like or dislike programming?,” the responses from students revealed some striking similarities with 10 women and 9 men saying they liked programming, while just one man and one woman saying they disliked programming (see Figure 2).

Figure 2. Liking or Disliking Programming



One woman explains her attachment to coding: “I like programming. I guess it’s also this kind of instant gratification feeling again where if you can code something and then just clicking that one button and seeing it actually happen right there it just kind of okay wow I got that to (work) .. the feedback that you get that quickly is what I like about it. And then there’s all this problem solving skill that you have to go through, and if you can do that yourself and by coding it you prove to yourself that you could do it, that you could solve the problem. I think that’s what I like about it.” This man shows a similar attachment: “I love programming, very much ….in programming you are limited by the time you spend, not the computer. And, so I like that sort of fast feedback and being able to see things immediately.”

Initially, we sorted the responses into two main categories, “like” and dislike,” but it soon became clear that this was an oversimplification; indeed it was quite obvious that a third category had emerged, a category in which the responses were “mixed.”

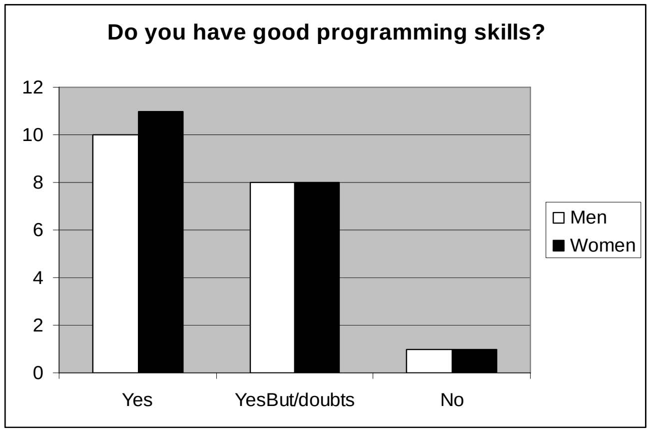
The “mixed” category is particularly interesting in that it shows the limitations of a simple oppositional yes/no answer. Gender similarities emerged again with 9 women and 10 men providing thoughtful, mixed responses as they tried to explain the complexity of their views. This woman answered “a little bit of both” while this man said “I have to say I’m kind of in the middle.” Another woman pointed out “I like higher level programming … (but) I dislike systems level programming, so it’s a mixed bag”; this man also qualified his response “I think it more depends on actually what I’m programming. It depends on the language and the field that it's being applied in …so, yes, I like programming in some cases, but not for everything."

Answers to the question of liking or disliking programming revealed a spectrum of attitudes which cut across gender and many students *qualified* their attitudes. Thus, liking and/or disliking programming was determined by a variety of factors, primarily what kind of programming was involved, what the purpose of the programming was, and the number of hours spent actually programming. While most students in this cohort say they like programming, or have mixed responses, most do not see themselves with future careers focused solely on programming. As one woman in the class of 2004 put it, "I enjoy programming. … I really like it. I guess I don't really enjoy it on a daily basis, for example if I had to do it 50 hours a week I don't think I would enjoy myself."

The findings illustrated in Figures 1 and 2 led us to look at the correlation between confidence and programming skills.

Confidence and Programming Skills: When asked if they had the skills for good programming, this same cohort of women and men reported a set of very similar skill factors: you have to be well-organized and able to think ahead; you need good problem-solving skills; you need to be able to think logically and analytically and, have lots of patience. Women reported slightly ahead of men, 11 and 10 respectively, in rating they had good programming skills (see Figure 3). This woman suggests that good programming skills develop with increased experience: "as you get more exposure to programming it's impossible not to develop these skills." Once more an interesting category emerged as we tried to understand the complexity of students' answers. This category, which we called "YesBut/doubts," covered a range of attitudes in which students either qualified their sense of having good skills with comments like "yes, to an extent," or expressed some doubts saying such things as "I did at some point." Again a strong gender similarity emerged with 8 men and 8 women falling into this middle ground category.

Figure 3. Rating of Programming Skills



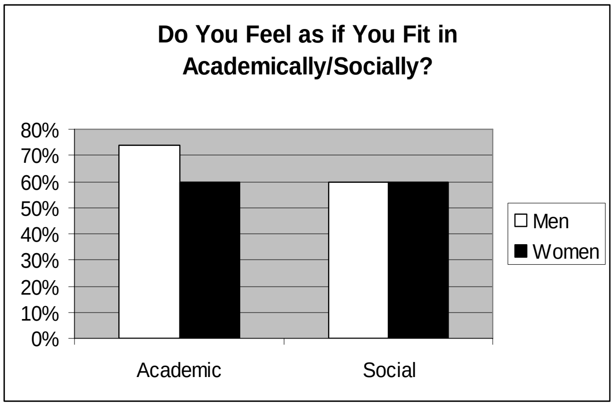
Clearly, this cohort of women shows a high level of confidence when it comes to programming skills; and strong gender similarities emerged in all categories.

At the same time, almost all students, men and women, reported programming as one part of their CS interests and the computer as a "tool" for their primary focus which often was applications. The image of "dreaming in code" as the dominant characteristic of male CS students and "computing with a purpose" as a primary focus for women were clearly being challenged. As one woman in the class of 2004 put it, "It's always fun to sit down in front of a computer and kind of producing code until something is done and it's such a good feeling. A lot of time once I sit down and do programming I find myself living in the cluster for a day without eating or sleeping." A male student showed his interest in the applications of programming: "I like programming. I think it's a good tool to reach an end. But I mean, on that note, I don't like programming just for the sake of programming … if I'm not interested in what the ultimate goal is, then I don't like programming." When students were asked to define CS, one of the predominant responses overall was "problem solving" and "a way of thinking." As one women in the class of 2004 put it, "I look at computer science as a sort of logic-based way to solve problems" [Blum and Frieze, 2005a,b].

These findings suggest that any gender divide in how students relate to CS, particularly with respect to programming vs. applications, is not a product of gender but rather a product of micro-cultural and environmental conditions.

Sense of Fitting In: The data for assessing students' sense of fitting in was collected during the academic year 2004-2005 as part of a CREU[13] project [Frieze, Chang and Fan, 2005]. Figure 4 below represents survey responses from 88 sophomores through seniors (60 men and 28 women). The surveys showed that in this cohort, both men and women claimed to feel they fit in well *both academically and socially*.

Figure 4. Sense of Fitting In After Freshmen Year



These findings indicate a marked change from the earlier studies at Carnegie Mellon [Margolis and Fisher, 2002]. Indeed, the early studies showed that in the pre-1999 atmosphere, women did not feel comfortable, academically or socially, while male students were found to have great camaraderie and, by virtue of their programming strengths, could perform well academically.

Furthermore, in contrast to the early Carnegie Mellon studies, and others that have been conducted in situations where there have been *very few* girls and women, *our findings show a similar spectrum of attitudes and attachments amongst women and men rather than a gender divide.* We argue: the experiences and perspectives of the women in these other studies were in part shaped by their minority, and sometimes token, status rather than by gender. To borrow Kanter's analysis of men and women (from the Indsco corporation) we might say, "It was rarity and scarcity, rather than femaleness *per se*, that shaped the environment for women in the [departments] mostly populated by men"

[13] The Collaborative Research Experience for Undergraduates in Computer Science and Engineering (CREU) Program is sponsored by the Computing Research Association's Committee on the Status of Women (CRA-W). See: http://www.cra.org/Activities/craw/creu/.

[Kanter 1977, p.207]. Likewise, our findings serve to confirm the importance of micro-culture and environment as significant contributors to student perspectives on computing.

Our conclusion here is that the observed gender differences from the 1995-1999 study tell more about the *biases in the former admissions criteria* into the CS program at Carnegie Mellon and, a narrow conception of the undergraduate program, rather than significant or intrinsic gender differences in potential computer scientists. During the latter half of the 1990's, the undergraduate CS program fed primarily into the booming high tech industry, thus the high school computer "geek" had a definite admissions advantage. Women and men with potential to become computer science leaders, but without long-standing programming experience or commitment, had little chance. The very few women who managed to get in had exceptional academic records. It is worth noting, that the identification of programming with computer science is mostly a late twentieth century phase in the field, one that unfortunately persists in the public's mind. Very few of the pioneers and current professors of computer science were "hackers." Many were motivated by their interest in logic and in understanding intelligence and problem solving. Today, in the twenty first century, with the increasing ubiquity of computing, women and men with this broader and deeper perspective are critical for the field and will drive its future [Blum and Frieze, 2005a,b].

3.2. Case Study 2: The Agile Software Development

This case study illustrates how the culture inspired by *agile software development* [Cockburn, 2001] enables women to gain new and better positions in the high-tech industry in general, and in software development teams, in particular.

During the 1990's, the agile approach towards software development started to emerge in response to problems in the software industry. Specifically, the agile software development approach, composed of several methods, formalizes software development methods which aim at overcoming characteristic problems of software projects [Highsmith, 2002]. The "Manifesto for Agile Software Development" (http://agilemanifesto.org/) appears in Table 1.

Table 1: Manifesto for Agile Software Development

We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value:

- **Individuals and interactions** over processes and tools
- **Working software** over comprehensive documentation
- **Customer collaboration** over contract negotiation
- **Responding to change** over following a plan

That is, while there is value in the items on the right, we value the items on the left more.

The agile approach reflects the notion that development environments should support communication and information sharing, in addition to heavy testing, short releases, customer satisfaction, and sustainable work-pace for all individuals involved. Recent managerial research studies attribute similar characteristics to "women's management style" Here are two examples from the literature (*italics* ours).[14]

- "Women's style of management is based on sharing power, on inclusion, consultation, consensus, and *collaboration*. Women work *interactively and swap information* more freely than men do. Women managers encourage their employees by *listening to, supporting, and encouraging* them" [Fisher, 1999, p. 32].
- "Recent research indicates women's management style, which is centered on *communication* and *building positive relationships*, is well suited to the leadership paradigm of the 90's" [Peters, 2003].

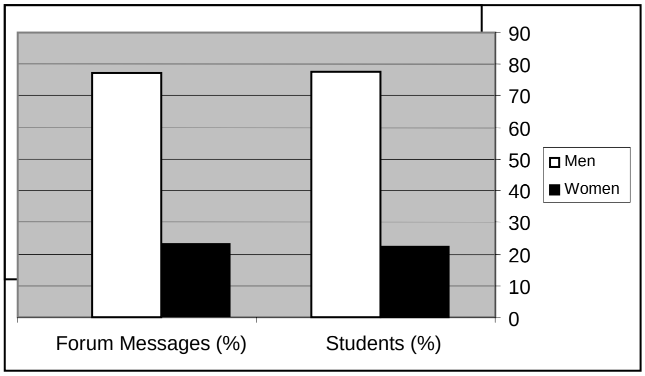
As the following data shows, agile software development environments can enable women's equal participation in agile teams. This data was gathered by observing a project-based operating-systems course in the Computer Science Department of the Technion-Israel Institute of Technology [Dubinsky and Hazzan, 2005]. The agile method

[14] We note that these quotes about women's management style further highlight the tendency to investigate gender differences – in this case with respect to management style. Moreover we note that these observations were found in a culture in which women are in a minority in management positions. But we also note that many attributions of "women's style," such as the ones highlighted in the quotes, are ones that men employ to advantage as well. The agile software development environment discussed here provides one such example.

has been used in this course since the summer semester 2002 by four teams of 10-12 students each semester. Each team is guided by an academic coach.

An examination of the communicative behavior of 294 students, who worked according to the agile method during eight semesters in 27 different groups, reveals that females are equally communicative in this setting. For example, when the communicative behavior was measured by monitoring the electronic forum used by students in the course, it was observed that the percentage of messages sent by females (22.8% or 1391 out of 6093) was essentially the same as the percentage of females in the cohort (22.4% or 66 out of 294). See Figure 5.

Figure 5: Men and Women's Communicative Behavior in Agile Teams



Based on this analysis, as well as additional findings [Hazzan and Dubinsky, 2006], it is suggested that the agile method reflects a "Women-CS Fit." For example, in addition to being a software developer in the team, each student plays an auxiliary role on their team such as coach, tracker, customer, etc. Roles are distributed uniformly amongst males and females, which in turn, reinforced the female students' voice in these teams.

In summary, this case study briefly illustrates how the agile approach towards software development, *formulated to address problems in the software industry* and *not in order to meet women's needs*, creates an environment in which women and men behave similarly to the benefit of all.

4. CASE STUDIES: EASTERN CULTURES

The two case studies presented in the previous section illustrate how subcultures can counter prevailing trends in their broader (Western) culture and demonstrate the "Women-CS fit." In this section we briefly consider two cases that show similar phenomenon within Eastern cultures.

4.1. Case Study 3: Israeli High School Advanced Placement CS Classes

Our main case study within an Eastern culture focuses on Jewish and Arab *Israeli high school Advanced Placement (AP) CS classes*. Most Jewish and Arab students in Israel attend separate educational systems with similar curricula in most subjects. Specifically, the AP CS classes are all coed, the syllabus is identical in both systems and the only differences are in the teaching language and the language of the matriculation exam.

Eidelman and Hazzan [2005] studied a population of 146 12th grade AP CS students from 9 typical high schools from both sectors (5 schools from the Jewish sector, 4 schools from Arab sector).[15] In the Jewish sector, 25 of the 90 AP CS students (i.e., 28%) were female; in the Arab sector, 34 of the 56 students (i.e., 61%) were female. That is, while female high school students in the Jewish sector are *under represented* in AP CS classes, they are *highly represented* in the Arab sector.

We focus here on the cultural factor 'support and encouragement' which is one explanation for the difference in the participation of female students in the two sectors [Eidelman and Hazzan, 2005]. One of the questions students were asked was: "Who encouraged you to choose computer science studies?" Figure 6 presents the distribution of the answers to this question.

[15] The gender mix in both Jewish and Arab high schools is about 50%-50%. See, e.g., data from the Israeli Central Bureau of Statistics: http://www1.cbs.gov.il/shnaton56/st08_19x.pdf.

Figure 6. Percentages of Females' Encouragement by Others

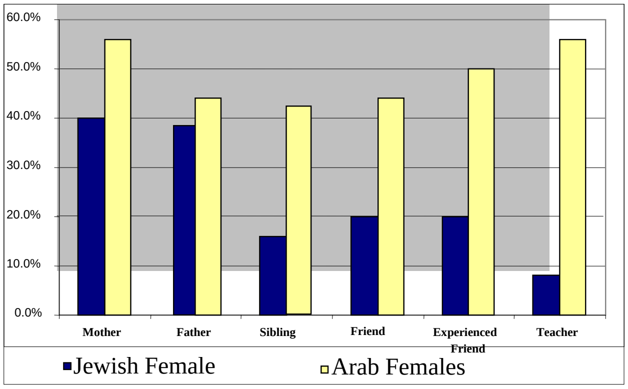


Figure 6 reflects an unequivocal conclusion: Arab female high school students receive much more encouragement to choose CS than do their Jewish counterparts. Specifically, Arab female high school students are encouraged more by their mothers (56% vs. 40%), fathers (44% vs. 40%), siblings (44% vs. 16%), friends (44% vs. 20%), acquaintances who had studied CS (50% vs. 20%) and – with the greatest difference – by their teachers (56% vs. 8%). This broad based network of encouragement that the Arab female students receive is supported by additional data [see Eidelman and Hazzan, 2005].

The noticeable differences in the extent of encouragement Arab female students receive from various agents can be explained by looking at findings from other studies that have explored *cultural and familial* differences between Arab and Jewish adolescents [Peleg-Popko, Klingman; Abu-Hanna Nahhas, 2003]. According to these studies, since Arab students are part of an Eastern collective culture, as well as a minority group in Israel, it is likely that they are strongly encouraged by their parents to higher scholastic achievement in order to improve their social status. In addition, Arab students perceive their family environment as more authoritarian than do their Jewish counterparts. The hierarchical structure of the Arab family is based on age and traditionally requires the young to obey the old and adhere to their expectations [Peleg-Popko *et al.*, 2003].

As can be seen, different social and cultural characteristics stimulate the extensive encouragement the Arab female students receive. This might lead us to the intermediate conclusion that in a culture that supports positive attitudes towards CS, we can probably attract more female students to study advanced levels of CS.

4.2. Case Study 4: Undergraduate CS at Carnegie Mellon-Qatar

Another Eastern case is taken from Qatar. In the fall of 2004, Carnegie Mellon opened a campus in Qatar (CMU-Q), offering an undergraduate major in CS with the same curriculum as its campus in Pittsburgh. We have yet to determine how cohorts of students on each campus can be compared, because of newness of the Qatar program and since there are so many variables to consider. Certainly, as the program progresses and evolves, this will be interesting to study. But in the cultural context of this paper, we can already present some interesting observations, particularly since women outnumber men in the Qatar CS program. While the reasons for larger percentages of women students are not entirely known, this is most likely due in part to families traditionally allowing more sons to travel overseas for their higher education while encouraging daughters to study in Qatar. Although this tradition appears to be changing, it most likely accounts for the higher percentage of women undergraduate students in Qatar. As for CS attracting more women, anecdotal evidence suggests that women in Qatar see CS as a means of interacting with, impacting, and experiencing the world without defying their cultural traditions.

Preliminary observations at Carnegie Mellon Qatar indicate that Qatar Arab students' perceptions of CS and of women's ability in math/science studies align with many of the observations from our case studies of the Israeli-Arab AP CS classes and of the new micro-culture in the School of Computer Science at Carnegie Mellon Pittsburgh. While some students are more excited by programming and debugging, others are more excited by applications such as robotics. Also, the CS women are certainly multidimensional and many are active in several other endeavors including student government (the student-elected president is a CS woman), and take leadership roles in many ways. Moreover, responses to initial questionnaires given to the Qatar CS students are quite interesting. Women students completed the sentence "I chose to learn computer science because" with "It has to do with logic," "I loved computers since I was a kid," and "Computer science is important in every domain of life." Family and teachers were the most important influencers for all students, men and women, in their decision to study CS. Another strong influencing factor is that all of the Qatari students are fully sponsored by industry to obtain their degrees at CMU-Q, and it is apparent that these industry partners are willing to sponsor women to obtain CS degrees. Surveyed women students overwhelmingly disagreed with the statement: "In my country, an equal number of men and women choose to study computer science." The reasons were surprising, elaborated as follows: "I believe in my country females feel that computer science is more important; men go to engineering and business field[s]" and "Women are [represented] more than men because they are 'more genius' than men." When asked why more women seemed to be interested in CS, one woman student responded "I think that the women here probably have more patience....so yes, while the guys are drawn to engineering...the women are discovering a new path through computer science."

Surprising to some, prior programming experience was not a factor that influenced these women (or men) to pursue a degree in CS – many of them had no prior programming experience and more women than men had some exposure to programming in high school. Future careers also did not influence most women to pursue a CS degree – in fact, most of them are unsure what career, if any, they will pursue following their graduation. While the men generally have more options and direction for what they wish to do post-graduation, many of the women wish to make a significant impact on their country or in the Gulf region or globally and are seeking for ways in which they can do this within their cultural boundaries. Most of them seem to have selected and continue in CS (despite very heavy workloads compared to their peers in some other undergraduate programs) because they wish to succeed in the challenge they undertook and because they enjoy the intellectual challenge of CS.

Longer-term discussions with students revealed that most of the CS students feel torn between their families and their educational demands. While their families are supportive of their higher education, CS is not a well-understood discipline in Qatar, and cultural requirements in terms of time spent with family, relatives, friends, and in community service are very high. Thus, the highly demanding CS program causes friction between the students and their families because the families do not fully understand why their children need to spend so much time on academic work. Despite the tremendous pressures that arise from not feeling like they are understood by anyone, the students rely on each other for support and encouragement, and persevere in their quest for a degree in CS with courage and determination against many odds.

Some endeavors by the faculty are also helping to ease this friction between students and their parents by giving parents opportunities to witness the accomplishments of their children, and to understand more about the challenges in computer science and related fields. One example was a poster session that allowed students to present their final projects from a robotics course to parents and colleagues. Students described the poster session as an empowering experience and parents enthusiastically hailed it as a learning experience which demonstrated the knowledge and accomplishments of the students. One father thanked the professors and said “I am so proud of my daughter … [and the fact that] she is learning to think in creative ways. … I now understand why she spends so much time in the lab.”

We will be investigating further such similarities, and differences, and the roles they play in the success – or not – of women and men in CS in the Qatar campus.

5. CONCLUSION

Whether referring to attitudes within larger cultures, such as the Israeli and Qatari-Arab sub-cultures, or a micro-culture, such as the computing culture of a specific undergraduate department, we hope to have illustrated the impact of culture and environment as determinants of women’s (and men’s) choices and participation in computing. We have offered evidence for an alternative model of thinking about gender issues rooted in the dynamics of culture rather than the self-limiting, and often misleading, oppositional model of gender differences. Our work leads to various questions for consideration. Two of which with clear implication for constructive and effective action are:

- How might thinking about culture (as opposed to gender) help us understand and impact women’s and girls’ (and men’s and boys’) choices of CS and computing related careers?
- What can different cultures learn from each other with regards to CS education?

Based on the perspective presented in this paper, we suggest that we should look to the environmental and cultural conditions that enable the "Women-CS fit." This paper presents several specific examples of such conditions and of interventions that help create them. Clearly there are more to investigate with the goal of enabling women and other under-represented groups to enter CS studies and contribute to computing related fields. These findings will also have broader implications both for opening up CS to a wider population and for the health and future of the field itself.

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