Gender-Specific Motivation and Expectations toward Computer Science

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ABSTRACT
This paper provides an analysis of current motives for choosing computer science as a subject of study, focusing on male and female computer science students’ perception about expectations and required qualifications for this professional career. A multi-method approach (qualitative and quantitative research) was applied in two studies in Germany to, firstly, explore which motivations dodge behind the decisions to study this complex discipline, and secondly, to examine if motives and the required skills are gender-specific or not. The results of the presented studies confirm that women and men are guided by different motives and expectations regarding the subject of computer science and in some cases evaluate their strengths and abilities in different ways.

CCS CONCEPTS
• Social and professional topics → Computer science education: Women; • Human-centered computing → Empirical studies in HCI;

KEYWORDS
Gender Gap, Computer Science Education, Interest in Science, Technology, Engineering and Maths, STEM, Motives for Computer Science Career

ACM Reference Format:

1 INTRODUCTION
There is a high demand for professional computer scientists in Germany [30]. In 2016, more than 51,000 open positions for IT specialists in Germany were reported, an increase of almost 20% within one year [9]. Due to this lack of trained personnel, the German Federal Employment Agency predicted an even higher need for computer science graduates [30]. But not only IT specialists

must have IT knowledge today, professionals in nearly all fields encounter advanced dealings with computers to ensure efficient work, modern logistics, intelligent transport systems, data privacy, and IT security and thus, could benefit from basic computational thinking skills and concepts. Examples are the use of databases, awareness of security threats, programmatic use of calculating tools, or the implementation of short programs to optimize workflows [56, 60].

This need for IT experts requires filling more students with enthusiasm for computer science. However, women remain underrepresented in computer science and show less interest for this sector [3, 30]. Apart from a lack of qualified computer scientists for the economy, the underrepresentation of women has further negative consequences, not only for society, but also for women themselves. For example, women miss out on beneficial opportunities the IT industry has to offer [28]. One of these opportunities are well paid and reliable employment conditions [40]. Moreover, serious design flaws were attributed to the absence of women’s perspective in the development process [28, 40, 52]. Examples include voice and video recognition software, performing worse for women’s voices, airbags only designed for male drivers [43], and intelligent personal assistants such as Apple’s Siri lacking the ability to offer advice to problems mainly women are concerned with, e.g. sexual assault [40, 44]. Women could offer more diverse perspectives on the development process and draw developers’ attention to special needs of women, like physical differences (e.g. in the design of airbags) or topics (e.g. information on sexual assault).

In the following subsection, the current state of women in computer science is presented (Subsection 1.1). Afterwards possible reasons for this gender gap are described based on previous findings in the literature (Subsection 1.2). Based on this overview our research approach in this paper is introduced in Subsection 1.3.

1.1 Women in Computer Science
A gender gap between male and female computer scientists can be observed globally in the western world, for example in the U.S. [18, 28, 52], Germany [30], and Spain [45]. The specific proportion of women in computer science study programs and the IT workforce varies but is described to be around 20% in the United States [3, 15], 22% in Sweden, 18% in the UK [23], and 19% female computer science students and 16% women in the IT industry in Germany 2014/15 [30]. Even though the share of women was at its highest point in the 1980ies, it is particularly alarming that the number of female computer science graduates is constantly decreasing [15]. This decline is even more astonishing since the IT sector in general is still thriving [52]. While other initially male-dominated fields such as medicine and chemistry achieved a balanced gender distribution,
STEM (Science, Technology, Engineering, and Mathematics) still suffer from a serious imbalance [14]. A large-scale study by Lehman et al. examined about 30,000 first year students and their intentions to major in computer science or other STEM fields and found out that there are significant differences regarding the proportion of women and their profiles in computer science and other STEM fields, revealing an even more serious gender gap in computer science [40].

The attrition rate of women in computer science can be compared to a leaking pipeline: While at the beginning of their school education a balanced representation of female and male students enter the pipeline, women drop out of it at disproportionate rates at the beginning of university and especially before higher positions in academia and industry [29]. However, several researchers have argued that the disproportion of gender starts as early as high school with reasons going back to their childhood [14, 17, 29]. Despite the positive effects of pre-college computer science classes on students’ interest in the subject [34], many high schools in the U.S. still do not offer these classes [33]. Furthermore at this level, female students are already significantly less interested in taking a computer science class or pursuing a related career [14, 54, 58].

Hence, by the time they enter college or university, female students’ intention to major in computer science is already four times lower than their male counterparts’ plans [14], resulting in the low numbers of female computer science students already discussed. Moreover, the gender gap continues after university with qualified women diverging from the sector [37]. In academia, only 21% of the researchers publishing in computer science conferences are female authors. However, while there still more papers published by only men in contrast of only women, the number of papers with at least one female author is increasing [2]. Another well-known yet nevertheless alarming finding is that women are still concentrated at lower and middle levels but under-represented at higher levels in IT industry [1, 3] and academia [20, 29].

Summing up, a critical gender gap between male and female computer scientists can be confirmed for all levels, starting at high school and going up to industry and academia. In the following subsection, the reasons for these differences will be examined.

1.2 Reasons for the Gender Gap

Several researchers examined the reasons for the gender gap, resulting in a large body of scientific research, which indicates significant social barriers [14]. A major influence confirmed by several researchers is women’s self-perception and lack of confidence to succeed in a computer science career [14, 21, 26, 28, 34, 40]. Girls and women consistently underestimate their abilities in mathematical, technical, and science subjects, resulting in reduced interest to pursue one of these careers [14, 21, 27, 40]. Even among men and women of comparable academic achievements, women still rate their academic strengths lower than their male counterparts [51]. This lack of confidence even goes as far as that female students who major in computer science nonetheless consider their computing skills lower than men who are not computer science majors [7]. Furthermore, Lehman et al. found out that women in computer science assessed their academic ability lower than women in other STEM fields [40]. However, the expectation whether or not to prevail in a field is of substantial importance to shape the career decision [42]. Hence, increasing women’s self-efficacy regarding their skills in science is particularly important to make STEM study programs more attractive for women [6, 11, 40, 61].

Women’s low confidence can also be attributed to a lack of experience with computer science. Previous research has shown that male students often have more experience in computing [12]. Investigating more than 1300 first year college students, Beyer found that a positive experience in their first computer science class had a beneficial influence on students’ intention to take another class [6]. The significance of early academic exposure to computer science was named one of four most influential factors determining girls’ interest in computer science in a report by Google [34].

The early exposure to science and technology can be greatly shaped by social encouragement [52]. If parents or teachers believe that science careers are inadequate for women, young girls might be unconsciously directed to follow different paths [14, 50]. On the other hand, positive reinforcement by family members, teachers, or peers can encourage young girls [34].

A prominent factor, which attracted particular attention in recent research, is the influence of stereotypes [12–14, 28, 42]. Popular TV shows such as The Big Bang Theory have painted a picture of scientists as Caucasian or Asian socially incompetent yet naturally brilliant men [14]. In people’s stereotypes, computer scientists are usually socially awkward geeks [48], who are only obsessed with computer science [42], prefer to sit in the front of the computer and play video games instead of socially interacting or collaborating [12, 14, 25]. Computer scientists are also believed to be brilliant geniuses, whose intellect was inborn in contrast to being learnable [41]. With the stereotypes described prominent, women in contrast to men have a feeling of dissimilarity with the description of the field, resulting in a lack of sense of belonging [11, 15]. However, the sense of belonging and identifying oneself with a field are crucial determinants of people’s decision to pursue that field. Thus, if students miss this sense of belonging, it might deter them from computer science even if they are interested in the subject [4, 32, 35].

The perception of these stereotypes begins as early as elementary school when girls already expect boys to be better at math [22]. Asking about 270 U.S. students for a description of a prototypical computer scientist and their perception of similarity to this prototype, Ehrlinger et al. discovered that women gave more stereotypical-consistent descriptions of the prototypical computer scientist than men. Moreover, women rated themselves to be less similar to this prototype [28]. Particularly the impression that computer science is not a people-oriented or even unsocial field which fosters working alone instead of collaboration has a daunting effect on both men and women, but a significantly stronger influence on females [12]. As a consequence, several researchers could show that successful role models who do not fit into the stereotypical clichés have a positive longterm effect on women’s interest [12, 13, 18].

Another negative consequence of these prevalent stereotypes is the denial of women’s competence in computer science. After the viral social media #ILookLikeAnEngineer campaign, in which women working or studying in STEM fields posted pictures of themselves with the Hashtag #ILookLikeAnEngineer, Banchefsksy et al. conducted two studies, examining the relationship between
people’s look and the ascribed probability of being a scientist. They yielded the results that women who looked more feminine were attributed a lower likelihood of being a scientist [4]. On the contrary, men’s appearance did not alter participants’ opinion on whether this man is a scientist. These and other findings (e.g. [46]) reveal that there is still discrimination in STEM fields, which could lead to women’s discouragement [14].

1.3 Questions Addressed and Logic of Empirical Procedure

The questions addressed in this paper refer to gender-specific aspects of the mastery of computer science as a professional field. The numbers presented in Section 1.1 show the alarming gender gap in computer science. In order to satisfy the need for IT experts in Germany, the sector has to be more attractive for women. A review of literature revealed that, firstly, there are still less women beginning to pursue a computer science career after graduating from school. Secondly, women, who begin a career in computer science, drop out in the early years of universities or before reaching higher in industry and academia.

According to our review an important reason seems to be that women are less exposed to computer science in their childhood and become less interested in entering a STEM study program. Thus, our first question addresses the motives of male and female computer scientists' perception of actually required skills and previous experience to manage the complex contents of the subject matter. These findings could help to foster these skills and experience already in school to improve female students’ confidence.

To address these empirical questions, we pursued a two-tier approach, combining qualitative and quantitative procedures. The qualitative approach aimed at understanding possible motives for studying computer science, relevant expectations as well as potential requirements that encourage or prevent students from planning a professional career in computer science. In order to get a deeper insight into cognitive and affective factors as well as possible beliefs about the study course and individual needs, we used semi-structured interviews in which participants were free to comment on selective topics which seemed important to them (cf. Subsection 2.1).

In the second part of the empirical process we quantified some selected aspects by using an online survey with a larger sample size. One focus of the survey was directed at participants’ inclination to using technical innovations and gadgetry (as a motivational driver). Another focus aimed at understanding how the participants evaluate skills and abilities perceived as important for the successful completion of computer science as a study field and professional work (cognitive and affective factors as drivers for individual self-concepts).

2 QUALITATIVE RESEARCH APPROACH

To understand students’ motivations for studying computer science, a qualitative research approach was chosen, which is suited to systematically scrutinize interviewees’ attitudes and opinions [5]. This research design promotes comprehending even complex backgrounds or contexts which have not been considered in research yet and therefore might not emerge when using standardized research methods [24]. A semi-structured interview based on a guideline promises the advantages of a social communication situation, which gives the interviewee a more mundane and natural impression of the actually artificial situation [24]. Therefore, semi-structured interviews were conducted to get a first in-depth insight into students’ motives. In a second step, these interviews can be used for forming categories [5], which can be investigated quantitatively (cf. Section 3). In the following subsections, the interview guideline and sample are presented before the findings of the survey are outlined.

2.1 Method

The interviews took place from July 13 to August 8, 2016 at participants’ choice of place (e.g. participant’s home). Participants spent about one and a half hours on the study, whereby the interviews attributed for 50 minutes on average. After concluding the interview, participants were asked to fill out a written demographic questionnaire.

The interview guideline for the semi-structured interview consisted of six units, including a (1) general evaluation of the computer science study program as well as favorite classes, (2) motivation and aims, (3) strategies for exam preparation, (4) group work, (5) dealing with failure, and (6) additional remarks. Due to the immense amount of information only the parts which are presented in the following sections are described here. First of all, students explained why they decided to study computer science and which reasons determined their choice. Apart from students’ motivation, they also pointed out expectations they had before entering university. These questions primarily served to establish whether students’ motives were intrinsic, e.g. because they were interested in technical subjects, or extrinsic, e.g. they expected to get a good job afterwards. These questions were based on findings that intrinsic motivation results in higher learning success [49] and a decrease in the likelihood of dropping out of the study program [36]. Since several researchers have tried to determine requirements for successfully studying computer science (e.g. [36, 59]), students were asked to name personal skills and experience qualifications they consider important for mastering computer science studies.

Evaluating the results from the interviews, all recorded interviews were transcribed in a first step. These transcripts served as the object of investigation, which were evaluated by the inductive text analysis method Grounded Theory according to Glaser. This approach was chosen since a literature analysis did not produce an existing framework for computer science education. Hence, a pure inductive analysis was applied to pursue an open exploratory approach, preventing that a prefabricated framework is imposed on the data and might lead to neglecting new categories [24]. In an
iterative and recursive process we identified interesting statements and afterwards sorted, grouped and classified them to categories on higher and multiple levels of abstractions.

2.2 Sample

Sixteen students participated in the interviews with five female and eleven male participants. Seven of the interviewees were pursuing a Computer Science Bachelor’s degree, three studied in a Computer Science Master program. Six participants were doing a Bachelor in Technical Communication, a two-subject degree consisting of 50% computer science on the one hand and 50% psychology and communication studies on the other hand. Four of the five female participants studied Technical Communication. The participants were 19 to 27 years old (average age: 24 years). They were in their second to ninth semester.

2.3 Qualitative Findings

In the following subsection the category system resulting from the interviews and the inductive and recursive categorization is presented. First of all participants’ motivations for studying computer science are outlined. Afterwards, the results from participants’ descriptions of their expectations in advance of beginning the study program are demonstrated. Eventually, participants’ assessments of required qualifications for studying computer science are explained, differentiating between personal skills and critical previous experience. Although it was not explicitly asked as part of the interview guideline, some participants commented on their views of stereotypical computer scientists, which are presented in the last subsection. The presented categories derived from the Grounded Theory analysis, in which we clustered and classified participants’ answers. To give an early impression of different gender perspectives, the tables provide the absolute frequencies of male (labeled by \( n_{\text{male}} \)) and female (labeled by \( n_{\text{female}} \)) participants, who indicated the according category. In addition, the total number of male and female participants is noted. However, it has to be stressed that due to the small sample of interviewees \( (N = 16) \) and the qualitative non-standardized approach these frequencies can only provide preliminary indications.

2.3.1 Motivation for studying computer science

As can be seen in Table 1, participants gave primarily intrinsically motivated reasons for their choice to study computer science. Thirteen participants decided to study computer science mainly due to their interest in technical and mathematical contents. For example, one participant pointed out that he has been interested in computer science for a very long time so that he expected computer science to be suitable career for him:

“Yes, because I rather like technical stuff […] And I found it interesting, it was fun for me and then I thought this could fit for a job later.” (P9, male, translated from German)

While also the majority of male participants claimed interest to be a critical factor for their decision, all five participating women emphasized the effect of this reason.

Five participants outlined that their motivation was based on an assessment of their personal abilities. They expected to have skills, e.g. mathematical reasoning, which are useful for being successful in computer science. For example, one participant stated:

“Math is important for studying computer science, you need this logical reasoning and I think these are things I am quite good at and that’s why I decided for it.” (P10, female, translated from German)

Although two participants expressed an interest in studying mathematics, they decided to study computer science because they favored its variety and practical application. Two participants explained that they appreciated the kind of learning in computer science. It is conspicuous that only women reported this reason.

On the other hand, three extrinsically motivated reasons influenced participants’ decision. However, only two participants mentioned solely extrinsic reasons whereas the majority stated intrinsic as well as extrinsic reasons. Extrinsically motivated reasons included good prospects of getting a job and an influence by friends and family, who favored the study program. Yet, for two participants (both male) the lack of restriction of admission as study’s entrance at the university played a role in their decision due to poor A-level results.

![Table 1: Participants’ intrinsic and extrinsic motivation for studying computer science, absolute frequencies of male (\( n_{\text{male}} \)) and female (\( n_{\text{female}} \)) participants, who indicated the according category.](image)

<table>
<thead>
<tr>
<th>Category</th>
<th>( n_{\text{male}} = 11 )</th>
<th>( n_{\text{female}} = 5 )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intrinsic motives</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest in computer science</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Personal abilities</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>More applied than mathematics</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Kind of learning</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td><strong>Extrinsic motives</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good prospects of getting a job</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Influence by friends and family</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>No restriction on admission</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

![Table 2: Participants’ expectations before entering university, absolute frequencies of male (\( n_{\text{male}} \)) and female (\( n_{\text{female}} \)) participants, who indicated the according category.](image)

<table>
<thead>
<tr>
<th>Category</th>
<th>( n_{\text{male}} = 11 )</th>
<th>( n_{\text{female}} = 5 )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Study program is demanding</strong></td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td><strong>More practical skills</strong></td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Being prepared to find a good job</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>No expectations in advance</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>More programming skills</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Developing better knowledge about</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>
Table 3: Skills for successfully studying computer science according to participants, absolute frequencies of male \((n_{\text{male}}\) and female \((n_{\text{female}})\) participants, who indicated the according category.

<table>
<thead>
<tr>
<th>Category</th>
<th>nr male</th>
<th>nr female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest in computer science</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Endurance</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Motivation</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Willingness to deal with complex contents</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Abstract, logical reasoning and mathematical skills</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Discipline</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Teamwork/Team spirit</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Patience</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 4: Required or beneficial experience for studying computer science according to participants, absolute frequencies of male \((n_{\text{male}}\) and female \((n_{\text{female}})\) participants, who indicated the according category.

<table>
<thead>
<tr>
<th>Category</th>
<th>nr male</th>
<th>nr female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Necessary qualifications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Previous computer science knowledge is necessary</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Beneficial qualifications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced mathematics class at school is beneficial</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Computer science experience is beneficial</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Unnecessary qualifications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced mathematics class at school is not necessary</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Programming skills are not necessary</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

2.3.2 Expectations before studying. First semester students usually have several expectations before entering university. In the interviews, participants were asked to remember their expectations before they began their study program. An overview of their expectations can be found in Table 2. Seven participants expected the study program to be demanding. For example, participant 10 explained that she was aware of the level of difficulty:

“I said if I go to RWTH University and study computer science, I don’t have the aim to be the best any more. I knew that it’s going to be demanding.” (P10, female, translated from German)

However, participants anticipated to gain more practical skills, especially regarding programming skills and knowledge about computers. This expectation was particularly reported by female participants.

“We only learned to code in the first semester but I expected to improve my programming skills.” (P4, female, translated from German)

Both male and female participants claimed that they assumed at the beginning of their studies that a degree in computer science improves their prospects of finding a good job after graduating. In contrast, four participants explained that they did not examine the contents of the study program in advance so that they did not have any specific expectations. It is striking that only male participants stated a lack of expectations.

2.3.3 Required Qualifications. When participants were asked about required qualifications for studying computer science, they predominantly named personal skills (cf. Table 3) instead of necessary experience (cf. Table 4). Interest in computer science subjects, especially in mathematical and theoretical concepts, as well as endurance to see the studies through, particularly during the demanding first semesters were mentioned most often. Therefore, students also have to be able to motivate themselves. Interestingly, four of five female participants stressed the importance of interest in computer science topics in contrast to only three of eleven male participants. Six of eleven male participants put emphasis on motivation whereas this skill was not mentioned by any female participants at all.

Furthermore, five participants claimed that students have to be willing to deal with concepts despite difficulties and setbacks until they finally understand them. Moreover, five participants recommended that first year students should have mathematical and logical reasoning skills as well as the ability to think in the abstract. Further mentioned skills included the ability to work in teams, discipline, patience, and independent working. While most of the skills did not indicate a different perception between male and female participants, it is conspicuous that only male participants pointed out the importance of team spirit in collaborative work environments. The requirement for these skills is summed up in a quote by a participant, who explained that students should not feel discouraged or give up but struggle their way through their studies:

“You mustn’t get discouraged, so you somehow have to stay tuned and don’t give up directly, you have to go through some stuff and struggle your way through. Yes, you have to want it, you have to enjoy it, you have to be interested in what you do because I think otherwise you can’t do it.” (P10, female, translated from German)

Regarding required previous experience for studying computer science, for example specific classes or knowledge, participants were in agreement that previous experience can be beneficial but is not necessary (cf. Table 4). Only one participant was convinced that previous knowledge about computer science was important. In contrast, eight participants pointed out that advanced mathematical classes are beneficial but not necessary to succeed. Seven participants agreed with this view concerning computer science experience, as explained by one participant:
“I don’t really think it [experience] is important. Being able to code might be useful because you can easily apply it but I don’t think it’s a requirement.” (P12, male, translated from German)

On the other hand, six participants stressed that advanced mathematical classes at school are not necessary at all and five participants claimed the same for programming skills. Interestingly, male participants predominantly described previous knowledge and experience as beneficial while most female participants indicated that they do not think that previous knowledge is important.

Although the perception of stereotypical computer scientists was originally not part of the interview guideline, it became a matter of discussion in some interviews. Hence, it has to be emphasized that these categories cannot be seen as complete since the majority of participants did not comment on this issue. However, the findings give first interesting indications which are considered in the questionnaire (cf. Section 3). Three participants (two female) depicted a computer scientist as someone who spends a lot of time with his computer. Furthermore, two female interviewees expected a computer scientists to have a profound knowledge of computers and programming skills. Another male participant added that a stereotypical computer scientist is not socially competent. An example description was given by participant 7:

“There are these stereotypes of computer scientists, who are not that socially competent, play a lot of computer games [...] and sit a lot in front of their PCs without many social contacts.” (P7, male, translated from German)

Summing up, the interviews revealed that computer science students have predominantly intrinsic motives for entering the study program. Interest in computer science was named by almost all participants. Moreover, we found that participants hold different expectations before entering the study program, especially learning practical or programming skills. In total, eight skills for successfully studying computer science were named, including interest in computer science, endurance, and motivation. On the other hand, participants stated that previous experience, for example with computer science or advanced mathematics, is not necessary for mastering the study program. The qualitative findings provide preliminary indications that there are differences between male and female computer science students regarding their motives, expectations, and the importance of skills. This assumption is evaluated in a quantitative way. In this publication, only an extract from the quantitative data is presented which complements the previously described qualitative data, focusing on students’ assessments of their skills and their description of prototypical computer scientists. The question concerning characteristics of prototypical computer scientists was included since some participants introduced the topic of stereotypes in the interviews and recent research pointed to their importance (cf. Section 1). The target group were students and alumni of computer science at different educational levels and with various major fields (e.g., computer science, media informatics, technical informatics etc.).

3.1 Method

Apart from demographic data, participants answered questions about the duration of their study (In which semester are you currently studying?), studying behavior and success (e.g., How often have you failed in computer science exams during your studies (so far?) in the first part of the survey. Furthermore, participants stated their perceptions regarding the ease of studying computer science (How easy / How difficult is it for you to study computer science?). These questions were addressed due to participants’ descriptions of their expectations of a very demanding computer science study program.

Due to the prevailing intrinsic motives of interest in computer science and perceived personal abilities, the next section focused on requirements for successful learning in computer science: Here, self-assessment of personal abilities (e.g., reasoning power) and skills (e.g., social competence) were inquired. The presented skills and abilities in the questionnaire were based on the previously presented statements in the interviews regarding required personal skills as well as previous experience and knowledge. Moreover, participants’ behavior and attitude towards technical innovations were examined (cf. Figure 1). Eventually, participants were asked to briefly describe their mental image of a prototypical computer scientist and to assess how this image corresponds with the actual image of themselves.

The second part of the quantitative method dealt with two scenarios regarding collaborative work in computer science with and without a learning tool. Hence, the focus of this part of the survey lied on the learning tool, which has to be regarded separately and was only the first step in a running study. Thus, according to the incompleteness of the scientific data and a slightly deviant topic, the results of the second part will be not included in the presented analyses but will be subject of future research.

The student participants who took part in the quantitative study were mainly reached at German universities (RWTH Aachen University, LMU Munich, TU Berlin). It took about 20 minutes to complete the questionnaire and the data collection of the survey lasted for about four weeks in 2016 and two weeks in 2017.

3.2 Sample

Overall N = 205 respondents were analyzed in the quantitative study. The vast majority of the participants (81%) was currently studying, thereof 61% pursued a Bachelor’s degree and 39% a Master’s degree. The remaining 19% of the respondents were – freshly and already earlier graduated – alumni. The age of the participants ranged from 18 to 63 years (M = 24.9; SD = 6.4) with a median value of 23 years.

The participation of women and men in the sample reflects a generic distribution of gender in computer science: 21% women (n = 43) and 76% men (n = 156) took part in the quantitative study (3% of the sample did not specify their gender). More than half of the respondents (56%) reported to have failed an exam at least once in the course of their studies. Even so, a large part of the sample was
I am only interested in particularly ambitious novel products/software.

I love to use technical innovations and gadgetry.

I actively search for information about novel technical gadgetry.

I always keep an eye on new technical innovations.

On average, men and women balanced their agreement.

Figure 1: Items and descriptive outcomes (means) of the attitudes toward technical innovations in both genders.

3.3 Quantitative Findings

The results of the reported quantitative outcomes are presented as follows: For a descriptive analysis, means (M) and standard deviations (SD) were calculated. For the inferential statistical analysis of differences between the gender groups, an independent samples t-test was used. The level of statistical significance (p) was set at the conventional 5%.

Table 5: Significant gender differences in abilities necessary in computer science (f=females; m=males).

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<thead>
<tr>
<th>Ability</th>
<th>t-test</th>
<th>Mf (SD)</th>
<th>Mm (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract reasoning</td>
<td>t(174)=−3.3, p≤0.001</td>
<td>4.3 (1.0)</td>
<td>4.8 (0.7)</td>
</tr>
<tr>
<td>Mathematic skills</td>
<td>t(173)=2.2, p=0.029</td>
<td>4.3 (0.9)</td>
<td>3.9 (0.9)</td>
</tr>
<tr>
<td>Social competence</td>
<td>t(173)=2.3, p=0.024</td>
<td>4.9 (1.2)</td>
<td>4.4 (1.2)</td>
</tr>
<tr>
<td>Interest in CS</td>
<td>t(173)=−4.7, p≤0.001</td>
<td>4.7 (0.8)</td>
<td>5.3 (0.7)</td>
</tr>
<tr>
<td>Programming</td>
<td>t(174)=−7.3, p≤0.001</td>
<td>3.0 (1.4)</td>
<td>4.6 (1.1)</td>
</tr>
</tbody>
</table>

Based on the outcomes of the qualitative study, participants assessed their own skills, which are perceived as necessary for successfully studying and mastering the complex subject matter of computer science. The aim was to validate the findings within a larger number of respondents and to examine whether women and men assess their competencies in cognitive, social and communicative skills, persistence, interest in computer science as well as programming abilities in different ways. Figure 2 depicts the particular skills and abilities in more detail, showing the mean values for women and men separately.

Independent-samples t-tests were calculated to examine if there are considerable gender differences in self-assessed abilities. The significant results of the statistical analyses and the descriptive values for both gender groups are summarized in Table 5.

The outcomes confirm significant differences between men and women’s perceptions regarding some of the respondents’ abilities. While female participants attributed themselves on average higher competencies in the social area and – contrary to the common stereotypes – mathematical skills, males considered themselves significantly superior in programming, abstract reasoning and the general interest in computer science. Regarding the other skills and traits which were considered requirements for mastering computer science, men and women did not differ significantly from each other. In general, both genders reached on average quite high mean values regarding skills and behavior characteristics referred to as relevant for the discipline of computer science, evaluating their know-how and persistence mostly as good and very good.

Participants were asked in the questionnaire to give a textual description of a prototypical computer scientist. Afterwards, the respondents assessed to what extent they match this characterization. The textual descriptions have not been evaluated in detail, yet. However, the findings demonstrated that there are significant differences between male and female participants’ assessments of correspondence to the stereotype [t(144) = −2.7, p = .008]. Men described their agreement in accordance with their description of a prototypical computer scientist (Mm = 3.8, SDm = 1.5) higher than women (Mf = 3.0, SDm = 1.4), who stated on average that the description does rather not apply. The difference is depicted in Figure 3. Nonetheless, it should be noticed that male participants were also cautious concerning their agreement with the prototypical characterization.

4 LIMITATIONS

In Sections 2 and 3, the research design and its appropriateness for the aims of this thesis were presented. Nonetheless, these methods
are subject to limitations, which have to be considered for adequate interpretations. Although qualitative interviews offer the advantage of high validity and depth, the reliability and controllability are limited [5]. Hence, an influence by the interviewer and social desirability cannot be excluded. However, since participants revealed many personal details and even admitted to failures, a positive atmosphere in the interviews can be assumed.

Although the sample of the online survey was significantly bigger than the sample of the qualitative interviews, its representativeness cannot be guaranteed. The group of female participants, yet representative of the overall computer science population, was small. Another aspect which has not been considered yet is the influence of study program or semester on the evaluation. For example, study programs with a specific focus, e.g., Media Informatics, could differ regarding specific skills like programming abilities. In addition, only subjective self reports were examined. Consequently,
This study aimed at collecting motives for studying computer science, while women encounter computer science in very early as children, while men could regard interest in computer science rather high to very high. However, despite female participants’ emphasis on the necessity of interest in computer science, women still rate their interest significantly lower than men. This difference could be attributed to women’s beliefs that a prototypical computer scientist has a large expertise in programming and technology [14]. When comparing themselves with this prototypical image, they might downgrade their own interest [43]. Furthermore, the findings from the questionnaire also indicate that women are less interested in innovative technologies than men, implying that women are less engaged with computer science topics in their leisure time.

The second most prominent motive for pursuing a computer science study program was an assessment of students’ abilities. Participants in the interviews claimed that they were convinced of having skills that might be useful for a computer science career, e.g., mathematical reasoning skills or programming experience. These results confirm previous findings, stressing the importance of self-perceived abilities considered important for mastering the field [42][40]. Looking at the profiles of both genders, it is evident that the trends are rather similar: Both, female and male computer scientists attribute (quite) high levels of abilities and skills necessary to master the subject matter. In their perceptions of essential characteristics like work persistence, discipline, motivation as well as team spirit they do not differ significantly, testifying a high sense of responsibility and disposition to bear the brunt.

Although there are high accordances between men and women’s assessments of skills and abilities, there are some intriguing differences. Female respondents averagely ascribed themselves higher social and communicative competencies, which is in accordance with previous findings (e.g. [36]). Concerning team work and spirit, no significant differences could be found. However, it is interesting that female interviewees did not mention team spirit as a required skill for mastering computer science studies although these programs usually include collaborative projects. Since previous research showed that a collaborative environment, which is often not associated with computer science, is important for the majority of female students [12], this aspect should be investigated further.

The general high assessment of mathematical and technical skills is in accordance with previous discoveries of self-assessed strengths by computer scientists [36]. Surprisingly, in contrast to previous findings [40, 51], female respondents rated their abilities in mathematics significantly higher than male participants. Since encouraging girls in mathematics was promoted during the last years, our findings might indicate that these efforts were fruitful. On the other hand, men assessed their abstract reasoning abilities as well as their programming skills significantly more pronounced than women. These results are supported by previous research on lower self efficacy in science among women [7, 40]. While mathematical as well as programming abilities are more likely to be improved by experience and education, abstract reasoning skills are often assumed by people to be innate [55]. Previous research has revealed that girls and young women have less experience with computer science.
topics than boys [14], which could have influenced female participants’ perception of their low programming skills. Experience with mathematical topics in school, however, is similar for women and men. Therefore, these results provide preliminary evidence that experience in an initially male-dominated skill set like mathematical abilities could increase women’s self-perceived assessment.

Whereas a certain part of male respondents did not have any expectations regarding studying computer science in advance, female interviewees reported to have given their decision particular thought. Since computer science is stereotypically male-dominated, female students are more likely to put effort into the decision and decide with awareness. Hence, women have clear expectations of learning gains during their studies, including advanced technical knowledge and practical skills (e.g., programming). However, our findings suggest that these skills are not fostered yet in computer science study programs and hence might disappoint women’s expectations.

Our results as well as previous research (e.g. [14, 34]) stressed the importance of perceived abilities considered necessary for the field to increase women’s confidence. Nonetheless, it should be noticed that female students themselves in the interviews reported that experience in computer science or advanced mathematics classes are not necessary for mastering the study program. Female participants in the interviews often referred to themselves as example for succeeding without prior experience while male participants usually had experience in computer science before beginning their studies, once again confirming previous findings [43]. Hence, the most important factor to improve the current gender gap seems to be convincing young women to actually begin with a computer science major in the first place. Therefore, interest by exposing women to computer science on high school levels as well as appealing and practical computer science education in universities addressing women’s expectations are critical according to our findings as well as previous research [13, 27, 34].

Similar implications were drawn in recent research [47]. Apart from interest, women pointed out the kind of learning as an essential intrinsic motive. Both findings corroborate recent STEM claims, published by Microsoft [47]. Their paper stresses policy and high school education as major components for attracting women to technical professions, based on an area-wide European study with more than 11,500 women. Among policy issues, it was claimed that computer science education should have a specific focus on technical didactics, integrating digital media literacy, data competency as well as programming skills in the broader curriculum. This approach would foster an early support of women in STEM fields and deepen the interest in these topics, which is perceived as essential by the female participants in our study.

Examining male and female students’ motives for majoring in computer science, an important factor is the opportunity to combine it with another field of interest such as medicine or business [12] or becoming aware of the variety of applications and the potential of social impact [34]. Thus, more hands-on experience with technical topics, their social contextualization and especially their relevance to societies’ well being is needed to make a lasting improvement on women’s interest in computer science [47]. Examples could include the application of STEM solutions for improving medical work or increasing car safety.

One possibility to achieve this aim are more experimental forms of learning that could be used in education and training, in line with innovative and technically enriched didactics. For example, collaborative learning environments are appreciated by female students and could be fostered in computer science study programs [12]. Furthermore, playful interactions with technology could be a promising approach to expose female students early to technology in schools since these learning didactics allow a more creative engagement with abstract concepts and could thus increase women’s confidence in dealing with complex and theoretical concepts instead of being detered by them [10, 53]. Therefore, future research should address new learning didactics in computer science, designed to address girls’ needs.

Moreover, our results indicated that students have inadequate expectations before entering a computer science university program. For example, participants in the interviews stressed that previous experience in mathematics and computer science is not required. Hence, we suggest that future research examines how adequate expectations and requirements can be communicated to pupils. A possible approach to overcome these obstacles could be role models. The power of role models for the forming of attitudes and interests in general, but particular in science education is undisputed [19]. Understanding the potential of women’s identification with successful models that allow female students to picture themselves in STEM fields and professions could support women’s internal focus on social contexts in IT and the strong interest in the contents from another side.

Beyond these findings concerning students’ motivation, expectations and cognitive abilities for the mastery of computer science, naturally, there are many more issues that might be relevant for the final inclination to study computer science. It is a well-known, deeply ingrained and pertinent prejudice that male computer scientists are nerds, with only low enthusiasm to share social engagements and low skills in social and communicative situations [8, 14, 39, 57]. Within the literature, there is much discussion about the geek culture in STEM education, the pertinence of stereotypes and the media as part of it [16, 38]. Our findings also suggested that female computer science students have stereotypical perceptions of a prototypical computer scientist, with which they cannot identify, confirming previous findings by Ehrlinger et al. Our future work will include to evaluate participants’ qualitative textual descriptions of a prototypical computer scientist’s characteristics to be able to address these stereotypes.

On the other hand, computer science students who do identify with the stereotypes should not be deterred from pursuing this career either. For example, several interviewees expressed praise for a professor who included Star Wars examples in his theoretical mathematics class. Instead of dismantling stereotypes completely, the diversity and variety of applications of computer science should be stressed.

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