The Social Closure of Undergraduate Computing: Lessons For The Contemporary Enrolment Boom

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***Abstract*—Software engineering and other computing fields have the unfortunate distinction of being areas in which the percentage of women has decreased in recent decades. Each time that undergraduate computing has surged in student demand, the percentage of women has decreased and never recovered. With a new enrolment boom currently ongoing, we were motivated to take a sociohistorical approach to understand how undergraduate CS is gendered. We use Anne Witz's closure theory to explain the gendering of computing, focusing on the history of enrolment booms in computer science. In doing so, we found that the closure of computing is affected by policies (such as admissions policies) and discourses (such as "computing is engineering"). We also found that when computing becomes more closed, the field also becomes more gendered, which has important implications for managing the current enrolment boom.**

***Index Terms*—history, gender, sociology, software engineering, computer science, enrolment**

I. Introduction

Software engineering and other computing fields have a unique status: they are STEM fields in which the percentage of women has *decreased* in the Western world since the 1980s. But why?

We're writing this paper (in Royal We) as somebody trained in the sociology of education. One of the things we were taught about social phenomena is that their history matters: social systems are deeply dependent on what happened in their past, and past patterns arise again and again.

In recent years, a literature has blossomed on how industrial computing masculinized in the mid-20th century (e.g. [1]–[3]). Contributing factors to the gendering of computing include: a gendered division of labour such as a woman "coder" working for a male "planner" [2]; managers not understanding the nature of computing work [1], [2]; the use of flawed aptitude/personality tests for hiring [1], [2]; sexism in hiring and promotion [2], [3]; and efforts by management to rebrand programming as work for "logical men" rather than "women's work" [2], [3].

But the masculinizing of computing did not end in 1970: women made up 40% of CS undergrads in the 1980s, and by the early 2010s, this had decreased to 15%. At present, little historical analysis has been done of the late 20th-century, presumably due to its recency.

Recent history, however, is still useful history. Undergraduate enrolments have recently been surging in CS departments, with departments struggling to cope with student demand [4]. But this is not the first time undergraduate enrolments have boomed: history can help inform policy decisions this time.

A. Approach

Our goal in writing this paper is to examine how enrolment booms have contributed to the gendering of computing. This paper presents a secondary analysis of existing histories — most centrally, Eric Roberts' history of enrolment booms.

We chose Roberts' history because it is, at present, the most comprehensive history of enrolment booms in CS. Roberts is an eminent computer scientist, well positioned to draw on extensive first-hand experience. But his historiography lacks social-theoretic depth, and does not foreground gender. So in our analysis, we add a feminist closure-theoretic lens to Roberts' history, and bring in more sociological and historical sources to bring gender to the forefront.

II. Closure Theory

Social closure refers to the process (and state) of social groups creating a boundary around themselves, establishing who is and who is not in this group. These closed groups can then maintain their resources through the exclusion of those not in the group [5]. The concept was first articulated by 19th century sociologist Max Weber, who suggested that nearly any group attribute, such as as race, language, social origin, or religion, could be seized upon to use for the monopolization of specific (usually economic) opportunities [5].

Contemporarily, closure theory has been further developed to study professions, particularly how professions become gendered over time. Anne Witz developed a feminist closure theory which she used to explain how British medicine, nursing, midwifery and radiology all varied in gender-typing over time [6]. This theory has been used to explain the masculinization of computing [7], [8] and of science [9].

In Witz's closure theory, there are three types of closure:

1. Exclusionary closure is the attempt of one group to secure itself a privileged position at the expense of another subordinate group. An example of a policy approach to exclusionary closure is the 1858 Medical Registration Act in Britain, which banned women from registering as doctors.

Witz notes two important strategies for exclusionary closure of an occupation: **exclusionary strategies** to make the occupation more difficult to enter, and **demarcationary strategies** to change the boundaries of the occupation. A discursive example of demarcation would be when doctors argued that only obstetricians had the "technical skill" to handle an "abnormal" labour, separating themselves from midwives.

2. Usurpationary closure is the use of power "upwards" by a subordinate group to get a slice of the pie [5]. Examples include protest movements, civil rights legal challenges, strikes by labour movements, and collective action by political groups. Witz classifies usurpationary strategies as either equal rights–focused (e.g., legal challenges to allow women to study in "normal" medical schools) or separatist (e.g., the London School of Medicine for Women). Though usurpation is usually

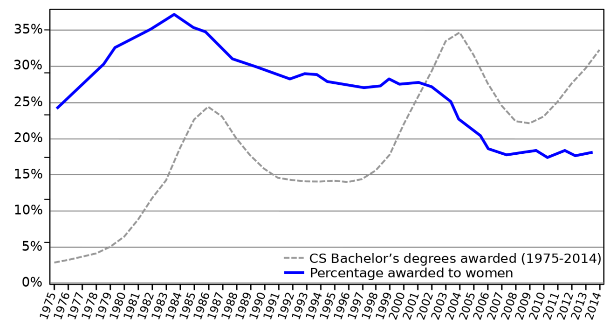

Fig. 1. From Roberts' history of enrolment booms [12]: The grey dashed line indicates *total* CS degrees awarded, illustrating the "enrolment booms" of the late-1980s, dot-com, and present. Note that as this is degrees awarded, there is a lag between enrolling and graduating. The percentage of the degrees awarded to women is shown in blue.

done collectively, it can also be done as an individual. For example, when Britain did not allow women into its medical schools, some women would become licensed doctors in countries that were willing to train them, and then the women would practice medicine in Britain with foreign credentials.

3. Dual closure is when a subordinate group uses both exclusionary and usurpationary strategies [6]. E.g., when nursing was professionalized in the UK, the educational and credentialing requirements were set so that low-class women would not be able to become nurses. This was done to improve the status of nursing, but also excluded low-class women.

Dual closure can also operate between occupations. E.g., when obstetricians were claiming dominance over midwifery, female doctors advocated for this change in order to demonstrate their greater status over midwives. While this helped female doctors gain legitimacy, it also promoted the exclusion of other women from paid work.

III. The Closure of Academic Computing

A. Early Days of Computer Science

In the 50s and 60s, CS was conducted through other departments, typically as a hobby or side-project [1]. In these early days of academic CS, programming stayed largely independent from industrial coding. The first CS classes were offered in the 60s, as the discipline struggled to assert itself [10]. 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 [1]. While there were early CS departments in this era, it would not be until the 80s that CS programmes were commonly offered through their own departments.

From the start, CS seemed like a "grab bag of various topics" [1] related to computers and attempts to define the discipline were inconsistent [1]. Was CS about information? Analysis? No consistent narrative emerged, though algorithms eventually became dominant [1]. Consistent with other socio-historical studies of science, it appears CS was formed less around a common epistemic goal and more around social closure [11].

B. The Capacity Crisis of the 1980s

As Roberts begins his history of enrolment booms, the early 1980s were a boom-time for student enrolment in CS [13] (See Figure 1.) This boom was linked to the rise of the personal computer. Prior to then, CS had only been pertinent to academia, military, and business.

The establishment of CS departments coincided with the sexual revolution. While CS was opening its doors, women were asserting their rights, including those to work and study. Many of the women who studied CS in this era arrived at the field from other areas, such as math, physics, electrical engineering, psychology, English, music, and linguistics [14].

By the mid 80s, 35% of enrolled CS students were women. CS had a larger increase in female participation from the 1970s to 1980s than other STEM fields. Indeed, writings from the time describe CS as a "woman-friendly" science [15].

Unfortunately, as Roberts documents, the nascent CS departments were ill-equipped to deal with surging student interest. To cope, departments began restricting admission to their majors. For example, Purdue restricted admission to its major in 1982, after which enrolments dropped to roughly one third of the previous number [12]. The University of Maryland enforced limitations on class size in 1982, and restricted admission to the major in 1984 [12], causing a similar drop in enrolments.

CS departments took a number of other steps to explicitly try to reduce enrolments, including adding new GPA requirements for taking particular courses, increasing the number of prerequisites, and retooling first-year CS as a weeder course [14]. These actions are examples of educational *gatekeeping*: exclusionary policy actions which affect how easy it is for students (or particular subgroups of students) to enter the "gate" to get an education.

In Roberts' words: "The imposition of GPA thresholds and other strategies to reduce enrolment led naturally to a change in how students perceived computer science. In the 1970s, students were welcomed eagerly into this new and exciting field. Around 1984, everything changed. Instead of welcoming students, departments began trying to push them away. Students got that message and concluded that they weren't wanted. Over the next few years, the idea that computer science was competitive and unwelcoming became widespread and started to have an impact even at institutions that had not imposed limitations on the major." [16]

Roberts notes that during this time period, CS departments hired more part-time/adjunct faculty and began hiring faculty from other disciplines, most of whom were from mathematics [16]. This contributed to the push to teach CS in a mathematically-focused manner rather than a multidisciplinary one. This had a gendered effect, since requiring mathematics backgrounds of students at a time when a disproportionate number of students who did not have math backgrounds were women. Furthermore, the retooling of first-year CS as a weeder course also resulted in a competitive, "chilly" atmosphere that disproportionately discouraged women.

The combination of gatekeeping policies and social changes to how CS was taught increased the social closure of the field. The closure disproportionately hurt the participation of women, as well as racial minorities [14].

C. The Second Bubble: The Dot-Com Boom

The enrolment boom-and-bust pattern reappears in the early 2000s: with the dot-com era came a new boom in CS majors, followed by a bust in student enrolment. The promise that a CS degree would lead to easy prosperity led to a resurgence in enrolments in the late 90s. During this period, we again see a sharp decrease in the percentage of women, from around 27% to around 17% in Figure 1.

Roberts notes that this bust was unlike that of the 1980s: it was not a result of a capacity crisis in universities, but because of the effect of the dot-com industry's bust [16]. But common to both booms were that the booms had gendered effects.

Some CS programmes began giving priority access to would-be majors who had taken high school CS, to filter applicants. This had a gendered effect, since high school CS was more male-dominated than the university population and women were more likely to first encounter CS at university.

The boom-time in the late 90s and early 00s led to a return of strict enrolment controls and a spree of hiring more CS faculty [13]. Cukier's work on how public universities in Ontario lobbied for more CS faculty gives us further insight to the occupational closure of computing. While most of the jobs in IT at the time were not based on a CS background, computing professionals successfully convinced policy makers that computer science (CS), computing engineering (CE) and electrical engineering (EE) were the only educational pathways into the IT sector, and therefore the only departments which should receive new tenure lines. The result was the exclusion of technological departments with more women, such as information systems (IS), business, and new media [17]–[19]. This contributed to demarcationary closure.

CS programmes became increasingly marketed as being about mathematics and engineering, rather than applicable/relevant to business, languages, or social issues [19]. The need for "soft skills" in technology jobs were similarly downplayed [19]. Dryburgh found that women in this era had the perception that computing was about working with machines rather than people, and did not realize that computing work often had a social dimension [8].

As a result of the above discursive shifts, women in technology who did not have CS/CE/EE backgrounds stopped identifying themselves as working in tech, but instead describing themselves as working in business, graphics, illustration, etc. [17] This was not the first time the industry used the tactic of discursively positioning computing as an engineering discipline in order to improve access to resources and status, in turn closing off the "women's" paths into the field. Abbate documents how in the creation of "software engineering" was used in the 1950s to try and improve the status of computing and distance it from the "women's work" of hand calculations and clerical tasks [2].

When the dot-com bubble burst, CS departments were left with a shortage of student interest. Some reports from the time describe it as a "crisis" in low student demand (e.g., [20]), and improving female representation was often cited as a way to improve the situation (e.g., [20]).

Roberts notes that after the dot-com bust, the IT industry became perceived as volatile and vulnerable to outsourcing, which dampened student interest for years to come [16]. Since many women — particularly women of colour — chose to major in CS as a way of climbing the social ladder and acquiring a reliable income [21], the perceived volatility of a CS career had a gendered effect.

D. The Third Bubble: The Present

Enrolments did not recover again until the mid 2000s — and then kept rising [13]. And while the *total* number of women in computing did eventually recover to the dot-com era numbers in the early 2010s, the *percentage* has not recovered [16]. While computing has become more popular, it appears to be much more so for men. At the time of writing, CS is facing its third enrolment boom, with enrolments now greater than the peak of the dot-com bubble [4].

More research is needed on female participation during the current enrolment boom. So far the research has been depressing: Patitsas et al. report that CS departments are not considering diversity when making policy decisions in response to the current enrolment boom [22], Barker et al. note that some departments are reducing or eliminating non-major service courses [23], and CRA's Generation CS report notes that departments which do consider diversity have higher female representation in their CS programmes [4].

Overall, a pattern of growing-but-cyclical enrolment emerges. Boom times lead to more students, then more enrolment controls. Bust times also result in disproportionately many women leaving the field, or not going in at all [13]. While the *total number* of women does appear to recover after a bust, a much larger number of men enter the field; each boom has a greater total number of students than the previous boom. It remains to be seen how CS will respond to and be affected by the current enrolment boom.

IV. Gendered Participation in Computing

From applying Witz to the history of undergraduate CS education, we see that female representation is affected by the social closure of computing. The closure can be affected by policy and discursive practices.

Both of Witz's major exclusionary strategies (exclusion and demarcation) contribute to the closure of computing. Exclusionary strategies have included not allowing married women to work after WWII [2], and in contemporary times, preferentially admitting students to CS undergraduates who have high school CS. Demarcationary strategies include the historical division of labour in early computing (e.g., a woman "coder" working for a male "planner"); and the contemporaneous demarcations between CS and IS/IT, and between "back-end" and "front-end".

A. Policy Practices

Policies play an important role in shaping education [24]. Formal gatekeeping practices such as university admissions policies, hiring policies, research grant reviewing, peer review, and credentialism all affect female representation in computing. For example, the use of personality tests in hiring has historically had an effect on who is hired — and the subsequent image of what a software engineer looks like [2].

Policies can also be used to open computing. For example, opening up new pathways for "non-traditional" students to enter the field has the promise to improve diversity, and has played a role in achieving university-level change at universities such as Carnegie Mellon [25] and Harvey Mudd [26].

Social gatekeeping factors, such as professors creating a "chilly" atmosphere in their so-called "weeder courses", are also the result of policy practices. Student-to-faculty ratios and the training and composition of faculty also are policy practices which affect the learning environment for students, in turn affecting closure. Policy practices such as providing first-year research experience for undergrads or taking students to Grace Hopper to provide a sense of community for female students also act to counteract the closure of computing.

B. Discursive Practices

As documented by Abbate [2] and Cukier [17]–[19], the discursive practice of presenting computing as a field of math and/or engineering acts to close the field. Efforts to highlight the multifaceted, interdisciplinary nature of computing act to open the field, and are attributed to the higher percentage of women in computing at some US universities.

The discursive construction of gender also matters. In Malaysia, gender roles are such that office work is "women's work" and outdoor physical labour is "men's work"; computing is presented as an office job and is therefore female-dominated [27]. Note that when computing was seen as a clerical job in the US and the UK, it was also female dominated [1]–[3], [28]. When the discursive presentation of computing is compatible with gender roles, we see more women in computing. Whether this is an appropriate goal for gender equality is debatable: if we discursively recast computing as compatible with traditional gender roles, we in turn reinforce these gender roles. For a further discussion of why this is counterproductive, see [29].

Another discursive shift that may be productive is moving from the "leaky pipeline" metaphor to one of "pathways." The leaky-pipeline metaphor has been critiqued and problematized for establishing a limited view of who may be in computing and further marginalizing "non-traditional" students [30].

Another factor identified in the literature is that the discourse of growth (or fixed) mindset has an effect both on the social experience of computing students as well as whether students feel they should study CS. Indeed, we see more women in academic fields where faculty believe that any student can succeed [31].

C. Interactions: Discourses and Policies

There are interactions between policies and discourses: policymakers are affected by discursive strategies and the effects of policies can promote or hinder particular discourses. The Generation CS report observed that CS departments which considered diversity in their policy-making had a higher percentage of women in their CS programmes [4]. More work is needed in CS education research to examine the process of policy-making in CS programmes.

V. Conclusions

In looking at the history of enrolments in CS, we see many of the same themes that have been documented by historians of technology when they have studied mid-20th century computing. Women are excluded from computing when it becomes more socially closed, and closure operates through policy practices and discursive practices.

Enrolment booms are key times for the gendering of CS education, with important implications for software engineering as a profession. Based on previous history it appears that the gender gap is only going to widen with the current enrolment boom. The question is: will we learn from history?

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