Is Computing for Social Good the Solution to Closing the Gender Gap in Computer Science?

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ABSTRACT

Computers are ubiquitous in modern western society, yet few people in the general public have a good understanding of what Computer Science is, and what Computer Scientists do. The typical view of Computer Science is of a male-oriented discipline that focuses on technology and eschews social interaction. This stereotypical view does not appeal to female students. As a consequence, there is a significant gender gap between male and female participation in Computer Science. This paper reviews research on how Computer Science is perceived and argues that the inclusion of socially relevant examples and exercises in early computing courses may help the discipline to be perceived in a more positive light, and subsequently improve participation rates of women in computing.

CCS Concepts

•**Social and professional topics** → **Women;** *Computing education;*

Keywords

social good, women, gender, Computer Science education

1. INTRODUCTION

Computers are used intensively by people in their daily lives, for personal activities as well as professional [5, 20]. The use of computers is growing, and there is an expanding job market for Computer Science graduates. Forbes lists Computer Science as the third top major with grand job opportunities [2]. Many universities around the world are experiencing substantial demand for Computer Science courses and are graduating increasing numbers of students [24]. However, even with the ubiquity of computer use and high demand for Computer Science graduates, few women are choosing to study Computer Science.

A longitudinal analysis of student enrolments in the USA indicated that the proportion of female Computer Science students peaked in 1980 (at 44 percent), and declined steadily over the next 25 years, reaching a low of 12 percent in the mid-2000s. It has since improved slightly, to around 15 percent in 2011 [22]. Despite widespread awareness of the gender gap in the Computer Science Education community for at least 15 years [14], the participation rates of women have not changed significantly.

An analysis of students graduating from the University of Auckland shows similar results to those published for the USA. Between 2005 and 2015, almost 12,000 students graduated with Bachelor of Science degrees from the University of Auckland, of which 49% were women. Among the 12,000 students awarded a BSc, 1,608 majored in Computer Science. It is notable that only 14% of these were women. Although women participate equally with men in the sciences, the gender gap in Computer Science is substantial. Figure 1 shows the proportion of female students graduating with Bachelor of Science degrees from the University of Auckland, compared with the percentage of female students graduating with a major in Computer Science.

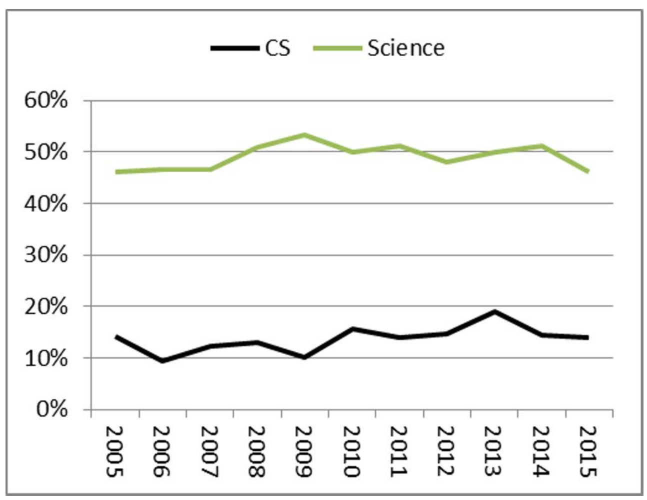

Figure 1: Percentage of female students graduating from the University of Auckland with a Bachelor of Science degree (including all majors), and with a Bachelor of Science degree majoring in Computer Science.

This paper argues that the perception of Computer Science is a critical factor in the gender imbalance observed in most Computer Science departments. We believe that tra-

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ditionally taught courses perpetuate many of the negative stereotypes associated with Computer Science. Integrating socially relevant activities into Computer Science courses, particularly in first year, may help to overcome these negative associations.

2. PUBLIC PERCEPTIONS

It is quite important to study perceptions of students towards the Computer Science discipline to recognize the problem scope before suggesting ways of improvement. Although some authors claim that students perceive the field of Computer Science to be boring and irrelevant [8, 13] and arcane [11], such claims are not supported by evidence. By contrast numerous research papers include student satisfaction surveys that indicate that students are generally quite interested in the courses they take. One such example [7] concludes that only 17.4% of current Computer Science students did not find their courses enjoyable and 8.7% uninteresting. The majority of students responded with positive replies regarding the courses. However, it is worth noting that these surveys only consider students who are already taking Computer Science courses and do not consider potential students who have chosen to avoid Computer Science because they perceive it to be boring and irrelevant!

The image of computing seems to be highly influenced by opinions that establish it as a solitary and indifferent environment consisting of mindless button-pushing [3, 25]. Further, the discipline is perceived to be grouped into very general sections as [25] questions the courses' content in reinforcing or challenging the image of computing as browsing websites, hacking and playing games. Additionally, students who were asked to describe computer scientists characterised their personal attributes as lacking interpersonal skills and being singularly focused on computers [6]. Both the subject itself and the people engaged with the subject are perceived negatively.

Mass media (films, television, books, advertising etc.) plays a role in reinforcing negative stereotypes of computing. An analysis of IT stereotypes in television shows viewed by high school students and their parents in Australia found that male IT professionals were more traditionally stereotyped than female IT professionals. Interestingly, many of the participants in the study failed to recognise the non-stereotyped roles as being related to IT. Additionally, they incorrectly identified some characters (such as those in *The Big Bang Theory*) as being IT professionals due to their negative personal characteristics combined with their computer use [18]. Although this research considered only a small number of television shows, these findings suggest that while the media sometimes reinforces negative stereotypes of computing, people also interpret the narrative of the show according to their own established stereotypes.

However, it is possible to change public opinion when these stereotypes are directly challenged. A study by Cheryan et al. [6] found that women were more interested in studying Computer Science after they read a fabricated newspaper article that described computer scientists as no longer fitting the traditional stereotypes.

Gender is deemed to be one of the obvious stereotypes as computing is seen as a male-oriented discipline [8, 20]. Peckham et al. [20] states that under-represented groups such as females and people of colour are assumed to not have any prior knowledge and interest in the field. They claim that this prejudice can result in an immediate loss of interest and a feeling of inferiority. However, their study does not provide any evidence regarding this claim.

Margolis and Fisher [17] report that even though women find the technical aspects of Computer Science interesting, it is only truly made meaningful for them when connections to other disciplines are depicted. According to Papastergiou [19] a significant percentage of students who chose not to study Computer Science said it was because they'd rather work with people instead of interacting with a machine all day. They also found that in their analysis that boys view Computer Science as a human and application oriented field, whereas girls identify the field as a more technical one (based on programming and algorithms). This may possibly result in students switching majors to a field that allows them to have a more social impact [3].

Buckley et al. [4] argue that the field of Social Sciences has a four times higher graduation rate compared to Computer Science because students usually prefer to major in something that has a fundamental, positive impact on the society [4]. The findings from Sax et al. [22] indicate that this may be particularly true for women. They identified the fact that women place greater value on social activism (i.e. helping others and being part of positive social change) than men as one of three most significant factors responsible for the gender gap in Computer Science.

3. CONNECTING TO SOCIETY

3.1 Context Computing

Peckham et al. [20] reports on institutional programs that practice context-based, interdisciplinary studies evade stereotypical thinking of many students. Some of the recommendations made in this study towards attracting under-represented groups, mirror factors from Google's study [1] about what impacts young women to study Computer Science. These include academic exposure to a range of Computer Science activities, realistic career awareness, increased social encouragement and strong belief in one's abilities. It is extremely important to have varied perspectives in producing extensively relevant solutions to critical problems for a wide population (including males and females, Computer Science experts and novices and people from other fields). Therefore, participation in Computer Science courses should be broadened to different groups of students in various disciplines. A context based approach provides a scaffold to ensure that the discipline works towards a positively general representation of Computer Science and combats the current image of computing in a hands-on manner.

Researchers have tried to frame practical domains around technical course content to enable deeper understanding for students. Context based elements are integrated within lecture content, laboratory activities, assignments and customized textbooks. These contexts provide a relationship to the concept being studied with the outer world. They are seen as the surrounding pieces to an individual puzzle piece in order to complete the puzzle. At Georgia Institute of Technology, three new introductory computing courses were introduced to suit three separate audiences: computing students, engineering students, and liberal arts, architecture and management students [13]. Each of the three courses was developed with the help of respective faculty members and to suit different contexts (MATLAB and media computation). Guzdial [13] observes success rates above 80% in the MATLAB and media courses, which shows how implementing context-based computing attracted a diverse range of students.

3.2 Computing for Social Good

As context computing only focuses on building content around domains and integrating multidisciplinary aspects, it does not highlight real world relevance in terms of social issues. The ACM Computing Curricula [15] states: "The inclusion of core hours in the Social Issues and Professional Practice KA under the Social Context knowledge unit helps to promote a greater understanding of the implications of social responsibility among students." This accentuates students being aware of social issues enough to continue being socially responsible throughout their careers, hence it is very important that a social context is provided across the computing curriculum.

Michael Goldweber discusses the concept of 'Computing for Social Good' (CSG) extensively through his work [8, 9, 10, 11, 12]. According to Goldweber, 'Computing for Social Good' (CSG) is "an umbrella term meant to incorporate any educational activity, from small to large, that endeavours to convey and reinforce computing's social relevance and potential for positive societal impact." [11] This notion opens up the opportunity to use computation as a means of suggesting highly applicable solutions to profound social problems. In courses where CSG is integrated, students are instructed to make a difference in the community in any small way [3]. Real-life problems are too compound to be solved by an individual, but the desire to make a difference is enough of an encouragement.

This is not a new concept. Schneiderman [23] argued in 1971 that Computer Science should not continue to be taught as a theoretical field and instead should include social relevance and implications to the field. He reports that the use of complex real world problems in projects was superior to the 'toy' problems presented in most textbooks. Despite being such a long-standing concept, few introductory courses in today's curriculum implement socially relevant features that consist of opportunities for societal impact.

Students in medicine work towards finding a cure for cancer or AIDS or other diseases. The Computer Science curriculum needs to inspire such foreseen goals within students that give them a long-term purpose. Buckley et al. [5] suggest students can see the discipline as a means of using technology to solve problems of personal interest and problems that are significant to communities at large. Computer Science can be the vehicle carrying passengers towards a certain, important destination. To suggest how CSG can be incorporated into the curriculum, Goldweber et al. [12] categorize various approaches into: standalone courses, integrated modules, embedded into examples and case studies and lastly learning by doing. The process and extent of integration can be decided upon by instructors, depending on their specific requirements and availability of resources.

3.3 Meaningful assignments

One the easiest ways to incorporate CSG into existing courses is to modify the assessed work that students are required to complete. Assignments can be made meaningful by introducing real-world relevance and adding value to their conception. According to Layman et al. [16], a meaningful assignment "seeks to engage the student by appealing to their practical nature and/or their desire to help society". This definition connects CSG to resources used for assessing students as a very important technique, since students spend hours on assignments, constructing strong opinions about the course. The study conducted by Layman et al. [16] illustrates a problem with external validity as only the top institutions were chosen based on the number of degrees awarded in Computer Science. Consequently, institutions that were towards the lower scale have no contribution in the study, making the results not applicable to a wider population.

A common assessment technique incorporating CSG is the possibility of structuring humanitarian projects around community problems. Buckley et al. [4, 5] discuss the three projects that students produced in the Software Engineering capstone course CSE 442. One student project team implemented an augmentative communications device for "David" who was unable to speak after suffering a stroke. The next project asked the students to create a child-centred version of the previous device with the main focus being on audio feedback and graphics. Lastly, a "DISCO" system was developed to provide teachers and therapists with a choice-making environment using light, music, and sound for physically and developmentally impaired children.

All of these projects resulted in vast changes in the self-perception of students, by participating in the community and being able to help others, they were able to see themselves as good citizens. Furthermore, students are able to see the work they have done as important and suddenly, developing something and delivering it to a client is not irrelevant and small any more [16]. Additionally, with a real client being involved in the scenario, students are compelled to understand their requirements and develop a plan and high-level design before they implement anything [16]. This gives them a good practical experience which would be useful in their future careers. Even though these projects are heavily focused on engineering (using software and hardware both) and are at a fairly big scale, they're not rendered as impossible to reproduce in the Computer Science curriculum. Considering the huge numbers of students in introductory courses, instead of practising scope similar to humanitarian projects, assignments can be produced at smaller level but incorporating related concepts.

Ideally, the difficulty level of meaningful assignments should be at the same level as traditional assignments; however, simplifying the context may cause the socially relevant problem to become unrealistic [21]. This stresses a crucial requirement to ensure that the difficulty level and practicality of an issue are both applicable for introductory Computer Science students. Researchers have further discussed that integration of CSG can be done without introducing new levels of complexity or extra cognitive load, only with a little creativity [10, 16].

3.4 Student perceptions of CSG projects

Studies assessing the effectiveness of socially relevant assessments are very limited. A recent study by Rader et al. [21] examines the effect of CSG based projects in introductory Computer Science and Software Engineering courses. In comparison between traditional projects and CSG based projects, the latter was not preferred especially when evaluated against game-based projects. Females ranked two of the humanitarian projects positively, but none of the projects were ranked similarly by males. The difference in opinion between genders exists despite getting positive responses from almost all students when surveyed about their interest in socially-beneficial projects: 79% CS1 students responded affirmatively, 88% of SE Search and Rescue project students and 93% of SE Disaster Management project students. These results pose an internal validity issue (which is acknowledged by the authors) due to the lack of female participants across Computer Science and Software Engineering projects. The study also concludes that the level of difficulty due to the open-ended nature of CSG-based projects is quite important to consider for introductory courses.

3.5 Beyond assessed activities

In order to provide meaning, focus and a sense of direction to the discipline, content in the lectures needs to be changed as well. Socially relevant examples and problems should be integrated into explanation of technical concepts. Goldweber [8] stresses the importance of the first day activity in reiterating the myths of Computer Science or renewing the image of the discipline entirely. It is important to clarify misconceptions about the field in the first class itself so the students have an unambiguous viewpoint of what the discipline is about, what will be expected of them and how they can have societal impact in the world. He suggests creating class-based activities that appeal to students' values and also display the scope of positive societal impact through Computer Science. As an example, the 'reuniting families' problem' is implemented where students in groups of 3–4 are asked to think about a natural disaster and devise a protocol for workers to reunite families. This helps them touch on important computing concepts such as algorithm design, repetition, selection and problem simplification while interacting with the problem at a practical level. There has been no formal assessment of this approach in the study.

As Buckley et al. [5] sum up everything: Computer Science needs to be portrayed to students in a way such that Computer Science enables them to make the world a better place, they can be cooler and have more fun while studying it, and be technological sensations with the latest software and application knowledge. This would engender a much more positive, and socially connected, image of computing to the general public. An image that would contrast significantly with many of the existing negative stereotypes.

4. CHALLENGES

Students may enter a given course with different goals, values and learning styles [20]. It is possible that, just as we expect some students to enjoy social relevance in lecture content and assignments, there may be a group of students that prefer the more technical and scientific side to the Computer Science courses. Expanding on this, the main interests of some students are focused on technological details as discussed by Goldweber [12]. Therefore, it would be important to find a way of serving both the population targets, without disregarding any group of students. Another problem is the delay in including CSG concepts only later on in the curriculum at some institutions, mainly in third year courses [10]. This causes a major crisis for the discipline as students in the first year are not able to experience the societal impact of their current study and end up switching to more "meaningful" majors. Such actions once again impact the image of computing and further represent it as a negative one.

The discipline of Computer Science suffers from a lack of teaching resources that relate to the outside world in a practical sense and exemplify social impact. Walker [25] and Buckley [5] discuss the emphasis placed on language syntax and technicalities of computing in introductory courses as a dreadful problem. During the first few classes, students should ideally encounter the flood of opportunities to tackle world issues using programming, algorithmic and problem solving skills. Unfortunately, this is not the case frequently. Following this Goldweber [10] highlights the importance of the activities students/instructors perform on the first day of the course, on their views of the discipline. Teaching strategies carry a huge weight in forming the course content and instructors' lack of domain knowledge [12, 10] about social issues hinder this greatly. This can result in an increased pressure and workload for instructors' as they have to prepare excessively to incorporate social aspects into the technical content.

Another vital problem across many introductory courses is the absence of notably useful textbooks which help students and are engaging at the same time. As most of the lecture content is usually created based on sections from the textbooks, examples should ideally be realistic and informative. Current textbook examples are highly dull built mostly around games, food and animals [3, 5]. Buckley exclaims that "there isn't a textbook out of the 60 I have on my shelf that makes me see computing as socially relevant" [3]. This displays a grim need for contextualized and customized resources that are able to display technical concepts in the light of social relevance. If instructors don't depend on textbook examples, they would be expected to come up with their own illustrations to further explain concepts on the spot in lectures. Guzdial [13] claims the process of modifying resources is a tough and costly procedure but the outcome can be effectively shared throughout Georgia Institute of Technology. Therefore, customized resources can be seen as very useful and relevant items.

5. CONCLUSION

The increasing use of computers in all fields across the work industry as well as the education institutions demands a diverse population in Computer Science. This cannot happen unless the current negative perceptions of students are challenged and the gender gap is resolved. Integration of real world relevance to computing is a means to challenge the traditional negative stereotypes and widen the appeal of Computer Science to under-represented audiences. Computing for Social Good provides various suggestions for enhancing the discipline's content: taking students' values into consideration for structuring the content, practising socially relevant first day activities and creating meaningful assignments and resources. This would not only provide a context to programming and algorithms, it would further make the students feel that they would be connected to others, and could themselves contribute something meaningful to the world.

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