A Historical Examination of the Social Factors Affecting Female Participation in Computing

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ABSTRACT

We present a history of female participation in North American CS, with a focus on the social forces involved. For educators to understand the status quo, and how to change it, we must understand the historical forces that have led us here. We begin with the female "computers" of the 19th century, then cover the rise of computing machines, establishment of CS, and a history of CS education with regard to gender. In our discussion of academic CS, we contemplate academic generations of female computer scientists and describe their differential experiences.

General Terms

Human factors

Keywords

Computer science education, women in CS, studies of CS

1. INTRODUCTION

Increasing the participation of women in computing is well-established as an important and difficult task in the CS education community [36, 15]. Much of why it is hard to increase the participation of women – and other underrepresented groups – is because social structures are complex, dynamic systems. We cannot reduce the matter down to a few issues that, if fixed, would change everything. For example, meta-reviews of diversity initiatives outside CS have found that historical trends must be considered when designing initiatives, since *"the disruption [of the status quo] is usually not complete, nor fully shared by everyone, leaving traces of the old gender order to co-exist with an emerging newer and more complex notion of gender at work.* [8]

This paper presents a historical sociology of female participation in North American computer science. By *historical sociology* we refer to an approach to history which focuses on the social and cultural developments, forces and trends. Existing histories of female participation in CS instead focus on individuals, such as Grace Hopper, Ada Lovelace and the ENIAC Girls (e.g. [25, 17, 40, 2]).

The histories of female computer scientists are fascinating, and useful for presenting examples of female role models in the field. However, a focus on individuals takes away much of the context: what was it like being a computer scientist at that time? What was it like being a woman in society then? Understanding these social trends is important for changing a status quo where women continue to be underrepresented.

Not much has been written about the history of academic CS; most histories of computing focus on the technology, and end in the 70s (e.g. [12, 18]). For young CS educators, there is little detailed post-70s history. Our goal in this paper is to provide background information on what has happened with regard to female enrollments in CS since the 90s – which in turn requires us to look at what led to that point.

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1.1 Background Information

1.1.1 Types of Barriers

As we discuss the barriers faced by women in CS and STEM careers, we find it useful to categorize these barriers into a 2x2 grid:

	Intentional	Unintentional
Institutional	*De jure* discrimination	*De facto* discrimination
Individual	Explicit sexism	Implicit sexism

Institutional vs. Individual. Is it a policy, such as restricting enrollment in CS, or a lack of maternity leave? Or is it the direct behaviour of individuals, such as sexual harassment or a prejudice against women?

Intentional vs. Unintentional. Policies created without considering the effects on women, and subconscious bias against women, are examples of unintentional barriers; sexual harassment and the explicit barring of women from studying CS in some countries are examples of intentional barriers.

2. A PRE-HISTORY OF WOMEN IN CS

2.1 Women as Computers: from the 1820s to the 1940s

2.1.1 19th Century and Early 20th Century

The 19th century marked the rise of women's colleges in the United States [42] as policies barring women from education were loosened. This came hand-in-hand with first-wave feminism, in which women fought *de jure* discriminatory practices in North American society. Women campaigning for access to higher education did so on an argument that it would "produce better wives and mothers". For women of privilege in American society, a basic understanding of science and math in turn became "necessary for motherhood".

It should be emphasized that this was a trend for white women of *privilege* – most women who studied science in the 19th century were the daughters of scientists and other intellectuals. Consider, for example, that Ada Lovelace was a countess in a family of mathematicians [25].

For the women scientists that emerged from these colleges, there were few job opportunities. Teaching at the women's colleges was the main possibility. Working as a "computer" was another possibility [42]. Women pursuing PhDs or faculty positions were expected to be single or "in no danger of marrying"; marriage meant resigning from the programme or their job [42]. As time progressed and society progressed, women in these positions began to feel they could be both wives and scientists – when they resisted the norm of resigning upon marriage, they were met with opposition: they were threatened and usually fired [42].

1870-1900 marked an era of slow infiltration: women began entering doctorate programmes at traditional (male) institutions in countries such as the US and Germany [42]. Most universities were hesitant to allow the women into the PhD programmes, but would instead admit them as "special students" and give them bachelor's degrees instead. Engineering schools, however, remained resistant to women [40, 42]. While by 1910 women were starting a presence in science at traditional institutions, there was no equality in employment, and jobs remained deeply "sex typed".

With the slow rise of women in science came the corresponding rise of "women's work" in science [42]. So-called women's jobs typically were "assistants" to scientists, or working as computers for larger groups. These women were systematically ignored in the larger scientific community, left out of lists of scientists, conferences, and histories [43]. Indeed, from 1911 onward there were overt efforts to reduce the numbers of women in science.

2.1.2 Women's Work

It should be emphasized that computation was considered "women's work" in the 19th and early 20th century. Looking at the history of the social sciences in this time, quantitative methods were considered "low" enough that women could do them – but qualitative methods required "the intellect of a man" [35]. The reversal of the status (and gendering) of quantitative vs. qualitative work in the social and biological sciences happened well into the 20th century (sometime between the 30s-50s) [35].

During the World Wars, women were stereotyped as better programmers: "programming requires lots of patience, persistence and a capacity [for] detail and those are trains that many girls have" [25]. This stereotype persisted into the 40s [17], and even as far as the 60s: a 1967 issue of *Cosmopolitan* featured Grace Hopper describing programming as "*[it's] just like planning a dinner*" [18].

2.1.3 The World Wars

By the 1920s, women in academia were still largely kept to the women's colleges [42]. The colleges, however, provided a place to organize campaigns for change. Women began fighting for access to education, using evidence from psychology and anthropology that women too were capable of science/math [42].

The 20s and 30s marked an expansion of government-employed scientists, who were assigned "women's work" (assistants, computers, etc) and were grossly underpaid and undervalued [42]. The World Wars increased the scope of "women's work" as labour shortages necessitated it. By 1938, the numbers of women working in scientific and technological roles for the US government had dramatically increased – despite overtly hostile job conditions [42]. Women were given lesser job titles such as "assistant" due to their gender [40]. And despite the large number of women working in tech, all of the leaders and managers were men [25].

Nevertheless, the women of this era remember it as a time of excitement [25]: it was a chance for them to be involved in something technical/scientific. And indeed, the World Wars also marked the birth of digital computing. Computing machines were devised in the UK for cryptographic purposes. These machines, and the hand computations done in the wars throughout the world, were commonly performed by women. ENIAC, arguably the first real computer, was announced in 1946. The plan to run the ENIAC was such: a male scientist would be the planner, deciding what was to be computed – and a low-rank, female "coder" would do the actual machine coding [18].

2.2 The Continual IT Labour Crisis: the 50s through 70s

For the men running computing labs, what was not anticipated was that the coding would actually be difficult [18]. As computers began being used for commercial purposes in the 50s, a labour shortage emerged. Computing in the 50s and 60s can be characterized by a large, shotgun approach to recruiting "good programmers" when little knowledge of what a "good programmer" was. Programming began to be seen as a "dark art" [18]. Due to the individuals who began programming at that time, programmers began to be seen as asocial [18] – kicking off a feedback loop that persists today.

Women continued to have a large presence in programming in the 50s. They contributed to the development of programming languages [25] and scientific computation [17]. But traditional gender roles in many way persisted. Women in the 50s still had to leave when they became pregnant [40]. And women hit what they dubbed the "glass ceiling": a collective barring from managerial and senior positions [17].

As computer programming rose in prominence, it became masculinized. Women were still allowed entry to the jobs due to the desperation for quality labour. However, lazy hiring practices that focused on spurious aptitude and personality tests hurt female participation in the industry [18].

Inconsistent professionalization efforts also hurt female participation by restricting what it meant to be a programmer. The men running the show did not intend to push women out of computing – instead, they simply did not consider how their hiring practices discriminated against women [18]. In short, *de facto* discrimination was the dominant driver of women out of computing.

3. WOMEN IN ACADEMIC CS

3.1 Early Days: 1960s and 70s

Computer programming stayed largely independent from academic computer science. In the 50s and 60s, CS was conducted through other departments, typically as a hobby or side-project [18]. The first CS classes were offered in the 60s, as the discipline struggled to assert itself [12]. By 1969, MIT had opened an undergraduate programme in CS – and the 70s marked the beginning of bachelor's degrees in CS offered typically through electrical engineering or mathematics [18]. It would not be until the 80s, though, that CS programmes moved into their own departments.

From the start, CS seemed like a "grab bag of various topics" related to computers and attempts to define the discipline were inconsistent [18]. Was CS about information? Analysis? Algorithms? No consistent narrative was established, though algorithms eventually became dominant.

It should be noted that the establishment of CS departments coincided with the sexual revolution in North America. While CS was opening its doors, women were asserting their rights – including those to work and study.

3.1.1 The First Generation: women who entered in the 60s/70s

As documented by Etzkowitz et al in a 1994 paper, women of different academic *generations* in STEM have had wildly different experiences in academia. In a study of 30 academic

science departments in biology, chemistry, physics, CS, and electrical engineering in the United States, Etzkowitz found stark and sometimes conflicting differences between the women of different generations in these departments [20].

The First Generation of women in a given STEM department faces a very different environment than subsequent generations. Unlike today's undergraduates entering classrooms with women as minorities, these women often entered classrooms with *no other women* [20]. There were seldom other women in their field, and this continued into graduate school and faculty life. Such was the case for the majority of women who entered CS in the 60s and 70s – before CS was even an established discipline. Most came to CS via departments such as math, physics, electrical engineering, psychology, English, music, and linguistics [25].

One senior female scientist in Etzkowitz et al's study described her cohort as such: *"The ones who did [science] were really tough cookies. Now it's easier to get in. At one time it wasn't even acceptable to start. So if you started back then you were tough to begin with."*

In short, women with low self-efficacy simply did not go into that given STEM field. Only the strongest, the most focused and most ambitious stuck it out. And it led these women to expect that women had to be better than men in order to succeed [20]. Given the data that women today are subconsciously discriminated against with regard to job offers, postings, tenure applications, and collaborations (see [32, 49, 39]), it's not a surprising position to take – particularly when many of these biases were explicit and *conscious* when they began their careers. Women were underrecognized for their contributions [43], and when they were, they got "separate but not quite equal form[s] of recognition" [40].

With few other women around, these women worked in a culture which expected them to *"accept the strictures of a workplace organized on the assumption of a social and emotional support structure provided to the male scientist by an unpaid full-time housewife"* [20]. These women adopted lifestyles and approaches mimicking the traditional man, including a singular focus on research and career advancement [20]. Marriage and children were secondary, if done at all.

4. THE ESTABLISHMENT OF CS DEPARTMENTS: THE 80S AND 90S

4.1 The First Bubble: The 80s

The early 80s were also a boom-time for student enrollment in CS [47], which was linked to the rise of the personal computer. Personal computers had not been available until the late 70s; prior to then, CS was hence only pertinent to academia, military, and business.

However, by the late-80s, enrollments began dropping – and disproportionately so for women [41]. The decline was "largely the result of explicit steps taken by academic institutions to reduce CS enrollments when it became impossible to hire sufficient faculty to meet the demand." [41] Steps included adding new GPA requirements for entering CS programmes, requiring more prerequisites, and retooling first-year CS as a weeder course [41]. These actions disproportionately hurt not only female participation in the field, but participation of racial minorities as well [41]. These "non-traditional" students had disproportionately come to CS via non-traditional paths (such as via psychology or linguistics) and disproportionately lacked the prerequisites as a result. The retooling of first-year CS as a weeder course also resulted in a competitive atmosphere that deterred many women. Once again we see *de facto* discrimination pushing women out of computing.

4.2 Post-Bubble: The Early 90s

The situation for women worsened in the 90s. The personal computer led to further masculinization of computing [11]. Five reasons thought to have reduced female participation in the 90s were: the rise of video games, subsequent changes in stereotypes/perceptions of computing, the encouragement of boys to go into the field and not girls, an inhospitable social environment for women, and a lack of female role models [11].

The 90s appear to be when CS educators started worrying about female participation in CS. Before the drop in female enrollments in the late 80s, it had been fair to assume that reaching equal female participation in CS was simply a matter of time. Indeed, in the 80s and early 90s, CS was still seen as a "woman-friendly" science [20].

While women-in-CS initatives had existed in the 80s (e.g. The Anita Borg Institute was opened in 1987 [31]) – it was not until the 90s when they proliferated (e.g. The Committee on the Status of Women in Computing Research (CRA-W) was formed in 1991 [16], the Grace Hopper Celebration of Women in Computing was first held in 1994 [17]) and by the 00s they became "mainstream".

4.3 The Dot-Com Bubble: Late 90s

The birth of the World Wide Web in the 90s and its spread beyond academic/military use led to a second bubble in CS enrollments, known as the dot-com bubble. The hype of the dot-com bubble and the promise that a CS degree would lead to easy prosperity led to a resurgence in enrollments in the late 90s – particularly due to students who wanted to get rich quick. The dot-com bubble burst in 2000 – and enrollment with it a few years later [47]. Indeed, the NASDAQ has been found to be a predictor of CS enrollment at Stanford [37].

The boom-time in the late 90s and early 00s led to a return of strict enrollment controls and a spree of hiring more CS faculty [47]. Most of these new hires were relatively young, and of what we will refer to as the "Second Generation".

These boom-times also reduced the amount of service teaching: with CS programmes overburdened, CS departments had few resources and little motivation to teach non-CS students. At some universities, departments such as physics or math began offering their own CS classes to their own students – leading to CS becoming increasingly isolated from the other sciences – and from non-traditional students.

4.4 The Second Generation: women who entered in the 80s and 90s

Etzkowitz et al found that once women faculty were hired in a STEM department, *"it definitely changes the attitude of how male students react to women. They must take them seriously and this is positive"* [20]. Explicit sexist behaviour, such as public sexual joking and stereotyping decreased as a result [20]. Etzkowitz et al found there was a critical threshold at which women *in a department* begin to be treated more fairly, and blatant discrimination becomes uncommon. This appears to be at around 15% women.

The women entering this environment (in the 80s and 90s) had a different experience than the First Generation – who had had *no* female faculty when they were students[20]. The Second Generation was particularly eager about these First Generation female faculty. They had high expectations about these female faculty, and wanted to learn things from them such as *"how to dress, how to act at conferences, what to do when somebody is curt to you"* [20]. In a sense, some of these women saw the First Generation as their White Knights, to guide them through academia.

While the First Generation was preoccupied with simply getting on in a man's world, being a *woman* in a man's world was a preoccupation for the Second Generation [20]. These women were concerned about how many women there were

in their programmes, hired as faculty, etc. Viewing science as only one part of their identity, these women also focused on how to balance career and family [20].

For Second Generation women, work-life balance was the key problem. Figuring out when to start a family, and seeking maternity and daycare support from their universities were priorities [20]. As noted already, many leave academia because they feel balancing both work and family care is untenable. However, more recent studies have found the decision making is complex: women who are more satisfied with their jobs are more likely to make having both academia and a family work. Women who feel they are discriminated against at work, and feel their promotion and tenure chances are unlikely, are more likely to leave the job to look after their families. [23] These women began most of the "women in science" type clubs, seeking to mitigate their feelings of isolation at work [20].

4.4.1 Conflict Between Generations

Etzkowitz et al observed that the different experiences between the first two Generations has led to a bifurcation of the women in their study's participating departments. When the Second Generation began most of the "women in science" clubs, some of the First Generation were leery of these organizations [20]. "*Fear of stigmatization led some [women] to deny the existence of gender-related obstacles. Calling attention to difficulties overcome could lead to countercharges of special privileges received*" – devaluing their hard-fought achievements that often took significantly more work than the achievements of their male colleagues [20].

Furthermore, "*frustrated by the emergence of women's issues, they regarded such concerns as indicative of a lack of commitment to science. They believed women's groups and programs [sic] to improve the condition of women harmed female scientists by making them appear 'different', and by implication less competent*" [20]. However, the sheer isolation, and blatant sexism experienced by the First Generation women led many of these First Generation women to support and lead diversity initiatives.

Advising was another source of inter-generational conflict. One female graduate student in the study reported that it was harder as an advisee of a senior woman, due to her advisor's "sink or swim" attitude. Many of the First Generation were harder on their female advisees, feeling they had to be to "prepare them to meet the higher standards they would be held to as women" [20].

5. AFTER THE DOT-COM BUBBLE

When the bubble burst, the "get-rich-quicker"s disappeared – and CS departments were left trying to get more "bums in seats". Enrollments did not recover again until the mid 00s – and have been on the rise since [47]. Indeed, recent reports paint enrollments at record numbers, even greater than the peak of the dot-com bubble [38].

Overall, a pattern of cyclical enrollment emerges. Boom times lead to more students, then more enrollment controls; bust times lead to more outreach. Bust times also result in disproportionately many women leaving the field, or not going in at all [47] – indeed, as of 2011, 18% of CS students are female [38].

5.1 The Third Generation: women who entered in the 00s/10s

The Etzkowitz et al paper was published 20 years ago, when the Second Generation was still growing. Women entering CS since the 00s have had a different experience of computing culture (arguably this has been true since the late 90s depending on the CS department). For the first author of this paper, who entered CS in 2007, approximately 20% of the CS faculty were women, predominantly women of the Second Generation. They have families and the Women in CS club was (and still is) highly visible and active, as is their delegation to Grace Hopper, as well as scholarship and research opportunities designed for women in CS.

The early 00s marked an era of focus on increasing female participation in CS. Margolis and Fisher's influential *Unlocking the Clubhouse* was published in 2002; this year also marked a SIGCSE bulletin special edition highlighting research on women in computing [26, 14]. For many (if not most) women of the Third Generation, their departments have made explicit efforts to improve the experience of women in their classrooms. The work by Margolis and Fisher, and others such as Joanne Cohoon, Maria Klawe, and Camp and Gurer, led to many departments working to remove *de facto* barriers for their female students. Follow-up studies at places that have implemented Margolis and Fisher-style recommendations have found a cultural shift that helps female students [9, 3].

And indeed, for female students entering CS in the 2000s and 2010s, there already exists a strong social network for women in computing. This network has been designed mostly by Second Generation women – and mostly around what the Second Generation women had wished they'd had when they entered the field. This is important as, again, people may take for granted the experiences of other generations.

For example, the findings we see in the 2002-era women-in-CS papers will discuss access to physical computers [26, 36]. For most women entering a CS classroom, computers have been ubiquitous for most of their life. Indeed, for these women, the Internet has been a world that girls use more heavily than boys [24]. Growing up, Third Generation girls performed equally well in science and math as boys. Finally, the Third Generation is far removed from the explicit sexism that the First Generation experienced.

5.1.1 Barriers for the Third Generation

Despite many improvements in the culture, female enrollment in CS hasn't significantly improved since hitting that 15% critical mass. Despite the uptick in the mid-80s, the numbers are now down to around 18%. Clearly, critical mass isn't enough on its own to get female participation to 50%. Concerningly, one issue affecting women in CS is backlash for the women-in-CS initiatives. Even in the Margolis and Fisher study era, female students have reported harassment along the lines of "you're only here because you're a girl" [36]. The stigma of receiving preferential treatment in science has been documented as decreasing self-efficacy for its recipients [52], decreasing the perceived competence of its recipients [30], and causing stereotype threat for its recipients [29, 48].

Implicit sexism appears to be the dominant barrier for women of the Third Generation. While *de facto* discrimination and explicit sexism (particularly sexual harassment) still occur, they are no longer predominant. The subtle biases that have been there from the beginning remain, such as:

- The CV of a woman applying to a STEM job is viewed as demonstrating less competence than the same CV with the name changed to a male name [39, 49].
- Conference abstracts with female authors are viewed as being of lower quality than if the abstracts are changed to have male authors [32].
- Articles written by women are cited less than those by men [50]. Women are less likely to be listed as either first or last author on a paper [53]. Similar disparities exist in funding [34] and earnings [45].

- Women are more likely to be promoted based on past accomplishments, whereas men are more likely to be promoted based on potential [6].
- Letters of references for female job candidates are more likely to use gendered wording ('warm', 'kind', etc) which in turn hurts a candidate's hireability [51].
- The language used in job postings has also been found to favour men: gendered wording is common, and women are less likely to apply for jobs using such wording [22]. An entire blog, "Tech Companies that Only Hire Men", which features job postings with gendered language in IT, has frequent entries [1].

With these implicit biases come other social-psychological barriers for women in CS, such as stereotype threat [33], tokenism [7], and benevolent sexism [28]. These subtle forms of sexism all continue to subtly push women out of CS through a "death of a thousand papercuts". Insidiously, many Third Generation women do not perceive any gender-based biases against them, and are unwilling to take action on what they consider a "problem of the past" [55].

6. DISCUSSION

In looking at how female participation in CS has changed over time in North America, we also gain some insight as to why female participation is different around the globe. CS is female-dominated or at gender-parity in places such as the Middle-East [27, 21], Eastern Europe [21], and South-East Asia [19]. A 1994 study by Barinaga set out to explain the cross-cultural differences in female participation in STEM. She found five positive factors, three of which are supported by the history of CS in North America [5]:

1. More women are present in countries with **recently developed science capabilities**. The academic culture is relatively unentrenched, and no "old boys network" has come to dominate. When CS was new, we saw more women in the field. This was true both in industry (female computers) and in academia (the 80s).
2. More women become scientists in a culture where **science is perceived as a low status career**. It is established in sociology that the lower the status and pay an occupation, the more likely it is that women will be found there [5]. When CS meant being a "computer" or a lowly "coder", women played these roles. When CS rose in prominence – such as during the 60s, and during dot-com boom, the percentage of women entering CS decreased.
3. For a given culture, if a woman of high class has higher social standing than a man of low class, we see more women in science. **Privilege** hence matters – and is linked not just to gender but also class and race. Women in CS are disproportionately from relatively affluent backgrounds [36]. Women of colour are disproportionately underrepresented. (Indeed, a weakness of this paper has been our focus on the history of *white* women in CS – more needs to be done to document the history of racial minorities in the field.)

While it is difficult to make CS "new" again, reducing the entrenched culture has proven benefits for attracting non-traditional students [9, 14]. It should also be noted that CS is not homogenous: fields such as gaming and security [46] lag behind with regard to female representation, and explicit sexism continues to be a problem.

What the history of women in CS shows is that this is probably best tackled one barrier at a time. The removal of *de jure* discriminatory policies allowed women to become "computers" and to attend engineering schools [40]. Such policies still exist in other countries, such as Iran, where women are barred from studying CS [44].

Once the First Generation of women arrived, explicit sexism was the next problem. When a critical threshold of women were present, explicit sexism decreased markedly in frequency. The change in culture produced the shift to the Second Generation, who focused on being both a woman *and* a scientist. *De facto* discriminatory policies have been the issue for these women, such as entrance requirements that disproportionately bar women from studying CS, and a culture that leads to social isolation for many women.

The Second Generation women have established a network of support for female students, from Grace Hopper to local women in CS clubs. While *de facto* discriminatory policies still exist, a larger problem facing the Third Generation are the subtle, social-psycological biases working against them.

Implicit sexism may be difficult to identify and fight, but it is possible [4]. Blind reviews in scientific journals, for example, lead to more women and minorities publishing [10]. Where possible, scholarships and research grants should use blind reviews. Social-psychological interventions have been found to reduce stereotype threat [54]. Changing the stereotypes about CS in popular media leads to women to have more interest in the field [13].

Meanwhile, enrollments in CS are now skyrocketing yet again: the 2012 Taulbee Survey found that CS enrollments have risen for the fifth straight year [38]. Facing packed classrooms and overburdened teaching resources, some CS departments are once again considering cutting interdisciplinary programmes and service courses. We hope that CS departments will maintain these initiatives, given their known benefit for women [14].

CS has come a long way since the day of female "computers", and progress has not been linear. Barriers remain, particularly for women of colour and women of lower class. Tackling these issues requires an understanding of all the forces at work – including our past.

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