

The experience of women students in engineering and mathematics careers: a focus group study

Alicia García-Holgado
GRIAL Research Group,
Computer Science Department
University of Salamanca
Salamanca, Spain
aliciagh@usal.es

Sonia Verdugo-Castro
GRIAL Research Group,
Department of Didactic, Organization
and Research Methods
University of Salamanca
Salamanca, Spain
soniavercas@usal.es

Angeles Dominguez
Tecnológico de Monterrey
Monterrey, Mexico
Universidad Andrés Bello
Chile
angeles.dominguez@tec.mx

Itzel Hernández-Armenta
Tecnológico de Monterrey
Monterrey, Mexico
armenta.itz@gmail.com

Francisco J García-Peñalvo
GRIAL Research Group,
Computer Science
Department
University of Salamanca
Salamanca, Spain
fgarcia@usal.es

Andrea Vázquez-Ingelmo
GRIAL Research Group,
Computer Science
Department
University of Salamanca
Salamanca, Spain
andreaavazquez@usal.es

M^a Cruz Sánchez-Gómez
GRIAL Research Group,
Department of Didactic,
Organization and Research
Methods
University of Salamanca
Salamanca, Spain
mcsago@usal.es

Abstract—The gender gap is a problem that occurs in different forms in regions and countries around the world. It is a goal of large international organisations, governments, companies and other entities. Although it is not a new issue, it is important to continue studying it and seek mechanisms and strategies to attract and maintain more women in these areas. In particular, in the field of education and employment, the STEM areas present large gender gaps whose reduction would not only impact the equality of men and women but would also have an impact on the economy of the countries and on improving the economic situation of women. In this context, there are initiatives in Latin America working on this issue, but it is necessary to look more deeply into the elements that influence the decision to study careers in these areas. In this context, two focus groups have been held as roundtables with STEM women from different Latin American and European countries, to answer a series of questions centred on their motivations and decisions before and during their university studies. The results obtained have provided some inputs for defining gender equality action plans in ten Higher Education Institutions from Chile, Colombia, Costa Rica, Ecuador, and Mexico. Furthermore, the results show similarities with previous studies involving STEM women with different Latin American profiles.

Keywords—gender gap, women students, STEM, qualitative analysis, engineer, mathematician.

I. INTRODUCTION

Nowadays, the gender gap in STEM (Science, Technology, Engineering, and Mathematics) is a challenge. According to the UNESCO Sustainability Development Goals (SDG), organisations and governments worldwide have plans to reduce the gender gap, not only in STEM but also in all the societies' areas, according to the UNESCO Sustainability Development Goals (SDG). This is not only a problem that affects women; it is crucial for the future of society. According to the World Economic Forum, the forthcoming future is characterised by the transformation of the industries favouring technological skills. The new technologies will merge the physical, digital, and biological worlds, impacting all disciplines and economies. STEM careers will have a crucial role in this transformation. However, women are underrepresented in those areas. According to the UNESCO Institute for Statistics, the mean percentage of female students

in tertiary education enrolled in engineering, manufacturing, and construction programs is between 6% and 7% between 2015-2018; in contrast, the percentage of male students choosing these careers is around 20-21%.

Implementing mechanisms and strategies in the higher education system are measures to close the gender gap. However, it requires a holistic approach that involves all educational and professional stages, integrating universities, industry, and government efforts to develop national policies towards reducing the gender gap. In this context, the W-STEM project, "Building the future of Latin America: engaging women into STEM," aims to involve higher education institutions across Latin America and Europe to establish mechanisms of attraction, access, and guidance of women into STEM careers.

Several factors influence the gender gap in STEM disciplines. Different studies focused on the contextual influences during active phases of educational or career decision making [1-5]. According to the Social Cognitive Career Theory (SCCT) [6] and the subsequent adaptations [7, 8], some of the main influential factors are self-perception, self-efficacy, interest in science, expectations of results, previous educational experiences, family and social context, personal characteristics of the person and his/her objectives when deciding which studies to take. Before enrolling in STEM careers, the support or barriers can impact the number of women enrolled in STEM careers [9]. However, the effort to reduce the gender gap does not finish at this stage; it starts in the first educational stages and continues during professional life, according to the Leaky Pipeline phenomenon. There are also a high number of women who drop out in STEM studies. During their studies, the university context can have an impact on the drop out numbers, comfort in the university environment [10], teachers support [1] or the support received from the faculty [11] are some factors identified in previous studies.

This study aims to analyse the perception of undergraduate and graduate students of STEM studies to identify the support and barriers that influenced their career decision-making, focusing on the socio-cultural context, and the support and barriers perception of women in the university context during

their STEM studies. A set of research questions were defined to achieve this objective:

- RQ1: Which motivations and ideas motivated or made it more difficult to choose a STEM career?
- RQ2: What influence has the socio-cultural context (family, friends, couple, etc.) had on the educational path?
- RQ3: What is the perception of support and barriers women have concerning the university context during their studies in STEM areas?

The rest of the document is organised as follows. Section 2 describes the roundtables organised with engineering and mathematics students. Section 3 presents the results concerning gender equality. Finally, the last section summarises the main conclusions derived from this work.

II. APPROACH

The study was carried out in April and May 2020, during the COVID-19 crisis. Two international focus groups were organised to answer the research questions. The focus groups were developed as online roundtables discussions with female students and graduates in STEM studies. The roundtables were organised as online events streamed through YouTube and Facebook Live (Figure 1). Furthermore, the events are framed as part of the W-STEM project's activities (Building the future of Latin America: engaging women into STEM), a cooperation project between Europe and Latin America funded by the European Union. The project aims to reduce the gender gap in STEM careers in Latin America, establishing mechanism and strategies in the processes of attraction, access, retention and orientation in Higher Education Institutions [12, 13].



Fig. 1. Flyers associated with the two roundtables.

Each roundtable was focused on a STEM area and related to an International Day to engage more people. The first roundtable was on 23 April during the Girls in ICT Day and it was focused on ICT-related studies such as Computer Engineering, Mechatronics Engineering or Systems Engineering. This roundtable involved 14 female students and graduates from Chile, Colombia, Costa Rica, Ecuador, Finland, Ireland, Italy, Mexico, United Kingdom, and Spain. It is important to notice that the roundtable was in Spanish, so the participants from non-Spanish speakers' countries were women who speak Spanish (Table I).

TABLE I. PARTICIPANTS IN THE ROUNDTABLE ABOUT GIRLS IN ICT

	Institution	Country	Degree	Situation
P1	University of Salamanca	Spain	Computer Science	Student

P2	Universidad del Norte	Colombia	Systems and Computer Engineering	Student
P3	Oulu University	Spain	Telecommunications Engineering	PhD student
P4	Politecnico di Torino	Colombia	Computer Science	PhD student
P5	Technological University Dublin	Venezuela	Systems Engineering	PhD student
P6	Tecnológico de Monterrey	Mexico	Business and Information Technology Engineering	Student
P7	Universidad de Guadalajara	Mexico	Computer Science	Student
P8	Universidad Técnica Federico Santa María	Chile	Civil Computer Engineering	Student
P9	Pontificia Universidad Católica de Valparaíso	Chile	Civil Computer Engineering	Graduate
P10	Universidad Tecnológica de Bolívar	Colombia	Systems Engineering	Student
P11	Instituto Tecnológico de Costa Rica	Costa Rica	Computer Engineering	Student
P12	Universidad de Costa Rica	Costa Rica	Computer Science	Graduate
P13	Universidad Técnica Particular de Loja	Ecuador	Electronics and Telecommunications Engineer	Graduate
P14	Universidad Técnica del Norte	Ecuador	Mechatronics engineering	Student

The second roundtable was related to the International Women in Mathematics Day on 12 May. We involved 15 female students and graduates from studies with a high mathematical component such as Industrial Physical Engineering, Mathematics or Civil Mathematical Engineering. The same countries were involved (Table II).

It is also important to note that the participants invited to both roundtables are STEM women who are not actively involved in bridging the gender gap in these areas and have no connection to the W-STEM project. This approach was aimed at reducing biases as much as possible. Besides, the participants had no prior instructions on how the discussion would be conducted.

TABLE II. PARTICIPANTS IN THE ROUNDTABLE ABOUT WOMEN IN MATHEMATICS

	Institution	Country	Degree	Situation
P1	Oulu University	Venezuela	Chemical Engineering	Graduate
P2	Politecnico di Torino	Italy	Mathematics	Master student
P3	Pontificia Universidad Católica de Valparaíso	Chile	Mathematics	PhD Student

P4	Technological University Dublin	Mexico	Mathematics	Graduate
P5	Tecnológico de Monterrey	Mexico	Industrial Physical Engineering	Graduate
P6	Tecnológico de Monterrey	Mexico	Engineering Physics	Master student
P7	Universidad de Costa Rica	Costa Rica	Mathematics	Student
P8	Universidad de Guadalajara	Mexico	Mathematics	Student
P9	Universidad de Guadalajara	Mexico	Physical & Mathematical Sciences	Graduate
P10	Universidad del Norte	Colombia	Mathematics	PhD Student
P11	Universidad Técnica del Norte	Ecuador	Electronics and communications engineering	Graduate
P12	Universidad Técnica Federico Santa María	Chile	Civil Mathematical Engineering	Student
P13	Universidad Técnica Particular de Loja	Ecuador	Civil Engineering	Student
P14	Universidad Tecnológica de Bolívar	Colombia	Mathematics	Graduate
P15	University of Salamanca	Spain	Mathematics	Student

The roundtables were in Spanish to facilitate the discussion. Each one took 90 minutes and was moderated by two women researchers related to mathematics and software engineering. The roundtables were divided into two phases. A first phase in which each woman answered the focus group questions and a second phase in which women answered the online attendants' questions. The questions were:

- Why did you choose to study ICT/mathematics, and what career do you hope to pursue?
- What is your experience as a student of ICT/mathematics? Did anything surprise you? Do you find it fun? Would you recommend it?
- What can be done to encourage more women and girls to study ICT/mathematics?

The qualitative analysis of the content has been carried out by having the literal speeches transcribed. Once the transcriptions have been read, the meta-categories and categories of the concept map have been created from the collected discourses. For the construction of the categories, the elements highlighted by the participants in the focus groups, in the answers to the questions, have been considered. Subsequently, it has been possible to coding the contents in the categorical system in order to link the narratives with the concepts of the map.

This analysis process can be carried out through qualitative analysis programmes that support the process of creating the meta-categories and subcategories, to facilitate codification [14].

III. RESULTS AND DISCUSSION

Three main questions have been asked in the focus

groups. The first one related to the reason for the choice of studies, which could be mathematics or ICT. The second question related to the experience as a student of mathematics or ICT and issues to be highlighted. The third question related to how to motivate other women and girls to study mathematics or ICT.

From the answers given by the participants of the two focus groups held, it has been observed that, about the reason for choosing these studies, the following stand out: tradition, care for others, participation in initiatives such as competitions, championships and Olympics related to science, interest in these studies, passion for the chosen studies and the usefulness found in these studies (mathematics or ICT).

Some of the women indicate that they chose such studies because they were good at the subject at school and therefore did not question other study options but were clear that it should be that option. This does not mean that family tradition also plays a role; if the parents or siblings, mainly the boys, have taken these studies, the daughters follow the professional path. This can be seen from the statements of two participants in the ICT focus group: **P4**. *Because at school I was doing well in physics and mathematics and in my time, it was like natural selection. If we were doing well in those subjects, we had to make a career out of them.* **P3**. *I liked science, maths and physics at school, but I did have a reference point. My father is a telecommunications engineer, so it was effortless for me to say, "I do the same thing and that's it".*

In other cases, the first option was studies linked to the care of other people, such as medicine. Even the family was more supportive of their daughters if they decided to go for this type of study. However, after thinking about it, they decided to opt for other kinds of studies such as mathematics and ICT, where they felt they could also contribute to society. This was stated by one of the participants in the mathematics focus group: **P7**. *I didn't know what to study, many years of my life I thought I would study social work because I had a very deep-seated part of me that I wanted to help people and that was the way I saw that I could help people. After a while, I realised that this career would not be very compatible with my personality. I know that you have to be an influential person. And I thought, "what am I going to do now, what am I going to study", and finally, several factors led me to mathematics.*

I chose to study engineering because I did not feel as capable as a doctor although I wanted to help people. And since in sixth grade, we all want to be doctors. Well, they want to be doctors. So I did not feel with the strength and energy to be a doctor, because I could not be with a person and help them and cure them, no. So, I said "how can I help people from somewhere else", and engineering seemed like something that I had an affinity for and was doing well, so I decided.

On the other hand, there is a transparent motivating element for the choice of mathematics and ICT studies, and that is the participation in championships, Olympics, etc. Two women from the mathematics focus group say: **P4**. *I like mathematics, just as I wanted physics, just as I liked even philosophy. So, since I was in secondary school, I have been in the mathematics Olympics, and that is where I liked the form, the approach that they give to it, that is to say, it is not*

so much the process, it is not so much the result, but the procedure that gives it more importance. And I liked that very much. **P7.** After a data center event, I met a lady who works at NASA. She studied computers and talking to other colleagues; she told us that for NASA, it is essential that people study science careers, and that there is work beyond being a maths teacher.

A woman from the ICT focus group highlights: **P6.** Yes, it was a process that changed in many areas, and I think something that helped me a lot was that I went to an event, to a camp, for fun. The event is called Campus Party, and it takes place in Mexico and various parts of Europe. It is a week developed so that the people who participate, of all ages, can learn about Information Technology. I went for pure fun, and when I went, I left with the idea of "how could I not have been presented with this option before", in other words, it was self-evident. My whole life profile pointed directly to an IT career; however, I never saw it, and it wasn't because someone had deprived me of the option to choose an IT career, it just hadn't come up.

The passion for mathematics and ICT studies is also of great value in deciding which tasks to choose. This is revealed in the mathematics group: **P3.** My passion for mathematics started at a very young age, and I found mathematics easy, but this is not what called me into this world. What encouraged me to enter this world was a contest that I had the opportunity to attend, which was of mathematical logic. It was this contest that changed my perspective on mathematics. And it is also indicated in the ICT group: **P5.** I always say and tell my friends that if I were born again, I would also study the same thing. Why? Because I love to dream. I love to dream. And maybe what I discovered with this career is that everything begins with an idea. And you bring ideas to life, bring projects to life, and the limit is in the imagination. It's not about being super smart; it's not about being the best at maths or programming. No. It's merely about having the idea and working on it. So, one of the best things that have happened to me in my life is this study of computers. **P13.** I think it's one of the parts of my career that I'm most passionate about. Engineering has a wide, vast field of application. It's amazing. You can do so many things. For example, in my career, I can be in telecommunications, I can be in electronics.

And accompanied by the passion for studies is also the interest, as three participants indicate: **P4.** In a moment of introspection, because I already had to do my paperwork to get into university, I started to think "it's effortless to say that you love something when it's going well, but when you're going through a difficult time, and you're still there persevering, you realise that you like this". That's when I decided to study for a degree in mathematics, and it's a decision I made almost two years ago, and I don't regret it (Math). **P12.** I was always very entertained by maths; it was like the only subject where I came with a desire to learn. After everything the teacher taught us, I would go home to find exercises and solve them like crazy (Math). **P11.** It was like love at first sight. It was as if my mind exploded, and I realised that I was super excited and wanted to know more and more (ICT).

Also, in the case of mathematics, the usefulness found in studies makes up a key element: **P11.** What has encouraged me since I was very young about mathematics is that it is unpredictable and straightforward for every aspect of

everyday life. Since I was very young, it was a skill that has been honed, which is also a fundamental tool.

On the other hand, another necessary category of analysis is social influences. These influences can be family, peer group, other references such as teachers, etc. However, these influences can favour or hinder the decision-making process. In the mathematics group, two participants indicate the family influence: **P4.** It was always something I liked since I was very young, and I always wanted to study by myself and take my big brother's books and see what he was doing. **P7.** I was helped a lot with the support of my father, who studied computers. Whereas in the case of ICT, you can see two different positions. On the one hand, you can see how family tradition can favour the choice of such studies. However, family tradition can also hinder the decision if it is loaded with stereotypes: **P13.** My mother told me "no, this is a career for men, you should study medicine or another career", so I asked "but why should this career be for men, why not for a woman? So, I think that is one of the factors that gave me strength, instead of discouragement. **P12.** It was a bit of divine enlightenment. Maybe computer science was my thing. And at the same time, it was also a bit about blood, because my parents studied the same thing, my older sister studied engineering, and my younger sister is also studying engineering. So basically, the genes and the family nucleus were an excellent motivation for me to study computer science.

However, it is not only the family that is an essential socialising element in influencing the decision, but also the teachers. In the case of mathematics: **P9.** I had an approach, but more than anything else I think what motivated me to study the physics-mathematics degree was a lecture I heard from a physicist while I was in high school, where, with a lot of passion and overflowing with an interest for his area and his specialisation, he spoke about the need we human beings have to understand the environment around us, to understand many of the phenomena that occur. And in the case of ICT: **P2.** I entered Systems Engineering, and I didn't know what I was getting into and I chose it. It was because of a physics teacher at the school who considered me to be very good at the subject and who had potential and told me "study this career, it has potential". This career has made me fall in love.

By looking at the elements that the participating women highlight in their studies, benefits and difficulties can be identified. Especially in ICT, the variety of areas in which a person can specialise, and work has been highlighted: **P9.** The good thing I find about ICT is that you can work in any area and learn any area of the same computer science.

Interestingly, of the five difficulties mostly encountered in training by these women, two are related to women's invisibility, and another problem is related to the invisibility of studies. Therefore, we should ask ourselves what is happening socially so that women feel that they are being left out of the scientific and technical education system or that they are not reaching it. In ICT, the gender gap is indicated: **P6.** It is impressive that there are far fewer women and there is far less presence of women, but there is also so much need for critical thinking that we women generate, and in my case, we are starting more than we are advancing. So, I think there are several challenges. The main challenge is that we need more women to study engineering careers. But now, how do you stay on course? You often check a career in engineering, and when you finish, because the field is so vast, not all of

them practice in the area of engineering. The number decreases, it decreases as a woman advances, so it's part of the challenge, and it's part of our responsibility to solve it. However, part of the origin of the gender gap is the gender stereotypes that are widespread in the contexts in which we develop, because of culture and the reproduction of biases. Therefore, it is necessary to be clear about some issues of gender equality and equal opportunities such as that all people have the right to access and representation, as indicated in the group of ICT: **P5**. *Girls are as good or better than boys, that we have a disadvantage because we are girls is false; we have a history of being very good at programming.*

On the lack of knowledge about the studies, in the group of mathematics, they point out: **P14**. *In the search, I found the mathematics, without really knowing everything that I was going to find within the career. Because it is not a well-known career within the entire portfolio of university careers. Let's say that I entered without really knowing much, and I know that many people may not know what can be achieved in a science career. P5. It wasn't easy to find information about careers offering this type of study, because there aren't that many. And the ones that do exist are not very publicised.*

However, two other difficulties identified are the difficulty of the studies themselves, as indicated in ICT: **P8**. *The truth is that race has been a rollercoaster ride of emotions. I'll be super honest; I wasn't very close to maths and physics, so when I took the challenge to enter an engineering school, it was scary and difficult. It cost me a lot. But with studies, with work, with dedication and the fact of not giving up, one manages to get everything out. And you also identify the difficulty of finding a job, as indicated in the maths group: P1. *There is something important, in the subject of studying mathematics it has always been saying "don't study mathematics, why would you study that, people are dying of**

hunger, people don't get jobs".

Once this point has been reached, women and girls need to be motivated to pursue the studies that they like and are excited about. We must move away from gender biases, from stereotypes. We must also move away from preconceived ideas that women are better able to care for others or will find more employment if they go to other studies. Positive factors must be promoted, such as those social references that female students have that encourage them to follow the path that they like. Therefore, to close the focus group sessions, participants are asked what they would say to other girls and women to encourage them to study mathematics and ICT. In the mathematics group, the following stand out: **P3**. *I want the girls who did not have the option like me to find that love for mathematics in that competition, to know that mathematics is much more. Maths is much more than calculus; it is super beautiful, and I would love to invite them to learn a little more about mathematics. Mathematics at heart is everywhere. P1. I see the faces of all these young girls and what I would like to say to them is that it is not easy, but there is something in their heart that tells them "that is the right way to go", it is a passion. Although it is the most challenging path, although it will not give you the immediate satisfaction that love, that passion is what will allow them to move forward. And in the ICT group, the following participant stands out: P11. *I believe that both women and men can take risks with the things or decisions they make. It is not a question of gender. It's each person, each person has different thoughts, and each person is going to make other decisions, so I think we must move away from gender.**

Figure 2 shows the concept map with the system of meta-categories and categories.

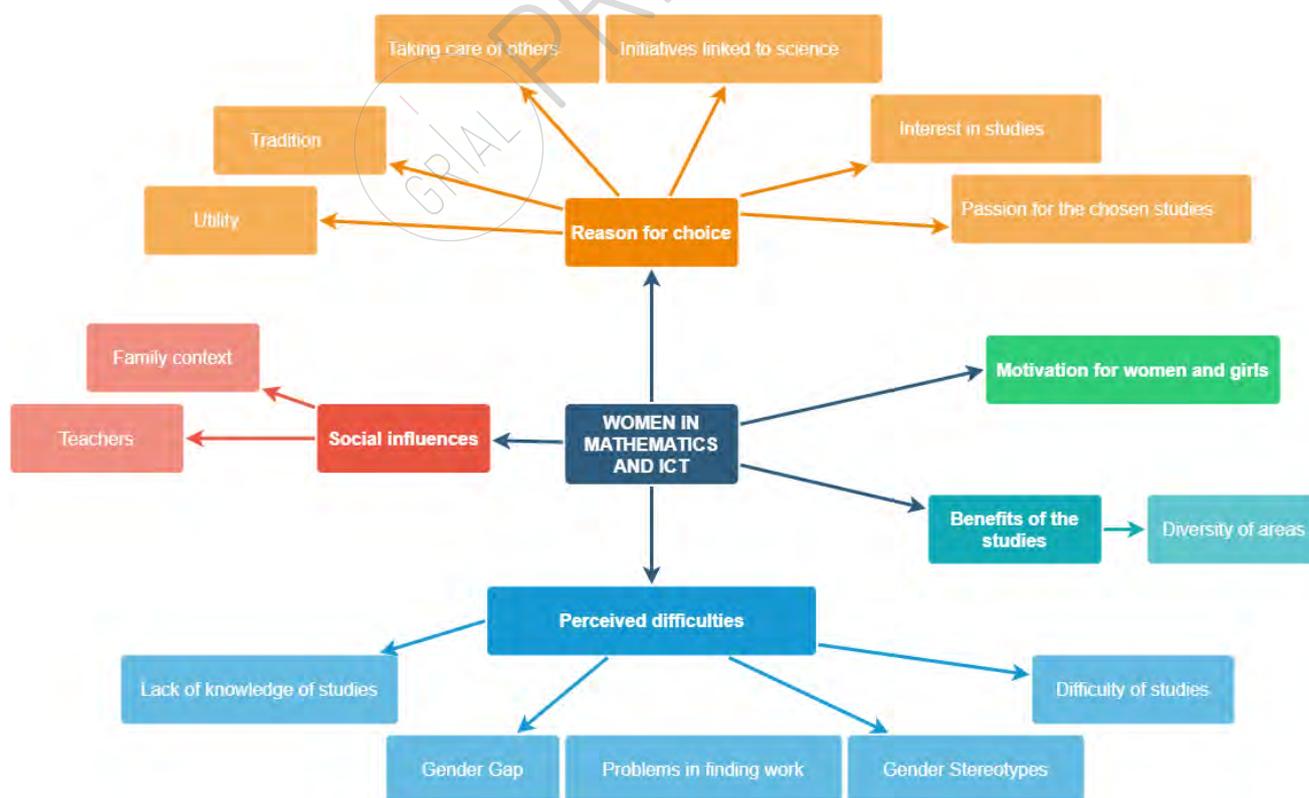


Fig. 2. Concepts map.

Following the results, it should be indicated that [15] produced similar results to those described in this study, within another experience of the W-STEM project carried out with women different from the current study. In this previous study, women also expressed their passion for their studies and pointed out that family and teachers have a unique role in choosing their studies. In some cases, the influence has been positive, and in other cases, the impact has contributed to women questioning their abilities, feeling less valid. Also, in [16], women were also strongly motivated to get other women and girls to fight for their dreams, away from the fear of daring.

As a society, we must work for equal opportunities; we must fight to mitigate the gender biases and stereotypes that still perpetuate inequalities. Prejudices that professions are gendered must be uprooted. And from the educational levels, interventions must also be directed towards the family and the environment of girls and women.

Finally, answering the three research questions posed in the study:

RQ1: Which motivations and ideas motivated or made it more difficult to choose a STEM career?

The women participating in the study highlight some of the motivations that encouraged them to study their studies. On the one hand, some of them have always been attracted to higher education; some even have a strong passion for it. Another motivation that these women find is the variety of areas they can specialise and work in, within mathematics and ICT. In this sense, the awareness of the usefulness of their studies has been a driving force in their decision to pursue them. Some of the women have previously participated in scientific-technical initiatives such as the Academic Olympiads, competitions and championships. Initially, when they participated in these initiatives, they were not clear about their professional vocation. However, participation in these initiatives helped to dispel their doubts. This is why it is important to encourage participation in initiatives of these characteristics, intending to explore personal interests. In another hemisphere, one finds motivations such as tradition. In this sense, some women have chosen such studies following the family tradition of their parents or brothers. However, these studies are also selected for their knowledge of the comfort zone. Those women who felt that they were good at the subjects associated with mathematics and ICT, in some cases, decide to follow that educational option. And finally, there are some cases where women wanted to devote themselves to caring for others, mainly through medicine. However, after trying this option or seriously considering it, they chose mathematics and ICT as a means of contributing to society.

RQ2: What influence has the socio-cultural context (family, friends, couple, etc.) had on the educational path?

The primary contexts that have conditioned the choice have been family and teachers. The family has conditioned the preference of their studies for and against. In contrast, gender biases and stereotypes continue to be reproduced. The preconceived idea that women should care for others and also teach continues to spread. Some women are sent the message that they are not good enough to be scientific and technical professionals.

On the other hand, the profession is also underestimated, conveying that "if you study that, you will starve and not find work". However, not everything is pessimistic. Some families support their daughters' decisions through modelling. There are women who follow this educational option because their family has been an example to follow.

On the other hand, teachers also provide motivating references for women, from which they can follow their example. This is the case with some teachers who verbally motivate the girls and even transmit their subject with passion.

Regarding teachers and families as a whole, some women stress that caution is required. In some cases, women are told "if you want, I can help you", assuming that they cannot do it alone. Doing this can make the person feel undervalued, so we must give the woman the possibility to explore her capacities and abilities, and if necessary, let her be the one to ask for help.

RQ3: What is the perception of support and barriers women have concerning the university context during their studies in STEM areas?

In general, all the women in the study give motivational messages to those women and girls who are attracted to mathematics and ICT, but who do not dare to pursue these studies. In some cases, fear holds back women who want to study science and technology. This is why these women are more self-confident and move away from the biases that exist towards women in STEM.

Some of the problems and difficulties they identify in the university context during their STEM studies are the gender gap, gender stereotypes, the lack of visibility of women in STEM, the lack of information about the studies, and also, the level of difficulty of the studies and the subsequent difficulty in finding work about it.

They point out that they felt strange in the classrooms as they were the only ones among so many men. Although they stress that they were well treated by their colleagues, they also highlight that the rates of representation of women are lower. Furthermore, the stereotypes in which they have grown up cannot be ignored. These stereotypes underestimate their ability to perform STEM work. However, sometimes there is not enough information about the studies they want to take, which also makes it difficult to access them.

IV. CONCLUSIONS

Among the outputs of W-STEM is the definition of gender equality action plans for the Latin American higher education institutions involved in the project. The action plans are focused on reflecting the strategies and mechanisms to improve the processes of attraction, access and guidance of women into STEM studies at higher education institutions.

The focus group study carried out with students from different universities across Latin America (Chile, Colombia, Costa Rica, Ecuador, México) and Europe (Finland, Ireland, Italy, Spain, United Kingdom) has provided some inputs for the definition of gender equality action plans in the involved institutions. Although it is not possible to generalise the results to all young women in Latin America, the results complement other quantitative studies. The application of focus groups as a qualitative analysis technique allows discussions on a topic

among different people, thus exposing their different experiences and perceptions. This in turn allows conclusions to be drawn about the overall experience of the people involved in the focus group. On the other hand, other methodological techniques such as the individual interview do not allow the presentation of the diversity of experiences, and the final reading of the data collection is a single case.

ACKNOWLEDGEMENT

This work has been possible with the support of the Erasmus+ Programme of the European Union in its Key Action 2 "Capacity-building in Higher Education". Project W-STEM "Building the future of Latin America: engaging women into STEM" (Reference number 598923-EPP-1-2018-1-ES-EPPKA2-CBHE-JP). The content of this publication does not reflect the official opinion of the European Union. Responsibility for the information and views expressed in the publication lies entirely with the authors.

This research was partially supported by the Spanish Ministerio de Ciencia, Innovación y Universidades under a FPU fellowship (FPU017/01252 and FPU17/03276).

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