Culture and Environment as Determinants of Women's Participation in Computing: Revealing the "Women-CS Fit"

Carol Frieze
School of Computer Science
Carnegie Mellon University
cfrieze@cs.cmu.edu

Orit Hazzan
Department of Education in Technology & Science
Technion – Israel Institute of Technology
oritha@tx.technion.ac.il

Lenore Blum
Computer Science Department
Carnegie Mellon University
lblum@cs.cmu.edu

M. Bernardine Dias
Robotics Institute
Carnegie Mellon University
mbdias@ri.cmu.edu

ABSTRACT
There are some arguments that suggest women need academic handholding, such as a "female friendly" curriculum, in order for them to participate and be successful in computer science and related fields. Then there are other arguments that suggest we need to change the field to suit women or help women adjust to the field. In this paper we present a different perspective that shows none of these may be necessary. The "Women-CS Fit" is already there! Specifically, under certain cultural and environmental conditions we can see that women fit very well into computing fields and what we have been attributing to gender is actually the result of cultural and environmental conditions. The reasons for women participating in – or not participating in – the field of computer science have *little* to do with *gender* and a *lot* to do with *culture*. In other words, we need to recognize that this is a cultural issue, and an issue that concerns us all. Appropriate local interventions in the micro-culture can have large effect. This argument is illustrated in this paper by three case studies.

Categories and Subject Descriptors
K.3.2 [*Computers and Education*]: Computers and Information Science Education - CS education, Gender and Diversity Issues

General Terms
Management, Human Factors.

Keywords
Computer science education, gender, culture, environment, Women-CS fit.

1. INTRODUCTION
This paper presents an approach to how we think about, and act on, issues relating to women and computing related fields. We suggest that women do not need handholding, or a "female friendly" curriculum, in order for them to participate and be successful in computer science (CS) and related fields, nor is there a need to change the field to suit women.

Specifically, we will illustrate how under certain cultural and environmental conditions women can be seen to fit very well into computing fields, just as they can, and do, fit any other academic area they may choose to study. We will argue that the ways in which men and women relate to computer science --which have traditionally been attributed to gender differences-- are actually a result of cultural and environmental conditions. In the US, and many of the "developed" nations, we now see men turning away from the field too. Indeed, these nations are somehow failing to attract, educate and encourage the next generations of computer scientists – men and women. At the same time, however, 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 [1, 17, 19]. By noting these situations it soon becomes clear that this is not a gender issue but rather a cultural issue that concerns us all.

We will share findings from three case studies that illustrate culture and environment as determinants of choices and 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 debate (which seems to be going round in circles), and open the way for more productive directions?

The first case study looks at *undergraduates in the CS department 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. Under specific changes in environmental conditions, the gender divide is shown to dissolve with students presenting a spectrum of relationships to computing [4]. The second case study shows how *the agile approach for software development* [5], which is becoming more and more predominant in the software industry, is shown to fit women's management and communication style, and leads to a situation in which both men and women are equally communicative [11]. The third case study focuses on the *Israeli high schools Advanced Placement (AP) CS classes*. We show that while female high school students are

highly represented in the Arab sector, in the Jewish sector they are under represented. This phenomenon is explained largely by the higher levels of encouragement that female Arab high school pupils receive from their environment [7].

2. CULTURAL FACTORS

With respect to all our case studies, we explore *cultural factors*, acknowledging that *culture* is a very complex term and open to various interpretations. To clarify, 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. It is important to note that culture is dynamic, shaping and being shaped by those who occupy it. Indeed, while a dominant culture may embrace and influence a community, counter-cultures and/or micro-cultures may exhibit unexpected features.

3. USA: UNDERGRADUATE CS

This case study is based on the work of Blum and Frieze [4] and shows that women's (and men's) relationships to computing are shaped by the culture in which they study and experience their undergraduate life. Specifically, this case study illustrates an evolvement of a computing culture as the environment shifted from an *unbalanced* to a more *balanced environment*.

Prior to 1999, the undergraduate CS environment at Carnegie Mellon University (CMU) was *unbalanced* in terms of gender, the range of student personalities, and professional support for women. The culture of computing supported a specific type of (male) student.

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 were relating to CS. The core of the divide, i.e., 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 [14]. The early research also found that women's confidence was extremely low (even "extinguished"). Not surprisingly women felt they did not fit into this kind of computing culture.

By the end of 1999 new admissions criteria were in place that provided conditions that (without reducing the academic criteria) allowed for diversity in the student body. In particular we saw an increase in the numbers of women (who today comprise about 30% of the undergraduate CS population, a three-fold increase from the mid-1990's) and an increase in the numbers of students with broad interests, both men and women. (See [3] for the full details of the factors that allowed for change at CMU).

Subsequently, the student body became more balanced in terms of gender, and in terms of students with a range of interests. At the same time, the organization Women@SCS 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 were often available naturally to the majority (men) students [9]. We note that *Women@SCS has evolved not as a "handholding" support group,* but rather as a highly visible, professional community, *an action oriented organization in which women have taken leadership roles that have enhanced the entire CS community.*

It is important to note that while the CS department at CMU clearly *allows for* diversity and a more balanced environment, *the CMU CS academic curriculum was not adapted to become "female-friendly", and in fact has continued to be one of the most rigorous CS programs in the US.*

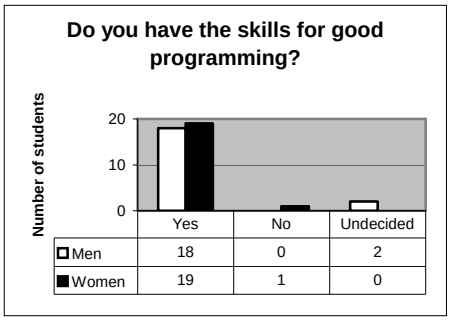
Over the past few years we have been examining how men and women relate to CS in this more recent and more balanced environment. In our research, over 80 students were interviewed using the early Margolis/Fisher interview protocol as much as possible, and over 100 student surveys were carried out, including discussions with faculty and administrators who have been at CMU throughout the last 10 years. Randomly selected cohorts of interviews and surveys were analyzed qualitatively and quantitatively. We found that as the environment has become more balanced, the culture of computing has evolved revealing a similar spectrum of attitudes towards computer science among women, and among men, rather than a gender divide. We now find that some men and women love programming and some don't, some men and women love applications, some don't, and most men and women show elements of both. Here we illustrate this shift further by pointing to some post-1999 specific changes, including confidence levels, perspectives on programming, and students' sense of fitting in.

Confidence Levels: In our studies we found that while men were still reporting higher confidence levels than women, most women in our cohorts reported an increase in their confidence levels. The confidence gap had narrowed significantly. Students, men and women, stated that although their confidence increased overall, levels varied greatly over the years, depending on the classes they were taking. Our findings tie in with those of Lunderberg *et al*., who looked at the dynamics of confidence and cultures around the world, concluding that culture influenced confidence to a much greater extent than did gender [13].

Attitudes to Programming: When asked if they liked or disliked programming, a randomly selected cohort of 20 men (seniors) and 20 women (seniors) were found to show almost identical results, with 18 men and 18 women declaring they liked programming. This led us to investigate further and look at the correlation between confidence and programming skills.

Confidence and Programming: When this same cohort was asked if they had the skills for good programming, women and men reported a set of similar skill factors and similar levels of confidence in these skills. 19 women and 18 men claimed a strong sense of confidence in their programming skills. (See Figure 1)

Figure 1. Females and males' confidence in programming

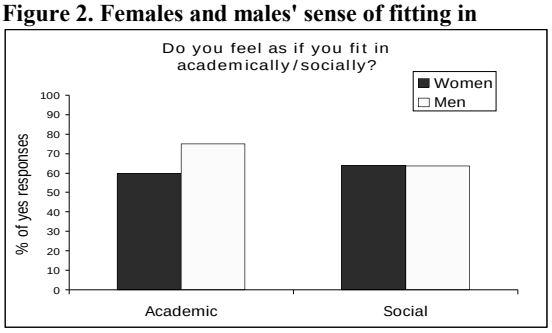


At the same time, almost all students, men and women, reported programming as one part of their CS interests and the computers as a "tool" for their primary focus which often was

applications. Additionally, when students were asked to define computer science, the predominant response overall was "problem solving" and "a way of thinking". 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: Surveys carried out among the undergraduate student body as part of a CREU project [10] showed that after their freshman year, men and women claimed to feel they fit in well both academically and socially (see Figure 2).

Figure 2. Females and males' sense of fitting in



Further, as students were questioned about themselves and their peers, we were interested to see the many ways in which our cohorts broke with stereotypes and both men and women showed a sense of well-roundedness that is not typically associated with majoring in CS. For example, the majority (of both men and women) had wide interests that took them (work permitting) outside of the CS environment.

It should be noted that the majority of US studies of gender and CS, by default, have been conducted in situations where there are *very few girls and women*. Such studies appear to find a strong gender divide in the way men and women relate to CS. In contrast, our findings emerge from an environment in which women are well represented. In this situation we see a spectrum of attitudes and attachments among men and among women rather than a gender divide. This finding points to the importance of micro-culture and environment as significant contributors to student perspectives on computing.

4. THE SOFTWARE INDUSTRY

This second case study illustrates how the culture inspired by *agile software development methods* [5] 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 frameworks which aim at overcoming characteristic problems of software projects [12]. The Manifesto for Agile Software Development (http://agilemanifesto.org/) appears in Table 1.

The agile approach reflects the notion that software 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 have identified that similar characteristics are attributed to "women's management style". Here are two examples from the literature (*italics* ours).

- "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." [8]
- "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." [16]

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.

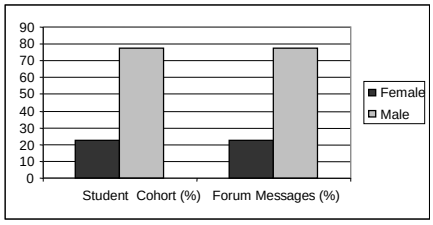
Indeed, as the following data shows, agile software development environments can provide women with equal participation in agile teams. This data was gathered by observing a project-based operating-systems course at the Computer Science Department of the Technion-Israel Institute of Technology [6]. In this course, the agile method has been used 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 as communicative as males in this setting. For example, when 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 3.

Based on this analysis, as well as additional findings, it is suggested that the agile method reflects a "Women-CS Fit".

For example, in addition to being a software developer in the operating-systems course, each student played an auxiliary role on their team such as coach, tracker, customer, etc. Roles were distributed uniformly amongst males and females, which in turn, reinforced the female students' voices in these teams.

Figure 3: Females and males' communicative behavior in agile 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 for the benefit of all. Again, we see that under certain conditions the gender divide is seen to dissolve and men and women's participation is balanced.

5. ISRAEL: HIGH-SCHOOL AP CS

The third case study focuses on the differences between two sectors in the Israeli high school system – the Jewish sector (majority) and the Arab sector (minority). Based on data collected in Israel, significant differences were found in the percentages of female high school students studying AP CS[1] among the two sectors. Specifically, while the percentage of female high school students studying AP CS is about 50% for the Arab *minority* sector, the percentage of female students studying CS at the same level among the Jewish *majority* sector is only about 25%.

Most Jewish and Arab students attend separate educational systems with similar curricula in most subjects. 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 [7] 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). Table 2 describes the distribution of the students according to gender and sector. CS teachers and school counselors were included in the research population as well. Questionnaires, interviews and observations were the main research tools.

Table 2. Distribution of Case Study 1 research population

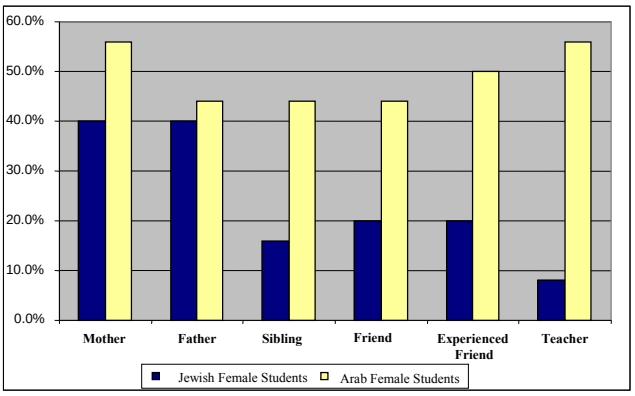
	Total	Male	Female
Number of students from the Jewish sector	90	(72%) 65	(28%) 25
Number of students from the Arab sector	56	(39%) 22	(61%) 34
Total	**146**		

In Eidelman and Hazzan [7] several findings were presented. In order to illustrate the "Women-CS fit", we focus here on one cultural factor – the finding of 'support and encouragement' – that may explain, among other factors, the high participation of Arab high school female students in AP CS classes.

Several questions in one of the questionnaires addressed how much support and encouragement to study CS students received from different sources. One of the questions was: "Who encouraged you to choose CS studies?" Figure 4 presents the distribution of the answers to this question.

Figure 4 reflects an unequivocal conclusion: Arab female high school students (*n=34*) receive much more encouragement to choose CS than do their Jewish counterparts (*n=25*). 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 wide support that the Arab female students received is supported by additional data [7].

Figure 4. Percentages of females' encouragement by others



In order to highlight the "Women-CS fit" that emerges from specific environmental factors, we now focus on the unique characteristics of the Arab–Israeli society that are likely to influence Arab female students to choose and persist in CS studies. Specifically, noticeable differences exist in the extent of encouragement Arab female students receive from various agents and this can be explained by looking at findings from other studies that explored cultural and familial differences between Arab and Jewish adolescents. 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 "pushed" by their parents to higher scholastic achievement in order to improve their social status [15].

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 [15]. Furthermore, it was found that peer influence in the Arab sector is much more positive than it is in the Jewish sector, possibly because of the relative independence from family and friends that exists in the Jewish sector [2]. This might explain the lower influence of parents and peers in the Jewish sector.

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

6. CONCLUSION

Whether referring to attitudes within larger cultures, such as the Israeli and Arab-Israeli 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 choices and participation. We have discussed three case studies, each illustrating a "Women-CS fit", and how culture can allow for this fit – or not. The first case study – an undergraduate CS program in the US – demonstrates how an unbalanced environment ties us into the limitations and misunderstandings of the "gender differences" discussion which is seen to dissolve once the environment becomes more balanced. The second case study – the software industry – highlights the agile approach as a software development environment which fits

[1] The programming part of the Israeli AP CS course is comparable to a typical US AP CS course. However, the Israeli course contains some additional theoretical material, such as computational models (automata theory), data structures and selected topics in graph theory.

women's management style. The third case study – AP CS classes in Israel – illustrates how the culture in the Jewish sector does not allow for the "Women-CS fit", while Arab culture is a better fit.

As an interesting postscript to this paper we conclude by noting another case where culture and environment are beginning to show their effects. We are starting to observe some initial data coming from the newly established Carnegie Mellon Qatar campus where women outnumber men in the CS program, in part because Qatar men often study abroad while young women are rarely given that opportunity. We are discovering that many of the women in the program chose CS because they find programming challenging and see CS as a means to impact the world in new ways while remaining true to their culture and traditions. The Qatar campus has a brief (one year) history. *Preliminary observations* suggest that Qatar Arab perceptions of CS and of women's ability in math/science studies differ from those in the USA. We will be investigating what these differences may be and the role they play in the success - or not - of women in CS in the Qatar campus. (See [18] for related studies.)

Our work leads to various questions for consideration. Two 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 boys') choices of CS and computing related careers?
- What can these different cultures learn from each other with regards to CS education?

Many associations undertake to promote women in the high-tech industry. In most cases, these organizations seek ways to help women adjust to the prevalent work framework that characterizes this industry, in general, and software projects, in particular. Based on the perspective presented in this paper, we suggest that women do not require adjustment, but rather 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 other examples appear in related work [1, 17 and 19]; clearly there is much more to investigate with the goal of enabling women to enter CS studies and contribute to computing related fields. These findings will also have broader implications for opening up CS to a broader population, to a broader discussion, and for the health and future of the field itself.

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