Frustrations Steering Women Away From Software Engineering

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// We share findings from a study of 139 women, revealing the frustrations they felt along their way to software engineering and pinpointing promising solutions, such as interdisciplinary education, which could be of enormous help to retaining women in computing. //

THE DEMOCRATIZATION OF digital innovation is a remarkable sociological shift driven by new technologies and lower costs, enabling individuals to design and share creations as never before. Efforts to build a sustainable and more balanced society require more diverse people in innovation, shedding light on the critically low number of women choosing software engineering (SE) education and careers. Enabling more people, particularly women (who constitute half the world's population), to fully participate in innovation not only guaranties more products for broader audiences but increases individuals' earning potential, ultimately strengthening the global economy.

Although progress toward more involvement of women in SE is barely visible, we are starting to understand the reasons and myths behind the problem. Harvey Mudd's president, Maria Klawe, summarized women's experience: "Number one is they think it's not interesting. Number two, they think they wouldn't be good at it. Number three, they think they will be working with a number of people that they just wouldn't feel comfortable or happy working alongside."[1]

Stereotypes about the environment and nature of the work (e.g., lacking social interaction and being boring and repetitive) are indeed responsible for discouraging many girls from engaging with SE before their first contact with it. A Google study conducted in 2014[2] showed that when it is not part of their curriculum, girls tend to spontaneously develop negative connotations about computing (using words like *boring*, *difficult*, and *nerd*), in contrast to girls who did have it (using words like *future*, *fun*, and *interesting*). Although the negative view of computing, combined with the confidence gap, as described by Klawe, plays a role in narrowing the pool of girls interested in SE, there is still a substantial number of girls and women who would like to pursue SE careers[3] but get discouraged by unnecessary frustrations they experience along the way.

In previous work,[4] we elaborated on one of the frustrations and introduced initial actionable recommendations for practitioners. Our suggestions were based on the fact that girls' first contact with SE typically happens in the presence of more experienced learners. This leads to an absence of success experiences. Girls often struggle on their on their own (as experienced learners tend to

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monopolize instructors' time) and gradually move into an outsider role within the classroom, feeling uncomfortable, missing a sense of belonging, and eventually dropping the course. Next to building an environment that is supportive of novice learners, effective interventions to recruit and retain girls in SE education include strategies that combat wrong stereotypes, spark interest by actively engaging girls' strengths, manage suitable first contact, build self-confidence, and sustain long-term commitment, as we summarized in Happe et al.,[5] where we accumulated knowledge from more than 800 publications via a cumulative review of the literature on the topic. Despite these interventions, which have been used for more than 20 years by the research community, government, and educational institutions, we have achieved little progress.[6]

In this article, we go further and identify and examine causes that underlie females' attrition in SE and understand the perceived frustrations that women report as the reasons why they dropped out of SE education despite being keen about it in general. To this end, we designed a retrospective questionnaire study, which revealed numerous insights into frustrations that women experience through different phases of their education and career. In our study, general terms like *computing* and *IT* were preferred by the respondents when referring to SE (traceable from example activities participants mentioned).

Design of the Study

The goal of the study, as opposed to others,[7,8] was to reach women who would like to reestablish their connection to SE and compare their responses with women who stayed in the field. We focused on the women's view of moments that formed the direction they decided to take (stay in or disengage), and we asked about the biggest obstacles and drivers along girls' way to SE and requested recommendations to improve the situation. The study was realized via a questionnaire (in English) designed to understand how and why women engage with SE as well as challenges girls and women face when participating in SE at school and home and factors that enable their entry and participation in further education.

The survey consisted of a number of questions, including six open ones asking respondents to reflect on and analyze their previous studies and ambitions. These questions inquired about participants' understanding of who computer scientists are, the drivers and obstacles on their way to SE, what made them enthusiastic about the field, and what they would recommend to improve SE education for girls. The results presented in this article are based on responses to the open questions (quoted as written), in combination with basic classification questions about participants' age, gender, and major interests.

We distributed the questionnaire among groups with an affinity for SE and at institutions providing adult education, such as Czechitas (www.czechitas.cz). The survey was circulated worldwide, mostly through Facebook groups targeting adult education for women. We specifically looked for respondents who likely had high potential to study SE in their earlier years, making our study different from similar ones.[7–9] We collected 139 responses (filtered from 151 after removing incomplete answers and those representing gender groups outside our target demographic) from women in three age groups (18% between 18 and 26, 41% between 27 and 34, 33% older than 34, and 8% without age indication). The study's population was represented by a near-even distribution of respondents (and personas) across three regions: the Czech Republic, Germany, and other. The questionnaire resonated with the audience: 90% of respondents filled out all the open questions, and many did it very thoughtfully and expressively. The responses were distributed among three personas:

1. *Persona 1* (*P1*): women who studied and stayed in computing (39% of respondents)
2. *Persona 2* (*P2*): women who transitioned to computing later

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in life, after studying another discipline (32% of respondents)
3. *Persona 3* (*P3*): women who never considered entering computing (29% of respondents).

P2 respondents had potential to stay in SE but in many cases reported a dilemma about whether to follow their interest. The insights into their struggle are a valuable part of this study. Thus, this article reflects on a comparison of responses from P1 and P2 to identify the frustrations that steered P2 away from computing. We analyze what formed the experiences of P1 and P2 when entering the computing world and what made them to decide differently later.

Results

The three factors hindering girls' entrance to SE mentioned in Klawe's quote (also see Fidelman[1]), i.e., stereotypes, confidence, and a sense of belonging, are confirmed by other studies, which add early access as a factor.[10] These factors were the first items added to our list of codes in the first cycle of our exploratory analysis, and qualitative responses were coded based on them. Within our code structure, besides the four key codes, a fifth factor emerged while we analyzed responses: feeling valued as women in computing careers. The code structure and results of the study are outlined in Table 1.

Table 1. Factors hindering women's participation in SE education: coded results.

Respondents	P1 39% (54)	P2 32% (45)
Code 1 (C1): access	**32% (17)**	**40% (18)**
C1.1: to suitable education	30% (10% of P1)	67% (27% of P2)
C1.2: to support and encouragement	41% (13% of P1)	22% (9% of P2)
C1.3: to a computer	29% (9% of P1)	11% (4% of P2)
Code 2 (C2): stereotype	**35% (19)**	**46% (21)**
C2.1: carried by others	79% (27% of P1)	38% (17% of P2)
C2.2: about the purpose of SE	5% (2% of P1)	19% (9% of P2)
C2.3: about themselves	16% (6% of P1)	43% (20% of P2)
Code 3 (C3): confidence	**26% (14)**	**42% (19)**
C3.1: self-efficacy	43% (11% of P1)	21% (9% of P2)
C3.2: imposter syndrome	50% (13% of P1)	58% (24% of P2)
C3.3: missing success experiences	7% (2% of P1)	21% (9% of P2)
Code 4 (C4): sense of belonging	**32% (17)**	**27% (12)**
C4.1: not comfortable to express themselves	82% (26% of P1)	58% (16% of P2)
C4.2: sexism and unwanted attention	18% (6% of P1)	25% (7% of P2)
C4.3: missing relatable peers	N/A	17% (4% of P2)
Code 5 (C5): feeling valued	**17% (9)**	**34% (15)**
C5.1: defensive culture	22% (4% of P1)	N/A
C5.2: women not valued	56% (9% of P1)	33% (11% of P2)
C5.3: nonstereotypical skills/interests not valued	22% (4% of P1)	67% (23% of P2)

Access

Studies summarized in Main and Schimpf[10] show that differences in the leisure preferences of children result in girls getting less exposure to computers, hence experiencing less psychological and material access to computing. Access to computing could be understood not only as exposure to computers themselves but opportunities for an engaging education, supportive teachers and family, and guidance.

Among participants who indicated this (32% of P1 and 40% of P2; see Table 1), some talked about limited access to a computer at a young age, either because the machines were expensive or their father did not allow them to use one. A computer scientist (P2) from Germany summarized her experience: "My father did not allow me to have a computer, so since I grew up, I totally fell in love with everything. I sometimes feel not allowed to be interested into computers because my uncle is a coder, and he always says that woman only can do healthcare work. So, I started to study very late (32) and without any knowledge of friends and family. And I love it."

Forty-one percent of P1 participants within C1 (P1–C1) and 22% of P2 respondents within C1 (P2–C1) referred to psychological access, emphasizing a lack of support and encouragement from their family and school, which is typically paired with stereotypical views of girls and boys. Another major aspect (30% of P1–C1 and 67% of P2–C1 respondents) was the topic of limited access to suitable education, which would not be understood as the "bonus subject for nerds" (P2) but as providing applicable skills to solve real issues.

Stereotypes

Although current discussions focus on stereotypes girls have about SE professionals, the nature of the work, and the purpose of the field, our study revealed a very different picture. Among participants who mentioned stereotypes in a negative or limiting way (35% of P1 and 46% of P2; see Table 1), 79% of P1–C2 and 38% of P2–C2 respondents referred to beliefs that society and their family, teachers, and peers have about women not being a good fit for tech. Often, women reported being discouraged by family and teachers who thought they were acting in their best interests and guiding them toward more suitable jobs, e.g., in caregiving. A young woman studying for a bachelor's degree in computer science (P2) said: "My family is still not supportive cause they do not like seeing their daughter doing manly stuff. I should get married and get kids instead of doing research." Others listed major obstacles, such as: "Society women don't do this, women are not interested in this, why don't you do something that is more a women's thing? It is hard to swim against the stream every day" (P1). And: "It is a man-dominated field stereotyped by our societies worldwide. As a woman you have to prove them wrong" (P1).

Next to this, 16% of P1–C2 and 43% of P2–C2 respondents mentioned a past belief that only extremely smart people can understand computer science (see the confidence discussion in the following), and some were not aware that computing was an option: "I did not think it was accessible to me. I just did not think of it as an option. I can't even say if I would have wanted to go there because it was so far off at the time" (P2). Finally, 5% of P1–C2 and 19% of P2–C2 respondents said they did not understand the purpose of computing and thus found it boring: "Boring computer programming in school put me off for decades. Why would I want to write a game I wouldn't want to play? Waste of time" (P2).

Confidence

The confidence gap is a gender difference observed across various fields.[11] In SE, it is widened by limited access to resources, equipment, education, and support. In effect, girls often find themselves in classrooms with more experienced learners, which makes the gap hard to close.[4] In our survey, 26% of P1 and 42% of P2 respondents (see Table 1) listed confidence as a major factor. Some, 43% of P1–C3 and 21% of P2–C3, referred to it as a tool to engage more girls in SE (via encouragement), while others, 50% of P1–C3 and 58% of P2–C3, referred to a lack of confidence as a major obstacle. They talked about imposter syndrome and a fear of not being good enough: "Many girls think that if they try, they will fail, and people will laugh at them" (P1). And: "Encouragement. That's what girls need. And community where they don't feel embarrassed that they are not experts in computing but they want to learn anyway. Community where they are not afraid to admit that they don't know how to change from English to Czech keyboard! But even though they want to learn programming and they will be amazing at it in the future, it's not the obstacle!" (P2). Some participants proposed that girls should be pushed early to engage in difficult assignments and experience success, with mandatory coding classes being part of the initiative.

Sense of Belonging

A number of respondents (32% of P1 and 27% of P2; see Table 1) listed a sense of belonging as a major concern. This is surprising in the case of P1 participants, who have been involved

with computing since their early education. Many do not feel comfortable in a predominately male environment—a "bro culture," as they call it: "Sometimes it's hard to work in field dominated by men. Right now, I would be really glad if more women worked in IT because I work in IT, and I don't like that feeling that I'm something extra or abnormal" (P2).

What women (82% of P1–C4 and 58% of P2–C4 participants) dislike about being underrepresented in the environment is that they do not feel comfortable expressing themselves and believe "other people [are] watching and/or judging me" (P1). Additionally, some referred to people in computing as being "narrow-minded" and using a strange language, which makes it hard to feel they belong, but they emphasized that "there is a large divide, I think, between the CS people and communities that are healthy, productive, and wholesome and those that are very toxic places" (P2). In addition, 18% of P1–C4 and 25% of P2–C4 participants reported sexism: "Had my share of, 'Hey, you're not bad at programming for a girl' and programmers keeping posters of girls in bikinis in their offices/on their computer" (P1).

Feeling Valued

Besides the four key factors, also confirmed by existing studies,[10] we add the fifth factor that emerged from the responses (17% of P1 and 34% P2; see Table 1). This observation matches research into the underrepresentation of women in leadership,[12] showing that women feel they are valued based on their ability to mimic strengths typical of the majority group while being expected to have other "feminine strengths" that are given less credit. In effect, women with strengths matching the majority group in SE (e.g., logical thinking and technical knowledge) feel annoyed by the need to keep proving their worth (a so-called defensive climate[10]), while women with different strengths (e.g., in user-centered design and multidisciplinary interests) believe they are seen as second-class. This causes discomfort and hinders women's career growth, which might result in them leaving the field.

Among P1 participants, 56% of P1–C5 explicitly expressed concern about women in computing not being valued, experiencing discrimination, and not feeling encouraged to use their full potential (e.g., multidisciplinary knowledge). Although rare, some respondents viewed the field as "being dominated by men that look down on women in computing" (P1). Others said "the work of female developers is rather not acknowledged" (P1), and some reported being advised that they "should not go into computer science because women are not being taken seriously in that area" (P1). The 33% of P2–C5 participants who expressed concern about women not being valued did so in a more implicit way, e.g., some of them believed they had to do something (e.g., invest more time, spend less time with children, study more, leave their other interests behind) to be more valued.

Furthermore, 67% of P2–C5 respondents said they feared that a tendency toward multidisciplinary interests would lead to them being valued less: "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" (P2). And: "IT should be part of every study we do today .... I think we should connect pure science with IT somehow; e.g., during my history studies we used computers only to make presentations in MS PowerPoint. We could learn how to model data and make predictions based on some historical events. We could make graphic designs of archaeological sites, whatever…but we didn't" (P2).

Discussion

What is SE lacking that makes women seek other interests, study programs, and professions as an alternative? To answer this question, we were especially interested in understanding what made P2 participants step away from SE and computing in the first place. Thanks to the admirable ability of the participants to reflect on their previous experiences, we could follow a pattern in the responses. The funnel into SE education is leaky. There is a likelihood of 0.27 (C1.1) that girls will not have an engaging educational offer in their areas of interest, 0.2 (C2.3) that they will be convinced that they and their interests do not fit and are not connected to SE, 0.24 (C3.2) that they falsely believe that because they have other interests and do not invest all their time in computing they cannot be successful in SE, and 0.23 (C5.3) that they will experience their nonstereotypical skills and interests as second-class, misunderstood, and unappreciated.

There is a silver lining to these leaks—multidisciplinarity. The women in the study had many major interests, on average, 5.5 besides computing (which was true for P1 and P2). Thus, the time when they could have practiced computing was filled with other activities, something

they never consciously noticed. This was nicely expressed by one participant: "In retrospect, I'd like there to be someone who noticed that I had my head on computers and kept me there. I had a lot of other interests: guitar twice a week, volleyball twice a week. I took computers like, 'Yeah, I'd probably like that,' but I had a lot of other things" (P2).

There is thus potential to create alternative pathways[13] to the field by building on individual interests. Since many women find it hard to identify themselves with computing (which is indicated by the confidence gap and missing sense of belonging), we might want to leverage their personal interests to create identities that resonate. We suggest that a different learning approach, i.e., an interdisciplinary one,[14] could be particularly promising for strengthening women's engagement in computing. Interdisciplinary subcultures can provide an environment where students who feel left behind can learn SE without a sense of being trapped by the dominant culture associated with the field.

To this end, different means and strategies can be utilized, from the integration of computing-powered solutions in noncomputing courses to the integration of noncomputing knowledge in computing courses via realistic applications and real-world projects. This would expand different entryways to computing, help students be more comfortable exploring and experimenting with computing, provide the stability of a familiar knowledge base, and foster an ability to self-identify with relevant problems. While mixing the "unfamiliar with the familiar," students might be more intrigued when unexpected things happened and feel more competent because they could explain new findings by using their strengths in a comfortable context. Interdisciplinary approaches could enrich formal education by integrating other sciences and humanities, promoting versatility for future workplaces and real innovation, which can hardly be achieved without computing crossing its own boundaries.

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Before concluding, it is important to keep the limitations of this study in mind. First, the accuracy of the responses depended on participants' ability to recall their experiences. Second, we used open questions to capture a full range of expression, which had to be conveyed in English. That required writing skills and an ability to describe feelings and experiences, which can be difficult for nonnative English speakers. Nevertheless, the study's results align with the assumptions and evidence reported in the literature,[1, 10] although those findings have not been confirmed by a project like ours. Further studies attempting to replicate our findings using larger samples for different gender groups would be welcome.

Computing-driven innovation and creativity cannot achieve their full potential if they are performed by a fraction of the population. The potential talent pool is significantly reduced without girls and their nonstereotypical strengths. However, measures to diversify the computing workforce should be motivated not only by attempts to balance the gender books but out of understanding that parity is an enormous advantage for our digitalized future. Our study shows a lack of understanding and appreciating diversity in SE.

On top of this, there is danger in some of the attitudes in SE, and it was visible in the responses of P1 participants. They emphasized experiencing hostile stereotypes (C2.1) and feeling uncomfortable expressing their true nature around SE practitioners (C4.1). Noticing and counteracting this should be a norm by today, and to one participant (P2), who stated that she did not enter SE because of the "necessity to change herself, to change her field, to get into the 'men's world'," we can hopefully respond that soon enough 1) each person will be able keep her own identity (as sporty, artsy, or feminine) in computing; 2) nobody will have to change her field, as SE will not be compartmentalized and will function across disciplinary boundaries; and 3) it will not be a "man's world" anymore—it will be everyone's. It will be ours.

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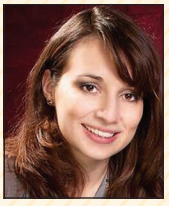

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