Female Teenagers in Computer Science Education: Understanding Stereotypes, Negative Impacts, and Positive Motivation

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ABSTRACT

Although teenage girls engage in coding courses, only a small percentage of them plan to pursue Computer Science (CS) as a major when choosing a career path. Gender differences in interests, sense-of belonging, self-efficacy, and engagement in CS are already present at that age. This article presents an overview of gender stereotypes by summarizing the negative impressions female teenagers experience during CS classes and also influences that may be preventing girls from taking an interest in CS. The study draws on published research since 2006 and argues that those findings point to the existence of the stereotypical image of a helpless, uninterested, and unhappy “Girl in Computing”. It may be even more troubling a construct than that of the geeky, nerdy male counterpart, as it is rooted in the notion that women are technologically inept and ill-suited for CS careers. Thus, female teenagers think they must be hyper-intelligent as opposed to motivated, interested, and focused to succeed in those fields. To make CS more inclusive for teenage girls, cultural implications, as well as stereotypization in CS classrooms and CS education, need to be considered as harmful and must be eliminated by empowering female teenagers through direct encouragement, mentoring programs, or girls-only initiatives.

KEYWORDS

Gender Stereotypes, Computer Science Education, Coding, STEM, Gender-inclusive Motivation Strategies, Adolescent Girls

1 INTRODUCTION

Recent statistics from Europe and all over the world indicate that women’s representation in technical professions has not improved and women’s employment in these occupations increased at a slower rate than men’s employment in the past decade (Lamborelle and Fernandez, 2016; Eurostat, 2017; NCWIT, 2017; European Statistics, 2018, Box, 2018). In 2016, only 18% of the tech workforce in the EU member states was female (Lamborelle and Fernandez, 2016). Although female underrepresentation exists in other disciplines of science, technology, engineering, and math (STEM) as well, the numbers are increasing slightly for women, e.g., in engineering and the physical sciences (Ashcraft et al., 2016). The real problem exists in CS, where the percentage of female graduates has slipped every year from 37% 1985 to a percentage lower than 20%, see Figure 1.
For instance, in 2015 out of 1,000 women with BA degrees in Europe, only 29 hold degrees in a CS-related field (Unesco, 2015). The question is why so few young women plan to pursue CS as a major. This question has been previously researched by many academics. One of the first comprehensive analyses was the research of Margolis and Fisher (2002) examining impacts at college and high school level which contribute to the gender gap in computing. On the one hand, their research and other authors found evidence that document girls’ low experience levels towards computer sciences, hence, contact with technology at an early age could perhaps change the attitude of women before stereotyping (Carter, 2006; Sadler et al, 2012). On the other hand, most of the (female) students either do not feel motivated to learn about technology nor they are engaged by friends or their family (Unfried et al., 2015; Master et al., 2016). Consequently, for them the only opportunity to gain knowledge in CS topics and to become more interested in tech exists during the regular CS classes. In 2006, a new concept by Wing (2006) focused on reinforcing Computational Thinking (CT) skills among students and promoted coding as a mandatory skill that opens a new way of thinking by introducing problem solving and critical thinking tasks in the classroom. Her findings have been incorporated into the US curriculum of many federal states of the US (Kahn, 2017), into K-12 movements (Mannila et al., 2014), and launched by Barack Obama in 2016 during the "Computer Science For All" initiative (Ladner and Israel, 2016). In addition, two more trends emerged at this time which contributed to the success of the ideas of ICT skills. First, a number of block-based visual oriented programming tools have been introduced which should help novice programmers and young learners in their first programming steps. The most popular visual coding environment is Scratch\textsuperscript{1}, introduced in 2007 by the MIT Livelong Kindergarten Group (Resnick et al., 2009). Unlike traditional programming languages, which require code statements and complex syntax rules, here graphical programming blocks are used that automatically snap together like Lego blocks when they make syntactical sense (Ford, 2009). Second, a widespread use of smartphones can change how learning takes place in many disciplines and contexts. Mobile phones are more frequently used than computers or tablets (Statista Market Analytics, 2016). They are already a part of our culture and are changing the way in which many people, particularly teenagers, act in social situations. For most adolescents, the smartphone performs several functions of their daily lives. As a result, a new generation of young digital natives emerged. Overall, girls and women have caught up with boys and men as users of this technology, but not as its producers (Siobhan, 2018). Our future will be digital and the next generation of jobs will be characterized by an increased demand for people with computational and problem-solving skills (Box, 2018). A university degree in CS is thus a lucrative educational prospect. If women are absent from this field, they will not participate in the

\textsuperscript{1}https://scratch.mit.edu
shaping of the world of technology and in the decision-making on technological research agendas.

This article is structured as follows: The first part, Section 2, explains the scope and purpose of this review and presents an overview of stereotypes in computing in Figure 2. Figure 2 presents a “dramatization” of studies researching problems female students face in computing. The individual parts of Figure 2 are described in greater detail in Section 3, which shows how stereotypes in CS are (re-)constructed, for instance, through missing role models/mentors, differences in interest, sense-of belonging, engagement, and self-efficacy, and perceived inequalities in CS education. The discussion section, Section 4, in contrast, draws on Figure 4, which shows empowerment strategies for students in computing of all genders suggested by the same studies. Finally, the outlook section, Section 6, presents two promising projects by the authors, one of which is still ongoing at the time of writing.

2 SCOPE AND PURPOSE OF THE OVERVIEW

We have reviewed literature on girls in CS classrooms, focusing on empirical literature since 2006, with the aim to provide a compact summary of findings since the mainstream introduction of coding in different school levels. The corpus of articles covers mainly the US, Australia, and Western Europe, countries that face similar problems in attracting female students for CS (Khazan, 2018). High school is an educational phase during which young people decide their future career orientations, develop a more realistic picture of their future jobs, and assess their career-relevant abilities (Appianing and Eck, 2015). Therefore, we begin with reviewing literature on computing science in secondary education, followed by experiences of female students actually studying in a CS-related field. The students themselves play an important role because they are shaping the CS culture and environment from the inside (Frieze and Quesenberry, 2015). This will help us to identify possible influences that participate in creating preconceptions and assumptions about computing during education experience and everyday life.

Figure 2 shows the results of a “dramatization” of gender”, a method that foregrounds the binary divisions by gender in order to develop sensitivity and awareness (Engler and Wieland, 1995). This figure represents the authors' summary of gender differences in computing, (social) inequalities in CS classrooms, and preconceptions about computing, as well as common attributes associated with young boys and girls in computing. The summary brings together the findings of a sample of 30 articles. Our aim was to illustrate the socially constructed stereotype of a teenage girl in computing. The literature search focused on a) international online bibliographic databases (ACM Digital Library, SAGE Journals, Wiley Online Library, Springer, ieeXplore), b) associations (APA PsycNET, AERA), and c) University press publications (MIT Press Scholarship Online, Oxford Academic, Cambridge Journal Education). These were supplemented with recent studies conducted at Harvard, by Microsoft, and Google. The keywords used in the searches included “Girls”, “Computer Science Education”, “Stereotypes”, “Coding”, “Programming”, “Role Models”, “Gender”, and “Games”. We limited the timeframe to the period from 2006 onwards, because of the emergence of new concepts in learning CS and of visual coding tools introduced in 2007 (see the previous section). The extracted picture of the “Girl in Computing” can provide a useful reference for educators and researchers in the area of gender-sensitive education. Since CS is stereotypically associated with the masculine role in the still prevalent gender binary, female teenagers are less likely to have a sense of belonging vis-à-vis CS and are less interested and engaged in these classes (Master et al., 2016). Consequently, they feel less self-efficacy and motivation to pursue a profession in this field. Creating safe learning environments with educators who are aware of the negative implications of the stereotype is thus of paramount importance (Hercy, 2009).
Figure 2: The decrease in motivation in girls: Social and cultural shaping of the negative stereotype of a “Girl in Computing” by its binary relation to the stereotyped “Boy in Computing” by and through the preconceptions and inequities in (CS-) education. Consequently, the motivators (interest, sense of belonging, engagement/fun, and self-efficacy) are reduced in girls. The articles used for this review represent published scientific literature on the topics of gender stereotypes in computing and on differences in coding classes at high school and university levels that shape the stereotypes of boys and girls in CS along with the attributes associated with both stereotypes.

Sources:
Cultural and social influences: (Cheryan et al., 2011; Cheryan et al., 2013; Young et al., 2013; Dasgupta and Stout, 2014; Galdi et al., 2014; Gabay-Egozi et al., 2015; Frieze and Quesenberry, 2015; Lynch et al., 2016; Master et al., 2016)
Preconceptions and differences in (CS-) classrooms: (Carter, 2006; Goode et al., 2006; Weibert et al., 2012; Giammokos et al., 2014; Alvarado et al., 2017)
Inequity in CS-education: (Grigoreanu et al. 2008; Cheryan et al.: 2009, , Zagami et al., 2015; Medel and Pournaghshband, 2017)
Internet sources: (Schwartz, 2013; Brewer, 2017; Microsoft, 2017; Google, 2018)

Naturally, the “dramatization” method has its limitations as it works with averages rather than individualities, differences rather than similarities, and it does not account for the plurality of genders. As such, it runs the risk of contributing to the strengthening of the very stereotypes it aims to expose and to the reinforcing of the gender binary. We used the method here in the sense of Spivak’s “strategic essentialism” to draw attention to the lasting effectiveness of socially constructed categories in CS (Spivak, 1990). The dramatization will serve as a springboard for the typology of research that critically engages with the stereotypes that we present below. The following chapter provides details to Figure 2 by describing authors’ arguments, studies, and research.

3 CONSTRUCTION OF STEREOTYPE(S)
Stereotypes influence people and produce misrepresentations (Matlin, 1999). They describe specific behaviors, attitudes, and capabilities purportedly associated with, for example, a certain
class, race, gender, or profession. Studies show that stereotypes in their fields disempower women at all levels (teenage girls, undergraduate female STEM students, and even successful female scientists) (Young et al., 2013, Galdi et al., 2014). For example, the geeky, nerdy, isolated, fanatical computer expert who represents the stereotype of computer science is certainly not something most young women strive to become (Cheryan et al., 2013, Lewis et al., 2016). The technology sector needs people with diverse skills, those who can design, develop, analyze, and manage information technology, rather than people with a narrow skills scope, such as only technology development or only programming.

This section looks at the various approaches since 2006 in research literature to the formation of stereotypes through media, parental influences, the importance of female role models and mentors, students’ apparent differences in behavior and in attitudes to CS classes, and preferences in relation to coding and games.

3.1 Cultural and Social Influences

The research of Dasgupta and Stout (2014) described different developmental periods in women’s lives and the obstacles they face in STEM. In childhood and adolescence, boys and girls become associated with stereotypical attributes and confronted with popular cultural representations from history, media, or from their own parents. This makes them believe that, for example, girls are less talented in math, and boys are worse in reading. In the next phase, emerging adulthood, peer acceptance is a central point and collaboration is particularly important. If female students feel that they do not fit in STEM classes, or are already outnumbered by male students, they are likely to shy away from such disciplines.

A survey of curricular choices of high school students by Gabay-Egozi et al. (2015) lists the reasons for gender-typical educational choices. Their results show the negative effects of parental preconceptions and influences, e.g., when families exclude computing or engineering as a possible career path for their daughters. While making educational choices, male and female students may follow these perceptions of an appropriate choice for their gender rather than their interests. The study points out that teenage girls are less likely to choose an IT-related path unless they were encouraged by their parents, by teachers, or by their peers. Self-doubt in female students towards STEM disciplines occurs if they feel intimidated because they need more help in CS subjects, thus thinking it must be attributed to their deficient ability. If the profession does not fit the traditional gender model, one is not as likely to pursue or feels discriminated against by someone who does. To be socially connected and respected is a strong initial motivator; it can “create a sense of belonging that can reinforce students’ self-efficacy and connections to community that support student perceptions of their ability within the field” (Veilleux et al., 2013, p. 64). According to that study, it is not important whether the father or the sister has a technical or natural science profession, rather, it is more about a general and supportive attitude of relatives or other important people in a girl’s life that encourages her to follow her own path.

For a successful professional development, female mentors and appropriate role models are two key elements that further strengthen girls’ self-efficacy and interest (Stout and Camp, 2014).

3.1.1 Absence of female role models.

Lockwood (2006) presents two studies that examined the importance of female role models for career choices in first-year female students. The results showed that 1) women prefer female career role models to male ones, and 2) that they derive special benefits from gender-matched role models, by naming their achievements. It is important that women see female role models who have succeeded and who promote positive beliefs regarding women’s abilities, which demonstrates that this job field can suit them as well. Since the technology sector is very male-
dominated, most role models are also male. However, the study emphasized that women who had to overcome gender stereotypes or are successful in traditionally male-dominated fields are most effective as role models.

Cheryan et al., (2011) argue on the basis of two experiments with female non-computer science majors that role models who were perceived as very stereotypical can have a negative influence on women’s choices. They give as examples role models who prefer stereotypical games or movies (e.g., Star Wars, Star Trek, etc.), have a very stereotypical appearance (e.g., the geeky female computer scientist who wears glasses), or a role model who is a supernatural genius in her field (e.g., a girl who had already started programming at the age of 11). Women who confirm the male stereotype have a negative effect in women’s beliefs about their ability to be successful in STEM. If role models are presented as somehow supernatural, it implies to girls, that if they work very, very hard, they may can make it, even in a field that is not typical for their gender.

A study conducted by Young et al. (2013) provides further evidence of the importance of meaningful contact with female role models. They mostly refer to university professors but also to female role models in STEM at every stage, e.g., female teachers at the secondary level in mathematics or science, female students, faculty members in higher education, and women working in STEM fields. These “ordinary” role models are associated with pro-science career aspirations and attitudes because it is easier to identify with them, and as a result, the subject is associated more with women. They help reduce or even invert the implicit stereotype. The authors concluded that female professors were viewed as more positive role models than male professors were.

These earlier findings find an echo in a recent ISAC global survey report (see Wisniewski, 2017): the absence of female role models is currently one of the top five reasons why women are underrepresented in technology (42% women mention this in the findings of this ISAC study).

3.1.2 Need for mentoring (programs).

A number of mentoring programs have appeared in the last years. Mentors are similar to role models but additionally provide guidance, e.g., by increasing one’s self-confidence during a task completion, or during the first semesters of university study. A study by Clarke-Midura et al. (2016) evaluated programs designed to encourage female high school students to volunteer for mentoring programs to help girls from the middle school in CS (with the goal of empowering both age groups). This near-peer mentoring provided a positive experience for both groups in terms of interest and self-efficacy.

Two studies by Ko and Davis (2017) investigated if mentoring enhances students’ interest, beliefs, and engagement level in CS. The results showed that students who had mentoring relationships, e.g., with different kinds of people, including friends, parents, siblings, cousins, teachers, and even neighbors, were influenced positively. For example, they were more interested in computing (e.g., incorporating computing into their identities), had more positive beliefs about people working in CS (e.g., the associated attributes were “creative”, “patient”, “intelligent”, or “hard-working”), and finally, felt more engaged in coding opportunities (e.g., encountering more programming languages).

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2 For example: http://computermentors.org/kidscode/, coder dojo: https://www.coderdojojoparramatta.org/, or mentoring programs: https://locations.sylvanlearning.com/us/mentor-oh/coding-for-kids
The recent report by The Association for Women in Science/AWIS (2017) clearly identifies mentoring as being among the most effective ways to bring about change, because it reaches across institutions, fields, and even generations. Mentoring unifies women, validates their experience, provides inside information about the system’s workings, trains groups of individuals to challenge the system, and provides the basis for generations of outsiders to both enter the system and, as insiders, demand needed change.

(The Association for Women in Science/AWIS, 2017)

In male-dominated STEM fields, female students need encouragement. However, the study did not indicate if mentors must be women or if it is only important to have somebody who believes in them and encourages them.

3.1.3 The influence of movies and games.

Numerous studies show that the movie and gaming industries contribute to the reinforcement of stereotypes (Kimmel, 2004; Barker and Aspray, 2006; Beekhuyzen and Dorries, 2008). At the beginning of the 20th century, computers and computer programmers were seen as something negative and strongly associated with women and low-paid secretarial occupations (Brewer, 2017). This image has changed dramatically over the last several decades. Researchers have tried to explain the huge decline from approximately 50% to 37% of women who are working in technology in 1986 to a mere 17% today (Ashcraft et al., 2016; NCWIT, 2016). Possible reasons for this phenomenon lead to the influence of pop culture and targeted marketing (Brewer, 2017). For instance, games in the 1980s established a stereotype of the “computer programmer” (e.g., “WarGames”) and the development of video game consoles and games targeted mostly young boys. Video, computer, and mobile games are not only entertaining and fun. The study by Davies et al. (2014) show that there exists a correlation between students who do not play video or computer games and those who describe their computer skills as insufficient or do not spend much time on technical devices. At the same time, IT jobs became more lucrative and “cool”, which appealed to boys and men hoping to secure high paying jobs, prestige, and technological knowhow (also known as the “Mark Zuckerberg effect” (Kumar, 2011)).

Oversexualization of women in games is one other contributing aspect to the reinforcement of the binary gender stereotypes in CS. A study by Lynch et al. (2016) shows that the trend peaked in 1995 and then declined, but that women still occupy secondary roles and are objectified more often for several reasons (e.g., marketing, lack of female game developers, or lack of game developers who are aware of gender issues). A closer look at the existing video games shows that nowadays, more and more strong women occupy the main role in video games. Examples from 2017 are a redesign of the famous character Lara Croft3 in Tomb Raider, who became a much more realistic young woman in her most recent incarnations (see Figure 3), the hero Aloy4 from “Horizon Zero Dawn”, an outsider with an interesting story, or “The Scythian”5 from “Sword and Sorcery”, a video game for mobile platforms (she demonstrates that women can also be heroes).

3 Tomb Raider: https://www.tombraider.com
4 Horizon Zero Dawn: https://www.guerrilla-games.com/play/horizon
5 Sword and Sorcery: https://play.google.com/store/apps/details?id=com.capybaragames.sworcery
Nevertheless, video games with female protagonists are still in the minority. Games continue to appeal to a male audience and exclude female gamers, there are fewer successful games available for girls than there are for boys (Google Inc., 2018), most games do not appeal to a female audience, and girls are less motivated to become gamers (only 30% consider themselves to be gamers (NewZoo, 1017)). A survey by Yee (2017) conducted with 1,266 gamers shows that 75% of the female gamers rated female protagonists as “very” or “extremely” important; more than three times as much as male gamers. However, male characters in games prevail and are not inclusive at all. For instance, Grand Theft Auto\(^6\) shows sexual harassment and killing of female characters, and female characters tend to be scantily clothed (e.g., Juliet Starling from Lollipop Chainsaw\(^7\)).

A study by (Google, 2018) concludes that game developers have to rethink their strategies now that games are becoming more appealing to wider audiences, in order to target all cultures, genders, and interests. In addition, Google encourages developers to put more emphasis on the personalities, emotions, and backstories of characters in the games because there exists less motivation for girls to become gamers.

### 3.2 Preconceptions and Differences in (CS-) Classrooms

The literature shows that younger female students (between 12-15 years old) do not show significant disinterest in CS related topics, but that the majority of teenage girls rapidly drop out of obligatory IT related courses during high school (Zagami et al., 2015). Especially in girls between 13 to 14 years, female participation or interest toward STEM subjects begin to decline (Beyer, 2016). Thus, many studies conclude that high school is the key to understanding the field-major segregation in higher education (Sadler et al., 2012, Mann and Diprete, 2013, Gabay-Egozi et al., 2015; Unfried et al., 2015). In the higher grades, male students express more interests towards physics and engineering, while girls are more likely to prefer biology (Gabay-Egozi et al., 2015), medicine, and health (Sadler et al., 2012). These preferences reflect typical gendered educational choices resulting from the gender socialization influences that were discussed above. Nevertheless, reasons for a low interest in a subject may not be always be gendered, but can originate in, e.g., teachers’ failure to attract or explain the subject well, or in the low curriculum allocation. This is the case in many European countries, including the authors’ country, Austria, with regard to CS, where classroom time for these topics is limited (Ebner and Grandl, 2017). Both groups of problems can lead to mis- or preconceptions in CS.

\(^6\) Grand Theft Auto: https://dotesports.com/the-op/news/grand-theft-auto-vi-news-21158
\(^7\) Lollipop Chainsaw: http://lollipopchainsaw.com/
The following section surveys the research on the differences in students’ interests, experiences, confidence, self-efficacy, and fun/engagement level in more detail.

### 3.2.1 Interest in CS activities and CS prior experiences.

The study of 836 high school students by Carter (2006) shows that boys were more likely to have prior experiences with CS (40% boys, 27% girls), more prior knowledge about CS (26% of boys versus 17% girls were able to provide a description of the CS major). In the latter case the answers included: “programming”, “networking”, “advanced use”, “repair”, “how computers work”, “computer stuff”, “good understanding”. Most students of both sexes, however, had “no idea” (around 650 answers = 80%). However, even if students had no idea of what computer scientists actually do or what programming is, 11% of them mentioned that they stay away from CS as a major because of programming. Other answers (occurring with a similar frequency in both sexes) included “sitting in front of the computer all day”, and that they would prefer a more “people-oriented major”. The most interesting finding was the rating of a combination of CS with another field of interest, such as business or medicine, as a positive influence for choosing CS as a major (rated as the number one positive influence for girls). However, computer games or previous experiences were also mentioned as positive influences (more by boys than girls). The study suggests improvements for CS education, e.g., to fix the image of CS (it is not only about programming), allow (female) students to gain CS experience in high school (to avoid misconceptions about that field), and make CS courses fun (make them more creative and relevant). Low or bad experiences lead, of course, to bad expectations: if young women are used to failing or think they will fail in a specific course, they will instead choose subjects that they know they are comparatively good in. Often, all it takes is one bad classroom experience to scare students away from a discipline.

A cohort study of more than 6,000 students by Sadler et al. (2012) showed that the interest during high school changes dramatically for female students whereas the percentage of males interested in STEM remains the same. The percentage of female students reporting an interest in STEM fell from 12.1% at the beginning of high school to nearly half of that (7.6%) by the end of the high school. By comparison, three quarters of the male students said that at the beginning of high school that they were already interested in STEM and that percentage remained more or less unchanged at the end. This gender disparity applied, particularly, to engineering subjects. The initial interest seems to be the best indicator of a career interest in STEM after high school graduation. The authors reported a greater difficulty in attracting female students to STEM fields during high school, which means in effect that the girls had no chance to become interested by attending the STEM lessons. The early interaction with STEM fields is crucial and female students may have fewer opportunities for engagement with them or feel less welcome in these classes. The authors also suggest that good grades in mathematics are another good indicator of a future interest in STEM.

A three-year STEM initiative in 43 school districts in the US conducted by Unfried et al. (2015) investigated the distributions of career interests between male and female students. Their results showed a similar trend as the earlier study: female students’ interest in STEM career pathways declines among older students, with the sharpest drops between 14 to 16 years old. These results may have been due to a large extent to the very low interest in engineering and energy careers that girls display.

The research of Master et al. (2016) see again the negative stereotype as a possible reasons for girls’ low interest. Girls are less likely than boys to enroll in the CS courses which are necessary to learn the basics, such as introductory computer science. Interest is an important motivational variable because it can affect learning and performance outcomes and, by extension, self-
confidence. The two conducted experiments (one with schoolgirls and one with female university students), investigated whether stereotypes continue to exert influence on the interests of female students on STEM fields. The authors concluded that, e.g., stereotyped CS classrooms intensify the feeling of not belonging, which affects the girls’ interest negatively. The authors then related the girls’ lower sense of belonging to the perceived “Lack of Fit” or “the Sense of Not Fitting” with the stereotypes associated with computer science.

3.2.2 Low self-confidence level during CS courses.

A survey of more than 166 undergraduate CS concentrator students at Harvard conducted by WiCS Advocacy Council (2015) shows, among other things, differences in self-confidence or self-perception towards students’ programming skills. Male CS concentrators rated their confidence in programming with 3.3 on the scale of 5 after 0-6 months of experience compared to 2.6 for female CS concentrators. Only after 8 years of programming, women stated the same confidence level as men after 0-1 years of programming experience.

Direct encouragement is often missing in schools and most girls who take computer science courses have already experienced some form of encouragement. A study that illustrated students’ interests at the Carnegie Mellon University towards CS from 1999 to 2012 observed the following main interests across the genders (Frieze and Quesenberry, 2015): problem-solving, building or creating something, working with useful applications, and long term opportunities. These answers are from participants who are already at university level whereas teenagers mostly put CS on the same level with programming. Furthermore, the female students in this study revealed the importance of working in groups when “times get hard through project work” - this plays an important role in the community-building as well. The female students at Mellon University in general: enjoy what they do, believe it makes them feel special, and some note that to be a woman in CS is not an issue while others express their concerns that there were too few women. However, their study showed further that male students have a consistently higher confidence level concerning their coding skills than their female colleagues but explain this phenomenon also with the general tendency that women downplay their abilities. For instance, this attitude is illustrated by the statement “I feel like everyone I know performs better than I do.” More than 50% of the women agreed whereas only 30% of the men did so. However, the authors found evidence of improvements of the female students’ performance during the degree program. In addition, this study shows that the STEM students at Carnegie Mellon University describe a typical CS student in more positive terms, e.g., as creative, passionate, focused, smart, and diverse.

A recent study by Alvarado et al. (2017) presents the results of a large-scale survey of students’ experiences in CS classes. They observed that female students refused to ask questions in class or interacted with the instructor (and also felt less comfortable doing so), and as a result, they were left with lower confidence in their abilities and with doubts about the learning content. This was more the case in advanced classes with more challenging content; the authors found evidence that women prefer to ask the tutor for assistance (after the class), while men asked their male peers first. The female students also indicated their low confidence in some of the answers. For example, they disagreed more often than men with statements like, “the class pace is too slow”, or “I want to be a tutor on my own next year”. Nevertheless, the lower confidence was not manifest in their grades (i.e., in a poorer learning outcome). The possible reason for this discrepancy could be that the female students felt that the male students were much more advanced in CS and that they were inferior to them.
3.2.3 Differences in self-efficacy, engagement, and fun-level.

An empirical study in Los Angeles public high schools by Goode et al. (2006) investigated students’ decisions (over 200 interviews) to study computer science as a major and evaluated both the structural and psychological factors. Results showed that the factors discouraging women from computer science courses included a) the image mobilized by the computer science subject itself, i.e., the lonely, introvert programmer/hacker, b) that their familial or social networks are not technology-oriented, and they do not understand computing work at all, and c) they do not see the connection of how computer science could support their academic and career plans. Especially the last point is critical: most found programming interesting but the decision not to pursue computer science was more a strategic decision for them, e.g., to fulfill the high school graduation requirements rather than play around with computers. Furthermore, the study showed that female students are more likely to enroll in programming courses when they already know somebody who is interested or has worked in the computer field. Once again, this study shows the importance of support from home to have a positive attitude to CS beforehand, e.g., through tinkering, reading books about the topic, learning through friends or relatives, or first attempts to create their own programs. In education and especially in the context of the Maker scene, tinkering refers to trying things technology (including coding) out without the fear of failure, in a playful way, e.g., using Scratch or Pocket Code (Slany, 2014; Harris et al., 2016).

During a qualitative study among female teenagers led by Weibert et al. (2012) a more practical curriculum had been implemented. The study showed the following as determining factors for career choices in the field of CS personal attachment: sympathy for the teacher, interests of their peers, and self-concept of their IT skills. The hindering factors included badly-structured computer science classes and negative career aspirations. The authors developed a curriculum, in which they integrated four modules: “Sensitization and Motivation”, “Product Development in Theory”, “Product Development in Practice”, and finally, “Evaluation”. Results pointed out that to link the subject of computer science directly with professional IT jobs positively influences girls’ interest in CS fields. In some CS courses, low engagement levels are the default norm. These courses focus not on problem-solving skills or creative skills but on basic input and output processes. Thus, the CS classes mainly rely on given examples in textbooks, with sections of code, and following directions without using logical reasoning. This setting is not only less challenging for all students, but also boring, and it even prevents them from truly understanding a programming language and the concept of coding itself. This approach does not show the multiple ways the students can use in solving the problem, does not foster any form of group work or class discussions, and finally, leads to negative experiences (for all genders). The setting that the authors of the study introduced proved helpful in positively influencing girls’ interest and engagement levels. The authors conclude that framing computer science as something that helps make the world a better place by creating programs and products or new ideas strongly contrasts with many of the existing negative stereotypes. The authors argue that many teenagers never quite understand what computer science is and how it relates to algorithmic thinking or problem-solving. Computer science, for instance, is not only programming but also a tool for solving problems or creating new ideas through meaningful assignments and resources. The question female students may ask themselves is “How likely is it that I need STEM knowledge in my future career?” This decision influences their motivation and persistence within that academic track.

A study by Giannakos et al. (2014) consisted of three workshop programs which examined the effect of enjoyment, happiness, and anxiety in 12-year-old girls during creative development activities. The findings show that happiness had a positive effect, anxiety had a negative effect, and enjoyment had a neutral effect on students’ intentions to participate in coding activities in the future. Happiness could be increased, e.g., by using humor, fun, and positive feedback, and
anxiety could be decreased by praising girls’ development skills and using collaborative learning environments. Female students seem to have more negative attitudes towards STEM classes, thus there is a much higher possibility to negatively rate this expectancy value.

For women, creativity and interest in STEM professions are often related, but they perceive low practical relevance of many of these subjects. A European-wide study by Microsoft (2017), in which 11,500 young women between 11 and 30 were interviewed, showed that girls between the ages of 12 and 16 are the most creative. Thus, female teenagers at this age should be supported especially in skill trainings and STEM. Approximately every third woman (33%) criticized how scientific topics were explained in schools, especially the topics in computer science. The study mentions that those subjects are taught from a more "male perspective". This European research study states that creative teenage girls are particularly interested in STEM subjects and could be attracted to programming with more innovative initiatives. It is therefore important to present STEM professions as creative. Research by Khaleel et al. (2015) argues that students often find coding activities in schools difficult or boring and end up memorizing the processes without understanding them. An enjoyable approach must be adopted in learning, especially for difficult subjects. Game elements and an additional fun factor influence the general outcome of the course and make it an interesting experience for all students.

3.3 Inequity in CS-Education

“Gender competence”, “gender-specific interest guidance”, or “gender-sensitive and aware education” are relatively new territories for many teachers and schools (Giltemeister and Robert, 2008). Especially in education, gender is constantly negotiated, produced, and reproduced by students as well as by teachers (West and Zimmermann, 1987; Basow, 2004). Teachers play an important role in the cycle of career assumptions. Gender-sensitive teachers recognize gender-stereotyped influences on students and counteract against them, reflecting also on their own teaching practices with the aim of creating equal opportunities for girls and boys.

This section reviews the importance of framing supportive classrooms, starting with the teachers’ roles, language used in classrooms, teaching materials, and ways of effecting change toward creating a supportive classroom environment. It concludes with an account of gender differences during coding classes, e.g., in tinkering and programming behavior.

3.3.1 Teachers in CS classrooms.

Cheryan et al. (2009) conducted different studies to prove that gender differences in interest occur when college women are confronted with stereotypical CS classrooms. First, they examined if environments can affect female students’ interests. To that end, they placed stereotypical objects (e.g., science fiction posters, electronic parts) in one room and non-stereotypically associated objects (e.g., art posters, general interest books) in another. Thus primed, women exposed to stereotypical objects said that they were less interested in CS than the control group. The difference in environment had no impact on men. A stereotypical classroom increased the women’s concerns about negative stereotypes, which decreases their sense of belonging and interest in CS courses. Even when groups consisting only of women were present in the stereotyped classroom, women’s interest in the objects distributed in the environment affected if they joined the group or not. Second, the authors tested students’ decisions when applying for generic web design companies, which included these kinds of objects in their presentations. The results were the same, as both men and women identified the stereotypical environments as masculine-coded.
Concerning teachers, a study by Schwartz (2013) indicates that male students are praised more often and also thought to be rebuked more often than female. On the one hand, it is important to appreciate sufficiently the students’ achievements, but more importantly, to formulate the feedback in such a way that it does not entail harmful attributions or tensions that would mobilize fear of failure. On the other hand, it is not helpful to praise girls for achievements that are not addressed also in boys. Praise for “normal” performance can damage self-confidence. While boys are often praised for their talents, girls are more often praised for being hard-working rather than for simply being good. Overall, it is important to praise the work of female students at least in the same way as that of the male students and to provide recognition of their work done.

A study by Wong and Kemp (2017) conducted 32 semi-structured interviews with digitally skilled teenagers (aged 13–19) and observed IT career assumptions and prejudices. The researchers suggest to draw more attention to the social elements of computing; beyond the transmission of expected technical skills, teachers should reduce gender-stereotyped views (e.g., perceptions of CS as being too difficult or point to CS as a masculinized environment), and finally, teachers should promote IT careers that are more driven by creative thinking and design (for instance, computer animation, game design, and web design). The authors point out that when students work in pairs, girls-only pairings might positively stimulate the identities of girls in computing classes through collaborative learning and peer support (but this should not be forced by the teacher). CS teachers should not strive to train the next generation of computer scientists, programmers, or technology entrepreneurs but to promote digital literacy and excellence for digital creative purposes.

The above mentioned study by Microsoft (2017) concludes that teachers’ guidance and advice are major influences over students’ educational incentives and attitudes. The study included 11,500 European women and found that more than half (57%) said that they had a teacher who encouraged them to pursue a STEM career. It is important for teachers to question their own stereotypes. Teachers who are not aware of inclusive and gender-sensitive education can create a classroom in which male students are placed in the more knowledgeable position by default, rather than merit.

### 3.3.2 Gender-awareness in language and CS content.

A gender-sensitive language is particularly important in languages that employ grammatical gender extensively and use the generic masculine to subsume also other genders. The feminine form is banished into a footnote, at best (Braun, 2008). The use of a gender-inclusive language is essential because

1) “Language creates pictures” and that picture is often of a masculine gender (masculine bias; by Formanowicz et al., 2015). For example, the statement “[a] scientist in his laboratory is not a mere technician: He is also a child confronting natural phenomena that impress him as though they were fairy tales” invokes the image of a male scientist in his laboratory, but it is actually a quotation from Marie Curie Sklodowska from 1937.

2) The article by Vervecken and Hannover (2015) showed that if stereotypically male occupations are spoken about using both genders instead of the generic masculine, children assess women and men equally in them (while if the terms of reference are masculine, the children rate men as more successful) and girls tend to be more interested in these professions. If companies/universities want to appeal to female talents, but are using masculine gender in language or images, they may present their programs as less attractive to women.
The study by Zagami et al. (2015) highlighted 12 different strategies to encourage female students to study CS in the US. The authors criticize that the construction and evaluation of CS programs is insufficient, stating that “[c]urrent school IT curricula do not inspire or interest girls and this is a major reason why girls do not go on to study IT further”. The authors then mention the stereotypes widely used in textbooks and teaching content, and admonish the fact that no social learning in groups occurs. They call for the identification of appropriate resources and pedagogical approaches (e.g., they refer to the different brain development of the sexes) to affect change.

The research of Medel and Pournaghshband (2017) go further and examine three distinct problems in CS teaching materials to show that CS teaching materials may not be as supportive of female students. They argue that the materials do not support diverse interests or address activities preferred by women. Instead, they draw on established trends of male-centered representation, imagery, and language that may promote gender inequality. The authors proposed replacing the characters/names with animals (e.g., replace character Eve the “eavesdropper” with an owl who “watches”) and employ gender-equitable imagery. The concept means using more positive images of women in examples or textbooks (e.g., instead of the objectifying imagery of “Lena” used as an example for graphic design, use standardized images, e.g., of known monuments). In language, females are often less positively portrayed and the authors suggest to use the singular pronoun “they”, in the case of the English language, to refer to nouns with unspecified gender. Finally, the authors tested their more gender-equitable material in a computer security class, and their results indicated an improvement in female students’ confidence in understanding the material, and no negative effect on male students.

3.3.3 Differences in coding and tinkering behavior.

Only little research exists on differences in programming between boys and girls. The study of Beckwith et al. (2006) focused on differences in feature discovery and show that male users adopt higher amounts and different types of features compared to female users. Female students were significantly slower in trying out new features and were also less likely to use them again, whereas males tried less familiar features early on. Fewer uses of features correlated with a low self-efficacy, particularly in girls. The study also refers to differences in tinkering behavior and states that male students seem to benefit more from it. However, tinkering also helps females to gain valuable information about the features and increase their self-efficacy. Low tinkering interactions and low self-efficacy occurs in girls if they use environments that are described as too complex. The study concludes that gender differences exist in the way students solve problems, which may indicate a need for a more supportive feature designs.

According to the three case studies in a summer course named “Gaming for Girls” by El-Nasr et al. (2007) that elaborates game design and development for middle and high schools girls, such courses increased students’ self-efficacy, helped them in acquiring design and coding skills, and engaged them in the coding activity. Due to time constraints, the authors describe that it was harder for the students to absorb the design and programming techniques. Thus, for the second course, the structure built more on tutorial games and discussions. Results showed that girls integrated game-play, map design, usage of music and sound effects, or a background story to their games and were interested in creating their own characters. Next, the authors described that girls had little interest in revisiting and reflecting on their games once they were completed.

This is also reflected in the research by Grigoreanu et al. (2008) who state that boys relate more often to testing and debugging activities. The authors conclude that there exists a gender gap in software environments, for example, in end-user programming tools (programs designed to accept user-written components in appropriate places; visual programming is one technique of
end-user programming\(^8\)). For instance, the authors refer to differences in problem-solving strategies; strategies used more often by women, e.g., code inspection or specification checking, are not supported sufficiently by the tool, compared to the most often used strategies by men (testing and dataflow). This affects female end-user programmers’ self-efficacy, attitudes, usage of testing and debugging features, and performance. Instead of providing female users with more manuals or tutorials for the features preferred by males (i.e., forcing them to adopt the male-perspective in debugging), the authors see a greater chance for future work in supporting those features more often used by females. The study concludes that it is possible to design features that lower the barriers to female effectiveness and help to close the gender gap (e.g., with video/text strategy explanation snippets).

In addition, the study by Craig et al. (2013) observed that the participation of girls in computer classes is not the same as those of boys: girls tend to spend more time on visual customization while boys spent more time on solving logical puzzles, and the authors point out that it is essential to consider gender differences in logical and computational skills. According to this study, it may thus be more effective to get girls interested in technology by asking them to design games rather than to focus on the learning of specific programming skills. Presentations in CS classrooms should integrate appealing visuals and interactive elements, while also having a story to tell that is fun, informative, and engaging.

The research of Krieger, Allan, and Rawn (2015) observed tinkering strategies across genders in undergraduate students of CS via interviews and a questionnaire. According to the authors, tinkering means exploring and is generally considered as an informal practice. Thereby, they see it on the same level as to use problem-solving abilities or how students ask for help. Results showed different definitions or perceptions of tinkering activities by sex, and that girls are less likely to see themselves as “tinkers”. Thus, the authors proposed to think of teaching tinkering for non-tinkerers as well.

One of the previously mentioned strategies by Zagami et al. (2015), points out that female students sometimes find it difficult to engage equally in traditionally male-dominated disciplines like CS. Courses which focus on girls only take advantage of the preferences for being uncompetitive and social learning opportunities can enhance female participation. On the one hand, the authors describe the positive influence of creating situations where females are preferred to males; on the other hand, this can lead again to a range of negative impacts (stereotypes, threats, discrimination, etc.). Overall, the key benefits of girls-only initiatives are social encouragement (reinforcement of CS by peers, mentors, role models), self-perception (interest in problem solving, creative and collaborative environments), and career perception (job clarity, personal relevance). Furthermore, facilitators and teachers report the difficulty in engaging girls and boys equally in traditionally male-dominated subjects such as computing. Thus, coding initiatives for girls may improve women’s participation in such activities. According to Alvarado et al. (2017) girls’ initiatives create opportunities to focus on their interests and to enable them to socialize with other girls interested in computer science.

The review of McLean and Harlow (2017) presented data from three workshops to identify the affordances of activity design that engage girls in STEM play. They propose that in order to engage girls in coding, social relevance, storytelling, and design tasks should be part of the coding activities. Such activities provide the opportunities to participate in problem-solving by

\(^8\) End-user programming: http://www.cs.uml.edu/~hgoodell/EndUser/whatsEUP.htm
providing learners with resources and a given problem. Teachers who only focus on computer instruction may discourage many students (of all genders) from active participation.

4 DISCUSSION

Extra-mural coding initiatives that started in 2006 had predominantly male participation (Zagami et al., 2015). If coding activities for girls-only are promoted in schools, teachers will be faced with the conflict of having to provide similar activities for boys as well. Thus, girls-only initiatives outside of school are a promising alternative to get more girls involved in CS activities. However, overall, new, fun and motivating concepts for learning about CS disciplines first described by Wing (2006) and new tools for coding that emerged in the following years did not directly have a positive influence on getting more girls in CS degree programs and it did not change the present stereotypes in CS fields. The question is: has this perhaps even produced a negative affect? By putting CS on the same level with games, girls who are not used to playing games can feel less motivated/engaged, and by presenting coding as an extremely simple activity, girls may question their abilities, as there is still a lot of complexity in coding, unless they are convinced of the opposite.

This article provided a summary of literature that shows what encourages and discourages female teenagers in coding by focusing on motivators. While Figure 2 presented the negative influences on motivation (interest, sense-of belonging, self-efficacy, and engagement/fun), Figure 4 provides a summary of positive influences by suggesting inclusive coding environments and more balanced attributes suiting to all teenagers in computing, as it emerged from the literature that we discussed so far.
Figure 4: The increase in motivation by creating CS classes free from stereotypes: reshaping the picture of people in computer science, building non-stereotypical classrooms by gender-aware teachers.

Sources:
Cultural and social influences: (Lockwood, 2006; Cheryan et al., 2013; Young et al., 2013; 2017)
Preconceptions and differences in (CS-) classrooms: (Carter, 2006; Sadler et al., 2012; Weibert et al., 2012; Giannakos et al., 2014; Khaleel et al., 2015; Frieze and Quesenberry, 2015; Unfried, 2015)
Inequity in CS-education: (Beckwith et al., 2006; El-Nasr et al., 2007; Grigoreanu et al., 2008; Craig et al., 2013; Krieger, Allan, and Rawn, 2015; Zagami et al., 2015; Alvarado et al., 2017; McLean and Harlow, 2017; Wong and Kemp, 2017)
Internet sources: (Schwartz, 2013; Yee, 2017; Microsoft, 2017; Google 2018)

5 CONCLUSION

A girl in computing falls into one of the two stereotypes (see Figure 2): a computer freak or unfit for computing. It is still true that young women who decide to enter the computer science “pipeline” are pioneers or token women who have to struggle against prejudices. The world would be a much nicer place if women in computing were seen as role models, mentors, or simply experts in their field even if they do not comply with the stereotypical attributes.

This article reviewed empirically-derived reasons behind the low number of women in CS. It concludes with the argument that it is important to directly encourage female teenagers in CS to improve the situation for all (companies, industries, or working teams). We reviewed a range of influences that indicate that the gender gap begins in childhood and is most critical in students
in secondary education. When female teenagers between 12-15 years decide their future careers, many influences steer them away from a CS career, e.g., stereotypes that have a huge impact, preconceptions, the masculine tech/gaming industry, absence of female role models/mentors and, of course, a lack of sense of belonging, summarized in the image of Figure 2. The review of research literature since 2006 confirmed that stereotypes, preconceptions, and inequality in CS classes continue to have impact. A CS classroom is often not a place that encourages females to get involved. Consequently, the authors have concluded that it is the environment that has to change to fit the women, not the other way round.

In their previous work the authors refer to the importance of learning how to code in a playful way and summarized experiences from both the students’ and the teachers’ perspectives (Spieler et al., 2016; Spieler et al., 2017a; Spieler et al., 2017b). Game design activities and Game Development-Based Learning (GDBL) can provide engaging, goal-oriented, and creative experiences in classes. In this way, GDBL is used to support the construction and transfer of knowledge in a fun and pedagogic manner (Wu and Wang, 2012; Johnson et al., 2016). What seems to be a promising opportunity for all students to learn about coding in an entertaining way raised the question of whether such game-based concepts also help to fix the gender gap of women in CS related fields. In more recent contributions, the authors presented results from the European H2020 No One Left Behind (NOLB) project (2015-2017) which aimed at supporting female students in particular with the coding app Pocket Code during different classroom projects (Spieler, 2018; Spieler and Slany, 2018a; Spieler and Slany, 2018b). The results suggested promising ways of empowering female students in coding classes with game design and creative activities, although locally designed courses are not a guarantee of long-term success. Still, if other STEM fields have successfully increased female participation, it is also possible in CS (National Science Foundation, 2016).

6 OUTLOOK

This overview sets the background for more practical explorations, namely, for the “RemoteMentor” research project and the “Girls Coding Week” initiative.

“RemoteMentor” is a project in which all the authors of this paper are currently involved. It is a one-year investigation that started in January 2018 with funding from NetIdee, a private internet foundation9. In this project, female students between 14 to 15 years used our app Pocket Code10 (an app developed at the Graz University of Technology/TU Graz) during their CS and arts lessons. Pocket Code is an Android-based visual programming language environment built to allow the creation of games, stories, animations, and many types of other apps directly on phones or tablets (Slany, et al., 2018). The visual “lego”-style programming language used is very similar to that which is used in the previous mentioned web environment Scratch and should support users in their first programming experience. During the project, students created their ideas by using storyboards (a framework that supports them in their idea creation by defining a genre, a main character, and the interaction level with the objects). During the arts classes, students additionally chose famous paintings and created interactive memes (i.e., altered them in a creative or humorous way) through animations and games. During these regular school lessons with Pocket Code, students received real-time online mentoring by students from the TU Graz. Thus, students were able to call a mentor during a 30 minutes session and share their screen with them to show their scripts and ask for advice, see Figure 5.

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9 NetIdee project Remote Mentor: https://www.netidee.at/remotementor
10 Pocket Code app: https://catrob.at/pc

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Preliminary results show that this concept is a promising approach to keep female students motivated. In group interviews conducted after Phase 1 of the project, the girls evaluated the one-to-one support in realizing their game ideas as very positive. However, some of them also appreciated the time outside of the mentoring sessions, as they were able to try out different functions of the app themselves and apply their newly acquired knowledge independently. After the first test run in June 2018, the girls, despite some challenges that had to do with programming, realized their game ideas and were satisfied with both the mentoring experience and their finished games.

Figure 5: “RemoteMentor” project funded by NetIdee. Female students get remote mentoring by university students through screen-sharing and audio transmission.

Additionally, TU Graz introduced a “Girls Coding Week” in summer 2018 aimed at empowering female teenagers between 11-14 years old with new and engaging ways of learning to code with the app Pocket Code. 13 girls took part in this workshop. Following the findings of the literature review presented here, the goal of the first day was to provide an understanding of coding in general and the profession of people in IT. During this warm-up phase, girls were introduced to coding with unplugged coding activities (i.e., to teach coding without the use of a computer, for instance, to program a classmate like a robot), and had discussions in groups about their coding experiences, role models, and other CS relevant topics (Brackmann et al., 2017). During the second and third days, the understanding of coding/computational thinking was delivered through ten hands-on coding units. Each unit started with an unplugged coding activity\(^\text{11}\), a short theoretical part, a coding example created together with the whole group, and finally a coding challenge as individual work. The girls had two more activities on the fourth day: First, they were introduced to LEGO®-Mindstorms NXT robots, and second, they were able to stitch their creative programmed patterns with an embroidery machine on bags. All coding units provided the necessary preparation for the girls to create their own games on the fourth and fifth days of the workshop. The girls started with a storyboard (textual as well as graphical). First, they presented their game ideas to their peers. Second, they started creating their own games by including their own artwork. At the end of the workshop, all of the girls created their own individual games, which all included the “Shape of a Game” (title, instruction, game, and end screens), several levels with difficulties, interactivity with objects (e.g., by using different sensors of the app), and variables for points and levels. They presented their finished games in front of their parents. Preliminary results show that all the girls felt motivated and engaged, and they welcomed the opportunity to create their own games with Pocket Code. This concept for the “Girls Coding Week” will be offered again in summer 2019. Impressions of the workshop are part of Figure 6.

\(^{11}\) CS unplugged: https://csunplugged.org
In the future, we plan to establish a “Girls Coding Club” for female teenagers at TU Graz to perform long-term studies in order to observe any effects in the future. This club will meet outside of the regular school setting, and will emphasize creativity, allowing the girls to explore IT and technology in a fun way to spark their initial and long-term interest. Materials for performing such girls coding clubs around the world will be made available online. In addition, mentors selected from university students will encourage them in their learning. Our goal is that girls involved in our “Girls Coding Clubs” will represent vulnerable learners in terms of risk of exclusion. The authors hope that such environments will support the inclusion of girls in a currently male-dominated field and will empower them from childhood to effect a positive change in their futures.

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