Conceptions and Stereotypes About Computer Science and Women: The Uppsala University Case

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ABSTRACT

Computer Science (CS) is a field practiced mainly by men, even though women have been of great importance to the field throughout history. This paper aims to examine gender imbalance in CS and starts off with an introduction of gender division and stereotypes in science. Augusta Ada Byron Lovelace and Grace Murray Hopper are presented along with their contributions to the history of CS. Conceptions of CS are examined based on existing research. Assumptions of women and CS are tested with statistics on the proportion of women in the twenty most and least popular CS courses among women at Uppsala University. The statistics of Uppsala University reflects that women seem to prefer courses where CS is used as a tool and avoid courses that are about programming, data structures and algorithms. The paper is concluded with a reflection over possibilities for upcoming women in CS and suggests that, to attract women to CS, one option is borrowing teaching techniques from the field of mathematics.

Categories and Subject Descriptors

K.2 [**History of Computing**]: *people*; K.3.2 [**Computers and Education**]: Computer and Information Science Education—*computer science education, curriculum, information systems education*

General Terms

Human Factors, Measurement, Theory

Keywords

Computer Science, Gender, History, Statistics, Stereotypes, Uppsala University, Women

1. INTRODUCTION

Science has long been dominated by men and today many fields of science are still practiced by a majority of men. In 2012, only 30% of the world's researchers were women according to UNESCO Institute for Statistics [3]. In Sweden, statistics show a different division for students in Bachelor's programmes, where women form a majority of 60%. However, at higher education levels in Sweden the number of women declines, with 49% female doctoral students and 36% female researchers. Reasons for gender imbalance in science can have different causes, but the influence of gender stereotypes can be argued to have great impact.

The stereotypical association of men and science was shown in tests performed on over half a million, both male and female, participants from 34 different countries [12]. Over 70% of the participants associated men with science and women with liberal arts. Women who associated men with science were more likely to report low interest in science. Research has also shown that fields which are believed to require innate talent have an underrepresentation of women while fields believed to require hard work are well represented by women [10]. The assumption that women possess less talent than men may be a stereotype which hinders women from pursuing careers in fields which are believed to require innate talent. The finding that women are more drawn to fields that require hard work, however, disproves requirements for hard work as an explanation for low numbers of women in science.

In her book *Lära Kvinnor Chefa Män* (Teach Women to Lead Men), Barbro Dahlbom-Hall states that men and women are born the same but are treated so differently that they become different [5]. Dahlbom-Hall's statement can sound reasonable in today's society where gender roles can be seen at young ages and various cultures expect certain behavior. Conceptions or stereotypes can influence the success of those affected by it. In science, women's ambitions and performance can be influenced by stereotypes such as men naturally having higher talent and interest in science fields. Reminding students of gender stereotypes before exams has been shown to reduce performance of the students at the exams [9]. Women who associate men with science have also been shown to predict worse performance on exams at the start of semesters [8].

Despite stereotypes, which may not provide good environments for women in scientific fields, there are cases throughout history showing that women have already been successful in Computer Science (CS).

2. WOMEN IN COMPUTER SCIENCE

Throughout history, many women have been of importance for the field of CS but there are two pioneer women especially worth mentioning. Despite of common views of roles and

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abilities of men and women, these two women showed an ability to see future directions of CS: Augusta Ada Byron Lovelace and Grace Murray Hopper [6].

Lovelace, born 1815 in London, England, was a strong-willed, creative and intelligent woman during the Victorian Era, when women in science were rare [6]. She was raised and tutored by her mother who was a mathematician, which Lovelace turned out to become as well. Lovelace is known for her work on Charles Babbage's early mechanical general-purpose computer, the Analytical Engine. Her notes on the engine were the first algorithm intended to be carried out by a machine, which makes her known as the first programmer within CS and a founder of scientific computing. In honor of Lovelace's contributions, the United States Department of Defense's high level programming language, Ada, is named after her [7]. Ada has been used in countless projects by the Unites States military. The military standard for the language, MIL-STD-1815, is the number of the year of Lovelace's birth.

Grace Murray Hopper was an admiral in the U.S Navy who invented the compiler, an intermediate program that translates programming language into the language of a computer [11]. Grace was also involved in the development of the FLOW-MATIC programming language, which at the time was the only implemented business data processing language [6]. Grace was not only admired and respected for her technological achievements, but also for her energy, willingness and enthusiasm to serve as a mentor.

One might argue that these two isolated stories are nothing compared to the very long history of science. However, it is interesting to note that Augusta Ada Byron Lovelace and Grace Murray Hopper managed to dedicate their lives to a field, which they had an important impact on, without much external motivation.

An important aspect regarding stereotypes is that they evolve with time; during the World War 2 in the 1940s, women took on a variety of roles. In 1943 almost all "calculators" or "computers" were women [6]. "Computers" worked on calculating weapons trajectories and women were perceived as the best for the job as they were considered to have several abilities needed for programming such as patience, persistence and attention to detail. The radical changes of the perception of female computer scientists since the 1950's, cast a new light on stereotypes within the field of CS.

3. CONCEPTIONS OF COMPUTER SCIENCE

CS is a field often associated with "nerds", "geeks" or "hackers" which can give it a negative image. The lack of social life is often referred to when talking about CS. Stereotypes about CS can be thought to scare both men and women. However, a study on the underrepresentation of women in CS showed that women were more likely to see CS as a promising career and showed more respect towards CS students than men [4]. Women in the study also associated CS with positive traits such as intelligence and hard work more than men. Men in the same study were more likely to describe CS students as "nerdy" and believe overuse of computers to be harmful to people and society. Results from the study indicates that women have less negative stereotypes towards CS than men, however, women showed more interest in interacting with people rather than things which can be a contributing factor for women not taking interest in CS. Another factor for low numbers of women in CS can be low self-confidence as women in the study were more likely to believe that they would not do well in CS.

Writer Paul De Palma [13] claims that young men, unlike young women, are drawn to CS because they like gadgets, to tinker, and taking things apart and putting them back together. De Palma means that young men are particularly attracted to CS because it helps them understand technology, which can imply that men want to gather knowledge about technology *for its own sake*, and that they are less interested by the applications of technology. De Palma also claims that to make CS more attractive to women, one could copy several properties of teaching of mathematics, which is a field that has shown to be more attractive for women. For instance, sequences of five-minute exercises are very common in Mathematics education. Programming assignments can, however, be quite cumbersome design, code, debugging, testing, and documentation, all together. De Palma suggests modeling programming assignments as a sequence of short and similar exercises, to mimic mathematics.

For women to have female role models in CS may be of great importance. Same-sex experts in CS can induce identification and connectedness, which can favor self-efficacy [15]. For students to feel their instructors are fair and good may also be of importance. Students that have a positive experience of a CS instructor have been shown to take interest in additional CS courses, while students not experiencing an instructor positively have been shown to take no interest in any more CS classes, independently of instructor [4].

4. STATISTICS OF UPPSALA UNIVERSITY

In order to test several of the presented assumptions on stereotypes and perceptions of women and CS, we decided to examine statistics provided by the Swedish Council for Higher Education, about the gender balance of students taking CS courses at Uppsala University, during the spring semester – from January until June – 2015 [2].

Students at Uppsala University are free to *choose* which courses they are going to take. The students are therefore free to change courses and "navigate" among different topics during their studies. There are of course some constraints – mandatory courses – related to the program students are enrolled in.

To obtain meaningful statistics, we chose to remove all courses which did not have a strong link to CS. One of the main difficulties encountered in the process of removing courses was the fact that the limits of what the field of CS *encapsulates* and what it does are quite unclear. In the same fashion, it can be complex to quantify how much a course *belongs* to the field. Therefore, those limits were quite arbitrary in our process. Among the list of courses, those with a total number of students lower than the first quartile (i.e. with less than 12 students attending) were also filtered out. The process of eliminating irrelevant courses resulted in a list of 221 courses. We decided to sort the courses by proportion of women in the population – number of female students divided by total number of attendees – and compare the twenty most and least, popular courses among women. The

statistics are displayed in Figure 1. Courses are highlighted depending on the department providing the course, blue: Department of Informatics and Media, green: Department of Game Design, red: Department of Linguistics and Philology, yellow: Department of Information Technology. The total number of students is not shown since any correlation between the presence of women and overall popularity of a course was not found.

The statistics (*fig. 1*) show that there are courses related to the field of CS, which are popular among women to the point where the proportion of women in the course exceed 50%. However, it is important to note that there are no courses with less than 30% men, while courses with less than 10% women are common.

Course title	Percentage of female students
Media and communication studies	70,37%
Media and communication studies	69,40%
Information Systems A/Social Media and Web 2.0	65,66%
Media and communication studies	64,02%
Graphic Design for the Web	63,43%
MCS/Organizations and Communication in Global Society	62,86%
Languages, Computers, and Text Processing	58,82%
MCS/Cyberculture and Politics	53,33%
Information Analysis and Decision Support	50,00%
Concept Art	46,79%
Scientific Computing II	44,76%
Vector Graphics	44,73%
Scientific Computing I	44,23%
Automatic control I	44,03%
Information Retrieval	42,86%
IT Systems and Human Factors	41,94%
3D V - Real-Time 3D	41,67%
Graphic Design for the Web	41,18%
User Centered Systems Design	40,26%
Modelling of Dynamic Systems	39,36%

Course title	Percentage of female students
3D Modelling and Visualization with Z-Brush	11,54%
Distributed Systems	11,11%
Algorithms and Data Structures	11,11%
Mobile programming for Android	10,53%
Database Design I	10,34%
Algorithms and Data Structures	10,20%
Testing Concurrent and Parallel Software	9,52%
Machine Learning	8,77%
Cryptology	8,51%
Introduction to Artificial Intelligence for Game Programming	8,12%
Game Programming IV	7,69%
Programming of Embedded Systems	7,69%
Global Software Product Development Project	7,41%
Game Programming II	7,14%
Operating Systems and Process Oriented Programming	6,25%
Game Programming V	6,25%
Low-level Parallel programming	6,06%
Computer Graphics	4,08%
Independent Project in Information Engineering	1,96%
Technical Writing and Presentation Techniques	0,00%

Figure 1: Statistics on the proportion of Women in various courses related to computer science at Uppsala University.

5. DISCUSSION

Gender imbalance in CS is an increasingly relevant issue today. To investigate this issue we examined literature related to the issue and notable women in CS, and compiled statistics over the proportion of women in CS courses at Uppsala University.

The first notable aspect of the statistics is that almost *all* courses that are in the top twenty are courses which relate computers to *something else*. Courses provided by the Department of Informatics and Media are related to the influence of technology on society, courses provided by the Department of Linguistics and Philology are related to language processing and linguistics, courses provided by the Department of Game Design are related to artistic purposes and courses about scientific computing can be related to other scientific fields, such as biology or physics.

Among the twenty courses which have the *worst* proportion of women, it is interesting to note that for seven of them, the word *"programming"* appears in the title of the course. *"Programming"* is, however, a word that the names of the twenty most popular courses among women do not contain. More generally, it seems that women prefer courses where CS is used as a tool, as courses which focus on CS as a subject of studies – e.g. courses about programming, data structures and algorithms – are unpopular. A discrepancy that Paul De Palma [13] has already pointed out, by saying that men study CS in order to understand technology itself, instead of focusing on *how* to use the available technology. The statistics seem to agree with Palma's conception.

The difference between what an algorithm *is* and what problem it *solves* can be exploited if algorithms and data structures are mentioned only *when needed*, instead of formulating courses as exhaustive lists of algorithms on particular subjects. For that matter, it is interesting to note that L.Rich, H.Perry, and M.Guzdial included the word *media* when choosing the name of *Introduction to Media Computation*, a CS1 course designed to address interests of women [14]. It is as if they tried to emphasize that the course was focused on *purpose* – i.e. media computation – instead of focusing on the *task*: programming. Moreover, they applied the paradigm of introducing new algorithms and new data structures only on *explicit demand* of students, with great success.

Several aspects in this case study can be criticized. One aspect is the problem of where the *borders* of CS are drawn. One could indeed argue that, for instance, media and communication studies are only loosely related to CS, as they only focus on the influence of media on society. The Media and Communication Studies courses have been included in our list because they were provided by the Department of Informatics and Media and seemed relevant considering the department also provides courses about algorithms and data structures, though those courses still have a poor gender balance which shows that a new context did not help.

Another aspect of this case study that can be criticized is the fact that some CS courses are required for certain programmes. Some female students may take introductory courses in programming only because these are required for their programme. Requirement to take a course may, for instance, seem true for courses about scientific computing. This aspect would be the result of the influence of computers on science in general, not the reflection of an interest in programming, no matter the purpose.

The problem of the borders of CS extends to the limit between CS and mathematics. It is well known that almost *any* scientific field can be considered as "applied mathematics", but, as Paul de Palma suggests, despite being a very technical scientific field, mathematics still attract more women than CS [13]. This reality is also reflected by statistics from

Uppsala University. In autumn 2014, 32% of the applicants to the Bachelor's Programme in Mathematics were women, while only 11% of the applicants to the Bachelor's Programme in CS were women [2].

In his article, E.W.Dijkstra criticizes the lack of mathematical rigor in CS education [1]. According to Dijkstra, the teaching of formal methods and logic should be of great importance and programs should be built as provable theorems. This theory shows that the limit between CS and Mathematics has been fuzzy for a long time. However, it is notable that Paul de Palma and E.W.Dijkstra are not on the same level when it comes to the relationship of CS and mathematics. The former focuses on adapting *teaching methods* from the department of mathematics to CS content, while the latter focuses on what CS should *become*, and on banishing confusing approximations and anthropomorphisms while teaching CS.

6. CONCLUSIONS

The final reflection of this paper is: can a new Ada Lovelace, or a new Grace Hopper be expected in the next few years? The data indicates that there is still a lack of passion for the roots of CS among female students. However, it is clear that women are not afraid of becoming mathematicians anymore. Borrowing some of the mathematical rigor and teaching techniques mathematicians use in CS classrooms may improve both the quality of software and the learning environment for students, as well as raising the interest of women. CS education could also be improved *on a larger scale* by borrowing from mathematics. Therefore, investigating this complex relationship between computer scientists and mathematicians may be a good opportunity for future research.

Another good opportunity for future research is the fact that Sweden is not the only country were the choice of courses is rather free. Therefore, performing similar studies in different cultural contexts, but keeping a context where students have freedom of choice when it comes to their studies, might also provide interesting results.

The field of CS may benefit from the polyvalence of female students. Female students have shown their will to "blend" different disciplines together and their capacity to avoid being the "stereotypical" computer scientist. This profile of students blending several fields of study together can be profitable for CS. That being said, focus needs to be put on reducing stereotypes in CS as they play a damaging part in its' practice.

The fact that new students often lack knowledge about the very nature of programming may also be a good track to follow for researchers, though it is outside of the scope of this paper. Also slightly outside of the scope of this paper, since we decided to focus on the world of academia, is that positive effects can be expected from the fact that technology nowadays is used by all genders at all ages. Using a computer stopped being an expert's task a long time ago, so the act of writing a small script for automating tasks may become quite common as well.

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