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Female Engineers in a Transitional Economy: Perceptual Facilitators for and Barriers to Studying in STEM Fields

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Female engineers in a transitional economy: perceptual facilitators for and barriers to studying in STEM fields

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Abstract

The challenges faced by female engineers in a transitional economy are unique in the sense that central efforts for gender mainstreaming often co-exist with persistent vertical discrimination, which may reduce incentives for women to upgrade their skills. Even in countries that improved their relevant indicators in recent years, still face hidden issues that require careful consideration. Thus, this study was conducted to shed light on the influences at the individual, interpersonal, organizational, and societal levels that are present as barriers to and facilitators for advancement in STEM studies and in particular engineering for females.
The authors conducted 18 individual semi-structured in-depth interviews with female undergraduate students at a leading, English-language and American style research university in Kazakhstan in 2022. Kazakhstan, being the leading country in Central Asia, represents interesting case study as it has achieved gender parity in its research workforce, but not in engineering. According to national statistics, only 32% of undergraduate students in STEM disciplines are female and this percentage is decreasing as women dropout from STEM as they move forward in their education. The analysis of the interviews revealed the main barriers, challenges, and issues influencing females and ranked their importance. A key outcome of the study is the importance of support, mainly from family and teachers, as it has the biggest impact on building confidence and retaining female engineers in their careers.

Keywords: Transitional economy, STEM Education, Gender Gap, Female Engineers, Kazakhstan.

1. Introduction

The study of science, technology, engineering, and mathematics (STEM) fields can be a challenging pursuit for women in a transitional economy, where traditional gender roles may still predominate and access to educational resources and opportunities may be limited. Despite these barriers, there are also perceptual facilitators that can help and encourage women to pursue careers in STEM fields. The challenges faced by female engineers in countries undergoing economic changes can be considered specific and unique. Despite the existence of central gender equality initiatives, persistent prejudice and biases continue to impede women's motivation to improve their skills, hindering their progress in the field [1].

The study in this paper conducted in Kazakhstan, the leading Central Asian country, which has experienced an impressive economic growth over the past two decades and equally impressive achievements in gender equality. Indeed, in 2005, the government of Kazakhstan enacted a 10-year strategy to improve gender equality in the country [2]. At that time, core gender issues were related to a lack of awareness about the importance of gender equality and

a strong belief in traditional gender roles. However, from the government side, there was also a lack of legislation protecting gender equality, and a lack of collaboration with nongovernmental organizations that promote women's rights [2]. In line with this strategy, the government has begun to incorporate gender-related concerns into the development of new policies.
Equal career prospects are not only a moral but mostly an economic necessity for the transitional economy to thrive. As a result, the representation of women in Kazakhstan in various sectors was improved. For example, in the year 2022, the number of women reached 47.6% in the lower house of parliament [3].

Additionally, the country has achieved and surpassed gender parity with an impressive 52.4% of researchers being women as well [3]. However, despite that, this number disguises some noteworthy under-representations. This positive indicator of women's participation in research does not translate to similar patterns in STEM majors. Female students make up only 32% of the overall population of undergraduate students in STEM disciplines and are more likely to 'leak' from the STEM educational pipeline as they advance in their education [4]. Therefore, this research was carried out to shed light on the various factors that act as hindrances or enablers for women's progress in STEM fields.

The study aimed at exploring the following issues: i) the factors that encouraged and prompted females to study and persist in studying a STEM major; ii) the barriers or factors that they had to overcome to continue their degree in STEM; and iii) their relative rank of the two categories indicating what influenced them the most. As gender disparities continue hindering female engineers to achieve their professional excellence, the determination of these factors will provide a framework for institutional and personal growth for female students in engineering.

2. Literature review

Over the last decade, Kazakhstan has had significant improvements in the gender gap. For instance, as per Global Gender Gap Index Kazakhstan has improved its ranking by 15 positions reaching 65th place out of 146 countries [5]. Also, the country particularly excels in the enrolment of female students in primary, secondary, and tertiary education. In schools, gender parity can be observed from the results of the Programme for International Student Assessment (PISA) exams, where girls outscore boys by 7% in reading and by 2% in science and perform comparably in math [6].

Despite that, women's representation remains insufficient in engineering and technology fields even though they comprise 53.2% of undergraduate students [3]. Specifically, in engineering, manufacturing, and construction majors, only 30.2% of students are females. Further, in information and communication technology women are just 29.4% of students [7].

Multiple theories attempt to explain the underrepresentation of women in STEM fields. One of those is stereotype threat theory, which is widely recognized and supported by replicable scientific experiments [8]. According to Steele, women experience pressure, negativity, and distracting thoughts about STEM because of the stereotype associating the female gender with underperformance. Experiments consistently show that if women are reminded of this stereotype right before math tests, they are likely to score low [9]. The perpetuation of gender stereotypes can make the already challenging process of enrolling in a university and succeeding in STEM even more difficult. Recent studies have demonstrated that exposure to

stereotypical media messages, such as commercials, can significantly reduce women's motivation and willingness to pursue a degree in STEM [10].

Another factor contributing to the gender gap in STEM is unconscious bias in the education system [11]. Numerous studies demonstrate that parents, instructors, and academics behave in a way that discourages women from seeking achievements and opportunities in the STEM field. For example, STEM teachers express more support toward male students irrespective of demonstrated identical performances by both male and female students [12]. Additionally, the prejudice that can be present in academia is evident in the discriminatory treatment of women during the selection and appointment of faculty positions. These biases, along with many psychological, sociocultural, and cognitive factors, resulted in the underrepresentation of women in STEM majors.

3. Methodology

An analysis was conducted on semi-structured interviews with a cohort of eighteen female students who participated in the study. This qualitative research project collected data from undergraduate students from the leading research university in the country over the span of a year. The purpose of the study was to investigate the factors influencing the development of women in STEM. An invitation for voluntary participation was sent to the potential interviewee via corporate email. As approved by the Institutional Research Ethics Committee (IREC), the semi-structured interviews were conducted in a one-to-one format via Zoom lasting for about 30 minutes which included leading and extended questions to obtain quality data.

After informing the participants about the purpose of the study, their voluntary informed consent form was signed before they answered the questionnaire. Their personal information remained confidential throughout the study. The participants were asked five demographics (Fig. 1), two qualitative questions and factor ranking by importance and impact.

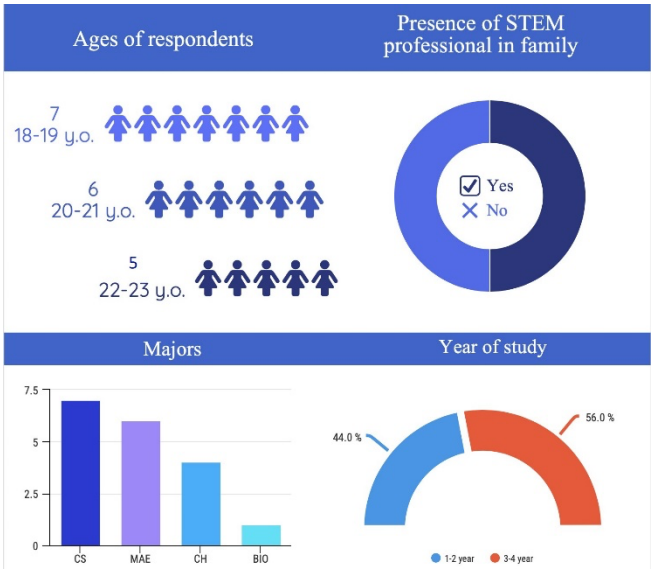

Fig. 1. Demographic information of respondents.

Overall, in the study female students aged between 18-23 participated. The responders were from four different majors -Computer Science (CS), Mechanical and Aerospace Engineering (MAE), Chemical Engineering (CH), and Biology (BIO). 44% of the participants were

studying in the first and second year of their bachelor's degree, and 50% of them had a family member who is a professional with a STEM background (Fig.1). The qualitative questions were about facilitators and barriers affecting both the personal and academic lives of female students. In addition, the participants ranked the factors and evaluated their influence. The interviews were recorded and transcribed for further analysis to minimize potential bias.

4. Analysis and discussion of results

During the analysis of the data obtained from the interview process, the authors of this study were inspired by the conceptual framework presented in the study [1]. Thus, the mentioned model was used with slight modifications as the basis for the division of the factors which affect female engineers as shown in Fig. 2.

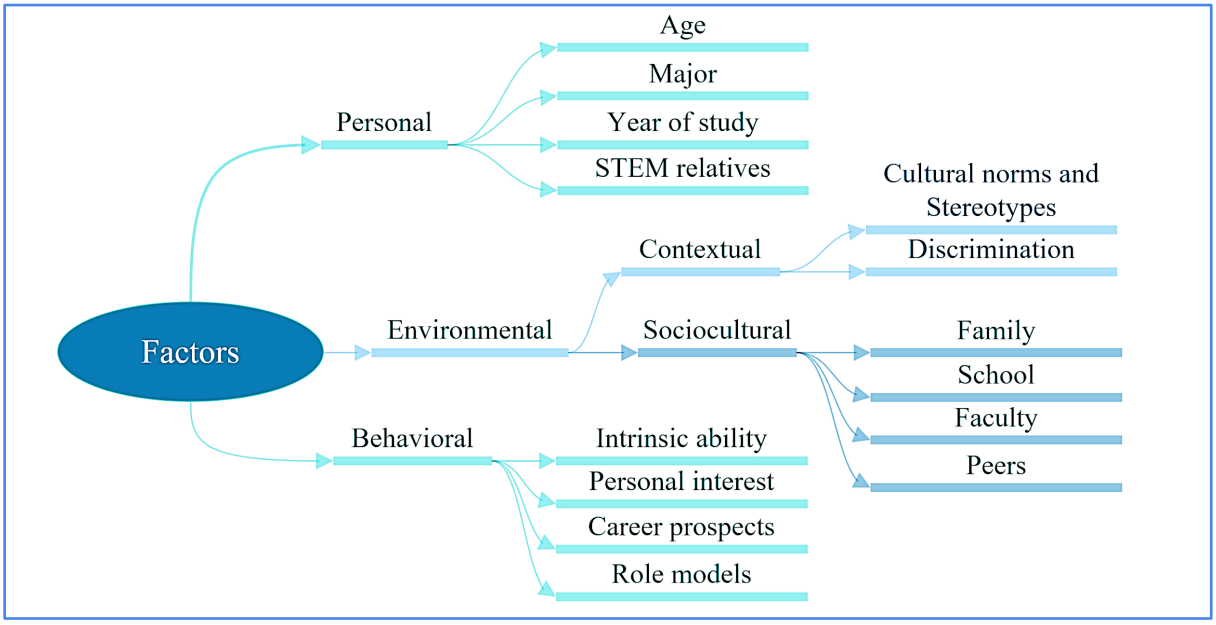

Fig. 2. Factors (facilitators/barriers) generated based on answers of respondents.

4.1. Environmental factors

4.1.1. Contextual factors

The *family contex*t is quite ambiguous. This factor was divided into 2 parts: *the closest relatives* as parents, brothers, and sisters, and *the distant relatives* of the respondents. From the conducted interviews, it follows that the support of a family, namely parents and siblings, does not depend on the professional field of each family member. Moreover, the number of family support (parents, siblings) does not show a discrepancy for both cases of the family with and without STEM professionals (Table 1). For comparative purposes, the quotes are referenced by their quotation IDs as defined in the full list presented in the Annex of this paper.

Table 1. Comparison of answers of interviewees with and without family members in STEM

Answer of respondents with family members in STEM	**Answer of respondents without family members in STEM**

"My parents did not restrict me in my choice and from early age encouraged me to be educated and aroused interest." ***Q1***	*"My mother was very encouraging because Computer Science degree has more career prospects."* ***Q2***
"As I felt that predisposition to STEM field, they supported my decision to enter at physics and mathematics lyceum." ***Q3***	*"My family members suggested me that there are good job opportunities after graduation pointing out that STEM fields are under development in our country."* ***Q4***
"My parents advised me to choose profession from STEM fields, because those professionals are well-paid and have better career opportunities." ***Q5***	*"My mother advised me to talk with a professional. She did not want me to make a wrong decision."* ***Q6***

However, there are reported no cases where *families with STEM* specialists put pressure on or dissuade, in other words, become barriers for women to choosing STEM fields. On another hand, in *families without professionals in STEM*, this barrier may occur (Q7). The reasons mentioned are doubts about career prospects, specifically regarding the prospects of women in technical specialties and science, as well as cultural stereotypes regarding women being better suited for household chores after marriage (Q8).

The support from close relatives does not erase the emergence of barriers from distant relatives. For example, if the father fully supports his daughter in her choice, however, relatives are stereotyped about women in STEM, then they still may doubt her abilities, which certainly has a negative effect (Q9, 10, 11).

Most of all, women with close relatives who specialize in STEM benefited due to access to information in this area. In addition, females whose parents are STEM professionals are more confident in their choices. While in other cases, apart from misconceptions related to the STEM field and what it can bring to women, there is room for the appearance of personal doubt which leads to switching back and forth within the STEM and other disciplines due to a simple lack of self-confidence (Q12, 13).

One of the most mentioned factors as well as the first exposure to STEM education are schools. Early exposure to STEM with hands-on learning experiences can help to foster an interest in these fields and build a foundation of skills and knowledge. Accordingly, the most mentioned and controversial factor in this study is the *school context* (a high, middle), specifically the influence of teachers, the level of the school, and the facilities provided by the school (Fig.3).

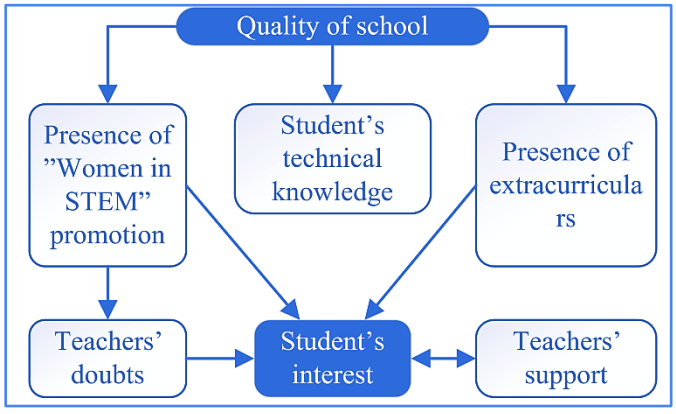

Fig. 3. Factors generated by the school environment.

In Kazakhstan, 73% of teachers are women and only 27% are men, most of which take positions of directors, workers, and physical culture teachers [3]. In the conducted interviews, most of the respondents indirectly confirmed either positive or negative influences received

from female teachers. Some did study at girls' lyceums where teachers are only female representatives (Q14, 15, 16, 17, 18).

The controversy lies in the fact that teachers at the same school can both inspire and encourage female students for showing interest and abilities in STEM and simultaneously dissuade them from STEM career paths. In the example below, the respondent mentioned that while the physics teacher encourages her students to study, the non-STEM teacher dissuades the students from this career path.

> *"At school there were no inequalities in terms of whether you can learn subject or not. For example, my physics teacher was female, and she never favored someone based on the gender at the same time teacher who taught foreign languages used to discourage me from pursuing STEM field. When I announced that I want to be a computer scientist at first time, my English teacher said that it is not for girls. The most suitable profession for you will be a teacher or doctor."* ***Q19***

Although teachers contribute to the development of students and encourage their abilities and success during education, they may show a share of doubt in schoolgirls about the potential difficulties of the chosen path when it comes to deciding on a career path (Q20, 21). It also can be one of the important factors that most average schools in Kazakhstan do not have the practice of promoting schoolgirls in STEM (Q22). Such cases can be true even for some lyceums, which are different due to a higher emphasis on physics and mathematics. However, more cases of support appear from those schoolteachers, who taught a course in which the respondents demonstrated abilities and interests.

The *level of education at a school* matters a lot, especially when it comes to STEM. 3 out of 7 respondents studying at the CS noted that lack of prior knowledge in this area, made it difficult for them to adapt which affected their *learning environment*, while at the same time some of their classmates, in addition to knowledge, even had prior work experience. 2 of the women even doubted their choice and thought about changing their specialty (Q23).

> *"It is called imposter syndrome. I came with zero knowledge of programming to computer science classes, and I saw peers who had already worked in CS fields & companies. So, I thought maybe I was not that person who should be here. I think that was a major reason why I was hesitating about my choice while being a first year UG student. But now I managed to accept it and not it is okay."* ***Q24***

One of the women also studying at the CS who changed her schools mentioned that the more intellectual the school environment, the more equality it possesses. Other participants of the interview, who do not have STEM specialists in their family, mentioned an example of how the schools' extra-curricular activities, such as laboratory visits and career orientation tests were carried out. One of them even had a chance to talk to a professional in her field on a career orientation course (Q25).

> *"My school provided professional orientation sessions to help us decide with the field of study."* ***Q26***

It is also necessary to highlight *university activities* as well as *representatives of the faculty* who help and encourage their students both in academic and non-academic terms (Q27).

> *"The faculty of the CS department was more appealing and encouraging. Teachers at CS were more encouraging and helping. Teaching assistants in the department were especially helpful."* ***Q28***

4.1.2. Socio-cultural factors

The learning *environment* is multifaceted and often cannot be simply positive or negative. Often, the positivity of this environment can be taken for granted, but women who have already encountered stereotypes at the beginning of their journey can notice this (Q29, 30).

"My friend also changed major from biology to CS, and she was very supportive during my transfer to CS. I received support from my peers and other female students in the ACM-W club." ***Q31***

At this point it can be noted, that access to supportive networks, such as mentors and peers, can provide encouragement and help women navigate the challenges of studying and working in STEM fields.

Since the interviewees are students at an advanced university in Kazakhstan, the *learning environment* is substantially competitive, especially for undergraduate students. It also leads to *toxicity* as was mentioned by some respondents. Moreover, *the presence of a gender gap* and *the absence of women* in both classrooms and faculty reflect on female students in STEM (Q32, 33, 34).

"There are few girls in CS. Male peers usually group together, while girls stay alone. It was difficult for me to find female friends from CS, all my friends are from different majors. Moreover, at CS the professors are mostly males. I wish there were more female professors." ***Q35***

Two more respondents noticed that the *toxicity* of an environment comes from male peers and the *masculinity* of STEM professions (Q36). One of the female students even began to adopt this characteristic of her *environment* in order not to be different from others (Q37, Table 2).

Table 2. Comparison of answers of interviewees facing toxicity in a learning STEM environment and non-STEM related environment

Toxicity in a learning STEM environment	**Toxicity from a non-STEM related environment**
"Smart students from the specialized school were pushing the other down. She describes the environment among the students in the major as Unfriendly. She attributes the high competition to the Toxic Masculinity." ***Q37***	*"There are certain prejudices about men and women. One of them is the incompatibility of femininity with science. In my opinion, femininity is thought to be associated with lightness, while science requires deepening, problem solving, and it is associated with masculinity."* ***Q42***
"When I announced that I want to be computer scientist male students were also not supportive. They advised me to choose something easier, to get married, have kids and so on. It is because they had stereotypical thinking." ***Q38***	*"Surprisingly, most of the time I encounter stereotypes from girls. They may ask me with wonder: Do you like your major? When the answer is obvious: Yes, I am a 4th year student. Females see me and question my progress because I am a girl."* ***Q43***

One of the reasons for the wording "*Toxic masculinity*" in addition to the lack of women in STEM may be the *stereotypical* statements, attitudes, and thoughts of male students in relation to female colleagues. This barrier was formulated as *Social Stigma or stereotype* (Q38, Table 2). More than half of the girls faced similar social stigmas from relatives, teachers, classmates, etc. (Q42, Table 2). Such representatives of society manage to express their stereotypical thoughts, from the author's perspective, mainly to women who are on their career path in STEM. And some female students adopt this kind of view over time and catch themselves on it (Q39, 40, 41).

In the example of the schoolteachers described above, non-STEM teachers appeared to discourage female students from career paths in STEM. There are also other female non-STEM students who question the success of women in STEM (Q43, Table 2). At the same time, such prejudicial behaviors motivated someone to achieve even more in the area. Therefore, it also strongly depends on the individual perception of a particular stereotype (Q44).

"I have never thought that I could do worse than men just because I am a woman. I can work, I can learn, and I can do even better than my fellows." ***Q45***

4.2. Behavioral factors

Every second respondent mentioned *intrinsic ability* as the main facilitator and the top three in terms of influence on the choice of STEM areas (Table 3). Most of the interviewees felt a predisposition to mathematics and physics, or these subjects just came easier for them than others (Q46, 47).

Some women did not mention this facilitator in the main part of the interview but included it in the factor ranking as one of the most significant ones in choosing their academic path. It should also be noted that the *intrinsic ability* in 6 out of 10 cases goes along with *personal interest* in STEM areas. In most cases, respondents mentioned these facilitators together or consecutively. If some of the interviewees simply liked to solve logical and mathematical problems, others were lured by the simplicity of these courses or the difficulty of cramming humanitarian subjects. Moreover, some respondents spoke about dreams and desires since childhood to be in science, engineering, or for example, study space (Q49, 50, 51, 52).

Role Models are women who have successfully pursued careers in STEM fields and can serve as examples for other women to help to demystify the field and highlight the opportunities that it can provide.

The presence or absence of *role models* has a very significant impact on female students' confidence in their choice (Table 3). It is interesting that the role model does not necessarily have to be another woman or an acquaintance. It is obvious that the role model from childhood in the face of relatives offers obvious advantages, but this is not the only way. People are inspired by the career paths and achievements of various persons. And this instills in women, especially at the beginning of the career path, a deep conviction that they can achieve similar heights in STEM (Q54).

Table 3. Comparison of answers of interviewees with intrinsic ability versus when they had a role model

Intrinsic ability	**Role model**
"The predisposition to subjects of STEM fields influenced my decision to study at physics and mathematics lyceum." ***Q48***	*"My role model is a former student of the leading Kazakhstani university from whom I got motivated during the webinar."****Q53***
"Interest in space since childhood, which is linked with an interest in technology." ***Q51***	*"My sister's husband is a software engineer and I got inspired by his journey. However, this was after I had already selected my major, so he kind of validated my choice. I still can call him a role model though and can say that I want to pursue the same path."* ***Q55***

Women in STEM encounter sociocultural factors at all stages of their lives and careers are no exception, perhaps the beginning of a career presents the peak of discrimination experience. Most of the respondents do not yet have work experience, but they have already heard about *cases of discrimination* from their acquaintances and senior colleagues. And such cases, of course, greatly affect their expectations of *prospects in their STEM career* (Q56).

"After one interview that I saw where a woman in STEM was discriminated against, I felt apprehensive that I might experience this, which in turn also might encourage me to quit STEM." ***Q57***

As mentioned earlier, the beginning of the career path is perhaps the peak of women's discriminatory experience in STEM which may be due to the combination of lack of experience, and social stereotyping about the capability of females in STEM. For example, two respondents from the CS during their internship have already faced discrimination from men in high and leading positions (Q58).

> *"I also faced discrimination at my internship, when a male supervisor assigned all girls tasks on front-end development, while males were doing harder tasks because, as he stated, they were smarter and tougher, while girls are soft."* ***Q59***

Often the specificity of narrow STEM fields creates uncertainty in the career path, regardless of gender. However, such a burden of uncertainty along with gender discrimination can greatly undermine the desire of girls to continue to stay in STEM.

> *"There is lots of uncertainty about the job opportunities. What is the demand for professionals of Chemical Science in the labor market? Sometimes I thought why I have chosen such a specific field."* ***Q60***

However, the development of technology and science cannot be without the diversification of the community of people consisting of different classes, races, views, and genders. The prospects for STEM fields provide the students with great opportunities both financially and career-wise. Moreover, it is imperative that women themselves, no matter what life stage they are in, believe that they can contribute to any direction they choose. And the task of society is to provide this opportunity to everyone irrespective of gender (Q61, 62).

> *"The rate of employability after graduation has attracted."* ***Q63***

4.3. Impacts and ranking of factors

During the third stage of the interview process, respondents were asked to rank the factors based on their perceived level of influence. The factors were then collected and averaged, resulting in the identification of the top five factors with the greatest influence. (Table 4).

Table 4. Ranking of factors.

Factor (facilitator/barrier)	**Mean rank**	**Comparative Ranking**
Intrinsic ability and Personal interest	2,1 and 2,3	I
Family context (Parents and siblings)	2,7	II
School context (Schoolteachers)	3,0	III
Peer group	3,4	IV
Cultural norms and Stereotypes	3,6	V

In addition to the fact that *intrinsic ability* and *personal interest* were usually mentioned together or subsequently, their average rank was approximately on the same level.

Consequently, they were placed in the same rank. Compared to the previous factors that were mentioned only in a positive way, the *family and school contexts* in addition to positivity also had a negative effect on female students. Moreover, the factors mentioned above elicited complex and controversial responses, making them the most discussed.

Among the clearly negative factors, the factor of *social norms and stereotypes* was mentioned by every second respondent. This factor is deeply rooted and has no definite clear framework. Even if stereotypes are not part of the socio-cultural sub factor, the family and learning

environment is the place where this context spreads. In addition to behavioral factors, social norms and stereotypes strongly influence the desire of students to choose and continue STEM directions.

There are factors that were only facilitators or barriers for respondents, such as internal ability and stereotypes. Moreover, some of the factors mainly that have contextual nature acted as a facilitator for one of the interviewees and a barrier for another, from the example above, and both for the other person. The spider charts below are the visual representation of the Table 4 and represents the top 5 facilitators and barriers by impact mentioned by the respondents (Fig.4). Factors having their spike further from the center are considered to have more influence as facilitators or barriers.

Facilitators: The interviewees ranked intrinsic ability and personal interest as the top facilitators for pursuing STEM fields. The family context was identified as the subsequent factor of significance.

In the ranking, school teachers and role models were positioned in the fourth and fifth places, respectively

Barriers: School environments (including teachers) had a mixed impact and were heavily debated. As a result, this factor ranked as the top barrier, even though it can be the facilitator simultaneously. The peer group is the next highly ranked barrier, followed by social norms and stereotypes, cited by half of the respondents as negative factors affecting female students' interest in STEM. Finally, school level and career prospects occupy the last place in the ranking hierarchy.

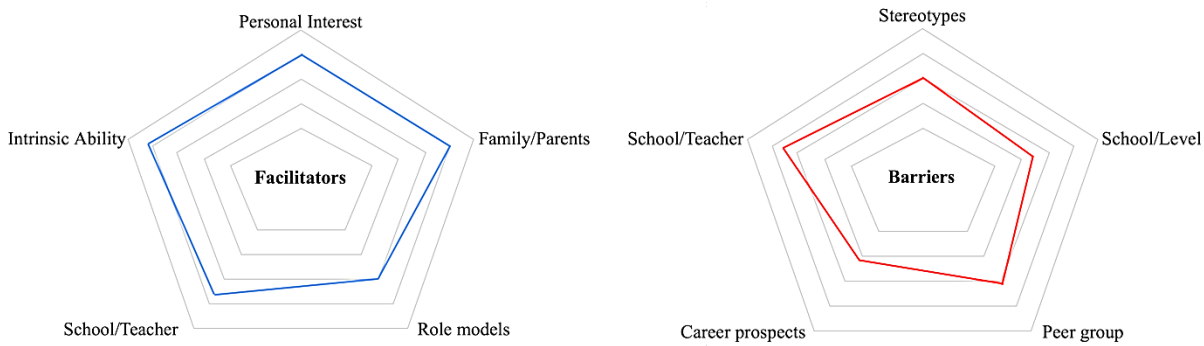

Fig. 4. Spider charts of the impacts of facilitators and barriers on respondents.

5. Limitations

The present study has some potential limitations such as the small participant pool and the lack of racial and ethnic diversity. In addition, and despite the strengths of the semi-structured interviews, participants may find it difficult to express themselves especially when they lack adequate verbal communication skills due to their young age. Another factor in this study was that the interviews were conducted in English, not in the mother tongue of the participants who often resorted to Russian or Kazakh for more nuanced responses. There is the danger that some issues that were communicated in the local language were not translated in their full context. But of course, having the direct voice of the participant included in a study has a certain appeal and thus these limitations can be disregarded, especially when it is difficult to engage informed opinions from such populations through other methods [13].

6. Conclusions

This study has shed light on the perceptual facilitators and barriers that young women in a transitional economy face when considering a career in STEM fields. During the interviews, each respondent felt confident in their abilities and a strong attraction to STEM careers, while simultaneously they felt discouraged by the familial and societal opinions about women in STEM. Their anticipation of discrimination in the workplace seriously undermined their desire to pursue a career in STEM. As a result, the major facilitators were identified as having the intrinsic ability and encouraging teachers and family, while the barriers were lack of access to STEM education, gender stereotypes, and cultural norms. Overall, overcoming the barriers to studying and pursuing careers in STEM fields requires a multi-faceted approach that addresses the root causes of these challenges and provides women with the resources and supports they need to succeed. This is an important result, coming from a country with an established record on gender parity, that demonstrates the universal nature of these issue in transitional economies and beyond.

Identification and further research of these factors will facilitate the development of counseling/guidance programs that shall prepare students to participate effectively in their current and future career goals. At the same time, it is crucial for policymakers and educators to address these barriers and create a supportive environment for women in STEM to ensure equal representation and opportunities in the industry. Likewise, parental workshops to create awareness on the importance of supporting the career choice of females, and self-efficacy workshops on enhancing students' career choice and their readiness to enter STEM will be the heart of the visionary platform to support families and students of this transitional economy.

Summing up, this study highlights the importance of encouraging and empowering women to pursue careers in STEM, which can have a positive impact on the future workforce and overall economic growth.

Ethics approval: This research had ethical approval from the Human Research Ethics Committee of Nazarbayev University (project no: 021220FD0751).

6. References

[1] V. Tandrayen-Ragoobur and D. Gokulsing, “Gender gap in STEM education and career choices: what matters?” *Journal of Applied Research in Higher Education*, vol. 14, no. 3, pp. 1021–1040, 2022.

[2] Akorda, “Strategy for Gender Equality in the Republic of Kazakhstan for 2006-2016.” 2005. [Online]. Available: https://www.akorda.kz/upload/nac_komissiya_po_delam_zhenshin/5.2%20%D0%A1%D0%93%D0%A0%20%D1%80%D1%83%D1%81.pdf

[3] Bureau of National statistics of the Republic of Kazakhstan, “Statistics of Innovation,” 2022. https://stat.gov.kz/official/industry/23/statistic/6 (accessed Nov. 21, 2022).

[4] A. Almukhambetova and A. Kuzhabekova, “Factors affecting the decision of female students to enrol in undergraduate science, technology, engineering and mathematics majors in Kazakhstan,” *International Journal of Science Education*, vol. 42, no. 6, pp. 934–954, 2020.

[5] World Economic Forum, “Global Gender Gap Report 2022,” 2022. [Online]. Available: https://www3.weforum.org/docs/WEF_GGGR_2022.pdf

[6] OECD, “Programme for International Student Assessment (PISA) Results from PISA 2018, Kazakhstan country note,” 2019. [Online]. Available: https://www.oecd.org/pisa/publications/PISA2018_CN_KAZ.pdf
[7] Eurostat, “Graduates by education level, programme orientation, sex and field of education,” *European Comission*, 2022. https://ec.europa.eu/eurostat/web/products-datasets/product?code=educ_uoe_grad02
[8] C. L. Hoyt and S. E. Murphy, “Managing to clear the air: Stereotype threat, women, and leadership,” *The leadership quarterly*, vol. 27, no. 3, pp. 387–399, 2016.
[9] M. Cadinu, A. Maass, A. Rosabianca, and J. Kiesner, “Why do women underperform under stereotype threat? Evidence for the role of negative thinking,” *Psychological science*, vol. 16, no. 7, pp. 572–578, 2005.
[10] M. Bertrand, “Gender in the twenty-first century,” *AEA Papers and Proceedings*, vol. 110, pp. 1–24, 2020.
[11] M. Tsakalerou, “Understanding the factors influencing women’s career trajectories in STEM education in Kazakhstan.,” *International Conference on Gender Research*, vol. 5, no. 1, 2022.
[12] A. Alam, “Psychological, Sociocultural, and Biological Elucidations for Gender Gap in STEM Education: A Call for Translation of Research into Evidence-Based Interventions,” in *Alam, A.(2022). Psychological, Sociocultural, and Biological Elucidations for Gender Gap in STEM Education: A Call for Translation of Research into Evidence-Based Interventions. Proceedings of the 2nd International Conference on Sustainability and Equity (ICSE-2021). Atlantis Highlights in Social S*, 2022.
[13] M. Sandelowski, “Reembodying qualitative inquiry,” *Qualitative Health Research*, vol. 12, no. 1, pp. 104–115, 2002.

Annex - Complete list of interviewees’ quotes

Quote ID	Quote	Interviewee ID
Q1	“My parents did not restrict me in my choice and from early age encouraged me to be educated and aroused interest.”	Int MAE.1
Q2	“My mother was very encouraging because Computer Science degree has more career prospects.”	Int CS.3.3
Q3	“As I felt that predisposition to STEM field, they supported my decision to enter at physics and mathematics lyceum.”	Int CH.4
Q4	“My family members suggested me that there are good job opportunities after graduation pointing out that STEM fields are under development in our country.”	Int CS.2.1
Q5	“My parents advised me to choose profession from STEM fields, because those professionals are well-paid and have better career opportunities.”	Int CS.4
Q6	“My mother advised me to talk with a professional. She did not want me to make a wrong decision.”	Int CH.3
Q7	The parents were worried about the prospect of a career in chemistry and offered the economy as a kind of safety cushion because of the uncertainty. Until now, from time to time they push me to double major.	Int CH.1.1
Q8	Well, sometime my father hints on the possibility of getting married and tries to implicitly push me to do it earlier.	Int CS.2.1
Q9	When I moved to my hometown during the quarantine and lived some time among my relatives, I felt how my willingness to study decreased and views started to change. If before the pandemic I rejected the need to become married for 100% and career was the main priority, today the rejection is 10-15%.	Int CS.3.2
Q10	Some relatives have said that girls don’t fit in STEM.	Int CS.3.3

Q11	It wasn't like my family members, but from relatives, it was quite sad to hear something like there's no need for girls to study the stem field. Some conservative relatives think that there's no need to study for girls and they should only do households and raise a child.	Int CH.1.2
Q12	Because there was not much information about what I can do in this field, I was wondering where I can go with this degree.	Int CS.3.1
Q13	First, I was thinking about civil because from the school. So, then I thought about the School of Mining and Geoscience. But I was afraid of like chemistry, and I didn't like it. So, at the end I decided to choose mechanical engineering.	Int MAE.2
Q14	Mainly, all my teachers were females because I studied in an all-girls school. Instructors encouraged me to study hard to become a teacher but no facilitation to pursue a degree in STEM.	Int CS.3.1
Q15	“Teachers at my school supported girls and usually preferred to praise girls.”	Int CS.4
Q16	Female math teacher instructor who saw the potential in me when I was in 5th grade and prepared me to various math competitions. This motivated me to study math, physics and other tech courses which led to STEM profession.	Int MAE.1
Q17	“My teachers persuaded me to stay in chemistry because it was my best potential.”	Int CH.1.2
Q18	“Biology teacher in high school was from Germany. She encouraged me studying biology. Honestly, I always found it difficult and hard field, but teacher showed biology from another side, interesting and diverse.”	Int Bio.2
Q19	At school there were no inequalities in terms of whether you can learn subject or not. For example, my physics teacher was female, and she never favored someone based on the gender at the same time teacher who taught foreign languages used to discourage me from pursuing STEM field. When I announced that I want to be a computer scientist at first time, my English teacher said that it is not for girls. The most suitable profession for you will be a teacher or doctor.	Int CS.1
Q20	I think my teachers also positively influenced my choice in a sense that due to my constant encouragement to do more than I thought I could do. It was during my school when I expressed interest towards science and academia, but my teacher told me that well you had to have family and if you go to academia and you would not be able to have a social life.	Int CS.2.1
Q21	“The first one is our like career guidance from schoolteacher. I came to my teacher her and asked what I should choose physics or math. She was really like biased about girls. She said, no, girls only go to civil engineering. That's all you have.”	Int MAE.2
Q22	“Everyone questioned my abilities at the first school. It hurt my pride, so I started studying math. I wanted to enter a mathematical lyceum. And at this lyceum, the second school, I was lucky that my teachers knew how to encourage and support the interest of students.”	Int CS.3.2
Q23	“High competition and no prior knowledge in CS were an obstacle during my studies I even considered changing majors, but then changed my mind, and overcame the challenges.”	Int CS.3.1
Q24	“It is called imposter syndrome. I came with zero knowledge of programming to computer science classes, and I saw peers who had already worked in CS fields & companies. So, I thought maybe I was not that person who should be here. I think that was a major reason why I was hesitating about my choice while being a first year UG student. But now I managed to accept it and not it is okay.”	Int CS.2.1
Q25	“In my school there was a social project related to visiting workplaces of our parents and relatives. I took part in this project twice at high school. I visited laboratories and found this job very interesting.”	Int CH.3
Q26	“My school provided professional orientation sessions to help us decide with the field of study.”	Int CS.3.1

Q27	“At my university, she was able to attend many CS related events, such as Alumni talks, coding marathons, which further fueled her interest in STEM.”	Int CS.3.1
Q28	“The faculty of the CS department was more appealing and encouraging. Teachers at CS were more encouraging and helping. TA-s in the department were especially helpful.”	Int CS.3.3
Q29	“My fellow female students were somehow supportive and motivational even in competitive environment.”	Int CS.3.1
Q30	“The society where I grew up in general was positive to my decisions.”	Int CS.1
Q31	“My friend also changed major from biology to CS, and she was very supportive during my transfer to CS. I received support from my peers and other female students in the ACM-W club.”	Int CS.3.3
Q32	“There were less students who choose CS major and are female. Because of that I also got discouraged. I thought probably what these people are saying right. Why don’t girls want to choose these major?”	Int CS.1
Q33	“According to my personal observations, specifically girls do not seek to dive into science, and many winners of the Olympiads of those whom I know are boys.”	Int CH.1.1
Q34	“I had this male dominance also at school, but I didn’t feel that stress at school. At university we don't look at each other as friends, we are each other's competitors. And it's not just from the male peers, but from the female peers as well.”	Int MAE.3.1
Q35	“There are few girls in CS. Male peers usually group together, while girls stay alone. It was difficult for me to find female friends from CS, all my friends are from different majors. Moreover, at CS the professors are mostly males. I wish there were more female professors.”	Int CS.4
Q36	“I like to be feminine myself, but studying at CS, I noticed how I replicate the style of my classmates (more masculine) in order to be similar to the environment.”	Int CS.4
Q37	“Smart students from the specialized school were pushing the other down. She describes the environment among the students in the major as Unfriendly. She attributes the high competition to the Toxic Masculinity.”	Int CS.3.3
Q38	“When I announced that I want to be computer scientist male students were also not supportive. They advised me to choose something easier, to get married, have kids and so on. It is because they had stereotypical thinking.”	Int CS.1
Q39	“Sometimes I hear how parents’ friends say: «Okay, your girl is always studying, but for me it is more important if my girl will get married». I often hear such words, but they don’t really hinder my desire to pursue STEM field.”	Int CS.2.2
Q40	“Negative stereotypes about men being smarter than girls. Sometimes I caught myself on this kind of thought like if a man and woman (both in CS) would sit in the room, I would expect male to be more knowledgeable.”	Int CS.3.1
Q41	“The female is supposed to give birth earlier or to marry earlier and females should be married in their twenties. Also, we do have the term "overstayed (sat) girl" and all the other things. Some like conservative, old people surrounds, they can still put some pressure, not significant, but they still can.”	Int CH.1.2
Q42	“There are certain prejudices about men and women. One of them is the incompatibility of femininity with science. In my opinion, femininity is thought to be associated with lightness, while science requires deepening, problem solving, and it is associated with masculinity.”	Int CS.3.2
Q43	“Surprisingly, most of the time I encounter stereotypes from girls. They may ask me with wonder: Do you like your major? When the answer is obvious: Yes, I am a 4th year student. Females see me and question my progress because I am a girl.”	Int CS.4
Q44	“Many people told me that it was not “female specialty”, which made me feel like I have to prove otherwise.”	Int MAE.1

Q45	“I have never thought that I could do worse than men just because I am woman. I can work, I can learn, and I can do even better than my fellows.”	Int CS.2.1
Q46	“From the 5th grade I liked math very much. I always thought that if I had to choose my future profession, I would select the one which is related to math.”	Int CS.2.1
Q47	“My skills are good at these subjects, especially in mathematics.”	Int MAE.2
Q48	“The predisposition to subjects of STEM fields influenced my decision to study at physics and mathematics lyceum.”	Int CH.4
Q49	“I felt a predisposition to technical subjects like Math and Physics, while had difficulties with humanitarian subjects.”	Int CS.4
Q50	“For me STEM seemed more logical and required more comprehension rather than memorization.”	Int CS.3.1
Q51	“Interest in space since childhood, which is linked with an interest in technology.”	Int MAE.1
Q52	“In my dreams, like I always wanted to be scientist or doctor, and I really liked studying chemistry.”	Int Ch.1.2
Q53	“My role model is a former student of the leading Kazakhstani university from whom I got motivated during the webinar.”	Int CS.3.1
Q54	“I saw some graduates from this field, from this major. So, I followed them, and it made me more interested in this major, especially, women. One of them were from the leading university in Kazakhstan, and the second one from the university in Dubai. I like their like career, they worked for different international companies. It's travel. They have like access to a lot of opportunities.”	Int MAE.2
Q55	“My sister’s husband is a software engineer and I got inspired by his journey. However, this was after I had already selected my major, so he kind of validated my choice. I still can call him role model though and can say that I want to pursue the same path.”	Int CS.2.1
Q56	“I think younger women have less chance to get hired or promoted because a potential employer might think that she would get married sooner or later. Consequently, they will take parental leave and will not be devoted to work 100%. I also heard some cases when employer sets a lower salary limit for women compared to men because the former one is supposed to feed his family.”	Int CS.2.1
Q57	“After one interview that I saw where a woman in STEM was discriminated, I felt apprehensive that I might experience this, which in turn also might encourage me to quit STEM.”	Int MAE.1
Q58	“During my internship, the attitude of my supervisors was like they don’t believe and trust my skills and expertise.”	Int CS.3.3
Q59	“I also faced discrimination at my internship, when a male supervisor assigned all girls tasks on front-end development, while males were doing harder tasks because, as he stated, they were smarter and tougher, while girls are soft.”	Int CS.3.1
Q60	“There is lots of uncertainty about the job opportunities. What is the demand for professionals of Chemical Science in the labor market? Sometimes I thought why I have chosen such a specific field.”	Int CH.4.1
Q61	“I pursued a degree in CS because I wanted financial independence from my family.”	Int CS.3.1
Q62	“My parents advised me to choose profession from STEM fields, because those professionals are well-paid and have better career opportunities.”	Int CS.4
Q63	“The rate of employability after the graduation has attracted.”	Int CS.3.3