Chapter

Gender Equity in STEM Education: The Case of an Egyptian Girls' School

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Abstract

This chapter explored gender equity in STEM education within the context of an Egyptian STEM school for girls. An intrinsic case study design was used to explore the experiences of girls in STEM from a socio-cultural perspective within a critical theory framework. The participants were STEM school graduates currently enrolled in engineering tracks in higher education institutions in the United States. Though STEM fields, especially engineering, are stereotyped as male dominated fields, Egyptian girls at a Cairo single sex STEM school pursued further studies in STEM fields. Findings show that gender gaps in STEM fields in Egypt and girls' education and work decisions were deeply influenced by their childhood background, family education level, socioeconomic status, and idiosyncratic factors like self-efficacy and resistance. At the school level, teachers' support, challenging STEM curriculum, dynamic formative assessment, student-centered pedagogies, female friendly teaching approaches, and a positive school environment played a great role in developing Egyptian female students' potential to pursue STEM fields in higher education institutions.

Keywords: gender equity, STEM education, case study

1. Introduction

Gender equity in education, especially in science, technology, engineering, and mathematics (STEM) education, is a global priority [1]. For example, only 20% of bachelor's degrees in the United States were awarded to women in physics and engineering, with only 35% of degrees across all STEM fields being awarded to women [2]. Women's under-representation in STEM has been observed in 50 countries around the world, making it a global issue present in both post-industrial and developing countries [3, 4]. Research in this area has explored underlying reasons behind the gender gap in STEM fields through consideration of biological, social, cognitive aspects or career preference and initiatives designed to promote females' pursuit of STEM [2, 5, 6].

Most of the research in gender equity in STEM education has been conducted in the Western world, whereas in the Arab world, gender equity is primarily reported by international organizations such as the World Bank [7] from a developmental perspective. Gender equity in the Arab world—a diverse grouping of 22 countries in the Middle East and North Africa—ranks lowest in the world [8] and Arab countries have the lowest female employment rates in the world. The few women in male-dominated fields experience traditional gender dynamics, are promoted less, and have little access to decision-making positions [9]. The roots of the gender disparity in the Arab World are arguably related to (1) the patriarchal structure in the region, (2) dominant public sector employment and weak private sector employment, and (3) an inhospitable business environment for women because of the conservative nature of gender roles [10]. Within the Egyptian context, women have not exceeded 24.2% of the overall workforce, with even lower participation in the male-dominated field of engineering [10, 11]. Attempts to address this have been underway since 1990s, including the establishment of STEM schools which provide the context for this study.

Two public STEM high schools (one for boys in 2011 and one for girls in 2012) were established to provide an alternative to the existing traditional teaching and learning approaches in Egyptian education system [12]. This was considered a bold move towards ensuring equitable STEM education opportunities for both male and female students [13]. All graduates from the first STEM school cohorts have joined STEM tracks in higher education institutions inside and outside Egypt. These STEM schools have unleashed the STEM potential in Egyptian young people, male and female [12, 13], and thus warrant exploration into their success in motivating Egyptian females into STEM careers. Hence, this study was initiated and guided by the following research questions:

1. What were the experiences of the female graduates of the Egyptian STEM high school that motivated them to pursue STEM fields in higher education?

2. What were the underlying social, personal, and school factors that made these STEM experiences successful?

2. Literature review

2.1 Egypt and gender inequity in education

The Egyptian general Secondary Education (EGSE) Certificate is the official gatekeeper for higher education in Egypt. The percentage of girls passing the EGSE exams in 2016 was 92.3% compared to 87.8% for boys and in 2017 87.7% for girls and 84.0% for boys [14]. Yet female numbers in science and engineering in higher education do not reflect these scores. Further, a comparison between females joining engineering schools and those who take up engineering professions reveals a further gap between academic study and employment [11]. The share of women within professional and scientific fields in Egypt is among the lowest in the world [7, 15].

Family background and geographic differences all contribute significantly to these gender disparities [10] in a country where women are seen as fragile and unable to compete with men in jobs like engineering. Culturally, this type of work is seen as taking a woman away from family which is considered the appropriate role for women [10], inevitably reinforcing the institution of marriage as a permanent alternative to work [16], especially when husband has the financial ability to sustain the household.

2.2 Research perspectives on gender gap in STEM

Different perspectives have emerged as to what constitutes barriers to women in the STEM fields [5, 17, 18]. These perspectives are reviewed in the following section.

Some researchers argue that girls' and boys' interests are inherently different [18]; girls are more interested in issues to do with human health and well-being, whereas boys are more interested in things to do with technology and physics (1). Even within science, it has been reiterated that women with an interest in science are more likely to enter fields such as psychology and the biological sciences. Indeed, interest in physical science on the part of boys and biological and social sciences on the part of girls has been found in children as early as first grade [17].

There is conflicting evidence regarding gender and academic performance in STEM. From one perspective, research posited that women come to know things in ways different from those of men; men tend to consider facts in isolation, while women integrate them into a broader context and tend to start from a personal experience. Thus, traditional mathematics teaching that targets algorithms and emphasizes abstraction, logic, and certainty may impact females' achievement especially in mathematics [19]. Even those women who were extraordinarily adept at abstract reasoning were found to have a preference for starting from personal experience [19]. However, a meta-analysis of 100 studies found that gender differences in mathematics performance are small [20]. For instance, it was reported that while males scored significantly higher on college entrance exams in the United States, females obtained significantly higher grades while in college [21]. Girls are expected to perform better in mathematics if teaching builds on the strengths of connected learners, focusing on experience, conjecture, induction, creativity, and context [22].

Socioeconomic and cultural elements also play a major role in determining female students' attraction to STEM related fields [2, 23]. The dominating social and economic culture, as well parental influence, that can be overt or subtle, may have a great effect on female students' academic preferences [16]. Eight key findings that point to environmental and social barriers to female interest and pursuit of STEM fields were identified—chief among them are stereotypes, gender bias, and the climate of STEM departments in colleges and universities—that continue to block women's progress in STEM [2].

Stereotype threats are considered a major factor contributing to gender disparity in STEM [24]. A stereotype threat "refers to the experience of being in a situation where one recognizes that a negative stereotype about one's group is applicable to oneself" ([25], p. 5). Stereotype threats include the belief held by many pre-college women that they would be isolated in engineering tracks due to their gender and that they do not have a strong enough mathematical background to pursue an engineering career [24] arguing that stereotypes predict national gender differences in science and mathematics achievement, rather than simply a consequence of generalized national gender inequality. There is need for building a positive learning environment to enable female students to develop positive STEM identities that persist across K-16 and into STEM careers and dispel stereotype threats [23].

2.3 Pathways to improve gender equity

Confronting gender disparities in STEM requires efforts on several fronts: sociocultural, personal, and school levels including fostering self-efficacy and improving the classroom environment to create a female friendly atmosphere to overcome stereotype threats [26]. At the school level, teachers need to change the way they give critical feedback; foster intergroup conversations among students from different backgrounds; allow students, to affirm their most valued self; help students develop a narrative about the setting that explains their frustration while projecting positive engagement and success to improve their sense of belonging and achievement [27]. In this sense, calls for girl-friendly instructional strategies are timely [28].

These strategies include making content relatable to everyday applications through societal connections and connections to prior experiences [22]. Participation in hands-on activities and extra-curricular STEM activities has also been shown to enhance girls' skills [18, 29].

Fostering girls' self-efficacy is a significant factor in improving equity in STEM [30, 31]. Self-efficacy refers to one's belief about their ability to succeed in a certain task [32]. Increasing self-efficacy can overcome the stigmatized stereotypes of women being perceived as not compatible for STEM fields [5, 24]. Integrating STEM project-based learning into the curriculum and providing female role models can enhance STEM self-efficacy and professional commitment to engineering [33, 34].

Research findings reported that the academic performance of friends of the same gender significantly predicted course taking in all subjects for girls [35]. Specific to mathematics and science, "the effects of friends' performance are greater in the context of a predominantly female friendship group, which suggests that such groups provide a counterpoint to the gendered stereotypes and identities of those subjects" ([35], p. 221). The creation of same sex learning environments is also responsive to what the American Association for University Women (AAUW) [36] refer to as indicators for gender bias in co-educational classrooms, both at the K-12 and higher education levels. American Association of University Women (AAUW) maintains that females have historically received less teacher attention than boys, feel less comfortable speaking out in class, face threats of sexual harassment in school [36]. These indicators suggest single-sex schools or classrooms as a solution to the gender gap in STEM. The National Association for Single Sex Public Education also indicates that girls in single-sex educational settings are more likely to take STEM classes as girls have more freedom to explore their own interests and abilities in single-gender classrooms [37].

However, there are conflicting findings concerning single sex educational experiences [38] that warrant further research. Both single sex and coeducational schooling can provide successes or failures depending on how these school systems are implemented, indeed "sex-segregated education can be used for emancipation or oppression. As a method, it does not guarantee an outcome" ([39], p. 189). In other words, the quality of the education provided in terms of professional well-trained teachers; well-equipped schools, and well-designed, engaging curriculum; and positive school atmosphere is the main factor for success in either system.

Based on the literature reviewed, it can be argued that girls are able to excel in STEM related fields when they are placed in a learning friendly atmosphere, where quality education is provided and social barriers such as stereotyping and gender bias are absent. Providing female friendly school environments, using dynamic formative assessments, STEM focused curriculum [40], working in a non-competitive, and in some cases same sex environment [38, 39] can be assets towards improved girls' performance, excellence and understanding of STEM related fields.

3. Conceptual framework

The nature of gender inequity in STEM can be conceptualized as an outcome of intersectional power dynamics between social, cultural and personal frameworks [41, 42] reflecting a recursive relationship between social structures and cultural representations [42]. Within this social critical theory framework, the commitment to justice liberates individuals from conscious and unconscious constraints that interfere with balanced participation in social interaction [42, 43] in an effort to analyze the constituents of the cultured context and replace them with emancipatory ideologies. Accordingly, knowledge generation and identity formation can be based on a critical reflection of the power relationships which are embedded in the structures and functions of society where society is structured by meanings, rules, convictions or habits adhered to by social beings [41, 43].

In spite of all the written documents, laws and codes of ethics that guarantee equity in all fields, the low representation of females in different male dominated fields might underlie, in addition the social intersectional power dynamics, the less-than democratic character of STEM occupations [44]. There is compelling evidence that gender roles are largely created and maintained in structured social order, with specific roles assigned to each group that reflect a myriad of cultural, social, religious, and political beliefs and boundaries [45, 46]. Davies [45] alluded to the subtle perception disseminated among family members and society at large that girls are looked upon as "fragile, weak, and powerless" ([45] p. 68), making a decision to pursue engineering as a career is a challenge to this social image reflecting different contextual barriers to such career choice [47]. "Resisting this prevailing pattern gender inequity, occurs on three levels: personal level; the group or community level of the cultural context created by race, class, and gender; and the systemic level of social institutions" ([43], p. 227).

4. Methodology

4.1 Context of the study and research design

The STEM high school for girls in Cairo, Egypt, along with another school for boys, were the first two model STEM schools in the country. The girls' STEM school was established during the turmoil and rising aspirations of January 25th, 2011 revolution. The STEM initiative in Egypt was supported by a grant from the United States Agency for International Development (USAID), with Education Consortium for the Advancement of STEM in Egypt (ECASE) leading the process of curriculum development, teacher professional development and technical support [13, 48]. As part of the project, the ECASE released quarterly reports on the development of all aspects of the STEM schools' projects including teachers and students' achievements [49]. The number of STEM schools has now expanded to 11, located in different Egyptian Governorates with hopes of having a school in each of the 27 Governorates [50].

The first two STEM high schools were boarding schools, with students being selected from across the country using a merit-based criterion. Teachers were selected mainly from the existing teachers in the Ministry of Education through a competitive process that included an online language exam, subject matter test, and interview with Ministry of Education officials [12, 13]. The language of instruction is English, while most of the students come from schools where Arabic was the language of instruction.

Students in the girls' STEM school experienced the same curriculum as the boys' school, including project based learning. The female graduates have been successful in terms of enrollment and achievement in the STEM fields. All the graduates of the first two cohorts—except for two who joined business administration—joined STEM tracks in higher education institutions. Around 70% joined science and engineering programs at universities inside and outside of Egypt. The other 30% joined medical-related fields, like medicine, pharmacy, and physiotherapy. Students participated and won prizes in science and engineering fairs at the local and international levels, encouraging more girls to follow on their footsteps, as evidenced by the large numbers of girls competing to join these schools and the number of girls applying for STEM schools outnumbering boys in 2017 [51].

The first author started working at the STEM school for girls in the second semester of its first year as a teacher of English as a foreign language. Subsequently, he took over the role of a coordinator of professional development for the teachers and supervising the students' capstone STEM projects completed each semester. This experience lasted for three consecutive years where he had built very good relations with students and teachers alike. This provided a rich understanding of the school context and familiarity for the participants in sharing their experiences.

An exploratory, descriptive intrinsic single case study design [52] was used as the purpose of the research was to look at the experiences of the STEM girls in its entirety including social, school, and personal aspects corresponding to the nature of an intrinsic case study wherein the participant, in this case the female STEM graduates, itself is the primary interest [52]. In this case study, the individual female participants represent the units of analysis. The study was reflective and retrospective in nature as the participants graduated from the school 3 years ago. This provided a robust design as the participants had a chance to reflect on the impact of their experiences at the STEM school on their learning at the university level.

4.2 Participants

Participants (see **Table 1**) were purposefully selected [53]. The criteria used for selection were (1) female graduates of the STEM school who joined engineering schools in higher education, (2) lived in the United States at the time of the study as the first author was there doing his doctorate, (3) came from different geographical locations in Egypt to reflect the different socio-cultural background of different locations in the country, and (4) from the first cohort of girls at the STEM high school to reflect both the challenges and success of the introduction of STEM schools. Selecting students living in the United States was a delimitation as a response to logistics reasons. Five graduates who pursued engineering at higher education in the United States were selected.

4.3 Data collection

Semi-structured interviews were conducted with the five participants. One of the interviews was done face to face, while the other four interviews were

Name*	Where from	Parents' background	HE major
Aida	Cairo	Father is an engineering professor and mother is in management position	Computer Engineering
Alia	Cairo	Father is an engineer	Biomedical Engineering
Fareeda	Delta	Father passed away while at elementary student and mother is a teacher and brother is an engineer	Chemical Engineering
Latifa	Delta	Father is a civil servant and mother is a language teacher	Computer Engineering
Muneera	Upper Egypt	Both father and mother are high school education level and all her siblings are medical school graduates or students	Biomedical Engineering

**Names are pseudonyms.*

Table 1.
The participants' names, geographical locations, family background and HE majors.

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RQ	Sample interview questions
What experiences did the graduates of the Egyptian STEM high school have that motivated them pursue STEM fields in higher education?	How would you describe your experience at the STEM school? How was working with girls from different backgrounds for you? What was it like? What was special about the school's curriculum? Describe how were teachers' teaching approaches different? How was assessment different from those in your previous school, if at all?
What were the underlying personal, social, and school components that made these STEM experiences successful?	Tell me a little about your family? What is your father's occupation? Your mother's? What were your major interests before joining STEM school, literature, mathematics, science? If the MoE decided to build more STEM schools, what would they consider? Tell me a little bit about how you thought about mathematics and science in middle school?

Table 2.
Sample interview questions aligned with research questions.

conducted using Skype. Interview questions were designed to inform the research questions and address the different aspects of the conceptual framework of the study (see **Table 2**).

5. Data analysis

The interviews were recorded, transcribed, and coded. Content and relational inductive open coding was conducted vertically (for each participant) and horizontally (across the different participants) [54]. Next, axial coding was used to identify emerging themes. The data was revisited multiple times to make sure that the emerging themes and subsequent assertions were backed by the participants' words and perspectives.

An in-depth data analysis was used to synthesize the findings between the separate cases to understand similarities and differences among them [54]. These final themes were then connected to the theoretical and conceptual framework of the pertinent research on gender equity in STEM [2, 6, 23, 26, 43]. Ultimately, a contextualized intersectional argument depicting a layered pattern of supports and barriers for equity in STEM education in this case emerged.

5.1 Findings

In this section, cross-case narrative and analysis of the participants' unique experiences is provided. The themes that emerged from this cross-case analysis are discussed in depth providing an intersectional pattern of supports and barriers to gender (in) equity in STEM education in this study's context. **Table 3** portrays these emerging themes. The themes are categorized into three levels: family and social; personal; and school.

5.2 Emerging themes for the cross-case analysis

5.2.1 Family supports and barriers versus personal choices

The interaction between the social and personal power dynamics among the participants revealed a direct relationship between family bias and the girls'

Themes	Subthemes (codes)
Family and social barriers and supports	Parents' support Stereotype threats and (gender) biases
Personal aspects	Self-efficacy Persistence Resistance
School level supports and barriers	Challenging curriculum Dynamic formative assessment Teachers' support Student centered teaching strategies Positive school environment Extracurricular activities Single sex school setting

Table 3.
Supports and barriers for gender equity in STEM education that emerged from the qualitative interviews.

resistance. Three of the five participants in this study faced family biases against their dreams to be engineers. Fareeda's family members and teachers in primary and middle school adopted the perspective that "engineering is not for a girl." Fareeda's brother, who was an engineer himself, told her that "engineering is hard for me as a boy; what about you as a girl?" Likewise, Latifa, whose father was a civil servant and mother a teacher of Arabic, used to dream of being a doctor deeply affected by her mother's thoughts that "engineering is more like for guys, but medicine is very good for girls." Muneera's parents saw "engineering as having a lower status than medicine." With a middle-class family background with a high school education, Muneera's siblings, were either in or had graduated from medical school; "they [parents] wanted me to be a doctor and I wanted to be a doctor, too. Being an engineer didn't come to their or my mind at all."

Fareeda's teachers at primary and preparatory schools, all of whom were female, had the same perspective telling her that being "a doctor is good for a girl." Additionally, Fareeda's late father was hoping that she would be a doctor 1 day, so in addition other family and teacher preferences, she also wanted to honor her late father's wishes. Before joining the STEM school, Latifa was interested in mathematics which "has always been my favorite subject at school, even before STEM school, because for me it was very easy to do, like it's just simple, but I didn't like social studies because it needed a lot of memorization." While at the STEM school, she realized that as she was "better at math [ematics], it only makes sense if I become an engineer." When she decided to major in mathematics in high school as the pathway to engineering, her mother was initially upset. However, she did not press Latifa since she trusted her choices; "my mother believed in me."

Fareeda was able to confront the family and social bias with high degrees of self-efficacy, resistance, and persistence. Fareeda insisted, now "I see myself as an engineer and I will be an engineer." However, while at the STEM school, she decided to join the science major as this was the path to medical school in the Egyptian system, whereas entry into engineering would have required her to major in mathematics in high school. Her scores qualified her to join the school of medicine, however, she told her mother and brother while she realized their dreams, but she wanted to pursue her own dreams and instead applied for an engineering school in the United States, where she was accepted with a scholarship. She recalled, "They did not object this time. And my brother started to support me in my new adventure." Latifa followed Fareeda's suit, her parents became "so proud of" her and started to look at her as "an idol [model]" for other students to follow after she followed her passion for engineering. Interestingly, this did not prevent Latifa's mother from occasionally reiterating her wish that her daughter had chosen "the biology major and then she can become a doctor." Muneera also decided to break the family norm and become an engineering major. Yet she faced huge opposition; she had to join school of medicine for one semester before the call for engineering became irresistible. She joined a school of engineering in the United States after being accepted for a scholarship to fund her studies. Muneera's parents could not accept the idea that she would be an engineer and as Muneera reported "They still don't like it."

On the other hand, Aida's parents were supportive of her choices. Aida's father, who received his PhD from the United States and is currently an engineering professor, and her mother, who holds a managing position in a big company, "encouraged [her] and said let [her] try and discover things on [her] own." Prior to attending the STEM School, Aida attended a school where mathematics and science were taught in English, unlike other public schools in which this was done in Arabic. This was an asset for her in the STEM school where instruction was all in English. However, earlier in her primary and middle schools, she was more interested in "sports." Later, she discovered that she was good at mathematics; "I do calculations fast, and understood mathematical problems, but I did not imagine spending my life doing that [dying mathematics]." She became interested in "the value of education and especially engineering' only after witnessing the January 25th revolution and understanding how Egypt needs more educated people, scientists, and engineers to change its status quo. Aida believed that her study and career choice was not only affecting herself, rather "education especially engineering will help improve our country in the future" and that as an engineer she would "have a bigger impact than just like being a politician, architect, or doctor."

Likewise, Alia's father, being an engineer himself, "pushed her forward." She stated, "my parents were really encouraging and whenever I was in doubt. They were pretty supportive. I don't think they had any negative feelings towards STEM school at all." Her favorite subjects were mathematics and science which "were not challenging for me at all, what was challenging was the memorization-based subject like Arabic and social studies."

5.3 School level supports and barriers

5.3.1 STEM school experience and extra-curricular work

The different atmosphere, school culture, curriculum, relationships and assessment systems at STEM school provided a new opportunity for the participants to unleash their STEM potential beyond expectation. Aida argued that the STEM school changed her view about education as not just "buildings where students go to learn subjects like math and science" to the view that education is "about changing our way of thinking." Alia considered her STEM experience as "a very good one that [she is] grateful for being part of it." She maintained how the STEM school experience made them "independent [learners] in terms of that we had to self-learn, think, collaborate, and create … and come to class prepared to present." In her opinion, this was "interesting as it was student centered and taught us teamwork." Along the same lines, Latifa considered her STEM experience as "the greatest thing that happened and will ever happen in my life and I'm not exaggerating." It helped her to become "a good learner and a researcher." She stressed the perspective that the things she learned in STEM school would not have been possible in any other place: "I learned teamwork…how to talk with different people who have different perspectives and everything literally everything …all that I learned in STEM school way practice and [with] teachers' guidance." The school as a boarding national school was a mini cosmos. Through their experience with girls coming from "different parts of Egypt with different cultural backgrounds" in Aida's words, they gained a lot of experience dealing with people from different backgrounds which was "very helpful for her life in college in the United States."

Fareeda greatly valued her experiences at the STEM school. The teachers, in her view, were "like our parents" and "they were caring for us and tried to help us the most." She cited the example of the physics teacher when she talked to him about "her dream to be an engineer while [her] family wanted [her] to be a doctor', he advised her to 'follow [her] dream as [she] won't excel in a thing [she] doesn't like." Aida described the teachers as "very friendly even at the moments we made sit-ins and called for reforms to make our school better, they backed us." She went on to say, "they escorted us in our journeys outside the school looking for materials for our projects, and meeting with other experts in different places." She added, "they helped us to find new ways to get information, they used different teaching approaches like discussion." Latifa remembered how teachers were careful to warn students that "being different [as STEM students] does not mean being better than anyone else we're all good in our own unique ways." She maintained how the teachers used different teaching approaches: "some let us prepare materials and present them and they gave us comments and guided our discussions." Muneera also praised her teachers as supportive using "different strategies, but the majority helped us to be independent learners. I can depend on myself now at college if I don't understand something." In some classes, learning "was completely student centered where we did the entire presentation and the teacher was supervising us and only corrected us when there was something wrong."

However, all participants were concerned that "the teachers needed more training and professional support in STEM," especially with regard to assessment as "we were, not trained enough to answer the kind of questions we faced in the final exams." Latifa alluded to the need for teachers' readiness stating that "if teachers do not know or do not understand the [STEM] system, that would be a big problem for students because if students don't understand what the system is, teachers should know because they're supposed to teach students how to do things."

All of the girls valued the challenging and rigorous curriculum. For example, Aida stated, "the curriculum was so challenging with college level material" citing the different modes of assessment used at school as very conducive to learning. As a result of the challenging curriculum and assessment, Aida "had [knowledge] about nearly all the topics in my freshman year in classes like physics and calculus." Because of the college level content at the STEM school, Latifa was "tested out of calculus 1, 2, and 3 [because] most of these topics I covered in high school and also like physics one and two and chemistry one. I had all these topics [covered] in high school. Now I'm in physics 3 and I study some topics about waves and resonance and I remember how I used to watch videos explaining these topics in high school." She added that other things like "presentation skills and collaborative work [she learned at STEM school] were very helpful at college level." Alia noted that "the curriculum was very different from regular schools in Egypt and challenging." She found the college level material very helpful and shared that when she went to college, she "found many things especially physics and math I had covered in STEM school… and the way was taught it was special."

What was unique about the curriculum in Latifa's thought was the idea of not being restricted to text books; "you can understand the learning outcome from different references: the internet, teachers, colleagues." The curriculum at the STEM school was "more open" in Muneera's terms. She argued that "in subjects like biology and chemistry at the school I had the opportunity to dig deeper into the things I was interested in and I really appreciate that." That helped her a lot at university but "this openness was not good all the time. In some cases, it was not very straightforward [clear]. The goals of the curriculum or what do we have to learn after studying this subject were not clear."

For the capstone, for instance, Muneera mentioned that "each group was required to submit the following: a prototype or model of their solution, a scientific poster of the whole project, the project portfolio, and do biweekly journal reflections." Alia also mentioned the capstone project as "pretty challenging but also very useful in terms of helping us to acquire more knowledge, research skills, such as problem solving and technical skills like for creating the prototype, not to mention enhancing presentation skills." Latifa thought that the capstone projects were "the biggest point of the learning in STEM I guess... how we were supposed to deal with real-world problems and like find practical solutions for them. That was big." This was initially challenging for her as she was not used to this approach to learning and also that the teachers were learning this new system alongside the students.

In Aida's words, assessment was "different and difficult" with a "final exam each semester which accounted for 30% of the final grade where we worked collaboratively to solve one of the grand challenges of Egypt following the engineering design process." This was completely different from the mainstream secondary schools where grades were based solely on traditional final exams. Assessment, however, was challenging as it was completely different to traditional schools and "there were no direct questions because you have to think. You don't have to memorize ...they were super challenging the first 2 years." Muneera described assessments as "checking understanding not checking memorization." Challenging as it was, assessment was more manageable and conducive to learning than "memorizing a book from cover to cover and then forget everything after the exam is over." Alia noted that the "assessments were different from the ones they had been used to, but we could eventually answer most of the questions." She found the college level material very helpful and shared that when she went to college, and "the way it was taught was special."

As learning dose not only happen inside the school premises, out of school extra-curricular work was seen as an integral part of the STEM school experience. The school provided different civic engagement opportunities with several organizations that gave students opportunities to visit universities and research centers to discuss scientific and engineering ideas. Muneera, for instance, was interested in chemistry outside of school and she used to "interact with those responsible for the chemistry Olympiad. They were faculty from universities." In addition to her work in the capstone and extra effort needed to finalize projects she "visited a lot of universities and interacted with professors there." Fareeda viewed engaging in different out-of-school activities and field trips as one of the greatest assets of the STEM school. She described the International Science and Engineering Fair (ISEF) experience as the "best thing that happened" to her in the STEM school. She learned a lot from that experience, in addition to winning the first award and participating in the United States international competition and winning the third place in their category, she learned "group work, presentation skills," and how to defend her ideas "in front of Nobel laureates." Latifa described her participation in a programming camp as a great learning experience: and "in the second year of high school I participated in Intel ISEF competitions and science fairs with EEE science fairs with the capstone project."

The research work required of students at the STEM school also pushed them to seek support outside the school walls. Aida recounted, "when I was in school, I worked on a project with the physics department at the American University [in Cairo]. I also went to Cairo University, and different [other] universities for school [projects] that helped me understand how research is done in university." Aida thought that these activities were of great value in her college level studies. Alia mentioned visits to "different universities and research centers and talking to professors about their projects" as reinforcing their STEM identity as they were "able to ask questions and discuss our work in a free way." Alia described the physical work they used to do build their projects prototypes; "in addition to engineers and professors who helped us in designing our [capstone projects] prototypes, we also sought the help of technicians like plumbers, carpenters, electricians to build certain parts of these prototypes."

Among the challenges faced by two of the participants (Muneera and Fareeda) was studying engineering while not being a mathematics major in high school. Muneera said it was a challenge at the very beginning but she added "I am doing very well in math now" and that the skills from the STEM school rather than content were the reason as, "now [at college] when I am stuck in anything, I can teach myself... I do not need someone to teach me...I can go find books or the internet, or any way to understand so I really think this was great from the school. I learned how to work in a group, though I speak different [foreign] language [with accent] I had the strong personality to face challenges... I had learned a lot how to deal with people." Alia argued that the experience at STEM school was invaluable in terms of helping them address any academic challenges because it helped her to be "an independent learner and know how to collaborate." On a personal level, she felt "it [STEM school experience] made me more confident and made my first years at college easier."

5.3.2 Single sex school setting

Being in a single sex school was not a new thing for almost all participants who come from Egyptian public schools. The general rule is that starting from grade seven most schools are segregated except for a certain track called "distinguished public language schools" in which mathematics and science are taught in English. Fareeda was a staunch supporter for single sex STEM schools as long as "they provide quality education and have similar teachers [to our school] and [similar school] environment." She argued that the female students "felt more comfortable" and had "the chance to work together freely without pressures, to compete in the female way to excel." She concluded, "it was a great experience all over. We worked together in a friendly way." Aida thought that single sex schools are "good, but they need more planning." If she were to choose between a co-ed or a single sex school, she would "choose a single sex school because the friendly atmosphere developed at the school made the students closer to each other in a way you can't find in another school." Along the same lines, although Alia initially stated that she "did not have a preference" for single sex versus co-ed schools, she "would choose the single sex school just because we created a community in which we lived together as sisters, it was kind of empowering." Therefore, if she were given the choice, she "would definitely go for single sex schools."

On the other hand, when asked about the single sex learning experience, Latifa was vocal in resisting that type of schooling. She said, "I think it would be better if both sexes were in the same school because I believe that this system and the way of thinking will be more inclusive of the two ways of thinking [male and female]." Latifa posited the reason behind the fact that girls' school "was relatively better at getting like high grades, while they [boys] win more robotics competitions and programming and like the technology stuff" is due to "a natural difference between the two [genders] in terms of foci and interests."

Muneera said, "if I went back I would prefer mixed schools." She had a hard time adjusting to the coed nature of higher education. All of her pre-university education life, including the STEM school, was single sex. Therefore, her ability to communicate with people from both sexes was affected by this long education experience. She explained "it was kind of the challenge when I came here. At the beginning I could not deal with guys. It was hard because I didn't have experience. I did not go somewhere else. I was all my life in that single sex school system." However, her experience in the STEM school pushed them "to build the environment where we're supporting each other and learning from each other as different people coming from different backgrounds."

6. Discussion

From a cross-case perspective, a multilayered pattern of the supports and challenges [47] that impact gender equity in STEM education in the Egyptian context were delineated (see **Table 3**). The intersectional nature of the educational and sociological phenomena [41–43] is clearly reflected in the journey of the participants in this study. The participants endeavor towards STEM fulfillment reflects the power dynamics and relationships which are embedded in the structures and functions of society where society is structured by meanings, rules, convictions or habits adhered to by social beings [42, 45, 46]. As a result of the data analysis, the underlying mechanism of factors that support or impede girls' pursuit of STEM tracks show complexities of the phenomenon of creating gender equity, both broadly and especially in the Egyptian context. This is clearly manifested in the emerging themes from the data analysis (see **Table 3**). The intersectional pattern includes the impact of the power relationship of the socio-cultural, educational, and personal aspects.

For instance, the existence of stereotype threats and biases [27] was salient in most of the participants' experiences. However, this was diminished by both factors at the personal and school levels epitomized in the girls' resilience and the supports they received through their experiences at the STEM school. The girls did not concede to family and social pressures; they pursued their own dreams. In their emancipation journey, they showed high degrees of persistence, self-efficacy, and resistance to the social norms and stereotype threats at the family level and the immediate social network [42, 45, 46]. In spite of the challenges they faced, the girls were able to navigate through this experience and benefit from it in their higher education engineering institutions.

In addition to the intersectional nature of the socio-cultural phenomenon of gender equity in STEM, these cases present a clear example of how gendered roles are created at both the social and family level [42, 45] and how they can be disrupted. One way to challenge such fossilized gender roles either explicitly or implicitly, especially in the absence of social collective effort, is through consolidating personal traits like self-efficacy and persistence [30, 31, 33]. This is apparent in girls' defiance to the commonly accepted stereotype that it is hard for girls to be engineers. There seemed to be a strong relationship between the degree of bias and the level of resistance on the part of the girls; in the cases where gender bias was explicitly reiterated, there was markedly higher degrees of resistance to such stereotype threats [27, 42]. However, to address gender inequity in STEM, more work at the social level and at school level is required [6, 29, 34, 44].

The school and teachers provided additional support to the girls' personal resilience. All participants referred to factors at the school level that were effective in deepening their interest in STEM, especially engineering. At the curriculum level, one of the common features was rigor and challenge. Moreover, at the assessment level, participants agreed that assessments were not checking memorization; they were checking understanding which has helped them in their higher education institutions. Not only did the participants refer to the challenging curriculum but the way that curriculum was delivered. The primary support came from the girl-friendly pedagogies they encountered at school. They referred to quality teachers utilizing student-centered approaches to teaching and learning, linking learning to real-world situations, group work, peer teaching, providing opportunities for students to increase their interest in STEM, linking content to prior experiences, providing first-hand experiences, encouraging discussion and reflections of the social importance of STEM fields, engaging students in collaborative learning, and a safe learning environment which all concur with research concerned with bridging the gender gap in STEM fields [6, 23, 26, 28]. This was documented in the ECASE reports as early as 2013 [47] in which it was noted that teachers have improved considerably in maintaining collaboration and adopting student centered pedagogies in their teaching [47]. Teachers were also viewed by all participants as supportive, encouraging and caring being viewed by most of them as “parents”, though in almost all cases, students referred to the fact that teachers were still in need of more professional development. Research shows that quality caring teachers’ support is crucial for a female equitable STEM experience [18, 22, 23, 29, 36].

Although there was variation of perspectives around the idea of single sex schooling, there was consensus that it provided a safe, comfortable environment for learning where collaboration and minimized competition was present. However, from the input provided by the participants, single sex school experience in itself and by itself was not a guarantee for gender equity learning experience in STEM [36, 38, 39]. In two cases, the outcome of the experience was not positive in the long term. It was hard for some of the girls to adapt to an environment where they had to deal with male and female students together in an academic environment. As a result, they felt frustrated at certain points for not being able to socially adjust to a coed institution environment though they were academically well prepared and maybe over prepared to these institutions.

The tension between providing a female-friendly, safe, and comfortable environment for female STEM students to work in; and at the same time nurturing the skills of being a part of a wider society was problematic. There is a need, therefore, for a balanced educational situation where girls are provided with the safe environment to learn and at the same time get involved in a socialization process that prepares them to the college level where a coeducational setting prevails both inside and outside Egypt [1, 3, 13]. Indeed, in the new STEM schools in Egypt, girls and boys attend the same school with classes inside the schools segregated by gender. Though this decision was made for economic reasons because it is hard to build a separate STEM school for each gender in each city, it can be one way to alleviate the tension between providing the female friendly safe environment while helping consolidate the socialization process that they will need later on in their academic and professional life.

7. Conclusion

Gender inequity in STEM in Egypt is a complex issue. While research denotes different reasons that would influence a girl’s preference of an education pathway, the education and career choices of the participants in this study were deeply influenced by their family and community [47]. With the socio-cultural aspects in the background personal aspects like self-efficacy, resistance, and persistence play a great role in students’ decisions to pursue STEM fields [24, 25]. As indicated in the literature, girls experience stereotype threat throughout their schooling related to the pursuit of a STEM career. In Western countries, these biases are often implicit and experienced as micro-aggressions [3, 4], however, in the Arab world, girls experience explicit and direct bias from family and society [10, 11]. Thus, the government stance of providing STEM schools for girls is an important statement to the community that girls can be successful in STEM.

Without effective and equitable school settings factors at the personal and the social level cannot have such deep effects on the girls' free career and educational choices. School level factors like curriculum, positive environment, female friendly instructional approaches, teachers support are key factors as shown by the girls' experiences in the STEM school [29]. Moreover, success in post-secondary STEM degrees is strongly influence by students' high school preparation, particularly in mathematics [33, 55]. Thus, it is important that girls receive the same level of high school STEM preparation so they are prepared for success in college. All of the girls indicated how well prepared they were for academic success. Equally important, is that the school experience fosters girls' interest and STEM identity through using a female friendly approach to teaching [23, 55].

With the different model of teaching and learning at the girls' STEM school in Cairo, the girls had the opportunity to unleash their STEM potential. This emancipatory effect of the STEM school experience has not only increased the girls' persistence and resistance to the gender bias and stereotype threats concerning STEM fields as male dominated but unleashed the girls' social and transformative potential towards building a more equitable society.

It is, therefore, recommended that much effort at both the academic and social levels is needed in order to create an environment where girls have an equal opportunity to study and excel in STEM fields. These recommendations include embracing a female friendly instructional paradigm while adopting a school system where girls are provided safe space for practice, competition, collaboration and ease of communication with others. Higher education institutions should be providing a more flexible admission system similar to that found in the United States and Europe giving access to students from different tracks at high schools to be admitted to their colleges of preference based on their interest and aptitude as some of the participants in this study applied to colleges abroad because the admission system in Egypt public universities would not allow a student graduating from high school with a science major to enroll in the school of engineering. Finally, at the social level, combating negative stereotyping is a necessity for building a sound education system for all. This is a long journey where a lot of work is needed in schools, homes, and media level. Therefore, there is a need for moving forward from the dictum concerning equity to real actions.

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References

[1] Penner AM. Gender inequality in science. Science. 2015;**347**(6219):234-235

[2] Hill C, Corbett C, Rose A. In: Hill C, Corbett C, Rose A, editors. Why so few? women in science, technology, engineering, and mathematics. Washington, DC: The American Association of University Women Educational Foundation; 2010

[3] Reay D. "Spice girls," "nice girls," "girlies," and "tomboys": Gender discourses, girls' cultures and femininities in the primary classroom. Gender & Education. 2001;**13**(2):153-166

[4] Sikora J, Pokropek A. Gender segregation of adolescent science career plans in 50 countries. Science Education. 2012;**96**(2):234-264

[5] Ahlqvist S, London B, Rosenthal L. Unstable identity compatibility: How gender rejection sensitivity undermines the success of women in science, technology, engineering, and mathematics fields. Psychological Science. 2013;**24**(9):1644-1652

[6] Baker D, Krause B, Yasar S, Roberts C, Sharon R-K. An intervention to address gender issues in a course on design, engineering, and technology for science educators. Journal of Engineering Education. 2007;**96**(3):213-226

[7] World Bank. Arab Republic of Egypt: Inequality of opportunity in the labor market. Report no. 70299-EG. 2012. Retrieved from: https://blogs.worldbank.org/files/arabvoices/jan_2013_blog_-_inequality_of_opportunity_in_the_labor_market-_report_no_70299.pdf

[8] World Economic Forum. The Arab World competitiveness report. Geneva: SAGE Publications. 2018. Retrieved from: https://www.weforum.org/reports/arab-world-competitiveness-report-2018

[9] Abirafeh L. What's Holding Arab Women Back from Achieving Equality? The Conversation. 2017. Retrieved from: https://theconversation.com/whats-holding-arab-women-back-from-achieving-equality-74221

[10] Krafft C, Assaad R. Inequality of Opportunity in the Labor Market for Higher Education Graduates in Egypt and Jordan. Working Paper. 2015. Giza, Egypt: The Economic Research Forum (ERF). Available from: https://erf.org.eg/wp-content/uploads/2015/12/932.pdf

[11] Central Authority for Public Mobility and Statistics (CAPMAS). Annual version of "Egypt in Figures 2018" booklet. http://www.capmas.gov.eg/HomePage.aspx [Accessed: 30 November 2018]

[12] Rissman-Joyce, El Nagdi. MA Case study-Egypt's first STEM schools: Lessons learned. Proceeding of the Global Summit on Education (GSE2013). 2013. Retrieved from: https://goo.gl/FVSkT8

[13] Abouserie R, Merlino FJ. A revolution inside a revolution: Tales of radical educational transformation in a new Egypt, Part 1. In: Paper Presented at the Annual Meeting of the American Education Research Association. Philadelphia, PA; 2014

[14] Egypt Ministry of Education (MoE) Statistics and Indicators. Available from: http://emis.gov.eg/matwaya_egov.aspx?id=401 [Accessed: 25 March 2018]

[15] Schmuck C. Women in STEM Disciplines: The Yfactor 2016 Global Report on Gender in Science, Technology, Engineering and Mathematics. Cham, Switzerland: Springer; 2017

[16] Verme P, Barry A, Guennouni J. Female labor participation in the Arab world: Evidence from panel data in Morocco. Labour. 2016;**30**(3):258-282

[17] Clewell B, Campbell P. Taking stock: Where we've been, where we are, where we're going. Journal of Women and Minorities in Science and Engineering. 2002;**8**:255-284

[18] Little AJ, león de la Barra BA. Attracting girls to science, engineering and technology: An Australian perspective. European Journal of Engineering Education. 2009;**34**(5):439-445

[19] Belenky M, Clinchy B, Goldberger N, Tarule J. Women's Ways of Knowing: The Development of Self, Voice, and Mind. 10th Anniversary ed. New York: Basic Books; 1997

[20] Hyde JS, Fennema E, Lamon SJ. Gender differences in mathematics performance: A meta-analysis. Psychological Bulletin. 1990;**107**(2):139-155

[21] Mau W-C, Lynn R. Gender differences on the scholastic aptitude test, the American college test and college grades. Educational Psychology. 2001;**21**(2):133-136. DOI: 10.1080/01443410020043832

[22] Häussler P, Hoffmann L. An intervention study to enhance girls' interest, self-concept, and achievement in physics classes. Journal of Research in Science Teaching. 2002;**39**(9):870-888

[23] Schellinger J, Billington B, Britsch B, Santiago A, Carter S, Hughes R. Gender equitable teaching and learning in STEM spaces. In: Proceedings of the international NARST Annual International Conference; 9-13 March 2018; Atlanta, Georgia

[24] Nosek BA, Smyth FL, Sriram N, Lindner NM, Devos T, Ayala A, et al. National differences in gender-science stereotypes predict national sex differences in science and math achievement. Proceedings of the National Academy of Science. 2009;**106**(26):10593-10597

[25] Steele C. Expert report of Claude M. Steele. 1998. Retrieved from: http://www.umich.edu/-urelladmissions/legal!expert/steele.html

[26] Rosser S. Female-friendly science-including women in curricular content and pedagogy in science. The Journal of General Education. 1993;**42**(3):191-220

[27] Steele C. Whistling Vivaldi: And Other Clues to How Stereotypes Affect Us. New York: W.W. Norton & Company; 2010

[28] Dare EA. Understanding middle school students' perceptions of physics using girl-friendly and integrated STEM strategies: A gender study. Retrieved from: ProQuest Dissertations and Theses A&I; (1725906382) 2015

[29] Baker D. What works: Using curriculum and pedagogy to increase girls' interest and participation in science. Theory Into Practice. 2013;**52**(1):14-20

[30] Heilbronner NN. Stepping onto the STEM pathway: Factors affecting talented students' declaration of STEM majors in college. Journal for the Education of the Gifted. 2011;**34**(6):876-899

[31] Heilbronner N. The STEM pathway for women: What has changed? The Gifted Child Quarterly. 2013;**57**(1):39-55

[32] Bandura A. Self-efficacy: Toward a unifying theory of behavioral change. Psychological Review. 1977;**84**(2):191-215

[33] Yi-hui L, Shi-jer L, Ru-chu S. The investigation of STEM self-efficacy

and professional commitment to engineering among female high school students. South African Journal of Education. 2014;**34**(2):392-407

[34] Lourens A. The development of co-curricular interventions to strengthen female engineering students' sense of self-efficacy and to improve the retention of women in traditionally male-dominated disciplines and careers. South African. Journal of Industrial Engineering. 2014;**25**(3):112-125

[35] Riegle-crumb AC, Farkas G, Muller C, Chandra M. The role of gender and friendship course taking advanced predicts. Sociology of Education. 2006;**79**(3):206-228

[36] American Association for University Women. Tech-Savvy: Educating Girls in the New Computer Age. Washington, DC: The American Association of University Women Educatonal Foundation; 2000

[37] National Association for Single Sex Public Education (NASSPE). n.d. Retrieved from: https://www.singlesexschools.org/ [Accessed: September 2018]

[38] Datnow A, Hubbard L, editors. Gender in Policy and Practice: Perspectives on Single-Sex and Coeducational Schooling. NewYork RoutledgeFalmer, Psychology Press; 2002

[39] Kruse AM. Single-sex settings: Pedagogies for girls and boys in Danish schools. In: Equity in the Classroom: Towards Effective Pedagogy for Girls and Boys. London: The Falmer Press, UNESCO Publishing. 1996. p. 173. Available from: https://bit.ly/2WYCHbY

[40] Peters-Burton EE, Lynch SJ, Behrend TS, Means BB. Inclusive STEM high school design: 10 critical components. Theory Into Practice. 2014;**53**(1):64-71

[41] Crenshaw K. Mapping the margins: Intersectionality, identity politics, and violence against women of color. Stanford Law Review. 1991;**43**(6):1241-1299

[42] Collins P. Intersectionality's definitional dilemmas. Annual Review of Sociology. 2015;**41**:1

[43] Collins P. Black Sexual Politics: African Americans, Gender, and the New Racism. New York: Routledge; 2004

[44] Slaton A. Meritocracy, technocracy, democracy: Understandings of racial and gender equity in American engineering education. In: Christensen H et al, editors. International Perspectives on Engineering Education Engineering Education and Practice in Context, Volume 1. Dordrecht, London: Springer Cham Heidelberg, New York; 2015

[45] Davies B. Shards of Glass: Children Reading and Writing beyond Gendered Identities. Broadway, Cresskill, NJ: Hampton Press; 2003

[46] Kumashiro K. Troubling Education: Queer Activism and Antioppressive Pedagogy. New York: Routledge Falmer, Taylor and Francis; 2002. p. 2002

[47] Lent RW, Brown SD, Hackett G. Contextual supports and barriers to career choice: A social-cognitive analysis. Journal of Counseling Psychology. 2002;**47**:36-49

[48] World Learning. Education consortium for the advancement of STEM in Egypt. n.d. Retrieved from: http://www.worldlearning.org/what-we-do/education-consortium-for-the-advancement-of-stem-in-egypt/ [Accessed: 13 March 2018]

[49] Education Consortium for the Advancement of STEM in Egypt (ECASE). Progress Quarterly Report, 3rd Report; April-June 2013; Cairo,

Egypt: 2013. Retrieved from: https://pdf.usaid.gov/pdf_docs/PA00JQ8D.pdf

[50] Egypt Ministry of Education (MoE). Egypt's STEM Schools. n.d. Available from: http://moe.gov.eg/stem/index.html [Accessed: 25 March 2018]

[51] USAID. Let girls learn: Today's students, tomorrow's leaders [Video file]. 2016. Retrieved from: https://www.youtube.com/watch?v=Zy33wq6_eK4

[52] Stake R. The Art of Case Study Research. Thousand Oaks, CA: SAGE Publications; 1995

[53] Yin RK. Case Study Research: Design and Methods. 5th ed. Thousand Oaks, CA: SAGE Publications; 2014

[54] Corbin J, Strauss A. Basics of Qualitative Research. 4th ed. Thousand Oaks, CA: Sage; 2015. ISBN: 978-1-4129-0644-9

[55] Gayles JG, Ampaw FD. Gender matters: An examination of differential effects of the college experience on degree attainment in STEM. New Directions for Institutional Research. 2011;**2011**(152):19-25