Barriers to Gender Diversity in Software Development Education: Actionable Insights from a Danish Case Study*

Extended Abstract†

Valeria Borsotti
IT University of Copenhagen
Rued Langgaards Vej 7
Copenhagen, Denmark
vbor@itu.dk

ABSTRACT

This paper contributes to the growing literature on the gender gap in computer science education by focusing on an exploratory case study conducted at the IT University of Copenhagen (ITU), Denmark. The specific objective of this study was to draw on existing research in order to empirically investigate the main socio-cultural barriers to female participation in the bachelor of Software Development at ITU, and to generate insights that would inform concrete and effective interventions. This investigation takes the form of an exploratory case study, providing insights into influential factors such as students' perceptions, attitudes and behavior towards software development education and gender differences in pre-university coding skills.

Empirical evidence has been collected through semi-structured interviews with 38 students (undergraduate and high school) and surveys with 395 students (undergraduate and high school). Research findings from the study have subsequently informed the design of local interventions that have led to the recruitment of double the percentage of women in the bachelor of Software Development at ITU in one year, from 11% in 2016 to 22% 2017. The study also describes and discusses such interventions.

CCS CONCEPTS

• **Computing Education → Computing Education Programs**; *Computer Science Education; Computer Engineering Education*; Gender

KEYWORDS

Gender Diversity, Software Development Education, Stereotypes, Computer Science Education, Exploratory Case Study.

1 INTRODUCTION

The IT University of Copenhagen in Denmark (ITU) offers a bachelor degree in software development. The program predominately attracts male applicants: in 2016, at the time this study was conducted, the percentage of female students admitted to the bachelor was just 11%. A similar or worse gender unbalance can be found in all of the other related study programs in Denmark, making the field of computer science one of the most male-dominated in the country. According to data from the Danish Minister for Higher Education and Science, in 2016 the Technical University of Denmark (DTU) had 12,5% of female students admitted to the bachelor in Software technology; the bachelor in computer science at Copenhagen University admitted 7,8% female students; the same program at Aarhus University admitted 8,4%; at the University of Southern Denmark 6%; at Aalborg University 2%.

These numbers are on the lower end of current figures for the European Union, where the participation of women in Computer Science (CS) degrees oscillates between 6 and 22% in the different member states [1]. Interestingly, however, a cross-cultural comparison with a few South East Asian and Middle Eastern countries reveal significant statistical differences. Studies over the past decade show that in Dubai the average percentage of female students in CS higher education is about 50%, in Qatar is 70% and in Malaysia is 60% [2]. A recent study from Carnegie Mellon University reports that the Palestinian territories have a much

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higher enrollment in CS at a high school level compared to their Israeli neighbors [3]. As these differences indicate, the reasons behind the low participation of female in CS education are not biologically determined, but rather socio-cultural.

The specific objective of this study was to draw on existing research in order to empirically investigate the main socio-cultural barriers to female participation in the bachelor in Software Development at the IT University of Copenhagen, and to generate insights that would inform concrete and effective interventions. This investigation takes the form of an exploratory case study, providing insights into students' perceptions, attitudes and behavior towards software development education and into their learning experience. The study also presents the interventions introduced based on research findings.

1.1 The Influence of Stereotypes

In recent years there has been an increasing amount of interest in investigating the barriers preventing women from entering the field of computer science education. Extensive research has shown that stereotypical perceptions of computing and IT careers play a big role in influencing the educational choices and career aspirations of girls and women. Common stereotypical beliefs associate competence in science with men and competence in math with men [4, 5] and are shown to have a negative effect on the way girls assess their capabilities and choose their career. Women tend to show low self-efficacy in domains that are perceived as typically male-dominated, like mathematics, engineering and computer science - inaccurately evaluating their actual skills and abilities [6, 7]. Biased self-assessment in STEM subjects influences education and career choice, contributing to the gender gap in science and technology fields [8, 9, 10, 11]. Teachers and parents, who are important influences in shaping children's attitudes and aspirations, also hold stereotyped views that might influence the girls' choices. A recent OECD study has shown that parents of boys and girls with similar performances in math and science expect their daughters to have a career in STEM to a significantly lesser degree [12]. Stereotyped ideas about what is suitable for males and females are surprisingly pervasive in countries that score high on the Global Gender Gap Index. A recent study conducted across 66 nations, with data from approx. 350,000 people, found that even countries with high gender equity have strong gender-science stereotypes *if the science fields are male-dominated* [13]. Scandinavian nations like Denmark and Norway showed even stronger stereotypes associating science with men compared to the U.S. Moreover, the existence in Denmark of a highly gender-segregated labor market, where men largely dominate the private sector and technical positions, and where 71% of those employed in healthcare, public administration and education are women [14] might reinforce a belief that working in computing is not 'for girls', while also contributing to a lack of female role models in computer science.

1.2 The Male Nerd Cliché and the Positive Effect of Role Models

Computing has been socially constructed as a male domain [15, 16] despite the fact that women have historically played an important role in shaping the field, and that in the 1960s women were proportionally more numerous in computing than in other engineering disciplines in the United States [17]. There is some correlation between the drop of women's participation in computing education in the mid 1980s and the concurrent rise of the 'male nerd' cliché in popular culture and in gendered marketing campaigns for the videogames industry [17]. Recent evidence suggests that the widespread stereotype of the computer geek - typically a male with poor social skills– as well as pervasive gender stereotypes related to computing careers operate as 'gatekeepers', keeping women away from CS education [18].

By challenging common stereotypes and preconceived notions, female role models play a significant role in increasing women's engagement in computer science [19, 20, 21, 18, 3]. Some studies suggest that female and male role models in STEM have been proven to be just as effective in increasing females' beliefs in their aptitude as long as they are non-stereotypical [22]. Increasing the number and the visibility of role models who challenge common stereotypes about the IT field and about gender has been shown to be an effective tool to counteract the low participation of females in CS education.

1.3 Lack of CS Education in School

A recent meta-study of more than 1200 papers about women's underrepresentation in STEM has disaggregated different fields and compared them to one another, showing the main reasons why some STEM fields, such as computing, physics and engineering, have a lower representation of women compared to others such as biology, mathematics and chemistry. Fields with a wider gender gap tend to have a masculine culture; presence of gender gap in self-efficacy and a lack of pre-college experience in the field [23]. Interestingly, according to the study, a lack of previous domain expertise may not cause gender disparity when it is not paired with a masculine culture, and subjects with the least gender imbalance are those that are ubiquitous and mandatory in high schools.

Computer Science is not a compulsory subject in primary school, middle school or high school in Denmark. The only exceptions are few study lines in technical high schools, where females are currently heavily statistically underrepresented [24]. This means that most Danish students are not introduced to the subject in a formal way, but primarily in informal settings through their family, friends and in other extracurricular or hobby activities (ie. game modding). Since girls are less likely than boys to undertake computing on their own in their free time [19], the introduction of proper formal CS education in school has been identified as an effective way to spark the girls' interest and engagement in IT related subjects.

Together, these studies indicate that the main reasons behind the gender gap in computer science education are: 1) stereotyped perceptions of computing and of who is most suited to be a computer scientist, 2) a generally male-dominated study environment in CS programs and 3) a general gender disparity in terms of previous familiarity with the CS domain are the main reasons behind the gender gap in the field. The objective of this study was to investigate to which extent these factors affect female

students in Denmark, and whether it was possible to create interventions that effectively address the issues.

2 METHODS

2.1 An exploratory case study

The use of qualitative case studies is a well-established approach in studies focusing on the gender gap in CS education. The benefit of this approach is to provide insights into students and prospective students' attitudes, perceptions, behaviors and motivational variables. Moreover, research findings from qualitative case studies offer a concrete point of departure to design interventions leading to increased gender balance in the field of computer science. Starting from 1999, a case study approach has been adopted at Carnegie Mellon University (CMU) by Margolis and Fisher to understand the reasons behind the gender gap in CMU computer science programs. Evidence from the study was used to develop an effective strategy to successfully bridge the gap. As a result, CMU increased the enrollment of female students in the undergraduate computer science program from 8% in 1995 to 48% in 2016.

A case study approach was chosen for this project in order to: 1) investigate gender differences in pre-existing coding skills for both undergraduates and high school students; 2) gain a deeper understanding of the attitudes, behaviors and perceptions of males and females students of Software Development at ITU towards computer science; 3) identify Danish high school students' perceptions towards CS education and 4) provide actionable insights to inform the design of interventions.

In 2016, semi-structured interviews were conducted with 28 undergraduate students enrolled in the bachelor of Software Development, 13 females and 15 males. Semi-structured interviews were also conducted with 10 high school students attending an elective programming class in a technical high school, 3 females and 7 males. Additionally, anonymized surveys were conducted with two cohorts of students: a) 196 students enrolled in the bachelor of Software Development (one survey conducted in the spring 2016 with students from 1st, 2nd and 3rd year; one survey conducted in the fall 2016 with 1st year students); b) 199 high school students. Empirical data was analyzed using the grounded theory approach [25]. The interventions described in the article were introduced shortly after the first elaboration of preliminary findings, halfway into the study, and they targeted prospective students and first year students. Seventeen of the interviews with bachelor students were done before the introduction of interventions (in the spring of 2016), the rest afterwards (fall 2016). All the students interviewed in the fall were first year students, in order to better evaluate the effect of interventions targeting them specifically. Insights from the study have been published in a report distributed internally at the IT University of Copenhagen in 2017. The report presented an analysis of data together with a set of recommendations.

2.2 Data Collection

2.2.1 *Interviews with bachelor students.* Bachelor students participating to the interviews were randomly selected. A slightly smaller sample of women were interviewed (13 participants) than the males (15 participants) because of the difficulty in recruiting female interviewees due to the significantly low proportion of women in the program. In order to identify the attitudes and perceptions of bachelor students towards software development education, the participants were asked: 1) How they became interested in software development, 2) Why they chose to apply to the bachelor, 3) Whether their parents, other relatives or friends expressed any opinion about their choice, 4) What interest them the most and the least about software development, 5) What skills they thought were necessary to be a software developer. In order to examine pre-university experience with coding and the current learning experience, students were also asked: 1) If they had written any code before enrolling in the bachelor, and if so how they learned to code, 2) If they felt inadequate or too inexperienced for the study due to lack of previous coding experience, 3) If the bachelor was a good fit and whether they experienced any difficulties, 4) If they felt they received enough support from teachers and TAs, or whether extra forms of support where needed, and which ones. In addition, towards the end of the interview, students were asked their opinion on the possible causes behind the gender gap in the IT sector and CS education.

2.2.2 *Interviews with high school students.* In order to identify the attitudes and perceptions of high school students towards computer science, the 10 high school participants were asked: 1) How they became interested in programming, 2) What interested them the most and the least in their programming class, 3) What they thought was the most challenging aspect of their programming course, 4) What they were planning to do after they graduating from high school (university education or otherwise), 5) If they knew people working with software development. The participants were randomly selected and recruited from a local technical high school among the students who are enrolled in a elective programming class. The sample of girls interviewed was lower than the males (3 out of 10 participants) because they were the only female students enrolled in the class.

2.2.3 *Survey with bachelor students.* Two surveys were conducted with the bachelor students in Software Development, in both the spring and fall of 2016 (before and after the introduction of several interventions). The proportion of males and females participating in the survey reflected the proportion of males and females admitted to the programs at the time of the surveys. In order to investigate previous coding experience and attitudes towards computer science education, participants were asked: 1) Whether they had previous programming experience (and if so they were asked to detail for how long), 2) In case they had previous coding experience, what programming languages they were familiar with, 3) What type of high school they came from, 4) How they became interested in software development.

2.2.4 *Survey with high school students*. The surveys were conducted with high school students visiting ITU together with their teachers or in occasion of related open events targeting students interested in any of the programs offered by the IT

University of Copenhagen. In order to investigate attitudes and perceptions towards computer science and software development, students were asked: 1) What they immediately associated with software development, 2) Whether they ever considered taking an education in software development, 3) What they planned to do after graduating from high school. Students were also asked if they had any programming experience and if so, in which languages.

3 RESULTS AND DISCUSSION

3.1 Gender Differences in Previous Domain Expertise and Previous Coding Skills

A number of issues and themes were identified through the interviews and surveys. This section presents both findings from the data analysis and a description of the interventions introduced at ITU, together with a brief evaluation of their effect.

The empirical data shows that students of the bachelor of Software Development share more gender similarities than gender differences, particularly in terms of learning styles and interests. When asked what interest them the most about software development, both male and female students listed a wide variety of aspects such as: problem solving, the hands-on approach in learning and a strong component of creativity. Few females and males also listed freedom and independence to decide over their future lifestyle. Similarly, when asked what skills they consider necessary to be a software developer, male and female students pointed to the same set of characteristics – in both groups 'a logical mindset' was named the more often, followed by 'good teamwork skills', math and creativity.

3.1.1 *Gender differences in pre-university coding skills*. The most striking result that emerges from the data is the existing gender difference in previous coding skills and domain expertise. Simple statistical analysis of the interviews and surveys with students admitted to the bachelor showed that females are less likely than males to have pre-existing coding experience before applying to university. Previous coding experience among males is statistically higher. Data from surveys with high school students also show that females are statistically less likely to have previous coding experience. Moreover, surveys with bachelor students also revealed that there exist a very wide variety of pre-existing coding skills within the whole student population.

3.1.2 *Diversity of pre-university coding skills affects learning experience*. When participants were asked about their learning experience in the bachelor, the majority of female and male students without previous coding experience felt that, despite the fact that the program did not require any prerequisites in terms of programming competences, it was not geared towards absolute beginners. Students felt at a disadvantage in a context where many of their classmates had a wide range of skills in different languages and several months or years of experience. This quote from a female student who was considering dropping out articulates a common concern:

> *"I think it's not true that you can study here without having programmed at all before. I feel lost all the time (…) That's very annoying because I am very dependent on the students who are more skilled or have tried it before."* (Female bachelor student, interviewed in spring 2016)

Another female student explained:

> *"Sometimes it really feels like…OK if I had coded 10 years before I would really have a bigger chance! I really think that if people are considering this education someone should tell them: go home and code before!"* (Female bachelor student, interviewed in spring 2016).

3.2 Need to Address Wide Diversity of Pre-Existing Skills

3.2.1 *Interventions to support the wide variety of pre-university programming skills.* All bachelor students with no previous coding experience interviewed in the spring of 2016 suggested the need to introduce extra support learning activities for new beginners in coding. Following the recommendation from students, faculty members in the ITU Computer Science department introduced the following learning activities in the summer and fall of 2016, specifically targeting first year students:

- **BootIT,** an optional, free and informal workshop held before semester start that targets first year CS students with no prior coding experience. BootIT is designed to support the portion of the student population who has no previous experience and provides hands-on experience with constants, variables, addition/subtraction/ multiplication/division assignments, comments, if-statements and while-loops in Java. The same subjects are also covered during classes in the first semester. The goal of the workshop is to expose students to the basics of programming in a stress-free environment, increasing self-confidence.
- The ITU **Study Lab,** opened in 2016, is a peer-to-peer support activity run by experienced students working as tutors. The overall concept is developed and supervised in collaboration with academic staff. Students drop in for peer-to-peer assistance with programming tasks, concepts and themes covered during the courses. The lab is open three times a week and attendance is optional.
- **Live coding** sessions take place once a week in combination with the course 'Introduction to Programming'. Experienced teaching assistants demonstrate how coding is done and encourage students to get more hands-on experience by following their example.

These support activities have been positively reviewed by both female and male first year students interviewed in the fall of 2016. Those with no prior coding experience highlighted that extra support activities positively affected both the learning experience and non-cognitive skills such as self-confidence, as this quote from a female student illustrates:

"In the beginning I was shocked (…) some people may have already coded for 3 year or 10 years, and well…I have learned coding from a two-hour tutorial. You feel inadequate, of course you do, and especially in programming where there is such a large spread. I was scared, but because we have BootIT I actually felt very prepared when we started and I feel like (…) I just got the confidence I could do this. Because it would have been really hard, in the beginning I would have thought…well I don't have the strength to do this."
(Female bachelor student, interviewed fall 2016)

3.3 Bias and stereotypes

3.3.1. *Stereotypes and bias are identified as significant barriers.* Interviews with bachelor and high school students revealed the existence of widespread stereotypes and bias about who is usually considered and/or expected to be the most suited for an education in computer science - typically a 'nerdy' male. Interviews also revealed the existence of widespread stereotypes about the lack of social skills and interpersonal communication associated with careers in software development. As this participant commented:

"I think stereotypes are the obstacle. There are still stereotypes on being a software developer…you are geeky and you are nerdy and you have to be a certain way…and you are usually male. And that's not necessary true!" (Female bachelor student, interviewed spring 2016).

Almost all respondents attributed the gender gap in CS education in larger extent to the existence of stereotypes. These views also surfaced in the interviews and surveys conducted with high school students. Several respondents to the survey, particularly from non-technical high schools, associated software development with repetitive jobs with no human contact, as the following quotes illustrate:

"It is not human enough, I don't relate it to people but with hardcore programming every single day." (Female student attending the Biotech specialization at her school)

"Not enough people to talk with."
(Male student attending the math and physics specialization at his school)

"I would like an education with practical projects and field work, not something where people are chained to a screen."
(Female student attending a technical high school)

Some of the students interviewed stressed that the fact that CS is male dominated does not make it an attractive environment for some women. One of the high school students interviewed, who is enrolled in an elective programming class, believed that the gender gap in coding classes is an indication that coding is not for girls:

"It's hard for girls to learn how to program because there aren't a lot of girls studying this subject." (Female student attending a technical high school, interviewed spring 2016)

3.4 Not an Obvious Choice for Women, but Role Models Among Family and Friends Influence Motivation

3.4.1 *Influence of role models is significant especially for women*. A significant gender difference in motivational factors was found in the interviews with bachelor students: females were significantly more likely than males to indicate their father, brothers or partner who worked in IT or studied computer science as an important influence in choosing software development education.

3.4.2 *Computer Science is not the number one choice for females*. In addition, the female bachelor students interviewed were significantly more likely than the males to either have started a different education and switched to the bachelor of Software Development after being exposed to hands-on coding practice, or to have considered taking a different education before deciding to enroll in the bachelor, often after being encouraged by friends or having viewed promotional material of the bachelor program on social media.

3.5 An IT Camp for High School Girls and a Re-Designed Ad Campaign

3.5.1 *Outreach intervention #1*: *IT Camp for Girls*. After a preliminary overview of empirical data, another intervention was designed and introduced in the spring of 2017 with the following goals: 1) address the existing gender gap in pre-university coding experience, 2) shift negative perceptions about CS, 3) counteract existing stereotypes and 4) increase opportunities for female high school students to become more familiar with the domain. The intervention took the form of a IT Camp for Girls. The camp was a free three-day workshop for about 50 high school girls. It was taught by male and female teachers and it introduced data science and programming concepts through a series of lectures and hands-on exercises. Female students from the bachelor were supporting the activities and acting as role models for the high school students. The camp was successful in inspiring and motivating some of the participants in choosing computer science education. 11 of the 50 participants were among the female students admitted to the bachelor in software development in the fall of 2017.

Figure 1: **Image from the IT Camp for Girls organized at ITU in 2017**

3.5.2 *Outreach intervention #2*: *A re-designed ad campaign to counteract negative perceptions*. To address the widespread stereotypes attitudes toward software development and towards who is better suited for a career in the field, ITU launched in the fall of 2016 a social media campaign with a new promotional video for the bachelor program showing a male and two female students acting as role models, explaining what computer science is and

highlighting the real-life applications of CS. In the video the students interview each other by asking questions like: *Is it necessary to know how to program before starting the bachelor*? and *Why did you choose software development?*

3.6 Research-based Intervention Led to Positive Effects in Recruitment of Female Students

3.6.1. *Positive outcome of research-based interventions*. Following interventions in the areas of learning (the introduction of BootIT, Live Coding, Study Lab, IT Camp for Girls) and outreach (It Camp for Girls, promotional videos and campaign) the percentage of female students admitted to the bachelor in Software Development doubled in one year – from 11% in 2016 to 22% in 2017. Figure 2 shows that this was the steepest raise in percentage of women admitted over the past seven years.

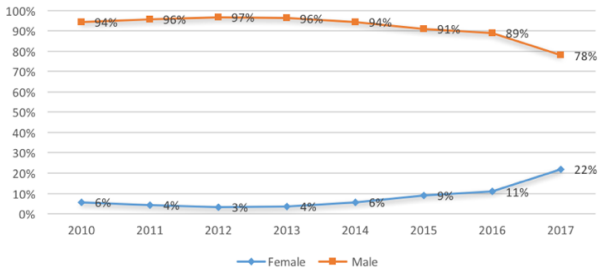

Figure 2: **Percentage of female and male students admitted to the bachelor of Software Development at ITU from 2010 to 2017.**

Together, these results provide important actionable insights into the socio-cultural barriers that are currently preventing female students from choosing a computer science education, and show that it is possible for educational institutions to introduce effective interventions based on explorative case study analysis and evidence from existing literature.

It is interesting to note that, despite the fact that Denmark is a country that rates quite high in the UNDP Gender Inequality Index [26], this study shows that girls and women still experience higher barriers in entering this line of study compared to males due to traditional social norms, stereotyped perceptions and prejudices.

One unanticipated finding of the study was the positive correlation between the existence of close male role models working as IT specialists or studying computer science (father, brother, friend or partner) and the subsequent motivation for females to pursue a bachelor within the same field. A possible explanation for this result might be that interaction with close role models increases both familiarity with the CS domain and IT careers, counteracting widespread stereotypical attitudes and perceptions towards the field of computer science. Further studies could usefully explore whether such correlation exists in other male-dominated, technical fields.

An unexpected outcome of the study was also the existence of a very wide range of pre-existing coding skills among bachelor students. This negatively affected not only females - more likely to have no prior coding experience - but also male students without prior skills. This result has led to the creation of support activities that aided and improved the learning experience of both females and males (BootIT, Live Coding, Study Lab), making the bachelor generally more inclusive towards qualified students with different backgrounds, and benefitting both females and males.

4 CONCLUSIONS

In this investigation, the aim was to understand the socio-cultural factors that prevent women from choosing to enroll in the bachelor of Software Development at the IT University of Copenhagen. The results are in accord with recent international studies indicating that the main barriers to female participation in CS education in Denmark are a combination of: 1) gender differences in previous domain familiarity and pre-university experience with CS; 2) widespread gender biased expectations about who is/should be most suited to pursue CS careers and 3) stereotyped perceptions of CS education and careers in software development. Findings from this explorative case study have informed interventions in two main areas: learning activities and outreach initiatives. Since females are less likely than males to have extensive previous coding experience, and the bachelor was not geared enough towards absolute beginners in coding, the introduction of support learning activities like BootIT, Live Coding and Study Lab has been an important first step in leveling the field and creating a better learning environment, making the bachelor more accessible for qualified students without prior coding experience. Besides addressing this structural barrier, ITU has focused on changing perceptions as well. The new video ad campaign addressed the need to counteract widespread gender prejudices about who is the most suited for a career in CS, and negative stereotypes about the field itself. More research is needed to understand whether such interventions will sustain further growth in the admission of female students in the longer term.

The scope of this study was limited to the gender gap in recruitment of students, but further research to understand possible gender differences in student retention in CS in Denmark is strongly recommended.

Lastly, this study has also important implications for policy developments in the field of software literacy in primary and secondary school, raising several questions about the possible need to introduce some elements of CS as mandatory part of the curriculum in order to prevent the gender gap.

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