Decoding the Gap: A Retrospective Analysis of Women's Experiences in Software Engineering

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Abstract: The persistent gender gap in software engineering (SE) poses a significant challenge in a world where digital innovation is crucial to societal progress. This paper explores the underlying factors contributing to the low participation of women in SE education and careers. Through a retrospective questionnaire study, we sought to capture the experiences and perceptions that deter women from pursuing SE despite initial interest. Our findings indicate that stereotypes, misconceptions about the field, and a lack of early positive exposure influence women's decisions regarding SE. The study reveals that barriers such as the perceived incompatibility of SE with personal interests, the daunting image of the SE work environment, and the absence of female role models are critical deterrents. Furthermore, we discuss how early and continuous engagement with computing can reshape perceptions and foster a more inclusive environment. The paper concludes with actionable recommendations, emphasizing that efforts to close the gender gap in SE should not only aim for demographic balance but also harness the full potential of diversity for driving innovation. Ultimately, the study underscores the need for systemic changes in education and policy to create a more equitable and dynamic SE landscape.

1 INTRODUCTION

The digital age has ushered in an era where innovation is no longer the sole domain of large corporations or research labs. This democratization of technology, characterized by accessible digital tools and lower barriers to entry, has transformed the landscape of creation and dissemination. Yet, as we navigate towards a sustainable and equitable future, a glaring disparity persists in the composition of those who partake in technological advancement – particularly in the field of software engineering (SE). This disparity is most pronounced in the gender divide, with women significantly underrepresented in SE education and careers. The integration of diverse talents, especially those of women who constitute half of the global demographic, is not merely a matter of social justice but a strategic imperative for innovation. A diverse workforce guarantees products that cater to a broader spectrum of society, amplifying the collective earning potential and, consequently, strengthening the economic fabric (Albusays et al., 2021; Rodríguez-Pérez et al., 2021; Lorenzo et al., 2018).

Despite marginal advancements in female participation in SE, the pace is lacklustre. The prevailing barriers are not insurmountable; rather, they are steeped in perceptions and myths that have long coloured the narrative of SE. As identified by leaders in the field like Maria Klawe (Fidelman, 2012), misconceptions around the allure, approachability, and professional milieu of SE contribute significantly to the reluctance among women to enter the field. However, evidence suggests that early exposure to computing can reshape these narratives. Google's 2014 study (Google, 2014) highlights the stark contrast in attitudes towards computing between girls who received academic exposure and those who did not. The former group associated computing with 'future', 'fun', and 'interesting', whereas the latter leaned towards 'boring' and 'difficult'. This underscores the impact that educational frameworks and curricula have on the perception of SE among young women.

Despite these insights, a significant number of women who exhibit enthusiasm for SE are deterred by the frustrations encountered in their learning journey (Happe et al., 2021; Happe and Buhnova, 2022; Marquardt et al., 2023; Marquardt and Happe, 2023). Addressing these barriers calls for interventions that extend beyond tokenistic efforts for gender balance (Gorbacheva et al., 2019). It necessitates a genuine

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recognition of the value that women bring to SE and a concerted effort to cultivate an environment that nurtures their interests and skills.

This paper probes deeper into the factors that dissuade women from pursuing SE. Through a retrospective analysis of survey data, we uncover the specific challenges and frustrations that lead to attrition among women in SE. We shed light on the often invisible hurdles and aim to pave the way for actionable solutions that will encourage and sustain women's involvement in SE. In our preceding study (Happe and Buhnova, 2022) (focusing on P1 and P2 only), we pinpointed various frustrations through quotations and the deployment of personas within our dataset. This paper builds upon that foundation by conducting a comprehensive and systematic analysis of the word lexicon employed in participants' expressions.

2 METHODOLOGY

2.1 Study Design

The primary goal of our study was to explore the experiences of women in computing, particularly focusing on those who have disengaged from the field as well as those who have remained. This approach differs significantly from previous studies such as those by Joshi et al. (Joshi et al., 2013) and Armstrong et al. (Armstrong et al., 2018). We aimed to understand the pivotal moments influencing their career paths, identify major obstacles and drivers in their journey, and gather recommendations for enhancing girls' participation in computing.

2.2 Data Collection

Our primary instrument for data collection was a questionnaire, crafted to delve into women's engagement with computing. In this study, we focus on six open-ended questions of the questionnaire, which encouraged respondents to reflect on their journey in computing. These questions covered perceptions of computer scientists, motivational factors, barriers faced, and suggestions for improving computing education for girls. Participant demographics such as age, gender, and major interests were also collected. The open-ended questions asked were:

- **Q1.** What do you think about computer scientists? Who are they? What do they do? Is there some experience you have and would like to share with us?
- **Q2.** What makes you feel most enthusiastic about and interested in computing? What do you use a computer for? What do you enjoy most?
- **Q3.** What was or would be the biggest driver on your way to computing?
- **Q4.** What was or would be the biggest obstacle on your way to computing?
- **Q5.** Are there any key points you think or feel we need to know to make computing education better for you or other girls?
- **Q6.** If you had any computing skills necessary, what would you do with it (e.g., get a new job, start a new company, become a teacher, implement your idea, etc.)?

2.3 Distribution and Sample

The questionnaire was disseminated through channels catering to individuals with an interest in computing, with a particular focus on organizations like Czechitas (www.czechitas.cz) that offer late-education opportunities for adult women. Our global outreach predominantly utilized Facebook groups dedicated to late computing education for women. This strategy was designed to attract respondents who had a strong potential for pursuing computer science in their earlier years, setting our study apart from previous research.

From the initial pool of 151 responses, we analyzed 140 valid submissions after excluding incomplete entries and those not matching our target demographic criteria, such as responses from men. Our respondents were categorized into three age groups: 18-26 (18%), 27-34 (41%), and over 34 (33%). The engagement level was high, with 90% of participants completing all open-ended questions, often providing thoughtful and detailed responses.

2.4 Analysis Method

The analysis of open-ended responses was conducted systematically through the following steps:

1. **Data Cleaning.** We began by removing filler and overly frequent words, such as redundant terms from the questions themselves or common filler language.
2. **Word Cloud Generation.** Utilizing MonkeyLearn's word cloud tool (https://monkeylearn.com/word-cloud), we identified prevalent words in the responses, which guided our initial categorization.
3. **Categorization and Labeling.** We scanned the responses for prominent words, their syn-

onyms, and expressions conveying similar meanings. These terms were then grouped into categories and assigned labels. Notably, responses often received multiple labels due to the nuanced nature of the data.

4. **Frequency Analysis.** Using the "COUNTIF" function, we quantified the frequency of each label. This was complemented by a custom "findIDs" function to trace the occurrences back to individual responses. The categorized data, transformed from qualitative responses, was then subjected to quantitative analysis.

2.5 Persona Segmentation and Typification

Our survey garnered a total of 140 valid responses, which were categorized into three distinct Personas (Happe and Buhnova, 2022) based on their career paths and relationship with computing (e.g. studied CS as a primary degree or secondary, first choice or later in life). This diverse participant pool spanned across three age groups and was nearly evenly distributed across the Czech Republic, Germany, and other regions.

Persona 1 (P1) (42% of Respondents). This group represents women who have pursued a career in computing from the outset. They typically have a background in computer science or a related field and have maintained a continuous trajectory in SE. This persona encapsulates those who found their calling in computing early on and followed it through their educational and professional journey. **Typical Quote.** *"I think computer scientists are cool people, generally socially awkward in my experience but well-meaning... Also, I think computer scientists have a hard time maintaining a work-life balance... computing problems require a lot of attention and sometimes everything else in life gets sidetracked."*

Persona 2 (P2) (17% of Respondents). Constituting women who transitioned to computing later in their lives, this persona reflects a non-linear path to SE. These respondents may have initially pursued education and careers in fields unrelated to computing but eventually found their way into SE. This group is particularly noteworthy as it highlights the appeal of SE to individuals with diverse initial career paths and the permeability of the field to professionals from various backgrounds. **Typical Quote.** *"I am not a person that enjoys computing on its own, I need some higher goal. I like to think of it as means of fulfilling my other goals in different fields. That's what I'd like to see more of – showing that IT is not just IT, more commonly it is connected to some other field and you can work with anything being in IT."*

Persona 3 (P3) (40% of Respondents). This persona includes women who have never considered entering the computing field. Their perspectives are crucial for understanding the barriers and misconceptions about SE that deter women from considering a career in this area. This group provides insights into external factors, societal perceptions, or personal preferences that influence the decision against pursuing a career in computing. **Typical Quote.** *"Hm, I wouldn't say there was one (obstacle). In retrospect, it was a smooth autodidactic slide (away from CS) fuelled by personal interest."*

2.6 Comparative Analysis Methodology

This comparative analysis aims to discern the experiences that influenced the career decisions of P1, P2 and P3. We specifically investigate what factors drove P2 to eventually pursue computing despite initial decisions against it, or P3 completely against it from the beginning, and contrast these with the experiences of P1 who consistently pursued a path in computing. The analysis seeks to uncover the frustrations and challenges that steered P2 and P3 away from computing initially and the driving forces that drew them back to the field.

3 RESULTS

This section presents the findings from our retrospective questionnaire study, aimed at understanding the reasons behind the attrition of women in software engineering (SE). The results are organized into several thematic subsections, each addressing a specific aspect of our investigation.

3.1 Q1: Perceptions of Computer Scientists

The key perceptions of computer scientists as identified by our respondents are described as 'problem-solving', 'diversity', and 'social skills', with 'problem', 'women', and 'work' being the most prominent words depicted. Table 1 reflects the frequency and percentage of specific terms mentioned by respondents when discussing their views on computer scientists.

Table 1: Frequency and percentage of specific perceptions of computer scientists.

Perception Category	All	P1	P2	P3
Problem solver	12 (9%)	5 (8%)	2 (8%)	5 (9%)
Normal, nothing special	12 (9%)	6 (10%)	2 (8%)	4 (7%)
Introvert, low social skills	8 (6%)	6 (10%)	1 (4%)	1 (2%)
Logical, analytical	7 (5%)	3 (5%)	1 (4%)	3 (5%)
Contributing, altruistic	7 (5%)	2 (3%)	2 (8%)	3 (5%)
Toxic, non-ethical	6 (4%)	2 (3%)	2 (8%)	2 (4%)
Intelligent	6 (4%)	4 (7%)	2 (8%)	0 (0%)

The data indicate a complex and multifaceted view of the computer science profession among the participants. While problem-solving skills are highly recognized, there is also an acknowledgement of the diversity within the field. Social challenges and gender disparities are noted, reflecting the need for cultural and educational shifts in the computing environment. The comparative analysis of the responses to the perceptions of computer scientists across the three personas (P1, P2, P3) reveals the following distribution of responses within various categories:

- P1, who studied and stayed in computing, responses suggest a more nuanced understanding of the field, with higher mentions of both positive (*problem solver, logical*) and negative (*introvert, toxic*) traits.
- P2, who transitioned to computing later in life, seems to have a slightly more idealistic view, emphasizing altruistic and intellectual aspects, as well as*contribution to society*.
- P3, who never considered entering computing, tends to have a lower incidence in several categories and may indicate less familiarity or engagement with the stereotypes or realities of the profession, as well as it seems they may not strongly associate *intelligence* with the field.

An interesting observation is as well that all personas perceive computer scientists as problem solvers at similar rates (8% and 9%, respectively), and the view that they are *normal* is held by 9% overall, suggests an emerging view of these professionals as ordinary individuals, challenging the stereotype of them being markedly distinct or eccentric from the general population. Overall, these observations point to a complex and evolving public image of computer scientists, one that balances the recognition of their specialized skills and intellectual capacities with an appreciation of their ordinariness and approachability. This duality suggests a shift towards a more nuanced and humanized understanding of professionals in the tech industry, which could have implications for how the field is perceived and engaged with by the broader society.

Table 2: Frequency and percentage of aspects associated with enthusiasm for computing.

Perception Category	All	P1	P2	P3
Social interaction	29 (21%)	8 (14%)	4 (17%)	17 (30%)
Programming	24 (17%)	9 (15%)	4 (17%)	11 (19%)
Creativity, creating, tinkering	12 (16%)	12 (20%)	5 (21%)	5 (9%)
Makes work easier	21 (15%)	5 (8%)	4 (17%)	12 (21%)
Finding answers, research	18 (13%)	6 (10%)	4 (17%)	8 (14%)
Data analyses, simulation	16 (11%)	5 (8%)	3 (13%)	8 (14%)
Learning, exploring	15 (11%)	5 (8%)	4 (17%)	6 (11%)
Solving problems	9 (6%)	4 (7%)	0 (0%)	5 (9%)
Endless possibilities	9 (6%)	5 (8%)	1 (4%)	3 (5%)
Supporting/helping others	9 (6%)	5 (8%)	2 (8%)	2 (4%)
Gaming	8 (6%)	4 (7%)	2 (8%)	2 (4%)
Entertainment (videos, music)	8 (6%)	4 (7%)	2 (8%)	2 (4%)

3.2 Q2: Enthusiasm and Interests in Computing

Respondents expressed a diverse range of enthusiasms and interests within the realm of computing, as depicted in the word cloud in Figure 1.

Figure 1: Word cloud visualizing the aspects of computing that participants find most engaging.

Respondents expressed a diverse range of enthusiasms and interests within the realm of computing. Communication, coding, and creativity emerged as the most engaging aspects, highlighting the multifaceted nature of computing that captivates interests. Table 2 details the frequency and percentage of the mentioned aspects, providing a quantitative measure of the specific areas that participants associate with their enthusiasm for computing.

The analysis suggests that while technical aspects such as programming and data analysis are significant, the social dimension of computing and the ability to facilitate work and creativity also play a vital role in sustaining interest in the field. The comparative analysis of enthusiasm and interests in computing across the three personas (P1, P2, P3) for selected categories reveals the following distribution:

- The category *Chatting/Communication/Interacting with People* is represented across all personas, with P3 (30%)

showing the highest association, suggesting that they might view computing as more collaborative than P1 (14%) and P2 (17%). This indicates a general interest in the social aspect of computing across all groups.

- In the category *Write Code/Programming/Coding*, P1 and P3 are quite similar in their number of responses, while P2 is slightly less represented. This suggests that coding is a significant interest area for those who stayed in computing (P1) and those who never considered it (P3).
- The category *Creativity/Create Something/Stuff/Tinkering* shows a notable difference, with P2 having the highest number of responses. This indicates that individuals who transitioned to computing later in life (P2) are particularly drawn to the creative and hands-on aspects of computing.

The data shows that **enthusiasm for computing spans a broad range of aspects**, from the technical (like programming and data analysis) to the more human-centric (like social interaction and helping others). Notably, P3 often exhibits higher percentages in categories related to practical applications (like making work easier and social aspects), whereas P2 show more inclination towards creative and P1 towards problem-solving aspects. This suggests that different groups may be drawn to computing for varied reasons, and these motivations need to be recognized and nurtured to foster a more inclusive computing environment.

3.3 Q3: Drivers to Computing

The driving factors that propel individuals towards a career or interest in computing were derived from the data collected and are illustrated in the word cloud in Figure 2. Personal interest, family influence (especially by fathers), and financial prospects were among the most cited reasons.

In this section, we investigate driving factors that propel individuals towards a career or interest in computing were derived from the data collected based on responses to the questionnaire item *Q6: What was or would be the biggest driver on your way to computing?*. A detailed breakdown of these motivating factors is presented in Table 3, showing the frequency and corresponding percentage of responses.

This distribution of drivers underscores the importance of personal passion and interest in computing as leading factors, followed closely by familial support where particularly often 'dad' was mentioned,

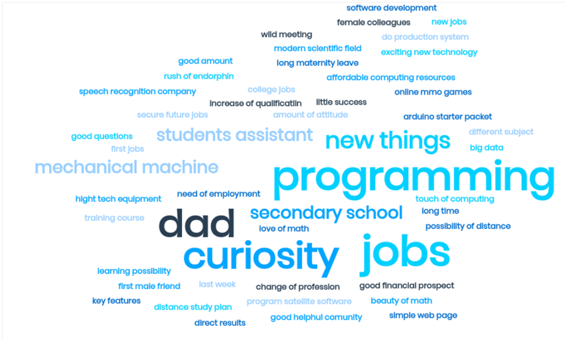

Figure 2: Word cloud representing the drivers to computing as reported by participants.

Table 3: Frequency and percentage of reported drivers to computing.

Perception Category	All	P1	P2	P3
Personal interest	22 (16%)	11 (19%)	6 (25%)	5 (9%)
Family	13 (9%)	11 (19%)	0 (0%)	2 (4%)
Job opportunities, money	11 (8%)	3 (5%)	3 (13%)	5 (9%)
Creativity, projects	11 (8%)	6 (10%)	2 (8%)	3 (5%)

and economic incentives. It suggests that while intrinsic motivation is paramount, external factors such as financial benefits and social environment also significantly influence one's pursuit in the field of computing. The comparative analysis of responses to the question about drivers to computing across the three personas (P1, P2, P3) for selected categories reveals the following distribution:

- The category *Myself/Curiosity/Passion* or personal interest and creativity is a predominant driver, especially for P1 and those who transition to computing later (P2), suggesting that intrinsic motivation is crucial for this group.
- *Family Influence* is most prominent in P1, indicating that early familial support or exposure plays a significant role in shaping a career in computing and suggesting that familial factors play a significant role in deterring the P3 group from considering a computing career.
- In *Financial Prospects*, Persona 2 (P2) is more represented, which could indicate a perception of better financial opportunities in computing and possibly reflect pragmatic considerations in their decision to transition into computing. The importance of job opportunities and financial considerations is consistent across personas (however it is less prominent for P1), reflecting a universal appeal of the field's practical benefits.
- For *Own Projects/Creativity*, P1 and P2 show a notable interest, indicating a draw to computing for creative and project-based work, especially

Table 4: Frequency and percentage of reported obstacles in computing.

Perception Category	All	P1	P2	P3
Lack of support, no guidance, discrimination	17 (12%)	10 (17%)	4 (17%)	3 (5%)
Lack of information/resources, language barriers	16(11%)	7 (12%)	6 (25%)	3 (5%)
Stereotypical surroundings	15 (11%)	12 (20%)	0 (0%)	3 (5%)
Fear of failing, self-doubt	12(9%)	6 (10%)	2 (8%)	4 (10%)
Stereotypes about knowledge	12(9%)	4 (7%)	2 (8%)	6 (11%)
Male-dominated environment	10 (7%)	5 (8%)	2 (8%)	3 (5%)
Time constraints, age-related barriers	9(6%)	2 (3%)	2 (8%)	5 (9%)
Family pressure, societal expectations	8(6%)	5 (9%)	1 (4%)	2 (4%)

among those who transitioned to computing later in life, and underscoring the importance of innovation and creative freedom in retaining talent in the field.

3.4 Q4: Obstacles in Computing

The obstacles that participants identified as barriers to entering or continuing in the field of computing include a lack of support, insufficient resources, and stereotypes within the educational and social environment. Table 4 provides a quantitative summary of these barriers, indicating the frequency of each obstacle as mentioned by respondents.

This data highlights the multifaceted nature of the challenges faced by women in computing. It emphasizes the need for a supportive environment, accessible resources, and positive role models to mitigate these obstacles and foster a more inclusive atmosphere in the computing domain.

The comparative analysis of responses to the question about obstacles in computing across the three personas (P1, P2, P3) for selected categories reveals the following distribution:

- *Lack of Support* are significant obstacles for P1 and P2, with P1 slightly more affected. This suggests that individuals who pursued computing initially or transitioned later face challenges related to support systems and P2 prominently as well to *Lack of Information/Resources* access.
- *Stereotypical Surroundings* are particularly high for Persona 1 (P1) indicating a shared perception of the computing environment as unwelcoming or stereotyped, potentially impacting especially those in computing.
- *Worries/Fear of Failing* is fairly evenly distributed across P1 and P3. Highlights the psychological barriers such as fear of failure and lack of self-confidence. This could be linked to the challenges of entering the field and the pressures associated with it.

Table 5: Suggestions for improving computing education for girls.

Perception Category	All	P1	P2	P3
Introduce female role models	10 (7%)	7 (12%)	2 (8%)	1 (2%)
Start technical education early	10 (7%)	4 (7%)	2 (8%)	2 (4%)
Avoid differentiating between boys and girls	7 (5%)	5 (8%)	1 (4%)	1 (2%)
Provide more encouragement	17 (12%)	4 (7%)	1 (4%)	2 (4%)
Offer all-female courses	7 (5%)	4 (7%)	0 (0%)	3 (5%)
Stop promoting stereotypes	7 (5%)	4 (7%)	0 (0%)	3 (5%)
Employ good and inspiring tutors	6 (4%)	4 (7%)	0 (0%)	2 (4%)
Teach useful and problem-solving skills	6 (4%)	3 (5%)	2 (8%)	1 (2%)

3.5 Q5: Improving Computing Education for Girls

Efforts and suggestions to improve computing education for girls range from introducing female role models to creating a non-discriminatory learning environment. The data in Table 5 summarizes the frequency of specific recommendations provided by respondents to enhance the computing education experience for girls.

The recommendations underscore the significance of early exposure, role models, and an inclusive environment as key factors for encouraging girls to pursue and thrive in computing education. The comparative analysis of responses on how to improve computing education for girls across the three personas (P1, P2, P3) for selected categories reveals the following distribution:

- *Female Role Models* are equally important for all, with a notably high representation in P1, indicating the importance of having relatable figures and mentors in the field to inspire and guide.
- The emphasis on *Starting Early/Teaching Children* is seen fairly evenly distributed across personas, suggesting that early exposure to computing is crucial for those who choose or transition into the field.
- *No Difference Between Boys and Girls* and *More Encouragement* are highlighted in P1, indicating the need for a more inclusive and supportive educational environment.
- *All Female Courses* and *Avoiding Stereotypes* are significant for P1, highlighting the importance of a non-discriminatory learning environment. Points to the potential benefits of creating a comfortable learning environment where girls can thrive without the pressure of gender dynamics.
- The value of Good Tutors/Teachers is acknowledged in Persona 1 (P1), underscoring the impact of quality education and mentorship.

Recommendations span from structural changes like early education and all-female classes to more nuanced approaches like mentorship and stereotype

Table 6: Aspirations with computing skills as indicated by participants.

Perception Category	All	P1	P2	P3
Obtain a new or better job	31 (22%)	7 (12%)	3 (13%)	21 (37%)
Start a company	14 (10%)	7 (12%)	3 (13%)	4 (7%)
Engage in IT teaching and clubs	10 (7%)	4 (7%)	2 (8%)	4 (7%)
Work on personal projects with friends	10 (7%)	6 (10%)	0 (0%)	4 (7%)
Develop apps, games, and designs	6 (4%)	1 (2%)	2 (8%)	3 (5%)
Pursue a research career and academic advancement	5 (4%)	4 (7%)	0 (0%)	1 (2%)

dismantling. The variation in suggestions among the personas indicates different needs and perspectives, suggesting that a one-size-fits-all approach may not be effective.

3.6 Q6: Aspirations with Computing Skills

The aspirations and desires that participants have with their computing skills are varied and ambitious, they range from securing a new or better job to starting their own companies and engaging in research. Table 6 details the specific aspirations and the frequency with which they were mentioned by survey respondents.

This data illustrates a strong connection between computing skills and personal growth ambitions, highlighting the empowering nature of technology in pursuing diverse and meaningful career paths. The comparative analysis of responses of aspirations with computing skills across the three personas (P1, P2, P3) for selected categories reveals the following distribution:

- The desire for a New/Better Job is particularly significant for P3, indicating a strong link between computing skills and career advancement opportunities. The high percentage of P3 respondents looking for job opportunities suggests that many see computing as a pathway to career improvement.
- The aspiration to Start their Own Company is more prevalent in P1 and P2, suggesting an entrepreneurial spirit among those who transitioned to computing later in life. P1's focus on research and personal projects indicates a deeper engagement with the field, beyond just career advancement. P2's interest in entrepreneurial and creative endeavours reflects their motivation to utilize computing in versatile and innovative ways.
- Teaching IT is mostly aspired to by P2, indicating a commitment to the field and a desire to contribute to the next generation of computing professionals.
- The lack of responses from P2 in Own Project/Idea Implementation suggests a more traditional career path, while P1 and P3 show interest in personal and creative projects, indicating diverse aspirations in computing.

3.7 Comparative Analysis on Activity Levels in CS Classroom

The data from the survey indicates that active participation in computer science (CS) classrooms is a strong predictor of continuing to study CS. Among the different personas, 44% of Persona 1 (P1), who studied and remained in the field of computing, were actively participating in class. This percentage is noticeably higher compared to the other groups. In contrast, only 31% of Persona 2 (P2), who transitioned to computing later in life, and 22% of Persona 3 (P3), who never considered entering computing, were actively participating. These figures suggest that higher engagement and active involvement in CS classrooms are closely linked to sustained interest and pursuit of studies in the field of computing, highlighting the importance of fostering active learning environments to encourage continued interest in CS.

The survey reveals a notable correlation between classroom participation levels and attitudes towards computer science (CS). Students who were passive in the CS classroom predominantly exhibited more negative attitudes toward the subject. This passivity also aligns with their educational choices: 100% of these students initially pursued disciplines other than CS, with only 27% eventually studying CS later. In contrast, among students who were active participants in the classroom, the trend differs significantly. While 63% of these active participants initially studied a different discipline, a much higher percentage, 73%, chose to study CS later. This contrast underscores the potential impact of classroom engagement on students' perceptions and career trajectories. Active engagement not only fosters a more positive attitude towards CS but also seems to influence students' decisions to pivot towards CS studies later in their academic or professional journey, suggesting the transformative power of an engaging and inclusive CS educational environment.

3.8 Comparative Analysis on the Age of First Computer Use

The data on the age of first computer use across the different personas (see Table 7) reveals patterns that offer insights into their early experiences with technology.

Predominantly, the larger cohorts within Persona 1 and Persona 2, encompassing individuals who either remained in computing or transitioned to it later,

Table 7: Frequencies for *How old were you when you first used a computer on your own?* for different Personas.

	P1	P2	P3
More than 14 years	15 (22%)	4 (17%)	10 (18%)
10 to 14 years	12 (17%)	6 (25%)	19 (33%)
7 to 9 years	19 (28%)	10 (42%)	14 (25%)
Less than 6 years	9 (13%)	2 (8%)	5 (9%)
N	59	24	57

encountered computers at a relatively young age, typically between 7 to 9 years. Nearly half of the respondents within the P1 group (41%) and P2 group (50%) had their first own experience with computers prior to the age of 9. Conversely, within Persona 3, comprised of individuals who never contemplated computing as an area of interest, merely 34% encountered computers before the age of 9. Among this subset, the majority had their first own experience with computers at an older age, with 18% encountering computers after surpassing 14 years, and 33% falling within the age bracket of 10 to 14 years for their initial exposure. These findings suggest a potential correlation between early exposure to computing and the propensity to sustain interest or pursue a career in this field, while delayed exposure might diminish the likelihood of embracing computing as a career or field of study.

Noteworthy is also the relatively high number of individuals within Personas 1 and 2 who engaged with computers during the formative years of 10 to 14, indicating that pre-adolescent and early adolescent exposure remains within a pivotal window capable of fostering enduring interest in computing.

There are fewer individuals across all personas who used a computer before the age of 6. This might be due to generational access to technology, as the youngest age group (less than 6 years old) for early exposure was less common historically.

Regarding the reasons for first computer usage, the data suggests that games and creative activities are the most common entry points across all personas. However, the use of computers for learning and homework also has a notable presence, especially in the context of schoolwork for Personas 1 and 2.

4 DISCUSSION

This discussion seeks to delve into the nuances of the survey responses, particularly focusing on differences in perception and aspirations between current computer science (CS) professionals and those not in the field, the impact of age on perceptions of CS, and the implications of terminology on student engagement.

4.1 Perception of Computer Science and Stereotypes

Our findings reveal a complex landscape of perceptions associated with computer scientists. Terms like 'problem-solving,' 'diverse,' and 'contributing to society' were frequently mentioned across all Personas, reflecting a positive view of the field. However, stereotypes such as 'introversion,' 'lack of social skills,' and 'male dominance' persistently emerged, echoing existing literature on the negative impact of these stereotypes on women's engagement in CS (Cheryan et al., 2015; Master et al., 2016, 2021).

The age of respondents appears to influence their perceptions, with older participants often holding more traditional views of the field. This could be attributed to cultural and generational shifts in how CS is presented and perceived. Moreover, respondents from different professional backgrounds or study fields showed varied perceptions, suggesting that exposure and experience significantly shape one's view of CS.

Some respondents' preference for the term 'Developer' over 'Scientist' suggests that terminology may influence interest in the field. This raises the question of how different terms are used in German, such as 'Informatiker/-in' for computer scientist and 'Datenwissenschaftler/-in' for data scientist, and whether these terms could be affecting student perceptions and potential engagement in CS. Moreover, it's worth noting that 'Informatiker', often equated with 'Programmierer' (programmer), might be appealing to those who are focused on programming. However, this equivalence can obscure the diverse opportunities available in the field, potentially deterring those who might be more motivated by the applications of programming than programming itself (Marquardt and Happe, 2023). This highlights the need to carefully consider how the roles and career paths in CS are communicated and labelled, as these designations can either narrow or expand students' views of the field's possibilities.

4.2 Differences Across Age Groups

Our study indicates distinct preferences and interactions with computing across different age groups. Younger individuals' affinity for social media and older respondents' preference for activities like online banking reflect evolving technological landscapes and usage patterns. This variation underscores the importance of age-specific approaches in CS education and outreach.

4.3 Drivers and Career Choices

Interestingly, those who view themselves or their family as the primary motivation ('biggest driver') are often already involved in CS. In contrast, those driven by financial or job prospects tend to be outside the CS field. This dichotomy raises questions about the obstacles that deter or facilitate a career in CS and suggests the need for targeted support and guidance to help individuals overcome perceived barriers.

4.4 Early Exposure to Computing

A recurring suggestion for improving CS education was to start early. Previous studies have found, that girls spend on average less time with computers in their private time at home than boys (Mumtaz, 2001; Selwyn et al., 2009). This leads to the question of whether CS careers are considered by children as early as kindergarten or elementary school and how these early career aspirations are formed. This gap suggests a need for educational materials and initiatives that introduce young children to CS in engaging and accessible ways, akin to resources available for other professions. It would be interesting to explore if there are educational materials for young children that introduce CS careers, similar to those for construction sites or hospitals.

4.5 Aspirations and Knowledge Barriers

While many participants aspire to leverage CS skills for career advancement or entrepreneurship, there is also a notable interest in teaching IT and participating in coding clubs. This points to a potential pool of individuals who, despite having basic CS knowledge, hesitate to engage due to perceived inadequacies. Addressing these knowledge barriers could foster a more inclusive and participatory CS community.

4.6 Methodological Limitations

This study's reliance on self-reported data and its cross-sectional design pose limitations. Notably, there were participants who chose not to respond to certain open-ended questions. This observation warrants an analysis of whether the same respondents consistently abstained across all questions or if non-responses were specific to certain queries. Additionally, it is pertinent to consider whether the motivation to answer free-text questions decreases towards the end of the survey and how this might affect the data collected. Furthermore, the self-reported nature of the data may introduce biases, and the cross-sectional design precludes causal inferences. Future research should aim to longitudinally track participants to better understand how these factors interact over time to influence women's decisions to enter, stay in, or leave the field of CS.

5 CONCLUSION

The journey toward gender equity in software engineering (SE) is not a mere corrective trajectory to balance demographic scales; it is a fundamental requirement for a robust, dynamic, and innovative digital future. This study has illuminated the multifaceted and often subtle barriers that deter women from participating in SE. Through a comprehensive analysis, we have endeavoured to move beyond the surface-level statistics to understand the deeper currents that influence women's decisions regarding SE education and careers.

Our findings reveal that the underrepresentation of women in SE is not a simple case of different preferences or inherent disinterest. It is a consequence of a complex tapestry of societal perceptions, educational experiences, and entrenched stereotypes. These factors coalesce to form a daunting barrier that many women find insurmountable. The stereotype of computing as an isolating and monotonous field, dominated by an unwelcoming male majority, continues to be one of the significant deterrents for women. However, the narrative can be changed. Our study points to the powerful role of early and positive exposure to computing in shaping perceptions. Educational institutions and policy-makers have a critical role in integrating computing into curricula in a way that is engaging, relevant, and accessible to all students, irrespective of gender. By showcasing the versatility, creativity, and collaborative nature of SE, we can begin to dismantle the outdated stereotypes that cloud the field. Furthermore, the aspirations of women in computing—ranging from entrepreneurial ambitions to social impact projects—highlight the potential loss to innovation when their talents are not nurtured. Encouragingly, there is a reservoir of enthusiasm among women for SE that can be tapped into with the right support systems and interventions.

In conclusion, the drive toward a more gender-balanced SE domain should not be pursued out of a sense of obligation to achieve numerical parity but from a strategic vision of what a diverse workforce can accomplish. It is a vision that recognizes the unique contributions of women to SE, appreciates the richness that diversity brings to problem-solving, and understands that the future of technology is the brightest when it benefits from the talents of the entire population. As we forge ahead, it is imperative that we commit to creating an environment in SE that is welcoming, inclusive, and conducive to the flourishing of all individuals who wish to be a part of the digital vanguard. **Finally, the power of words in shaping futures cannot be understated:** a thoughtful articulation of the various roles and career trajectories in CS/SE, the way these roles are termed and presented can significantly influence students' perceptions, either limiting or broadening their understanding of their opportunities within the field.

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