Frustrations Steering Women away from Software Engineering

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***Abstract*—Why do women choose particular interests, study programs and careers as alternative to software engineering? What are the triggers and benefits of these alternatives that software engineering is lacking? In this article, we share findings from a questionnaire study of 139 adult women, revealing the frustrations that women feel along their way to software engineering, whether they have stayed in, or have dropped out and are trying to re-establish the connection later. After identifying the frustrations, which all seem to be preventable, this article pinpoints the most promising solutions, such as the interdisciplinary approach to education, which could be of enormous help to girls' retention in computing education.**

THE DEMOCRATISATION of digital innovation is a remarkable sociological shift driven by new technologies and lower costs, enabling individuals to design and share their creations as never before. The direction towards a sustainable and more balanced society asks for higher engagement of diverse people in innovation, shedding light on critically low number of women choosing software engineering (SE) education and career. Enabling a broad diversity of talent, particularly women (who represent half of the world's population), to fully participate in innovation, not only guaranties more products fitting for usage by broader audience, but increases their earning potential and this way ultimately strengthening the global economy.

Although progress in higher involvement of women in SE is barely visible, we are starting to understand the reasons and myths behind the trend. Harvey Mudd's president, Maria Klawe, has summarized their experience as: *"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 work environment and nature of the work (e.g., lacking social interaction, being boring and repetitive) are indeed responsible for discouraging many girls from engaging with SE already before their very first contact. A Google study conducted in 2014 [2] has shown that when such a contact is not part of the curriculum, the girls tend to spontaneously develop negative connotations with computing even when having no experience with it (using words like boring, difficult, nerd), in contrast to connotations used by girls who had computing in their curriculum (using words like future, fun, interesting).

Although the negative view of computing together with the confidence gap, as described by Maria Klawe, play their role in narrowing the number of girls interested in SE, we see that there is still a substantial number of girls and women enthusiasts who would like to pursue SE careers [3] but get discouraged by unnecessary frustrations they experience along the way.

In [4], we have elaborated one of these frustrations and introduced initial actionable recommendations for practitioners, which stems from the fact that girls' first contact with SE typically happens in the presence of more experienced learners, with the absence of success experiences, while often struggling on their own (as the experienced learners tend to monopolize instructor's time) and gradually moving in an outsider role within the classroom, feeling uncomfortable, missing sense of belonging, and eventually dropping the class once possible. Next to the deliberate effort in building an environment that is supportive of novice learners, other effective interventions to recruit and retain girls in SE education include strategies that combat wrong stereotypes, strategies that spark initial interest by actively engaging their strengths, strategies managing suitable first contact, strategies for building self-confidence, and strategies for sustaining long-term commitment, as we have summarized in [5] accumulating joined knowledge from over 800 publications via a cumulative review of literature reviews on the topic. Despite these interventions, used for over 20 years by the research community, governmental, and educational institutions and aimed at increasing gender diversity in SE, we achieved little progress [6].

In this article, we go further and intend to identify and examine the causes that underlie females' attrition in SE and understand the perceived frustrations that women themselves report as the reasons why they dropped out of SE education despite being keen about it in general. To this end, we have designed a retrospective questionnaire study, which has revealed numerous interesting insights about frustrations that women interested in computing[1] experience along different phases of their education and career.

[1]In our study, general terms like "computing" and "IT" were preferred by the respondents when referring to software engineering (traceable from the examples of activities they mentioned).

DESIGN OF THE STUDY

The goal of the study, as different from other related studies [7], [8], was to reach the women who would like to re-establish their connection to SE, and compare their responses with the women who stayed in —focusing on their view of the moments that formed the direction they decided to take (stay in or disengage, although overall interested in it), while asking about the biggest obstacles and drivers on girls' way to SE together with envisioned 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 what are the challenges girls and women face when participating in SE activities at school or at home, and factors that enable their entry and ongoing participation in the further education.

The questionnaire consisted of a number of questions, including six open questions asking the respondents to retrospect and analyse their previous studies and ambitions. These questions asked about participant's understanding of who computer scientists are, what were the drivers and obstacles on their way to SE, what makes them enthusiastic about it and what they would recommend to improve SE education for girls. The results presented in this paper are based on the responses to these open questions (quoted as written), in combination to basic classification questions about participants' age, gender and major interests.

We distributed the questionnaire among groups with the affinity towards SE, especially educational institutions providing late-education offers (for adult women), such as Czechitas (www.czechitas.cz). The questionnaire was distributed world-wide, mostly through Facebook-groups targeting late education for women. We specifically looked for respondents who have likely had high potential to study SE in their earlier years, which makes our study different from other similar studies, e.g. [7], [9], [8].

We successfully collected 139 responses from women[2] in three age groups (18% between 18 and 26, 41% between 27 and 34, 33% over

[2]Filtered from 151 responses after removing incomplete responses and responses representing gender groups not targeted by this study.

34 years old, and 8% without age indication). This study's population was represented by near-even distribution of respondents (and personas) over 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) who studied and stayed in computing, 39% of respondents,
2) *Persona 2* (P2) who transitions to computing later in life, after studying another discipline, 32% of respondents,
3) *Persona 3* (P3) who never considered entering computing, 29% of respondents.

Persona 2 respondents had potential to stay in SE, but in many cases reported on the early dilemma whether to follow their interest. The insights on their struggle are very valuable part of this study. Thus this article reflects on the comparison of responses by *Persona 1* and *Persona 2* to identify the frustrations that steered *Persona 2* away from computing, despite their interest in it that is so strong that they are trying to re-establish the connection later in life. We will analyse what formed the experiences of the *Persona 1* and *Persona 2* when entering computing world and what made them to decide differently later.

RESULTS

The three factors hindering girls' entrance in SE brought in the quote by Maria Klawe (see the introduction and [1]), i.e. *stereotypes*, *confidence*, and *sense of belonging*, are being confirmed also by other existing studies, which further 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. The qualitative responses were coded based on these four factors. Within our code structure, besides the four key codes that we used initially to structure the discussion of the responses, a fifth factor emerged from analysing the responses, being *feeling valued* as women in the computing careers. The code structure and results of the study are outlined in Table 1.

1. Access

Studies summarized in [10] show that differences in leisure-time preferences of young girls and boys result in girls getting less exposure to computers, and hence experiencing lower psychological, material and usage access to computing. The access to computing could be understood not only as access to the computer itself, but as well as access to engaging education, supportive teachers, supportive family environment or guidance.

Among the participants who indicated limited access (see Table 1, 32% of P1 and 40% of P2), some talk about limited access to a computer in young age, either because computers were expensive back then, or because their dad did not allow them to use it. A female computer scientist (P2) from Germany summarized her experience as: *"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."*

41% of the P1 within C1 (P1-C1) and 22% of the P2 within C1 (P2-C1) respondents refer to psychological access, emphasizing the lack of support and encouragement from their family and school, which is typically paired with the frustrations of stereotypical view of girls and boys.

Another major aspect (30% of the P1-C1 and 67% of of the P2-C1) was the topic of limited access to suitable education, which would not be understood as the "bonus subject for nerds" (P2) but provide applicable skills to solve real issues.

2. Stereotypes

Although existing discussions focus on the stereotypes that the girls have about SE professionals, type of work and purpose of SE, our study has revealed a very different picture.

Out of the participants, who mentioned stereotypes in a negative or limiting way (35% of P1 and 46% of P2, see Table 1), 79% of the P1-C2 and 38% of the P2-C2 referred to the stereotypes that the society, their family, teachers or peers have about women not being a good fit for tech. Often, the women reported being discouraged by

Respondents	Persona 1 (P1) 39% (54)	Persona 2 (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 syndrom	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: non-stereotypical skills/interests not valued	22% (4% of P1)	67% (23% of P2)

Table 1. Factors hindering participation of women in SE education: Coded Results

their own family or teachers who meant it for the participant's best interests and often believed they are protecting them or advising them towards their future happiness in a more suitable job, e.g. in care-giving. A young woman studying a Bachelor 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 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 major reason, 16% of the P1-C2 and 43% of the P2-C2 respondents mentioned their past belief that only extremely smart people can do computer science (see the confidence discussion below), where some participants were not aware that computing would be 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)

Lastly, 5% of the P1-C2 and 19% of the P2-C2 respondents mentioned that 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)

3. Confidence

Confidence gap is a gender difference observed across various fields [11], which is in SE further strengthened by the limited access to resources, equipment, education and support (as discussed above). In effect, girls often find themselves in a classroom with more experienced learners, which makes the gap hard to close [4].

26% of P1 and 42% of P2 respondents (see Table 1) listed confidence as a major factor on girls' way to SE. Some, 43% of the P1-C3 and 21% of the P2-C3, referred confidence as a tool to engage more girls in SE (via encouragement), while others, 50% of the P1-C3 and 58% of the P2-C3, referred to its lack as a major obstacle, talking about the imposter syndrome and 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 comput-*

ing 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). As a specific suggestion, some participants proposed that girls should be pushed early to engage in difficult assignments and experience success, with mandatory coding classes being part of that push.

4. Sense of belonging

A number of respondents (32% of P1 and 27% of P2, see Table 1) listed sense of belonging as a major concern. This is surprising in case of P1 participants, who are in computing since their early education, and yet many are not feeling comfortable in the prevalently male environment, *"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 the P1-C4 and 58% of the P2-C4 participants) dislike about being underrepresented in the environment is not feel comfortable to express themselves and feel that *"other people watching and/or judging me"* (P1). Additionally, some refer to the mindset of people in computing as "narrow-minded" and using a strange language, which makes it hard to feel they belong, but emphasizing 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)

An 18% of the P1-C4 and 25% of the P2-C4 participants report on sexism: *"Had my share of 'hey you're not bad at programming for a girl' and programmers keeping posters of girls in bikini in their offices / on their computer."* (P1)

5. Feeling valued

Besides the four key factors, also confirmed by existing studies [10], we add the fifth factor that has emerged from the collected responses (17% of P1 and 34% P2, see Table 1). This observation matches the research on the underrepresentation of women in leadership [12] showing that women in these environments feel being valued based on their ability to mimic the strengths typical for the majority group, while being expected to have other "feminine strengths" that are given less credit. In effect, the women with strengths matching the majority group in SE (e.g. logical thinking, technical knowledge) feel annoyed by the need to keep proving that (so-called "defensive climate" [10]), while the women having another set of strengths (e.g. in user-centred design, multidisciplinary interests) feel uncomfortable bringing these strengths to the table, as these are seen as second-class. Whether the former or the latter, this causes uncomfortable feelings, hindering women's career growth, which might result in them leaving the field.

Among P1 participants, 56% of the P1-C5 explicitly expressed their concern about women in computing not being valued, experiencing discrimination, or not feeling encouraged to use their full potential (e.g. multidisciplinary knowledge). Although rare, there are views of computing as *"being dominated by men that look down on women in computing"* (P1), saying that *"the work of female developers is rather not acknowledged"* (P1), or even being advised that they *"should not go into computer science because women are not being taken seriously in that area"* (P1). The 33% of the P2-C5 who express their concern about women not being valued in SE, do so in a more implicit way, e.g., some of them believe that they have 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, tendency towards multidisciplinarity was connected for P2-C5 with fearing not feeling valued in computing (67% of them), as they do not want to focus all their attention on computing: *"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 shall 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 SE? To answer this question, we were especially interested in understanding what made the P2 participants to select away from SE and computing in the first place. Thanks to the admirable ability of participants to retrospect about their previous experience, we could follow a pattern in the responses. The funnel into SE education is leaky. When following the major leaks, there is a likelihood of 0.27 (C1.1) that girls will not find an engaging educational offer in the area of their interest, a likelihood of 0.2 (C2.3) that they will be convinced that they and their interests do not fit and are not connected to SE, a likelihood of 0.24 (C3.2) that they falsely believe that because of having other interests and not investing all their time into computing they cannot be as successful as others in SE, or a likelihood of 0.23 (C5.3) that they experience their non-stereotypical skills and interests being considered as second-class and the advantage of having them will not be understood and appreciated in SE.

Overall, there is a silver lining connected to these pipeline leaks—multidisciplinarity. The women in the study showed to have many other interests, on average 5.5 other major interests besides computing (true for both P1 and P2). Thus, the possible time slot where computing could be practiced was immediately filled with something other, without further conscious notice by the girls. This was nicely expressed in this response: *"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 a potential in creating alternative pathways [13] into the field by merely building on individual interests. As many women find it hard to identify themselves with computing as such (also indicated by the confidence gap and missing sense of belonging), we might want to leverage their personal interests to create identities that do resonate. We suggest that a different learning approach, i.e. *interdisciplinary approach* [14], could have a particularly strong potential for strengthening women's engagement in computing. These different interdisciplinary subcultures can provide an environment where all the students who currently feel left behind can learn SE without feeling trapped by the dominant culture associated with the field nowadays.

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

Before concluding, it is important to keep the possible limitations of this study in mind. First, the accuracy of responses depends on the respondent's ability to recall their previous experiences. Second, we used open questions to capture a full range of expression from the respondents, which had to be answered in English. That required writing skills and an ability to express feelings and experiences verbally, which can be difficult for non-native English speakers. Nevertheless, the findings align with the assumptions and evidence reported in literature [1], [10], although not yet confirmed by a study like ours. Further studies attempting to replicate these findings with larger samples for different gender groups separately would be welcome.

CONCLUSION

Computing-driven innovation and creativity cannot be cherished to its full potential if formed only by a fraction of the population. The potential talent pool is significantly reduced without girls

and their non-stereotypical strengths. However, the measures to diversify the computing workforce should be motivated not only by shallow attempts to merely balance the gender books, but rather out of understanding that such balance is of enormous advantage for our digitalised future. Our study shows that there is lack of understanding of the benefits of this SE diversity and also lack of genuine appreciation of these benefits.

On top of this, there is a danger peeking through the SE lining that manifests itself in the responses of P1 participants. Surprisingly, they reported highest on experiencing hostile stereotypes (C2.1) and not feeling comfortable to express their true nature around SE folks (C4.1). Noticing and counteracting this tendencies should be a norm by today and to the words of 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 can keep their own identity (as sporty, artsy, feminine) and learn computing anyway; (2) nobody has to change their field, as the field is not compartmentalized anymore and we do computing across boundaries of disciplines; and (3) it is not "men's world" anymore, it is anyone's, it is ours.

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