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Girls in STEM: A Qualitative Analysis of Factors and Actors Impacting on Girls' Engagement in International Computer Science Competitions

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Abstract. The study aims to explore the key-factors and influential actors impacting on girls' participation in international Computer Science competitions and on their overall aspirations in STEM career-paths. By analyzing societal perceptions, self-efficacy, and other social and subjective factors through qualitative analysis, the research wants to uncover both motivators and barriers that shape young women's interest in scientific fields. The findings will contribute to raise awareness of the social factors fostering the Gender Gap in Computer Science, providing useful insights to shape more inclusive and supportive learning environments for young women in competitive programming.

Keywords: STEM literacy, gender equality, inclusive learning, computer science.

1. Introduction

Gender equality in STEM (Science, Technology, Engineering, and Mathematics) education and careers remains a pressing challenge despite recent global initiatives aimed at fostering inclusivity and diversity. In fact, women continue to be significantly underrepresented in STEM disciplines – particularly in "hard science" fields such as engineering, computer science, and physics (Fry *et al.*, 2021; NCSE, 2021) – facing social barriers that not only limit their potential talent pool and innovation capacity (Cowgill *et al.*, 2021; Van Camp *et al.*, 2019), but also prevent them from fully participating in and benefiting from economic opportunities offered by these crucial industries (Carnevale *et al.*, 2011). The underrepresentation of women in STEM-related education not only represents an issue of social justice, it has indeed strong economic and developmental consequences in today's modern world. Present and future global challenges require in fact a multidisciplinary culture that combines humanistic knowledge with widespread STEM literacy. In the Digital era, STEM fields are essential for economic growth, technological innovation, and overall global competitiveness: the Fourth Industrial Revolution has amplified the need for STEM-educated professionals, making gender inclusivity in STEM a critical issue for workforce development (Elazab *et al.*, 2019). In this perspective, investments in techno-scientific education – fostering interdisciplinary learning, preparing students for dynamic and evolving career paths (Bybee, 2013) – contribute to national economic stability, promoting job creation, enhancing problem-solving skills, and driving innovation (Marginson *et al.*, 2013). Countries that invest heavily in STEM education and workforce development experience therefore significant advancements in infrastructure, sustainability, and industrial growth (Xie *et al.*, 2015).

Despite extensive research on gender disparities, a significant gap remains in understanding the specific factors that shape girls' participation in STEM competitive environments. While general barriers to inclusion have been widely studied, little attention has been given to the complex interplay between societal perceptions, self-efficacy, and the influence of key figures such as educators, mentors, and family members. Additionally, while biases and institutional obstacles are acknowledged, there is a lack of empirical data on how these challenges interact with individual psychological factors. Gaining deeper insights into these dynamics is crucial for designing targeted interventions that not only encourage more girls to enter competitive STEM environments but also support their long-term engagement and success in these fields.

This study therefore seeks to explore the underlying social and psychological mechanisms that influence young women's engagement with Computer Science competitions and their broader aspirations in STEM careers. By investigating the roles of societal expectations, self-efficacy, and key influencers such as teachers, mentors, and family, this research aims to uncover both barriers and motivators that shape girls' participation in these competitive environments. The study will provide a nuanced understanding of the complex interactions between individual aspirations and external influences, offering evidence-based insights to support the development of more inclusive STEM learning environments. Through this approach, the research will contribute to face gender disparities in STEM by answering the following main research questions:

- What psychological and socio-cultural factors influence girls' participation and persistence in Computer Science competitions and STEM fields in general?
- How can educational and institutional support improve gender inclusivity in Computer Science competitions and STEM fields in general?

By addressing these questions, this study seeks to contribute to the broader discourse on gender equality in STEM and provide actionable insights for improving diversity in these critical fields. In a world where the mastery of scientific tools is in fact a full-citizenship requirement, it is in fact necessary to make STEM literacy more inclusive, adopting a perspective of educational equity: this means supporting the many potential students held back by gaps in educational opportunities (Lee and Buxton, 2010) by addressing the obstacles to academic access – primarily linked to unfavorable social backgrounds (OECD, 2012) – and the biases associated with them, which are often internalized since childhood.

The findings will be of interest to educators, policymakers, and researchers aiming to develop strategies for improving inclusivity in STEM fields: addressing gender disparities in STEM will help institutions implement more equitable policies and foster a more inclusive educational ecosystem. By understanding the challenges faced by women in STEM, organizations can create targeted interventions to enhance female participation and retention in these high-demand fields.

2. Related Work

The underrepresentation of women in STEM is the result of a complex interplay of personal, social, and institutional factors.

At an individual level, Self-Efficacy, Motivation, and Confidence play significant roles in determining whether girls pursue STEM fields (Rosenzweig & Wigfield, 2016; van den Hurk *et al.*, 2019; Prieto-Rodriguez *et al.*, 2020): in fact, research suggests that when girls receive encouragement from teachers, parents, and mentors, they are more likely to develop a strong STEM identity and persist in these fields (Prieto-Rodriguez *et al.*, 2020). A sense of belonging has also been identified as a critical factor in women's persistence in STEM education and careers. Students who feel socially and academically integrated into their academic communities are more likely to persist in their chosen fields (Strayhorn, 2018; Murphy *et al.*, 2020). Support networks, mentorship programs, and inclusive institutional cultures play a key role in fostering this sense of belonging for women in STEM.

At a socio-cultural level of examination, the major challenge is represented by the continued presence of gender stereotypes that depict STEM professionals as predominantly male (Thébaud & Charles, 2018; Sáinz *et al.*, 2019). Gender disparities in STEM can be traced back to early childhood and adolescence: as a matter of fact, girls' interest in STEM subjects declines between the ages of 12 and 15 (Tsan *et al.*, 2016), largely due to social and cultural factors, including deeply rooted stereotypes that associate technical and mathematical abilities with men (Fouad & Santana, 2017; Lent & Brown, 2019). In fact, studies indicate that societal beliefs about gender roles contribute to the perception that women are less competent in STEM disciplines: the fact that male students are often perceived as more competent in STEM subjects can affect young girls' confidence and engagement in STEM activities (UNESCO, 2018; Sáinz, 2020), discouraging them from pursuing future careers in these fields (Leaper & Brown, 2014; Sáinz *et al.*, 2020). As a consequence, addressing these disparities requires interventions at various educational levels, starting in primary and secondary education (Wang & Degol, 2017). In particular, creating inclusive classroom environments and implementing gender-sensitive teaching strategies can help foster early interest in STEM careers among young girls (UNESCO, 2018).

Regarding the institutional level, gender disparities have been addressed through different STEM Intervention Programs ("SIPs") implemented to engage young women and provide them with the resources and support needed to succeed (Liben & Coyle, 2014; Rosenzweig & Wigfield, 2016; van den Hurk *et al.*, 2019). Providing institutional resources and inclusive learning environments can in fact help to mitigate the systemic challenges that disproportionately affect women in STEM (Cooper *et al.*, 2019).

3. The Current Study: Insights from Girls participating in International Computer Science Competitions

Despite Computer science being one of the fastest-growing fields globally, with increasing demand for skilled professionals (Xie *et al.*, 2015), the underrepresentation of women in this field remains a critical issue in STEM education and career pathways: lower participation and retention rates are attributable to strong gender disparities, structural barriers that preclude women's technical roles, especially in competitive and high-performance computing environments (Cheryan *et al.*, 2017).

Despite numerous initiatives aimed at fostering inclusivity, there remains a gap in understanding the personal journeys of young women in Computer Science, particularly those engaged in competitive programming. Competitive programming serves as an essential gateway to high-level technical skills, problem-solving expertise, and career opportunities in software engineering, artificial intelligence, and cybersecurity (Li *et al.*, 2019). Given its importance, examining the experiences of young women in this domain provides critical insights into how to better support female participation and persistence in the field.

While quantitative studies highlight disparities in participation and retention, qualitative research provides deeper insights into the lived experiences of young women in this field. Understanding these personal narratives is crucial, as they offer a nuanced perspective on the motivations, challenges, and structural barriers faced by young women entering competitive programming and computer science.

This study therefore employs a qualitative methodology through semi-structured interviews with female participants in international Programming competitions. By exploring their educational background, support systems, role models, challenges, and perspectives on gender diversity, the research aims to shed light on the factors that influence young women's engagement in competitive programming. The findings contribute to the ongoing discourse on gender diversity in STEM and inform future strategies to create more inclusive and equitable learning environments in computer science.

3.1. *Methodology*

To explore the factors influencing girls' engagement in international Computer Science competitions, the study employed a qualitative methodology based on semi-structured interviews. The research involved twelve female participants, aged 18 to 23, from diverse geographic backgrounds, including Sweden, Lithuania, Germany, Luxembourg, Italy, Algeria, and Switzerland. These participants were selected based on their involvement in STEM education and participation in the European Girls' Olympiad in Informatics (EGOI) 2024, held in Veldhoven, the Netherlands.

Data collection focused on participants' educational backgrounds, support systems, role models, challenges, and perspectives on gender diversity in STEM. The interviews, conducted in English, were transcribed verbatim and analyzed using thematic analysis. This approach enabled the identification of recurring patterns, categorized according to three levels of analysis: individual, socio-cultural, and institutional.

- Individual Level: regarding self-efficacy, motivation, personal aspirations, and the role of intrinsic interest in STEM.
- Socio-cultural Level: regarding family support, peer influence, and societal perceptions about gender roles in STEM.
- Institutional Level: regarding the impact of school curricula, teacher encouragement, mentorship programs, and broader policy initiatives on girls' participation in STEM.

3.2. *Results*

The Individual Level

Participants described diverse motivation drivers, identifying several entry points into Computer Science. Exposure to Mathematics played a foundational role for some participants, as problem-solving skills translated naturally into an interest in coding. Informal learning, such as self-directed study and online courses, also emerged as a crucial factor, particularly in cases where formal education did not provide sufficient programming instruction. In general, self-motivation emerged as a key factor in sustaining interest and overcoming challenges in male-dominated environments.

> *"I have always been good in math, initially I actually used to participate in math competitions; it was from there that I have been introduced to computer science"* (Serena, 18, Italy)

> *"I was fascinated by smartphones and how they work, and from there I started exploring coding"* (Vaiva, 23, Lithuania)

However, some participants struggled with sustaining long-term interest in Computer Science, particularly when motivation drivers – such as competition results – declined. When faced with these challenges, they tended to develop personal strategies to navigate biases and self-doubt: many emphasized resilience, self-motivation, and seeking supportive environments.

> *"I think the biggest challenge is my own self-esteem, sometimes I still feel like this is not really the world I belong in… I try to remind myself that I'm capable."* (Priska, 21, Switzerland)

> *"I faced discrimination from some lecturers, but I made sure to choose those who supported me."* (Vaiva, 23, Lithuania)

> *"I overcame self-doubt by focusing on my achievements and surrounding myself with supportive people."* (Noemi, 20, Italy)

In fact, participants' future aspirations often included working in the STEM field and improving its gender inclusivity.

> *"I want to explore both IT and design in my future career."* (Vaiva, 23, Lithuania)

> *"I want to create a strong IT community in Algeria for future generations."* (Maya, 20, Algeria)

> *"I hope to continue supporting young girls in Olympiads and competitions."* (Noemi, 20, Italy)

The Socio-cultural Level

In the family context, support varied across participants. Some reported highly encouraging environments, with parents who actively promoted STEM engagement by enrolling their children in STEM-related programs (many reported that they have been introduced to programming through family members who worked in related fields), while others described a more neutral stance, with parents providing only passive encouragement and approval by allowing them to explore their interests independently.

> *"My father is a PhD in Physics and now he is working in IT: that probably had some influence. And my mother is a doctor, so she also has some STEM background. I guess mathematical skills were always high valued"* (Priska, 21, Switzerland)

> *"My mom signed me up for course about programming and I got obsessed with it"* (Isabel, 19, Germany)

> *"My family has been fundamental. Programming competitions involve a lot of stress and also self-esteem levels are not regular: there are peaks of it after victories, but of course you also experience defeats… having someone who still sees you as capable, even when you think you cannot do it anymore, is key"* (Noemi, 20, Italy)

> *"My father has a degree in economics, he doesn't even know what computer science is; my mother too, she studied accounting... But in the end I think they are quite happy that I've found my way"* (Serena, 18, Italy)

In some cases, friends who were already active in the field also played an important role in introducing participants to the programming world.

> *"I saw a friend taking an online coding course, and I decided to try it too. That's how I got started."* (Zelma, 18, Germany)

> *"A girl in my school helped me enter the math-advanced group, and that made all the difference."* (Matilde, 18, Italy)

> *"I used to go to math camps, where I met friends who weren't really interested in math, they were there just because it was the closest thing to programming, and they introduced me to it... so yeah, it was because of my friends"* (Maya, 20, Algeria)

Opinions on overall gender diversity in STEM varied among participants, even though a recurring theme was an overall gender imbalance in STEM contexts, with many participants describing male-dominated environments (particularly in competitive programming). Social isolation was in fact a recurring theme, with many participants reporting being among the few girls in their programming classes or competitions: they felt socially excluded or found it difficult to integrate into male-dominated spaces, struggling to find a community of like-minded peers, particularly within their local environments.

> *"When I went to math competitions, there were almost only guys. I felt out of place."* (Anita, 22, Sweden)

> *"It was struggling to find a community of other people that lived in Luxembourg that I knew that were also interested in IT"* (Laura, 18, Luxembourg)

While some of them did not experience explicit discrimination, stating that their gender did not significantly impact their experiences, others faced actual gender biases from teachers, peers, or competition organizers, acknowledging subtle differences in treatment and representation. For instance, some of them described situations where especially male peers questioned their competence despite superior performance in competitions. The European Girls' Olympiad in Informatics itself was reported to be perceived as less prestigious than mixed-gender programming contests, reinforcing gendered perceptions of ability.

> *"A teacher literally told me: 'This is not for you.'"* (Maya, 20, Algeria)

> *Some lecturers didn't like girls in STEM, they treated us differently."* (Vaiva, 23, Lithuania)

> *"I was told several times that I was there (i.e. at female programming competitions) only because I am woman... there is still a lot of discrimination"* (Serena, 18, Italy)

Despite these challenges, many participants emphasized that gender biases appeared to diminish at more advanced levels of expertise and within more specialized communities, where peers and mentors were more open-minded: over time, those who engaged in external competitions or international programs were in fact able to establish a network of supportive peers, reinforcing the importance of community-building initiatives.

Institutional Level

Institutional support for girls in competitive programming varied significantly, as schools were found to play an inconsistent role in fostering engagement. As a matter of fact, some participants encountered supportive educators and had access to competitions and preparatory resources, whereas others faced a lack of of institutional encouragement and had to rely only on external initiatives.

> *My school supported me by organizing competitions, but most teachers didn't really know about coding."* (Anita, 22, Sweden)

> *"My teacher was amazing. She encouraged me to participate in Olympiads and supported me throughout."* (Priska, 21, Switzerland)

> *"Some teachers were great, but others were dismissive. I had to choose carefully who to work with"* (Vaiva, 23, Lithuania)

Mentorship programs were also identified as a crucial element in fostering participation, with several participants emphasizing the positive impact of female mentors and role models. In particular, several participants noted that growing up mentors or visible figures in the field would have helped them to maintain intrinsic motivation.

> *"If I had a role model, I would have been more motivated."* (Anita, 22, Sweden)

> *"One of my mentors created a space for women in Olympiads, which really helped."* (Priska, 21, Switzerland)

Synthetizing Findings

The study highlights key factors influencing young women's experiences in competitive Computer Science. While some participants reported positive experiences, challenges such as gender biases, social isolation, and limited access to specialized training persist. To make STEM subjects more gender-inclusive in the future, three focal needs emerged:

- Early exposure to STEM subjects: family support, school-based initiatives and competitions can spark interest and build confidence in young girls.
- Supportive environments: creating inclusive learning spaces and combating gender biases can improve retention and engagement.
- Mentorship and community-building: expanding mentorship programs and fostering networks for women in STEM can provide essential guidance and support.

Addressing these areas can contribute to a more equitable and supportive landscape for women in STEM fields, ensuring that more young girls feel empowered to pursue these careers.

4. Noemi's Testimony

My name is Noemi Gambirasio, and I am a woman who works, studies, and lives within the field of a STEM discipline: computer science. I consider myself lucky because, in my country, Italy, no one has ever actively prevented me from pursuing my passions. Don't get me wrong, there are still people here who believe that certain jobs or fields of study are meant for men and others for women, but I am happy to say that in Italy, they are just an annoying minority. The real issue here is all those social concepts, prejudices, or beliefs that still today make it seem like a woman in my field is an exception or something unusual.

To be honest, if someone asked me, "Why don't most women choose the same path as you?" I wouldn't be able to give a definite answer. Many in Italy would respond that it's simply a field that tends to interest men more, and that could be a factor, after all, there are no laws or rules here that prevent a woman from choosing to work or study in these areas. However, throughout the journey that led me to choose computer science not only as a job but also as a passion, I have experienced situations that make me believe that this is not the only reason for the low female participation in STEM disciplines.

I started my journey thanks to a school competition in competitive programming. To be honest, my choice wasn't entirely conscious, I signed up because the school notice described it as a "logical-mathematical problem-solving contest," and I had always enjoyed those kinds of challenges. It was only during the competition that I encountered an algorithm written in pseudocode for the first time. Needless to say, I didn't pass the competition that year, but those problems definitely sparked my interest. So, I began studying C and C++ and got into competitive programming. The following year, I passed the school-level round, then the regional round, reached the national competition, and from there, I was selected to attend training camps for the selection and preparation for international competitive programming contests. That was where, for the first time, I found myself in a predominantly male environment focused on a STEM discipline.

I won't deny it, the first impact was fantastic. I was surrounded by people my age who shared my passion. I could express a part of myself that I wasn't used to sharing with classmates or friends. I didn't want to lose that feeling. I wanted to be part of the group. Unfortunately, the first problems arose precisely because of this, and the prejudices I mentioned earlier weren't imposed on me by others, I imposed them on myself. In my mind, simply finding people with whom I could share a part of myself wasn't enough. I convinced myself that to truly belong, I had to eliminate everything about me that didn't interest them, which meant I decided it shouldn't interest me either. The unfortunate part is that this included many of my feminine traits, which I mistakenly began to classify as weaknesses or, worse, as a waste of time.

The point is that when people say STEM fields have a male-dominated environment, they are not only referring to the fact that there are more men than women. It also means that common interests, priorities, humor, and pastimes statistically align more often with those of men than with those of women. In my case, this led me to emphasize certain aspects of myself over others, but for different people, whether women or men, it could lead to distancing themselves from the environment and, consequently, from the field itself.

And so, we arrive at the core of what we must fight against in countries like mine. Over time, and with the support of those around me, I realized what I was unconsciously doing. With effort, and, I won't lie, with some pain, I regained balance within myself. The truth, however, is that this struggle is much more likely to be faced by a woman than by a man in STEM disciplines. The goal, therefore, is this: that a woman should not have to choose, whether consciously or not, between fighting against herself and others or abandoning her passions. There is still a long way to go, but thanks to experiences like EGOI, I have met women who were either going through or had already overcome the same inner conflict as mine, and nothing makes you believe you can succeed like seeing someone else who already has.

5. Conclusions

Despite progress in increasing gender diversity in STEM, significant challenges remain that hinder the full participation of women in these fields. Societal stereotypes, institutional barriers, and a lack of representation still contribute to the underrepresentation of women in STEM careers. These disparities are not only detrimental to gender equity but also limit economic growth, technological advancement, and innovation. Addressing these challenges requires a multi-faceted approach that targets the root causes of gender disparity at multiple levels: individual, institutional, and societal.

One key strategy for bridging the gender gap in STEM is the implementation of targeted intervention programs that address both structural and cultural barriers. Research has shown that mentorship programs, inclusive curricula, and initiatives that foster a sense of belonging significantly improve women's participation and retention in STEM fields. Early exposure to STEM education, particularly through hands-on and experiential learning opportunities, can shape young girls' interest and confidence in pursuing these disciplines. Additionally, increasing the visibility of female role models in STEM plays a crucial role in countering stereotypes and inspiring future generations of women to enter and thrive in STEM careers.

Institutional reforms are equally vital in creating inclusive academic and professional environments. Universities and workplaces must actively work to eliminate biases in hiring, promotion, and academic evaluation processes. Creating supportive networks, implementing gender-sensitive policies, and promoting leadership opportunities for women in STEM can lead to greater retention and career advancement. Furthermore, addressing implicit biases in STEM education through teacher training and curriculum design is critical to fostering equitable learning environments.

From a broader societal perspective, cultural and policy changes are necessary to challenge deep-rooted stereotypes that associate STEM fields with masculinity. Media representation of women in STEM should be enhanced to showcase diverse role models who break conventional gender norms. Public policies that support work-life balance, parental leave, and flexible career pathways can also help retain women in STEM professions, allowing them to sustain long-term careers while managing personal and family responsibilities.

Ultimately, gender equity in STEM is not just a women's issue but a societal imperative that requires collective action from educators, policymakers, industry leaders, and communities. Achieving true gender parity will require sustained efforts to dismantle existing barriers and create environments where women are empowered to succeed in STEM. By fostering a culture of inclusivity, innovation, and equal opportunity, we can ensure that STEM fields benefit from the full diversity of talent and perspectives necessary to address the complex challenges of the future.

The findings of the present study underscore the importance of early exposure, supportive educational environments, and the presence of role models in fostering female participation in STEM. While some participants reported positive experiences, challenges such as gender biases, social isolation, and limited access to specialized training persist. These results align with previous research indicating that women in computer science often face unique structural barriers, including implicit biases, lack of role models, and limited access to peer communities (Cheryan *et al.*, 2017; Wang & Degol, 2017). Moreover, the findings suggest that participation in competitive programming plays a crucial role in skill development and career opportunities, reinforcing the importance of integrating such activities into formal education settings (Li *et al.*, 2019). However, disparities in school support and motivation indicate the need for more targeted interventions to ensure inclusivity in these competitive environments.

Future research may explore a broader sample of participants across different educational and cultural contexts to generalize findings and develop more comprehensive strategies for fostering diversity in computer science. As Xie *et al.* (2015) suggest, strengthening STEM education and reducing gender disparities are crucial for technological advancement and innovation. By addressing structural and cultural barriers, we can work towards a more equitable and inclusive STEM landscape for future generations.

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