”I can do this”: Resilience of women students in engineering and technology courses in Portugal

Dr. Bill Williams, TUDublin, Ireland

Bill Williams originally trained as a chemist at the National University of Ireland and went on to work in education in Ireland, UK, Eritrea, Kenya, Mozambique and Portugal. He is Professor Emeritus of Instituto Politecnico de Setubal, Portugal, Adjunct Senior Fellow at TUDublin, Ireland and Researcher at CEGIST, Instituto Superior Tecnico, Universidade de Lisboa Portugal.

Dr. Shannon Chance, University College London

Professor Shannon Chance, PhD, is a Registered Architect holding bachelor’s and master’s degrees in Architecture from Virginia Tech and a PhD in Higher Education from William and Mary. She is Lecturer and Programme Chair (Honours BSc in Building Information Modeling/Digital Construction) at Technological University Dublin and Honorary Professor at University College London. She also is a LEED Accredited Professional and a Senior Fellow of the Higher Education Academy (SFHEA) in the UK. Shannon is Deputy Editor of the European Journal of Engineering Education and has served as Full Professor of Architecture in the USA, Chair of the Research in Engineering Education Network (REEN), Associate Editor of IEEE Transactions on Education, Fulbright Fellow to Ireland, and a Marie Curie Research Fellow (to both Ireland and the UK).

“I can do this”: resilience of women students in engineering and technology courses in Portugal

Abstract

To understand the factors that influenced female students to choose their degree programs and complete them successfully, we gathered data from 11 women undergraduate students in Chemical Engineering, Biotechnology, and Construction Management programs at a Portuguese polytechnic. All participants completed their courses within the two years following the interviews. The two authors analyzed the data gathered via interviews with individual students using thematic analysis and present four generated themes along with their implications.

The findings suggest that further research is warranted on the role of short-cycle programs within the Portuguese polytechnic sector in providing routes to help young women overcome obstacles and be successful on STEM degree programs.
In a broader context, they also suggest that outreach initiatives geared towards schoolgirls and their families could benefit from emphasizing how STEM degrees can provide a wide range of career options and are a good alternative for those still unsure what future career to pursue.

Introduction

When the Carnation Revolution in 1974 ended 48 years of dictatorship in Portugal, higher education was the preserve of an urban elite minority and predominantly served male students, especially in areas like engineering and technology. Education had been denied to most citizens for decades; data from the 1950s show that, at that time, around 42% of the Portuguese population was illiterate (the percentage among women was even higher), and only 0.04% of the Portuguese population had completed a university degree [1].

A broadening of access to higher education has occurred over the past 50 years, fueled by the creation of new universities and a complementary network of polytechnic institutes dispersed across the country, particularly in rural areas. By 2020, 33% of women in Portugal had post-secondary/higher education degrees, compared to 28% of men.

Although more young women than men have entered higher education in Portugal since 1990 [2], there is a gender imbalance in their choice of program. Men tend to opt for “Information and Communication Technologies (ICT)” (with 80.5% of the total being male) and “Engineering, manufacturing industries and construction” (68.3%) [3]. Among women, preference is given to the areas of “Education” and “Health and social protection”, constituting a proportion of 84.4% and 77.2%, respectively [3].

The number of female students choosing Science, Technology, Engineering and Mathematics (STEM) subjects currently stands at 27% [4]. Nonetheless, female enrolment in chemical engineering, biotechnology, and engineering management programs is markedly higher than in IT or mechanical, civil, and electrical engineering [4]. This pattern, while common in many Western countries, has not been extensively studied in the Portuguese national context. The lack of research on the pathways that

lead young women to opt for such programs is a pressing issue that needs to be addressed.

Literature Review

Much of the literature on under-representation in STEM courses has come from the United States. Presenting data from a study of engineering student trajectories, Pawley [5] commented that engineering schools (in the US, at least) often imply the normal, standard, or 'ideal' student is an un-married, white-skinned male, aged 18-22, who resides on campus and is free of responsibility for earning a life-sustaining wage or caring for a family. This shared perception tends to problematically impact students from minoritized groups. Such students can feel excluded from this implicit definition of an archetypical engineering student.

Stereotypes like these tend to change slowly over time, but repeated exposure to more diverse heroes, role models, and compelling stories can help promote change [6]. Fortunately, there has been increasing research interest in identifying the trajectories of less traditional engineering students who do not match the white male default norm. Smith and Lucena [7] studied engineering students from low-income households who were the first generation of their family to attend university. Their study included many women and members of other groups minoritized in engineering. The researchers concluded that such students bring valuable knowledge reserves to the university that they accumulated over time by fulfilling commitments to families, employers, customers, and the like.

Also studying the trajectories and experiences of students from low socioeconomic contexts in the US, Carrigan et al [8] gathered data from engineering students enrolled at a large US public university. Participants in the study experienced constraints of money and time, resulting from the need to provide paid labor or unpaid family care. The researchers summarized that "navigating between formal and informal institutions, and drawing support from both fictive and familial kinship ties, they persist to manoeuvre through institutions that often favor the habitus of the upper class" (p.162). Participants in the study [8] also described difficulty locating "appropriate and supportive resources in their college and departments" (p.163).

A subsequent study, by Wilkins-Yel et al [9], focused on resilience in engineering programs, found that "women employed a myriad of resilient coping strategies to create their success. This included perseverance, asserting one's legitimacy, cultivating support and belongingness, [9] recognition of strengths, and meaningful impact as a reason to thrive" (p.353). Wilkins-Yel and colleagues noted it is not enough to publish studies highlighting these issues – there is a real need for the findings to be acted upon. They concluded with the stated goal for their findings to "inform career practitioners, employers, and administrators in cultivating women's resolve to persist, but more importantly, to address the systemic issues that warrant such coping strategies in the first place" ([9]p. 365).

Family support has been recognized in prior research as significant in helping women choose careers in STEM. For example, quantitative analyses by Bieri Buschor et al. [10] identified parental support, learning experiences, and role models as crucial in the decision-making process for women who pursued STEM at ETH in Zurich. Parents

appeared to be completely supportive during the time they were choosing the location and major; these same authors found using qualitative methods. The parents were "deeply concerned with their daughters' needs and the high requirements of the rigorous ETH" ([10] p. 174). Bieri Buschor et al. inferred "that parents' (particularly fathers') worries concerning study or job-related requirements can be a barrier for students considering a STEM career" ([10] , p. 174). They supported this idea with prior research that identified fathers as role models of particular importance to individuals choosing to pursue engineering [11], [12]. [10] also found that women who, in high school, intended to study STEM did, in fact, later enrol in such courses. The loss of women from the "pipeline" did not occur at the point of transition from the second to third levels, but rather earlier. According to Gayles and Ampaw [13] parents' education level influences persistence toward earning STEM degrees. Highly educated parents typically provide high levels of academic encouragement, raising the likelihood of women entering STEM majors. Financial support provided by parents has been found to predict the completion of STEM degrees by women [14]. The quality of students' experiences at the third level also helps predict their persistence toward earning STEM degrees [15].

Former World Bank executive Steve Denning, in his book *The leader's guide to storytelling* [16], presents examples from large international organizations to illustrate how the use of compelling narrative "is one of the few available ways to handle the principal and most difficult challenges of leadership: sparking action". This chimes with earlier observations about the importance of stories to bring about societal change [6]. Within engineering education narrative approaches have begun to be adopted as a valuable methodological conceptualization for researching marginalized engineering students [17],[18].

Research question

Given that female enrolment in chemical engineering, biotechnology, and engineering management programs is markedly higher than in IT or mechanical, civil, and electrical engineering [4], we wished to explore why and how these women joined STEM courses and consider what factors they described as memorable.
We address the research question:
What lessons can we distil from this data-set to help educators understand the experiences, context, and various challenges and supports experienced by this group of women studying STEM subjects at a polytechnic institute in Portugal?

Authors' positionality

The lead author of this report is a male senior lecturer, bilingual in Portuguese and English who worked at the engineering school from where participants were recruited and had taught 10 of the 11 students two years previously.
The second author, a female US national, conducts cross-border research on these topics, interviewing women engineering students in multiple countries. She is based in Ireland, does not speak Portuguese and came to Portugal for 8 days to participate in and observe the interviews.
The two authors have considerable experience in gathering qualitative data via interviews of engineering students and engineering practitioners.

Context and methodology

This is a qualitative study based on interviews with women students in STEM areas, aiming to explore their academic trajectories and experiences. Adopting a musical metaphor, the study seeks to explore common themes in a choir of voices while also recognizing and honoring contributions of individuals. We use thematic analysis [19] to generate themes that help us characterize the shared harmony while also distinguishing specific melodies voiced by our participants .

This work is part of a larger project investigating the experience of female STEM students in higher education in Portugal, Ireland, and Poland. The overall study was designed phenomenologically, and the interviews were conducted in an open-ended, participant-driven way. In Poland and Ireland, the second author of this paper conducted all interviews in English. In the Portuguese polytechnic, few students were comfortable enough with English to converse academically, so interviews were conducted by the lead author and/or one of his colleagues, with the second author present. The logistics of the interview process involved coordinating convenience sampling with the timetable constraints of voluntary student interviewees and of the first author within the time window of the second author's eight-day visit. This resulted in two of the interviews (those of Paula and Carla) being conducted by a bilingual Portuguese faculty member who had also taught these students in a previous year but who was inexperienced in conducting qualitative interviews.

To elicit the most authentic and unfiltered narratives from participants, attention was given to maintaining a conversational tone in the interviews, We believe that the first author's interactions with the students in previous years and the voluntary nature of their participation in the study was helpful in this respect.

The phenomenological interview schedule is attached as an Appendix. While the Portuguese interviews did broadly follow the schedule, they did not fully adhere to the phenomenological protocols due the logistical constraints mentioned above. As a result, we used thematic analysis [19] to interrogate the Portuguese results rather than a thoroughly phenomenological approach. We believe the data-set holds value and seek to share the insights embedded in it that can help educators understand the Portuguese polytechnic STEM experience from the point of view of young women experiencing it for the first time and also suggest potential lines of research in other national contexts.

Sample

To recruit participants in Portugal, the lead author visited classes of students at second- and third-year levels of Chemical Engineering, Biotechnology, and Construction Management within a school of engineering at a Polytechnic Institute in Central Portugal and appealed to women students to volunteer to be interviewed as part of an international project about the experiences of female STEM students. Participation was voluntary and no incentives were provided to potential interviewees.

While the polytechnic competes directly with engineering schools at long-established higher education institutions in the capital and would not be a first-choice for potential students in most engineering programs, it was one of only two offering biotechnology programs. It was also one of the two polytechnics in the region offering short-cycle CET

courses; the relevance of this aspect will be discussed in the findings related to academic trajectory.

The interviews were conducted in Portuguese and subsequently translated into English by a team of native Portuguese speakers, some based in Portugal and others in Ireland. The translations were then cross-checked with the audio data by the first author to align local references (e.g. place names and course titles) and check the fidelity of the translations.

Ethics approval was obtained at all institutions involved (in Portugal, Ireland, and Poland), and interviewees received a participant information sheet and informed consent form in the local language prior to the interview. Pseudonyms were established to maintain the anonymity of participants:

	Degree Program
Nadia	Chemical Engineering
Zélia	Chemical Engineering
Paula	Chemical Engineering
Candida	Chemical Engineering
Gracieta	Chemical Engineering
Fabia	Construction Management
Rosa	Biotechnology
Mariana	Biotechnology
Telma	Biotechnology
Adriana	Biotechnology
Carla	Biotechnology

Table 1 STEM programs in which interview participants were enrolled

The 11 participants were in the 19 to 24 age range; nine had completed secondary (high) school in Portugal, whereas two (Zelia and Fabia) had come to Portugal from Lusophone (Portuguese-speaking) African countries to pursue higher education.

Analysis procedure

The two authors of this paper met in person throughout the process to: discuss the study design, identify the research method and framework, conduct several interviews together, discuss procedures for analysis, and generate themes. They wrote and edited this paper in tandem. The overall project involved iterative, interpretive, and hermeneutic phenomenological approaches to analysis, as described in van Manen's book "Researching Lived Experience: Human Science for an Action Sensitive Pedagogy" [20]. The work reported in this paper is underpinned by phenomenological philosophies, principles, and methodologies but is organized thematically.

The themes were generated by the first author entering each participant's responses to the interview questions (see Appendix) into an Excel spreadsheet that was then shared with the second author. The authors then discussed the responses until reaching a consensus on the salient themes that emerged from the data.

Results and Interpretation

In this section, we report results according to themes identified through our collaborative analysis: (1) academic trajectory, (2) parental background, and (3) family support. Each subsection presents the results via an overview and a selection of interview quotes and follows this up with a short interpretation from the authors. Following this thematic presentation, we present two "back-stories," in more detail, featuring notable experiences of two participants.

Academic trajectory

Before enrolling in the chemical engineering or biotechnology degree program, nine of the eleven participants had completed a Technological Specialization Course (CET) at the same institution where they now studied. In Portugal, a CET is a short-cycle higher education program [21] that in this case led to a laboratory technician diploma; it was a 12-month practice-based courses that included a short industrial internship. Fees for these CETs were lower than for degree programs. This lower cost was a primary reason several of the participants cited for choosing this route into higher education. The lower fees made this route feasible:

> ***Telma***: "I liked biology since secondary school, but I had doubts if I should go into this area or not. I was afraid – I saw colleagues who had finished school with me and came to university, and afterward, changed course. I wasn't in the financial situation to do this, so I chose to go to the CET as it wouldn't be so expensive, it was only one year, the college is well set up and has a range of levels. It was very good."
>
> ***Rita***: "Initially, it was not the course that I wanted to enter, but I was here studying here for the CET; I managed to get into the degree and found that it was a good option."
>
> ***Gracieta***: "My mother emigrated to France, and I stayed here. When I was in secondary [high] school my grandfather and I went to the Futurália education fair in Lisbon, and we saw that the CET would open here in this college near home, and that would give me and my friends access to higher education."

Another important reason for selecting the CET path involved mathematics, including their shifting perceptions of their math-related abilities (the plural, "maths," is used in Europe). The CET provided a lower entry threshold for participants who had not achieved high mathematics grades in high school but had the capacity to succeed when mathematics was encountered in more applied contexts in a degree program:

> ***Adriana***: "I was always good at maths. But, when I got to year 10, I am not sure what happened, all my tests for the year were around 6.0 (out of 20). Now, I get good marks again. In the recent algebra test, I got the highest mark of everyone."
>
> ***Telma***: "Finishing secondary school wasn't easy. My problem at school wasn't that I didn't know the material; it was that I was nervous about the exams. Now, I do get good marks in maths."
>
> ***Nadia***: "To be honest, Chemical Engineering was not quite what I wanted to do. I wanted to follow Pharmaceutical Sciences, Nursing, [something] more in the healthcare area. However, my exams for the twelfth year (i.e., "12th grade") at school were not so good, so I joined the CET course here. And then I ended up in engineering. I liked it."

Prior research [10, 11] indicates that similar barriers and perceptions keep many young women from selecting STEM careers. The CET seemingly provided a way for participants in this study to overcome initial roadblocks (i.e., anxieties and temporary drops in math scores) – to get a second opinion or challenge initial impressions about their fitness to study mathematics-intensive subjects.

Our sample group had five Biotechnology students (in addition to five Chemical Engineering and one Construction Management student). Some who selected Biotechnology described their choice as arising from a long-held interest in the field:

> ***Rosa***: "Genetics is about people and its science. I want to do something for future generations. We have to evolve in science and [for me] to try to contribute to this development would be fantastic."
>
> ***Mariana***: "I've always loved the medical area, the part about medical tests. The part about Forensic Science, I also really like. And I also like the part about the genetic manipulation of genes. [The concentrations for] my master's degree and my doctorate will be hard to choose."

It is inspiring to hear students who enter third-level (higher) education through this "non-traditional, more vocational route articulating lofty goals for contributing to the larger body of knowledge and completing the highest levels of education. This is particularly poignant given the lack of access to even basic education in Portugal faced by all generations before 1974, as described in the introduction to this paper.

Within our (convenience) sample, Chemical Engineering was perceived as providing a range of future careers.

> ***Paula***: "I didn't know specifically what I wanted to be, but I liked and still like Chemistry. And Chemical Engineering is a very open area."
>
> ***Zelia***: "I came to Portugal from Cape Verde to study, and while Chem. Eng. was not my first choice, I ended up doing it when my first choice didn't work out. Now I really enjoy it. It's a very broad area."
>
> ***Candida***: "I realized that I wanted Chemical Engineering because I like Chemistry and because Chemical Engineering is a very broad area."
>
> ***Gracieta***: "I wanted to follow something that involved Chemistry. Then it was suggested to me that Chemical Engineering is a broader area that would open up my horizon in professional terms and in terms of learning, and so I decided to follow Chemical Engineering."

This perception suggests consistency in the messages conveyed to students within this course, with all the above quotes containing the words "broad" or "open." While it is likely that that this perception was influenced in some degree by a narrative they were exposed to at department level, it did appear to resonate with them in their perceptions of their future.

Parental background

Three of our participants were first-generation higher education students:

> ***Telma***: "Nobody in our family has a degree. My father only stayed in school until year 4. He went to work in the Portucel factory, and my mother only got to the 8th year in school – she used to be a cleaner for the local authority but went back to school to do ninth year, and now she's in admin. there."
>
> ***Adriana***: "My parents didn't have the opportunity for higher education -- my mother worked on a production line for buses. My father worked on the buses."
>
> ***Nadia***: "I will be the first one to have a degree in my family."

These quotes underscore that the data-set we have collected capture a snapshot in an evolving history of access to higher and further studies. In a country where only a handful of third-level institutions existed prior to 1974, and the parallel tracks of universities and polytechnics were established following the overthrow of the country's dictatorship, it is not uncommon to encounter individuals with doctorates whose parents completed only primary or early secondary school (the equivalent of elementary and middle school in the USA).

Six of the eleven participants did not have engineers or technologists in their immediate family, whereas five did have contact with some form of engineering in their background. Candida and Rosa represent the first group:

> ***Candida***: "I didn't know any engineers before. Nobody in my family is one."
> ***Rosa***: "My mother is a teacher, and my father is a police officer. And the rest of the family are not engineers or scientists either."

While Zelia and Paula had familial ties to engineering:

> ***Zelia***: "I have family members who are in the engineering area, so it was an inspiration from grandparent to son to grandchild."
> ***Paula***: "My stepmother's two sons are engineers. One is a Mechanical Engineer, and the other is an Electrical Engineer. But they wanted engineering because it was engineering. It was not necessary them being engineers for me to follow as well. So, it was more self-motivated on my part."

Although Zelia described a generational hand-down of engineering interests, Paula did not feel this familial calling from her step-siblings' career choice. Nevertheless, it is perhaps noteworthy that all the engineers these participants noted within their families were male [11, 12].

Family support

The influence of family members was mentioned as important in all the interviews, typically from a positive perspective. Some described positive reinforcement to pursue education in general:

> ***Rosa***: "My parents always said to me: 'Daughter, choose the best for you.' They always supported me."
> ***Zelia***: "I was brought up in Cape Verde by my grandparents. They told me to study because in the future 'the one who has a pen in their hand has a better future.'"

Some described a more focused approach from their parents:

> ***Mariana***: "Neither of my parents influenced me in my choices; they always supported me and always told me to choose the course that I wanted; they always told me that I had to go to an area that I really liked. My mother always told me to go to Computer Science, because she says that I am very good with computers, but that area has never fascinated me."
> ***Paula***: "I live with my parents and my father gave me only two options and this one was closer to home."

One described feeling a personal sense of obligation in recognition of the substantial support she felt her mother provided:

> ***Nadia***: "I joined Chemical Engineering thinking: 'If it doesn't go well, I'll change the course, ask for a transfer.' And that was my thinking. But I finished the first year, I did the subjects. I didn't get such good grades, but I thought: 'My mother struggled to pay for me to be here, and now I'm going to give up? No. I will do the second year. If it goes wrong, I'll give up.' I started the second year, I

did Programming, did all the subjects. And they told me: 'You're already in the middle of the course.' And then I thought: 'Will I give up? No, I won't. Now I can do this.' My mother thought I would not be able to finish it. But I told her I'd try. When I entered the third year, my mother was so proud of me, especially because she had been the first one to say that engineering might not be for me."

On the other hand, two participants described tensions arising within their immediate families:

> ***Mariana***: "I have to study and never give up, but we have moments of frustration with ourselves, and sometimes it shows. It happens a lot with my parents, with the stress, sometimes I answer them in a way that hurts them, and that was not my intention."
>
> ***Carla***: I live with my parents and all of us are from different areas. My father is an economist, my mother is from literature and I'm from sciences. I feel pressure is playing its part and I can't share my anxieties with my parents because they don't understand my area. I accustomed them to my having good grades in the past, I guess, but sometimes now it really doesn't help having my parents always on at me.

Overall, the interview data indicate that most students live locally, residing with their immediate families.

Back-stories

Various of our interviewees had what we considered to be striking back-stories, and we will share two we see as being particularly notable.

Experiences of a STEM student who immigrated to Portugal

Fabia arrived from Angola as part of a 20-strong cohort of Angolan students to study at the engineering school, and when two years had gone by, almost half had dropped out. She had always earned good grades in Angola but had difficulty adapting to the new environment during her first year.

> ***Fabia***: "There were some very difficult moments. When I got here in the first year, I could not succeed like I had done at school. I passed only one subject, and I felt totally lost; it was the worst time I've spent. I wasn't used to seeing those kinds of grades, it was a big challenge.
>
> I could not understand things. I have come from a country that also speaks Portuguese, but when I got here, beyond languages, Portuguese communication didn't help. The study method was totally different from Angola. There were many difficulties. I could not understand what the lecturers were presenting; even when they were presenting well, I could not understand the material. I did study, but still could not succeed. Having low marks and not succeeding was really distressing, but I managed to overcome this in the second half of the year, where I passed four subjects. And from there, I've already managed to pick up the pace, and so far, things have gone well. Now, I still have difficulties, but I know the study method and what I have to do. It's different.

She developed new strategies, especially regarding project work in groups:

> ***Fabia***: "In the first year, we could choose the groups, and I formed a group with people that were already my friends, who had come with me from Angola, [naming one female and two male students]. I think it did not go very well. For us, it was a good piece of work, but the lecturer expected a lot more than we produced, and we didn't get a great mark.

So, then I decided that in the second year, it was better to try groups with Portuguese students. I chose to be in a group with [named two male students] because, in the first maths class, they had proved to be dynamic and really good students, so I wanted to be with people like that."

After her first year, she changed her degree course, and her grades improved:

Fabia: "I decided to switch to Construction Management because I thought it would be more useful to my country since there is no course like that there. It does have Civil Engineering, so I thought it would be better to innovate."

She described the challenges she perceived with having a career in a traditionally male-dominated area:

Fabia: "It's different being a woman, even though I think that it is a normal thing, people still see it as something different, because people can't see a woman in the construction area. It is easier to see a woman in business. Being a woman in construction or in engineering means that you are a great fighter and a winner."

A valuable message for educators, that we heard from Fabia and also from Middle Eastern women studying in a technical university in Ireland, involved the difficulty transferring learning and concepts across culture and language [21]. Even when immigrating students have previously encountered the concepts (in science and mathematics classes in high school, for instance), the slight differences in vocabulary and context as well as the tacit knowledge shared by the host nation's students and lecturers pose a significant barrier in connecting prior learning to the new. Research shows that novices of all sorts face such difficulties, and our work [21] suggests that educators might support foreign-born entrants to STEM subjects by helping them identify connections, or provide them space to search the concepts online or within their peer groups to connect to how the topic is described back home.

Experiences of a STEM student confident in her path

Mariana, one of the students who came directly into Biotechnology without doing a preliminary year in the CET program, had a clear idea of what she wanted from an early age:

Mariana: "Since I was young, I have participated in science competitions at the school level, national level, and then internationally. So from that moment, I always wanted something related to science – because for me it's very nice to do a project in this area. It can be a simple piece of work like a PowerPoint, but it can also be a big project [like the competition she experienced] involving universities, schools, and many dedicated working hours. And then with that project we could participate in national competitions, all in the science area. And to be different at a national and international level is great! And it turned out to be a driving force that influenced my choice.

She had started by participating in school and local competitions and gone on from there:

Mariana: "I was in the Young Scientists and Researchers competition, a nationwide contest in which several projects compete in various scientific fields; mine was always biology, and we competed with the project at the national level and presented at the Museum of Electricity in Lisbon. The jury there selected the projects that would represent Portugal in international competition. We didn't get selected, but just the fact that our work was recognized to be there to represent our high school and our land [region] was good. I never gave up, and I took part in another contest promoted by the Science Youth Association at national level, where we had to display the work for three weeks. And then we won! Our prize

was to present the project in Amsterdam, and I was there for a week presenting the work. Obviously, the spirit there was much more competitive, because they were the best works of each country. The project was subject to various reviews, and we achieved the third place at this international level, which was very good for us."

For Mariana her Biotechnology studies developed as a natural extension of childhood interests:

> ***Mariana***: "I love the cosmetic area because my mother is a hairdresser. So since I was young, I've always liked that area. And Biotechnology has investigation of cosmetic products including manipulation of any gene in a cream. We have to deal with things, manipulate, work with bacteria, micro-organisms. We have a theoretical part that later we will apply in practice, then it seems that all ideas are articulated with each other, and everything makes sense even DNA manipulation and everything."

We believe Mariana's story helps us see some types of connections and motivations that are often overlooked by academics. Mariana's motivation reflects family ties and challenges gender stereotypes.

Sharing stories like those of Fabia and Mariana could be valuable in outreach activities to attract more female students to STEM programs [6, 16, 17, 18].

While analyzing these interview data, we again recognized the value of considering both the "harmony" and the "melody" of the STEM chorus at this polytechnic; in this report, the harmony is communicated as cross-cutting themes the students' trajectory into a shared study setting, the family support it took to find and maintain this trajectory, and the commonalities in family background at this region-serving institution. Phenomenological research methods seek to capture the shared voice, this harmony. Yet, we also appreciate the individual stories, the melodies, that are interwoven with these theme and which articulate specifics that bring the stories to life. As researchers, the two authors work to develop ways to explore and communicate both the harmony and the melody in meaningful and compelling ways.

Implications for educational research and teaching practice

Although these CET programs are particular to the Portuguese context (and have since been replaced by more extended CTeSP programs [22]), they are an example of how providing a low-stakes decision for secondary school students and their parents can open pathways to bring under-represented groups of potentially successful students to STEM programs. Up to now there have been few studies of the role of CETs or CTeSPs in either English or Portuguese language literature [23, 24, 25] and none of them address the role of female students.

The participants' comments could also be relevant to recruiting young women to STEM programs. Anecdotally, many students arrive at the end of their secondary school education undecided as to their future choice of study, but while undecided young men may opt for IT and engineering areas, undecided young women may gravitate more towards humanities, health, or business. Therefore, outreach initiatives geared towards schoolgirls and their families could benefit from emphasizing how STEM degrees can provide a wide range of career options and are a good alternative for those still unsure what career to pursue.

Future Work

Investigation of the potential role of short-cycle CTeSPs provided by polytechnics in facilitating or encouraging the entry of young women into STEM degree programs in Portugal is a potentially valuable area that we intend to pursue. It would also be pertinent to broaden the scope to examine the extent to which short-cycle programs in other national contexts can be relevant.

Limitations

Limitations of the work reported in this study include (a) the volunteer or convenience nature of the sample, wherein students with certain characteristics (e.g., courage, curiosity, time) were more likely to volunteer than others, and (b) the language barriers that necessitated having multiple interviewers and transcribers and led to some inconsistency in probing and/or depth of conversation from one interview to the next. This variance in interview procedures rendered a data set viable for thematic coding but weakly suited to phenomenological analyses (d) as one author had taught ten of the participants, this previous connection could represent a potential participation bias.

Conclusions

The data-set allows a credible glimpse into the experiences and perceptions of eleven young women studying STEM subjects, with unique insight into women's experiences in Portuguese STEM education. The valuable role of the polytechnic – a more practical, hands-on, vocational track than is available via the Portuguese university education system, and particularly the CET (now CTeSP) certification route – come to life via the participant quotes. These are not findings that either of the researchers anticipated and they suggest that further research is warranted on the role of the CTeSP and the polytechnics in providing routes to help young women overcome obstacles and be successful on STEM degree programs.

While this study is situated in a specific Portuguese context, the generated themes also suggest lines of research in other national contexts in that they provide an example of how offering a low-stakes decision for secondary school students and their parents can open pathways to bring under-represented groups of potentially successful students to STEM programs. Finally, they suggest that outreach initiatives geared toward schoolgirls and their families could benefit from emphasizing how STEM degrees can provide a wide range of career options and are a good alternative for those still unsure of what career to pursue.

Acknowledgements
This work is partly financed by Portuguese funds through the FCT - Foundation for Science and Technology, I.P., under the projects UIDB/00097/2025 and UIDP/00097/2025 (CEGIST)

References

[1] M. E. Gonçalves, Ed., *Os Portugueses e a Ciência*. Lisboa: Publicações Dom Quixote, 2003

[2] M. Entradas, "Women in science: Rising numbers but an eternal glass ceiling," *Cultures of Science*, vol. 6, no. 1, pp. 23–33, 2023.
[3] Statistics Portugal, "2021 Census - Final results release," 2022. [Online]. Available: https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_publicacoes. Accessed: Dec. 29, 2024.
[4] UNESCO, *Global education monitoring report 2020: Gender report. A new generation: 25 years of efforts for gender equality in education*, 2020. [Online]. Available: https://unesdoc.unesco.org/ark:/48223/pf0000374514. Accessed: Dec. 29, 2024.
[5] A. L. Pawley, "Learning from small numbers: Studying ruling relations that gender and race the structure of US engineering education," *Journal of Engineering Education*, vol. 108, no. 1, pp. 13–31, 2019.
[6] K. Schmidt and B. A. Nosek, "Implicit (and explicit) racial attitudes barely changed during Barack Obama's presidential campaign and early presidency," *Journal of Experimental Social Psychology*, vol. 46, no. 2, pp. 308–314, 2010.
[7] J. M. Smith and J. C. Lucena, "'"How do I show them I'm more than a person who can lift heavy things?" The funds of knowledge of low income, first generation engineering students," *Journal of Women and Minorities in Science and Engineering*, vol. 22, no. 3, 2016.
[8] C. Carrigan et al., "Active agents and fictive kin: Learning from Pell-eligible engineering students' class standpoint," *Journal of Women and Minorities in Science and Engineering*, vol. 25, no. 2, 2019.
[9] K. G. Wilkins-Yel, A. Simpson, and P. D. Sparks, "Persisting despite the odds: Resilience and coping among women in engineering," *Journal of Women and Minorities in Science and Engineering*, vol. 25, no. 4, 2019.
[10] C. B. Buschor, S. Berweger, A. Keck Frei, and C. Kappler, "Majoring in STEM—What accounts for women's career decision making? A mixed methods study," *Journal of Educational Research*, vol. 107, no. 3, pp. 167–176, 2014.
[11] J. S. Eccles, "Understanding women's educational and occupational choices," *Psychology of Women Quarterly*, vol. 18, no. 4, pp. 585–609, 1994.
[12] A. F. Gilbert, "Étudiantes débutantes dans une filière technique: entre revendication d'égalité et expériences d'inégalité," in *Science et technique: l'enjeu du genre*, M. Merz, F. Crettaz de Roten, A.-F. Gilbert, and J.-P. Leresche, Eds. Lausanne, Switzerland: Observatoire EPFL, Politique et Société, 2003, pp. 109–130.
[13] J. G. Gayles and F. Ampaw, "The impact of college experiences on degree completion in STEM fields at four-year institutions: Does gender matter?," *Journal of Higher Education*, vol. 85, no. 4, pp. 439–468, 2014.
[14] G. Huang, N. Taddese, and E. Walter, "Entry and persistence of women and minorities in college science and engineering education," *Education Statistics Quarterly*, vol. 2, no. 3, pp. 59–60, 2000.
[15] H. S. Astin and L. J. Sax, "Developing scientific talent in undergraduate women," in *The Equity Equation: Fostering the Advancement of Women in the Sciences, Mathematics, and Engineering*, B. A. Babcock, A. S. Davis, and S. S. Ross, Eds. San Francisco, CA: Jossey-Bass, 1996, pp. 96–121.
[16] S.Denning. The leader's guide to storytelling: Mastering the art and discipline of business narrative (Vol. 39). John Wiley & Sons, 2005.
[17] S. Secules, A. Gupta, A. Elby, and E. Tanu, "Supporting the narrative agency of a marginalized engineering student," *Journal of Engineering Education*, vol. 107, no. 2, pp. 186–218, 2018.

[18] J. P. Martin and C. Garza, "Centering the marginalized student's voice through autoethnography: Implications for engineering education research," *Studies in Engineering Education*, vol. 1, no. 1, pp. 1–19, 2020.
[19] V. Braun and V.Clarke, (2019). Reflecting on reflexive thematic analysis. *Qualitative research in sport, exercise and health*, *11*(4), 589-597, 2019.
[20] M. Van Manen, *Researching lived experience: Human science for an action sensitive pedagogy*. Routledge, 2016.
[21] M Chance, B.Williams, & I. Direito, (2021, June). Studying Engineering Abroad: Intersectionality and Student Support. In 4th International Conference of the Portuguese Society for Engineering Education (CISPEE) (pp. 1-6). IEEE.
[22] "Short-cycle higher education," Europa.eu, 2024. https://eurydice.eacea.ec.europa.eu/national-education-systems/portugal/short-cycle-higher-education (accessed Feb. 18, 2025).
[23] Nunes Da Costa, A. Simões, G. Pereira, and L. Pombo, "Technological specialisation courses in Portugal: description and suggested improvements European journal of vocational training." Accessed: Feb. 18, 2025. [Online]. Available: https://www.cedefop.europa.eu/files/etv/Upload/Information_resources/Bookshop/570/46_en_Costa.pdf
[24] Monteiro, R. Pereira, and H. Marto, "The teachers' perception about CTESP's students and the academic success," 2019. Accessed: Feb. 18, 2025. [Online]. Available: https://www.isep.ipp.pt/files/CASHE_Poster6.pdf
[25] Pereira, "A Política Pública de Ensino Superior em Portugal pós Tratado de Lisboa: os Cursos Técnicos Superiores Profissionais. " 2022. Masters Dissertation, Accessed: Feb. 18, 2025. [Online]. Available: http://hdl.handle.net/10400.5/27245

APPENDIX

Interview Questions

Note to interviewer: It's best to let these topics flow from the natural course of conversation. Please start the interviewing saying you hope to say as little as possible, because you want to hear as much as possible, what's important to her.

1. If you were talking with a girl from your secondary school, who is interested in going into engineering, what would you tell her about your experience here (at X and also in engineering)?
2. Did you have complications when you were first trying to get used to being in college?
    a. How did you figure out solutions?
    b. Who helped?
3. Can you tell me about the most satisfying experiences you've had in the past year?
4. Can you tell me about the most difficult experiences you've encountered in the past year?
5. When you are working at home on an assignment and you have a problem you can't figure out, how do you solve it?
6. Can you remember a specific time when you decided to work together (with your classmates) to learn a concept or solve a problem?
    a. What was the concept or problem?
    b. Where -- what was the place like?
    c. Who was there?
    d. If no one knew the answer, how did you find a solution?
    e. How did this situation feel? (What is enjoyable/frustrating? What do you like best/least?)
7. Did any teachers ask you to work together on an assignment?
    a. How did you organize yourselves?
    b. Did you feel any tension, and if so, did you resolve it?
8. Can you tell me about a time you taught someone else something about engineering?
9. Can you tell me about a time when you felt when you felt a sense of confidence about engineering, or like you are already an engineer?
10. Can you tell me about a time you felt frustrated with a lecturer or tutor?
11. How did you choose engineering? What influenced your decision?
12. Did you know an engineer before you got here?
13. How did you choose X?
14. Do you feel like you belong here at X?
15. What is it like for you being a woman in engineering?
16. Do you know what a [biotech] engineer does? How do you / will you find this out?
17. Do you feel like you belong in engineering?
    a. Can you tell me what it feels like when you doubt your choice of engineering?

b. Can you tell me about a time you felt like you might change to another discipline?