

ENGINEERING OR COMPUTER SCIENCE, WHAT IS THE DEAL?

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ABSTRACT

There is still a gender bias in the Science, Technology, Engineering and Mathematics (STEM) sector. The progress towards gender balance has been very slow. The situation is not good enough in engineering education and is even worse in computer science. Many studies have been carried out and many projects and efforts have been made to accelerate the development over the years. Influencing factors are many when young people are deciding what subject to study at university and the trend is still for males to go for STEM studies and females to aim for health sciences and social sciences. This paper presents findings from a study on gender differences in engineering and computer science by questioning female students at the university level to learn what could be the reasons for more girls preferring STEM study and how they are doing in their study. This topic touches on CDIO Standards 1 (program philosophy), 7 and 8 (new methods of teaching and learning).

KEYWORDS

STEM, Gender differences in education, Choice of studies, CDIO Standards: 1, 7, 8

INTRODUCTION

It is problematic, not only for girls and women but for the whole society that females are underrepresented in Science, Technology, Engineering and Mathematics (STEMs). The situation affects the STEM industry and education as well as female's personal life, the situation is simply a drawback for society. STEM industry and education will need to be inclusive for future development. The situation is well documented but the many projects that have been carried out have not changed the situation, although they may have moved the trend toward a better gender balance. Anyhow, the number of women graduating in computer science in the USA has been decreasing from 37% in 1984 to 18% in 2018 (AAUW, 2018). In the EU the gender gap in STEM is particularly wide in IT and in 2021, women were 32.8% of the working force in high-tech manufacturing and knowledge-intensive high-tech services in Europe (Catalyst, 2022).

LITTERATURE REVIEW

In the UNESCO report, *To be smart, the digital revolution will need to be inclusive*, by Bello et al. (2021), it is emphasised that women are at risk to miss out on jobs of the future. The Fourth

industry revolution (4IR), or Industry 4.0, is changing the job market as many low-skills jobs will be automated, which calls for a higher level of education and skills and it has been anticipated that for one job gain through Industry.4.0, women will lose five jobs but men three (UNESCO, 2018). There is a shortage of skills in STEM which gives women the opportunity to step in and fill the gap but that calls for them to gain the “right” skills in e.g. artificial intelligence, computer science and engineering (Bello et.al., 2021). STEM academic degrees give access to many well-paying jobs that are fast-developing today (Cedefop, 2016; European Union, 2016; European Commission, 2017; World Economic Forum, 2021) but women are not grabbing the opportunity and men are still dominating the field. Even though women have a STEM education they may not be working in the field (Van Veelen, Derks & Endedijk, 2019). A report by Singh et al. (2013) indicates that around 30% of women who enter engineering ultimately leave the profession. And, if women choose engineering they are more interested in health-related subjects within engineering (Funke, Berges & Hubwieser, 2016; Lin, Ghaddar & Hurst, 2021) as a research from 2021 shows where female students choose biomedical engineering and male students mechatronics engineering (Matthiasdottir & Audunsson (2022).

The driving fields in Industry 4.0 is digital information technology, computing, physics, mathematics and engineering, the very fields wherein women remain a minority. This situation has been analysed and discussed in the literature over the years (Ashcraft, Eger, & Friend, 2012; Stoeger et al. 2013; Kolmos, Mejlgaard, Haase, & Holgaard, 2013; Liben & Coyle, 2014; Cheryan, Master, & Meltzoff, 2015; Matthiasdottir & Palsdottir, 2016; Funke, Berges, & Hubwieser, 2016; Matthiasdottir, 2018). Among the conclusions in Bello, Blowers, Schneegans & Straza’s (2021) report is “This trend is all the more problematic in that there is a skills shortage in many of these very fields, such as in artificial intelligence. This trend suggests that progress towards righting the gender imbalance could be compromised, unless strenuous efforts are made at the government, academic and corporate levels not only to attract girls and women to these fields but, above all, to retain them” (p. 25).

It is sometimes difficult for a young person to decide what to study. In the YouScience *Post Graduation Readiness Report (2022)* it is stated that “75% of high school graduates are not ready to make college and career decisions” (p. 1). What motivates and inspires students when they decide may be different between different persons and the process of concluding what to select can be long for many. It seems to be difficult to recognize what determines students’ choices of education. It may be a complex process and the roots can be as deep as in early childhood (Van Tuijl & van der Molen, 2016). In the YouScience report, *Career Insights: Women, STEM, and the Talent Shortage (2022)*, it is stated that there is a gap between what high school female students can do, their aptitude, and their interest in, e.g. they have “more than 10x the aptitude for careers in architecture and engineering than they do interest” (p. 3).

Van den Hurk, Meelissen & van Langen’s (2019) review of empirical studies lead them to categorise factors related to gender differences in STEM education into three levels: environmental factors, factors at the school level and factors at the student level. Built on their research they put forward the following model in figure 1.

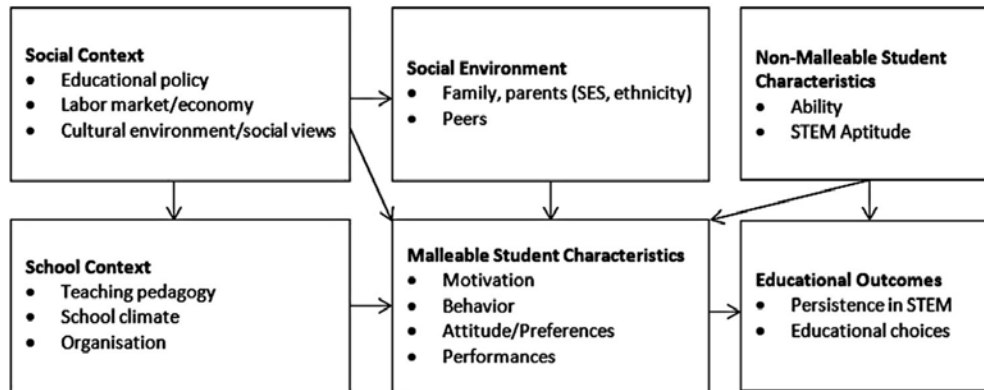


Figure 1. Model for academic choices and persistence in STEM education (Van den Hurk, Meelissen & van Langen, 2019, p. 155).

Alam (2022) looked into academic research over the last three decades and comes up with six explanations for why women are not going into STEM: (a) preconceptions and biases based on gender, (b) field-specific ability beliefs, (c) lifestyle values or work-family balance preferences, (d) professional inclinations or desires, (e) comparative cerebral capabilities, and (f) cognitive aptitude (p. 1).

Matthiasdottir (2018) shows that the genders give different reasons for choosing engineering studies. Females reported more interest in math and science and a success in those subject in upper secondary school and females were older than males when they decided what subject to study. Amelink and Meszaros (2011) emphasise the importance of faculty recognising that female students value respectful interaction and encouragement a lot.

Research have looked into more influencing factors, e.g., competitiveness (Buser et al., 2014), peer influence (Brenøe & Zolitz, 2018; Andersen, & Hjortskov, 2022), grade performance (Stinebrickner & Stinebrickner, 2011), wage gap (Redmond & McGuinness, 2017) and motivation (Robnett & Leaper, 2013). Moreover, research has even shown it influence girls in a positive way if other girls in their class also like STEM (Raabe, Boda, & Stadtfeld, 2019).

Students' STEM self-efficacy influences decision of further study (Jansen, Scherer, & Schroeders, 2015; Brown, Concannon, Marx, Donaldson, & Black, 2016). Social Cognitive Career Theory (SCCT) (Lent, Brown, & Hackett, 1994) suggests that people are neither controlled by their environment nor are they totally independent and each one has the capability to determine what to select but perceived self-efficacy influences the selection process (Bandura, 1989; Bandura, 1982; Bandura, 1977).

Stereotypes can shape young person's attitudes and diverse fields of STEM can have different stereotypes (Cheryan et al., 2015) which can appeal differently to different persons. Engineers and especially computer scientist or IT persons are often connected to nerdy male types that are not appealing to all but might attract some. Berge, Silfver, and Danielsson (2019) analysed nine different Engineering Mechanics programme websites and their result was that they expose stereotypical norms regarding gender and age. Powell, Dainty and Bagilhole (2012) conclude in their paper that women are aware of "masculine" stereotypes in many jobs but at the same time claim that these jobs are for everyone independent of gender.

The model in figure 2 from Master et al. (2017) shows some of the influencing factors and the situation regarding girls and STEM.

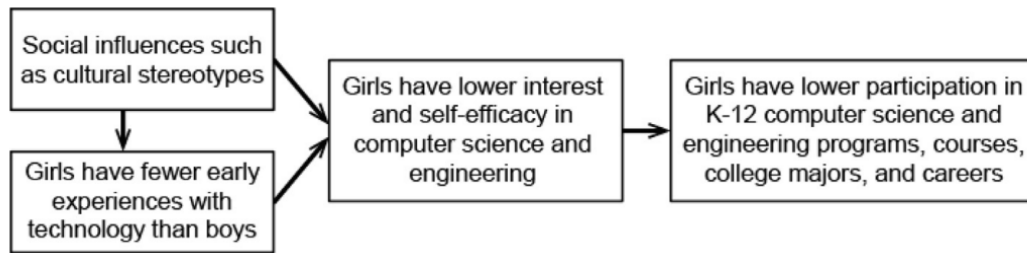


Figure 2. Cultural stereotypes and gender differences in early experiences contribute to gender differences in motivation in computer science and engineering. (Master et al., 2017, p. 94).

The need of belonging is important, so stereotypes need to be diverse enough to attract all students (Master et al., 2017). Experiencing support and encouragement from friends and family can support academic success and predict adolescent girls' motivation in math and science (Robnett & Leaperm, 2013). In a research (Lewis, et al., 2017), with data from nearly 3000 students with focus on pSTEM (p=physical sciences), the main conclusions are that women question their ability more than men and feel less sense of belonging. The sense of belonging outnumbers other ordinary explanations for women's reasons for keep going on in pSTEM.

The objective of this study was to better understand female engineering and computer science students' attitudes when they chose their studies and explore present situation in the two subjects. It is of interest to know what was and is the influencing model and what has been of support after they started their studies.

METHOD

Participants

The participants were a non-probability convenience sample, i.e., a group of students easy to contact for the author. The department office at the School of engineering and School of computer science at Reykjavik University were contacted and asked to provide female student e-mails. Also, female teachers in both departments were asked if they could point out female students that could be contacted. The female computer science student's association, /sys/tur, and the engineering student's association at RU were asked to advertise for participants. Totally 55 female students were contacted and 13 (24%) replied, 10 (28.5%) from computer science and 3 (15%) from engineering. The response rate was rather low and did not give the possibility to compare the groups.

Measures

It was decided to use e-mail to send out the questionnaire because after COVID the University is offering recordings of teacher's presentation more frequently and many students prefer to study from home and are not attending to the university building regularly. At home participants can answer and complete the questionnaire at their own pace which can be convenient and deliver written responses which can save time. Some can even feel less social pressure as

there is no visual or non-verbal judgmental cues which can also reduce the influence of the interviewer. Thus, it was hoped that by using e-mail would give more representative data. The questions were as follows:

1) When did you become interested in engineering/computer science and what do you think had the most influence on you, was most motivating? 2) When did you decide to start studying engineering/computer science and what do you think had the most influence on that choice, was the most motivating? 3) Which role models do you think have influenced your choice of study? 4) Did you feel that something hindered you in your choice, even discouraged you? 5) How are you doing in your studies? What do you think has motivated you and what has even hindered you in your studies? 6) What role models, if any, do you think you have in your studies? 7) Do you think that being a woman has had any effect on you in your studies and how few women are in the same study?

Procedure

An e-mail was sent to students in engineering and computer science with an introduction letter where they were encouraged not only to answer the questions but to discuss the topic openly. A reminder was sent twice. The answers were collected and separated from the student's names, and answers for each question were grouped together and analysed.

RESULTS AND DISCUSION

To gain interest and decide to study a STEM

The first two questions were related and the answers will be discussed together. Six of the women reported that they were interested in the subject from early on and the inspiration, for most of them, came from playing computer games that fathers and/or brothers had introduced to them or as one said:

I would say that I first got interested in computers when I started playing video games with my older brother. He got his first computer when I was 5 years old. Since I was quite young, I only got to play games like Bubbles and similar games on Leikjaneti [Game network]. With increasing age, I then got to play more and got his PlayStation 2 computer into my room when he upgraded to a PlayStation 3. Then I started playing even more games and started thinking more and more about what was behind the making of these video games. I say that the video games I played and my thoughts on them were the trigger for me to become interested in computers.

It is noticeable that she did not get a new PlayStation, but her brother did and she got his old one. This may be part of the reason why boys are more confident than girls regarding their technical abilities and computer skills even from an early age (Zviel-Girshin, Luria, & Shaham, 2020; Matthiasdottir, 2018). One of the women mentioned that when she was 12 she learned how to use Excel and that sparked her interest, one mentioned that her father was a computer scientist and introduced her to computers and taking a programming course in secondary school got one of them interested along with films and TV series with super girls hiding behind screens hacking into computer systems.

Seven of the women mentioned that they got interest rather late, and two of them in upper secondary school when they did well in math and science or as one said:

I'm in mechanical engineering...Got interested after taking a physics course in high school. I have always been interested in mathematics since elementary school and always did best in those classes.

Many of the participants even decided just before they applied what to study. It is interesting that three of the women said that they did not get interested in the subject until after they started their study and mentioned courses that flashed their interest. Anyhow, some of them were content after their decision or as one engineering student said:

In high school I did very well in science and math, getting good grades and doing well was motivating. I decided during my last year of high school, at the age of 18, to choose a graduate program based on math and science. I made the decision based on what opportunities I would have in the future, then the program had to give me the option of a well-paid job that could be done anywhere in the country.

One of the women recognised in her job that many time-consuming tasks could be automated by help of computers and pointed that out to the technical department. To be acknowledged made her want to learn to do it herself so she got into computer science. To lose a job in COVID was also mentioned as an incentive to study. One mentioned that films about hacking had always interested her and the computer classes at school were fun but she thought computers were not for girls.

The answers are in line with the literature. Some young persons are aware of their interest at an early age and know what they want in the future while others are in doubt, even all their life. We can look at children's life circle as school, family and community and these three settings are the main factors affecting their interest to study STEM (Lent & Brown, 2006). Research have indicated that interest in math and science is one of the reasons for females choosing engineering and applied engineering (Matthiasdottir, 2018; Matthiasdottir & Audunsson, 2022) but some just want to try to study engineering (Matthiasdottir, 2018). As mentioned before, research have shown that females are older than males when they decide what to study at university (Matthiasdottir, 2018; Matthiasdottir & Audunsson, 2022).

The obstacles

Here four of the women did not report any hindrances or obstacles in their environment but others did. COVID was mentioned three times for changing the situation, they could not attend school, especially lab sessions, and there was not enough opportunity to study at home because they had children that could not to go to school during COVID. Peers negative attitudes was also mentioned as an obstacle or as this said:

The only thing that has been a obstacle is when men don't believe in me because I'm a woman, but then I always end up having to prove myself and then it's not an obstacle.

It was also mentioned that more online programs should be offered because it gives those who have difficulties in attending in-house classes opportunities to study, e.g. older students, students that need to work while studying and students with young kids. Not to be able to study online was considered to be an obstacle for women.

Academic achievement

All except one of the women claimed that they had been doing well or very well in their studies although some courses were demanding. What has motivated them is different, one said it

was the will to finish the study and show people that she could do it, another mentioned to get a good job when finished. One mentioned especially /sys/tur, the girls society at the computer department, to participate with them gave her the opportunity to meet other women which made her feel she was not alone in the program. Family and friends were often mentioned as the main support as well as teachers that have a real passion for their work or as one said:

I have done very well in my studies. I think the friends I have met [in the program] are the most encouraging to me, we are able to learn together and get each other through the most difficult phases.

Sadly, the male classmates could be discouraging which in at least three cases affect their female classmates' self-esteem and courage to keep on. Here are two examples from computer science students:

What has perhaps hindered me the most in my studies is the way men, or preferably boys, often treat people. There are a lot of group projects where we are put into "random" groups and I end up with some guys who talks to you like you don't know anything. It is very discouraging to work into such groups.

From time to time, I have felt very lost in my studies, especially in group work where you might end up with a lot of boys in a group who you feel are much smarter than you because they really just talk the loudest.

Role models

Role model play an important part in shaping attitudes and awareness and research have exposed that stereotypes can influence gender disparities as girls are early less attracted than boys to stereotypes in engineering and computer science (Master, Meltzoff & Cheryan, 2021). In this group of women five reported they did not have any role models apart from a family member or friend (grandmother, mother, father, sister, brother, husband and friend) who encouraged them to study further, not STEM per se, but to go to university. All the same, the decision was often built on their own internal motivation as one said:

I wouldn't say that I had a specific role model in mind that influenced my choice to study computer science. It was more my own stubbornness to choose something that some people around me might have expected me not to be able to do. I have always been keen both to prove to myself that I can do things and also to prove to others. My role model in choosing a good education outside of my comfort zone is my mother. She has always been determined in her studies and persevered despite obstacles.

When it comes to what to study the role models come from all around, the people in their environment, a programming teacher was mentioned, engineers in the family, friends that had graduated with similar education, discussion in society and in social media, and one mentioned a female engineer that is a popular social media influencer telling about her work and family life. Female teachers seemed to be important role models mentioned by five of the women:

The role models I have had in my studies are the female teachers who have taught me. You often feel like the study is rather masculine, but when you have a woman as a teacher, you somehow feel more secure. It's admirable to watch them and I think it's great when they share their story.

Role models are also found in females that have already graduated and are working in the field and a male role model was only mentioned twice, a father and a teacher but as one said:

However, the coolest role models who personally inspire and motivate me the most are the girls I've worked with in group work during my studies.

The importance and influence of role models is clear in this group, they feel the stereotypes but they see support in other women around them although there are not many of them. This one gave a good description of the influence of a stereotype and how this influenced her self-confidence:

Probably the stereotype of a computer scientist/programmer. In most movies and TV series, there are some gorgeous male nerds who live in their mom's basement and just play video games. I remember my friends' reactions when I told them I was majoring in computer science. They thought it was very nerdy and immediately started asking if it wasn't just boys who went into that profession. I then started to feel a little insecure about the choice and whether I would belong in computer science.

Stereotypes can be a barrier for choosing STEM subjects but female role models can escalate the sense of fit in and support the ideas about how to succeed in STEM, e.g. with hard work (González-Pérez, Mateos de Cabo & Sáinz, 2020). Gender stereotypes and biases influence kids from early on (Van Tuijl & van der Molen, 2016; Alam, 2022), thus, to change societies attitudes and support is one of the factors needed to work with. It was often mentioned that the participants considered the study to be difficult and might not be for women, supporting the two stereotypes. It is clear in the present study that stereotypes have influences and mainly in a negative way.

To be a woman in STEM

The feeling of belonging supports students to stay in their study, other students and the teaching play a big role in creating good conditions that can influence the feeling of belonging, one described her situation like this:

Yes, there are a lot of people in computer science who are very smart. I often feel that I am not in the same place as many people who get 10 [out of 10] in everything. I think this program is very difficult and I don't think the teaching is good enough, I think the teaching is for people who have a good knowledge of programming or people who have been programming for a long time. I often feel that I am not doing well and I often feel that I do not belong in this program.

Four of the participants did not experience that being a woman had much influence on them and one even said that being much older than fellow students were more difficult than being a woman but anyhow they were aware of the gender unbalance and gender difference. Two considered it to be encouraging and empowering to be a woman in STEM but not all were content in their study. One did not find many women to contact in the program but one found a support in fellow female students and friends in the /sys/tur or as she said:

I have surrounded myself with female friends in the program [in /sys/tur] and therefore do not experience the gender difference. Although it is clearly there.

And one said:

I don't know about learning, but you can feel how few women there are in the program. Everything somehow revolves around the males in the program and there is a lack of this compassion that you are so used to as a woman.

The others had other stories to tell, some even sad, they did really feel they were looked down at and needed to prove themselves constantly which influenced their self-esteem and well-being as this comment shows:

... I would say that being a woman in the program sometimes had an impact. I haven't had anything demeaning said to me outright because I'm a woman in this program, but I've had a look at me and I've been treated differently. These expressions and this behaviour did not make me feel good about myself and have prevented me from seeing myself and my abilities correctly.

And one said

It's hard to explain but many boys in the program have annoying prejudices when it comes to working with women and the manifestation is either that they immediately decide that they can't be "themselves" and it takes a long time to win [their] trust which is very inhibiting in group work, some are very arrogant and have a great need to appear to be superior (mostly unfounded) and prefer women to take care of secretarial jobs, e.g. completion and reporting.

Instead of feeling of belonging in the group these women seek for feeling of belonging to same sex group and seek support and acceptance among other female students.

CONCLUSION

We need and want more people, especially women, to study engineering and computer science and we need to act to change the present situation. What to do and when to intervene to transform the circumstances depends on what we consider to be the most influencing factors. Recent studies have emphasised three factors, *environmental factors*, *factors at the school level* and *factors at the student level* (Van den Hurk, Meelissen & van Langen, 2019). It is also important not only to get female students into STEM study but also to keep them in the program and both the content of the program and the teaching methods are important but we cannot forget their fellow students.

In the present study women experience the study environment differently where the majority of the students and teachers are male, for some it does not matter much but for most of them it influences their well-being in the program and can harm their self-confidence. The answers from engineers and computer science students were similar but computer science students reported more negative attitudes from the male students.

Two stereotypes have been identified that affect the level of enrolment and preservation of women in STEM fields as they are believed to decrease female interest in STEM. First is the impression that STEM subjects are hard to study and mainly for brilliant or gifted students to flourish and secondly the characteristics of scientists and scientific jobs (Shin et al., 2016). Same-sex role models are believed to have beneficial influence, e.g. be a "social vaccines" protecting against stereotypes but do not change the stereotypes (Dasgupta, 2011). They can serve as a buffer for damaging experience in STEM, improve women test performance (Marx et al. 2009; Marx & Roman 2002; McIntyre et al., 2003) and strengthen the sense of belonging (Cheryan et al., 2009).

The feeling of belonging and being accepted is important for students (Ito & McPherson, 2018), it shapes their identity and influences their sense of developing in their education. For women, feeling of belonging can have a positive impact on educational success and retention in STEM (Rattan et al., 2015). Uncertainty can have harmful effects on students' identification in their

field, success, persistence, and career ambitions, especially among minority groups. Research have shown that perceived emotional and academic exclusion by other students increases female students' uncertainty in computer science but not male students (Höhne & Zander, 2019).

If we look at the answers in light of Van den Hurk, Meelissen & van Langen's (2019) model for academic choices and persistence in STEM education (figure 2) we see that social environment (family, parents, peers) is a strong influencing factor but also school context (school climate) and social context (cultural environment). We do also see that malleable and non-malleable student characteristic are often mentioned by students. This research supports Van den Hurk, Meelissen & van Langen's (2019) conclusion that programmes to improve the gender situation in STEM should focus on knowledge, ability, motivation and feelings of belonging.

Limitations and opportunities

To use an e-mail to send questionnaire can be considered as a limitation, it might have been possible to gain more detailed information with face to face interviews. Anyhow the results are in line with previous research and give more insight into why women choose to study engineering and computer science and give ideas about what is important to work at to encourage more females into STEM studies and to keep them in the programs. This calls also for more investigation into what projects or actions to get more female into STEM have been successful so far and where we should go from now.

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