Do Female Motives for Enrolling Vary According to STEM Profile?

Noelia Olmedo-Torre, Fermín Sánchez Carracedo, M. Núria Salán Ballesteros, David López, Antoni Perez-Poch, and Mireia López-Beltrán

***Abstract*—*Contribution:* Stereotypes and immediate environment are the reasons for low enrollment of women in STEM studies.**

***Background:* The low number of women in STEM degree courses has been the subject of much research, which has found that the lack of female enrollment is not evenly distributed across all STEM studies. In some areas, such as computing, communications, and electrical and electronic engineering (CCEEE), not only has the number of women not increased, it has even fallen.**

***Research Questions:* Is there a stereotype for women taking STEM studies? Is this stereotype different between women taking CCEEE and non-CCEEE degrees? What are the main reasons that lead women to enroll in STEM studies?**

***Methodology:* A survey was sent to 3699 female students and STEM graduates belonging to the authors' university in six schools with a lowest level of enrollment, and 1060 replies were received. A qualitative study based on data analysis triangulation was performed.**

***Findings:* The women surveyed consider social stereotypes (31.47%) and the immediate environment (14.5%) as the main reasons for the low enrollment of women in STEM studies. Surprisingly, the third reason (11.03%) is that women do not like engineering. New knowledge concerning what motivates female students to enroll in STEM studies, what stereotypes they must struggle against, and the existence of possible differences between CCEEE and STEM but non-CCEEE female students could help policy makers and academia to improve female enrollment in STEM and, in particular, in CCEEE studies.**

***Index Terms*—Engineering, enrollment, female, gender, equality, STEM, student diversity.**

Manuscript received May 30, 2017; revised September 15, 2017 and January 6, 2018; accepted February 22, 2018. This work was supported by the Education Sciences Institute (ICE UPC). *(Corresponding author: Noelia Olmedo-Torre.)*

N. Olmedo-Torre is with the Graphic Engineering Department, School of Engineering Barcelona East, Universitat Politècnica de Catalunya (BarcelonaTech), 08019 Barcelona, Spain (e-mail: n.olmedo@upc.edu).

F. Sánchez Carracedo and D. López are with the Computer Architecture Department, Barcelona School of Informatics, Universitat Politècnica de Catalunya (BarcelonaTech), 08034 Barcelona, Spain (e-mail: fermin@ac.upc.edu; david@ac.upc.edu).

M. N. Salán Ballesteros is with the Department of Materials Science and Metallurgical Engineering, School of Industrial, Aeronautic and Audiovisual Engineering of Terrassa, Universitat Politècnica de Catalunya (BarcelonaTech), 08222 Terrassa, Spain (e-mail: nuria.salan@upc.edu).

A. Perez-Poch and M. López-Beltrán are with the Education Sciences Institute, School of Engineering Barcelona East, Universitat Politècnica de Catalunya (BarcelonaTech), 08034 Barcelona, Spain (e-mail: antoni.perez-poch@upc.edu; mireia.lopez.beltran@upc.edu).

Digital Object Identifier 10.1109/TE.2018.2820643

I. Introduction

THERE is a lack of female enrollment in STEM studies, especially in those related with computing, communications and electric and electronic engineering (hereafter CCEEE). Raising the interest of women in these studies is an important goal for universities, national and local governments, and society as a whole. However, while most of the research has been focused on STEM studies in general, the lack of female enrollment is not evenly distributed across all STEM studies. Furthermore, although a considerable number of female students are enrolled in studies like life sciences, CCEEE is male-dominant.

Much of this research work is aimed at proposing ways to increase female vocations for STEM courses, but the question arises of whether women who opt for CCEEE courses have the same motivation as those who choose other STEM courses. Given the significant underrepresentation of women in CCEEE studies, extensive research is required to identify what motivates women CCEEE graduates to take those courses, and whether these motives differ from those of women who opt for other STEM courses.

This paper explores the differences between the motivations of women STEM students and alumnae who undertake CCEEE studies (hereafter, CCEEE women), and those who do other courses (hereafter, non-CCEEE women), when it comes to choosing what courses to follow. The authors of this work sent a survey on this topic to 3,699 female students and alumnae of the Universitat Politècnica de Catalunya – UPC·BarcelonaTech (UPC) (www.upc.edu), Spain; 1,060 replies were received. This research project falls within the quantitative and qualitative paradigm and follows a non-experimental, descriptive-type methodology that employs data analysis triangulation.

II. Background

European Union (EU) indicators show that although women account for more than half of all students in higher education, the proportion of women involved in STEM studies is far below 50%. This problem is common in other parts of the world [1], [2]. Burchell *et al.* [3] states that STEM studies are predominantly undertaken by men; women make up 24% of all professionals engaged in science and engineering. In 2012, the number of women graduates in STEM courses was 12.6% of the total of female university students; for men this figure was 37.5%.

Studies of particular populations, such as those carried out in South Africa [4], the USA [5] or India [6], revealed strong similarities in the motivations of women who opted for a STEM course, but also detected the influence of other factors such as race, caste or religion. This present study is focused on the STEM society in Catalonia, where there is little cultural diversity. It may even be said that the social differences between students are also relatively insignificant, all of which has enabled the authors to concentrate their attention on gender.

This is not the first study comparing populations in STEM studies. Hartman *et al.* [7] surveyed 83 first-year engineering women students and compared the responses from those engaged in mechanical and electrical/computing engineering with those from chemical, civil and environmental engineering students. He found differences in self-confidence and academic success between both populations, but found no significant differences between those who were asked their opinion about the expectation that a degree in engineering would help them make an important contribution to society. However, he did find significant differences, regarding the self-confidence of women taking chemical, civil and environmental engineering studies, where there is a higher presence of women. He found that self-confidence was significantly lower. Some studies [8], [9], warn about the problem of negative self-perception, such as the lack of confidence in many women about their skills in mathematics, which is regarded as the reason for the low enrollment of women in STEM courses. A relationship is found between autonomy or the degree of self-confidence, and the choice of such studies. This is due to the masculine view prevailing in society that the world of engineering [10], [11] is a rational, objective and neutral field, which stands in opposition to the traditional notions surrounding femininity [12]. This makes women feel removed from men in their professional lives, even in countries like Finland, where a greater degree of gender equality exists [1].

Perception of immediate environment is also a factor often quoted in the literature, in particular aspects such as the educational level of the mother, the presence of engineers in the family and the support provided by the family group [1], [13]. These studies point to the need to involve families and teachers in the search for a solution, as well as providing children with the opportunity to participate in outreach activities from an early age, since the level of interest in science and technology emerges in infancy in both sexes.

The situation in the geographical location under study is similar to that in other countries; with very few exceptions, young women began to study technical subjects in the middle of the twentieth century. One study [14] provided the personal circumstances of women who completed their engineering studies before 1980, and arrived at the following conclusions: (1) they found it difficult to find employment, especially their first job; (2) chemistry was the subject chosen for most degrees; (3) negative attitudes were evinced by male classmates, which gave rise to a feeling of exclusion; (4) difficulties existed of integration into groups consisting of the opposite sex; and finally, (5) some women felt that more was demanded of them because of their gender.

Finally, most studies are focused on the comparison between STEM and non-STEM students. While it is true that STEM is male-dominant, since women account for just 24% of science and engineering professionals, these figures are not evenly distributed across all STEM studies. CCEEE is the sector showing the lowest female representation, with only four out of every 1,000 tertiary graduates being female, compared to 20 out of every 1,000 men [15], [16]. For this reason, this study is focused on the comparison between CCEEE women and non-CCEEE women.

III. Research Questions and Objectives

This paper focuses on the research questions:

1) Is there a stereotype (description of an attitude or behavior) for women taking STEM studies? The initial hypothesis is that such a stereotype does exist; this work seeks to characterize it.
2) Is this stereotype different between women taking CCEEE and non-CCEEE degrees? The initial hypothesis is based on the assumption that no significant differences exist between the two populations.
3) What are the main reasons that lead women to do STEM studies? If these causes can be identified precisely, it would be possible to adopt ways to solve the problem and thus increase the percentage of female enrollment therein (especially in CCEEE courses).

The objectives of the research presented in this paper are to:

1) Analyze whether differences exist in the profiles of CCEEE women and non-CCEEE women.
2) Determine the influential factors at the time when STEM women chose what course to follow, and to analyze whether these factors differ from those in the case of CCEEE women and non-CCEEE women, with the aim of obtaining information to enable action to be taken on the emergence of STEM vocation in the female population in both childhood and adolescence.
3) Discover women's perceptions of why so few of them undertake STEM studies, in order to tackle these causes in the future.

IV. Methodology

Given the diversity of the objectives and the considerable number of factors that may exert influence on their outcome, this work presents a data analysis triangulation study based on the data collected from the survey. The triangulation is of the spatial type, in which the different regions are composed of two groups: CCEEE women and non-CCEEE women. The goal of this study is to select those hypotheses whose results are the most statistically significant, so that in subsequent work a detailed study of the validity of each hypothesis may be conducted (based on a randomly-selected population together with a control group).

The survey was addressed to women studying STEM courses with a low level of female enrollment, i.e., not overall enrollment. The survey questions ask about subjects studied; the family structure and conditioning factors; the reason for

the choice of course and the level of satisfaction; professional activity; personal characteristics, and personal and professional models, and more.

The survey was sent by email from the schools themselves, paying due regard to the protection of personal data, and ensuring that all recipients were registered women or alumnae. A motivational letter was sent with the survey, explaining its objectives and importance. Survey recipients agreed to receive any request for information that might be sent to them about their professional activity, and agreed to the retrieval of academic data related to their previous studies.

The survey was anonymous, conducted online (https://goo.gl/3wckLD), and drawn up using Google Drive forms. It was issued to a total of 3,699 female students and alumnae, from among whom 1,060 responses were received. 43% of these responses were from alumnae (461) and 57% from current students (599).

The survey is organized into groups of questions on various aspects, namely:

1) Family organization (number of brothers and sisters, their gender, the place they occupy);
2) University studies undertaken by family members;
3) Motives for the choice of courses and when the choice was made;
4) Personal opinion of how skilled they felt compared to their male colleagues when commencing their studies;
5) Degree of self-confidence about doing the course;
6) People who approved or disapproved of the choice of course;
7) Satisfaction as regards initial expectations;
8) Perception of the amount of time devoted to their studies in comparison with their male colleagues;
9) Personal reaction to disappointing academic results;
10) Perception of the influence of studying with a majority of male students;
11) Readiness to advise others to undertake similar studies;
12) Sphere of paid activity undertaken while studying or subsequent to studying;
13) Influence of professional activity of female role models;
14) Degree of personal self-esteem and type of personality;
15) Aspects of life regarded as most important;
16) Preferred sports;
17) Influence of role models and/or stereotypes during studies;
18) Perception of level of equality between men and women in the professional sphere.

The types and number of possible answers (in parentheses) for these questions were: multiple choice (30), drop down menu (2), check (6), grid of options (1), linear scale (4), and open field (1).

In 2016, a preliminary survey was conducted with 153 students in the framework of a final degree project. This survey, which served as the basis for the completion of this larger study, already contained many of the questions analyzed in this paper. Before being sent, the preliminary survey was submitted to a validation process carried out by four professors from UPC not involved in this study. This process had three objectives: (1) to explore whether the survey omitted some question areas, (2) to determine whether the questions were clear and well formulated, and (3) to detect possible errors in its preparation. The professors' feedback led to improvements in the formulation of the questions and the inclusion of some new questions. The 153 students were used as a control group.

Finally, a last open-ended question was added, where the respondents could freely express their perception of the reasons for the low enrollment of women in STEM studies.

The survey was addressed, and limited to, the first female graduating classes consisting entirely of students taught in accordance with the system introduced for adaptation to the European Higher Education Area, and who completed their studies in the academic year 2013/14. The students selected were enrolled in six schools, the UPC STEM Centers providing various degree courses and with the lowest percentage of women enrolled. These schools, providing various degree courses, are listed here:

1) FIB (Barcelona School of Informatics, 9% of women enrolled),
2) ETSETB (Barcelona School of Telecommunications Engineering, 18% of women enrolled),
3) EETAC (Castelldefels School of Telecommunications and Aerospace Engineering, 19% of women enrolled),
4) ESEIAAT (School of Industrial, Aerospace and Audiovisual Engineering of Terrassa, 19.5% of women enrolled),
5) EEBE (Barcelona East School of Engineering, 19% of women enrolled),
6) FNB (Barcelona Faculty of Nautical Studies, 16% of women enrolled).

For each question in the survey, the responses provided by CCEEE women were compared with those from non-CCEEE women. The Chi-squared test was applied to each group of questions to determine the corresponding p values. High p values indicate that no differences exist between the CCEEE women's group and the non-CCEEE women's group. On the other hand, $p < 0.05$ values indicate that statistically significant differences between both groups do exist for that question.[1]

The survey concluded with an open field question asking why respondents believe far fewer women opt for STEM courses than men. A qualitative analysis using the constant comparison technique was conducted to analyze these replies. The women interviewed expressed their personal opinions about the reasons for the low enrollment of women, so a reason could be expressed in many different ways. It was necessary to codify clearly each different reason given in the responses and to identify when a response refers to each reason.

An abductive methodology was used to define these codes; that is, codes emerged from the data iteratively. Firstly, half of the dataset was read to enable a list of codes to be identified. Then, by using these previously-identified codes, the entire dataset was processed. When all the answers had been

[1]A breakdown of all the answers from students who took STEM degrees (arranged by school, specialty, and CCEEE women and non-CCEEE women) is available at (https://goo.gl/oPvMhB).

read, new reasons were found that had to be coded during the analysis.

The objective of the study was to identify the main reasons expressed by the respondents, so a code of "other reasons" was also created for responses that occur less frequently. After examination of all the answers, those identified as referring to "other reasons" were re-read; some reasons appeared a sufficient number of times to be assigned an independent code (abductive methodology).

V. Results

A total of 3,699 women received the survey, from whom 1,060 valid responses were obtained. 434 (40.94%) of these responses came from CCEEE women and 626 (59.06%) from non-CCEEE women. The results of the survey were analyzed both quantitatively and qualitatively and are presented in the following two sections.

A. Quantitative Results

The survey results identify some factors common to both CCEEE women and non-CCEEE women, and others for which CCEEE women appear to possess a stereotype that differs from that of non-CCEEE women. The initial hypothesis is based on the assumption that no significant differences exist between the two populations, so this hypothesis will not be valid if $p < 0.05$ values are found. Details of the most significant results are given below. The statistical analysis of the data is presented here, and explanations are given in Section VI.

In reply to the question "*Why did you choose your course of study?*", no significant differences were found in the appeal of the course ($p = 0.1278$), the professional opportunities ($p = 0.0951$) or the expectation of a high salary ($p = 0.6651$). Nevertheless, differences were found to exist when the motive for choosing the course was working on projects ($p = 0.0043$), working as part of a team ($p = 0.0051$) or the possibility of cultural enrichment ($p = 0.0158$). CCEEE women were less likely to choose these three motives than non-CCEEE women.

In reply to the question "*What influenced your choice of study area?*", significant differences were found when respondents were asked about their average grade in the university entrance exam ($p = 0.0244$), and whether a member of their social or family circle had recommended a course of study ($p = 0.0171$). CCEEE women were less likely than non-CCEEE women to say average grade was a factor, and were more likely than non-CCEEE women to indicate the social or family circle factor. No significant differences were identified for other motives, such as admiration for a prominent figure (scientist, historian, engineer or architect, $p = 0.0728$) or some important event in their lives ($p = 0.2415$).

Significant differences were found in response to how capable, on commencing their university studies, they believed women to be in comparison with men, in five fields of knowledge. CCEEE women were less likely than non-CCEEE women to regard themselves as being more capable than men in: physics ($p = 0.0022$), chemistry ($p = 1.2E\text{-}14$), mathematics ($p = 0.0038$), informatics ($p = 0.0049$) and graphic expression ($p = 0.0157$). However, when asked about their self-confidence when tackling technological courses, the value obtained was $p = 0.4166$, which suggests that there were no significant differences in the level of self-confidence in either population.

Significant differences were also found for the question: "*Which people were totally in agreement with your choice of studies*?"; family ($p = 0.2804$), teachers during secondary education ($p = 0.0183$) and pre-university classmates ($p = 0.0342$). In all three cases, CCEEE women were less likely than non-CCEEE women to answer that these groups completely agreed with their choice of degree course.

Significant differences were found for the question: "*Did your studies satisfy your initial expectations?*" ($p = 0.0213$). CCEEE women expressed greater satisfaction about this than non-CCEEE women. Nevertheless, no differences were identified when asked if they would make the same choice of studies again ($p = 0.7231$).

Reactions to disappointing academic results were similar in both groups ($p = 0.1400$), but not in the approaches taken as a result ($p = 0.0160$). CCEEE women were more prone than non-CCEEE women to feel "*This is not for me, I don't think I'll be successful*", whereas CCEEE women were less prone than non-CCEEE women to feel "*My efforts are leading to good results*".

Significant differences were found in response to the question "*How does your salaried professional activity relate to your studies both before and after completing your course*?" ($p = 1.6943E\text{-}5$). CCEEE women were more likely than non-CCEEE women to answer "Yes, it is or was directly related". When only alumnae responses were taken into account, the results were still significant ($p = 0.0159$), but the main difference was found in the response "*I have not worked*", where alumnae CCEEE women provided fewer responses (2.3%) than non-CCEEE women (7.82%). Significant differences ($p = 0.0004$) were also seen in replies to the question "*Have female figures in your family environment, either currently or in the past, engaged in some paid professional activity?*". CCEEE women (26.89%) were more likely than non-CCEEE women (15.80%) to respond "No, none of them".

The question "*What is your perception of gender discrimination, on the part of men (i.e., men discriminating against them)?*" ($p = 0.0292$) yielded significant differences. While over two thirds of both groups perceived this, non-CCEEE women had a higher perception (74.76% versus 68.66% of CCEEE women).

No differences were identified in responses to the question "*Do you believe your professional careers may be affected by maternity and/or family responsibilities*?" ($p = 0.56726$). However, for the question "*Do you believe that, in certain professional positions, the selection process offers equal opportunities for men and women*?" ($p = 0.0440$), CCEEE women were less likely than non-CCEEE women to indicate that in most cases the system does not offer equal opportunities for men and women.

No differences were found with respect to the immediate environment (number of brothers or sisters in the family unit, their order of birth, gender of older siblings, p values of 0.7052, 0.6408 and 0.2863, respectively). No differences

were found for the question "*Has anyone in your family ever done or is currently doing university studies?*" ($p = 0.6789$), nor in comparing the field of such studies ($p = 0.6817$). For grandparents, uncles, aunts and cousins, the results were also similar. For the question of whether anyone in this category had done or was currently engaged in university studies, a value of $p = 0.2645$ was found, and the analysis of whether such studies do or do not belong to CCEEE yielded a value of $p = 0.6539$.

No differences were found in responses to the question "W*hen did you choose the field of your university studies*?" (childhood, adolescence, on enrollment, $p = 0.1176$). This agrees with responses to whether the courses studied were of a vocational nature or not (likewise no significant differences, $p = 0.2326$).

When asked "*Are you concerned about what family members, colleagues or people in general think of you?*", the replies showed no significant differences ($p = 0.3283$), similar results being found when asked what type of personality best defined them (rational, concerned about others, ambitious, individualist, cerebral, loyal, active, powerful, lazy), $p = 0.3930$.

When asked "*Were you influenced by masculine or feminine stereotypes during your universities studies?*", no differences were found ($p = 0.8428$), the majority of respondents stating that they had not been influenced by any type of model.

B. Qualitative Results

The open question "*Why do you think there are so few women doing STEM studies?*" received 810 replies (76% of the total, 351 from CCEEE women and 459 from non-CCEEE women), a very high percentage given that they spent between 15 and 20 minutes answering the other questions in the survey. After applying constant comparison, 22 different codes (plus "other reasons") emerged. Some responses refer to more than one code, so the number of reasons obtained (1167) is higher than the sample number, indicating that each response identified 1.44 reasons on average. The reasons are classified into six categories: childhood, pre-university studies, university studies, society and self-confidence, work and other reasons. Table I presents the reasons grouped by categories and the number of responses identifying each reason.

TABLE I
REASONS GROUPED BY CATEGORIES

CATEGORY	CODE	CCEEE	Non-CCEEE	TOTAL
Childhood	Stereotypes in education	36	30	66
	Discrimination by toys	20	40	60
	Immediate environment	61	56	117
Pre-university studies	Secondary school teachers discouragement	19	12	31
	Lack of information in secondary school	33	37	70
University studies	Discrimination in classrooms	19	13	32
	Engineering is not very social	16	5	21
	Women are more suited to social careers	8	9	17
	Women do not like engineering	37	52	89
	Discomfort in male classes	14	15	29
	Engineering is for freaks and nerds	8	3	11
	Engineering is difficult	25	22	47
Society and Self-confidence	Lack of women role models	27	37	64
	Social stereotypes	116	138	254
	Society undervalues women	8	13	21
	Social discrimination	10	15	25
	Personal undervaluation	12	19	31
Work	Lower salary than men	6	5	11
	Discrimination in the workplace	17	41	58
	Difficult to reconcile work and family	5	8	13
	Lack of laws to promote gender equality	8	4	12
	Maternity is an obstacle	2	9	11
Other reasons		35	42	77
TOTAL		542	625	1,167

VI. DISCUSSION

A. Quantitative Analysis

The p values obtained from the data analysis, together with the replies to the survey, clearly identify certain differences between CCEEE women and non-CCEEE women. Some of these differences are not immediately obvious and provide much food for thought.

When asked about the main reasons why they chose a particular course, significant differences exist in the responses "*the possibility of working on projects*" and "*the possibility of working as part of a team*". The number of CCEEE women stating that these did not form part of their motivation is much greater than expected compared to non-CCEEE women. This indicates that CCEEE women may be more individualistic, preferring to work alone rather than as part of a team. This characteristic coincides with the classic "nerd" stereotype attributed to people who work in CCEEE; that is, rational people who find intellectual stimulation very important while scoring very low on socially-oriented interests.

When asked "*What motivated your choice of studies?*", differences in importance of the average grade in the university entrance exam may indicate that CCEEE women were less influenced by this factor than non-CCEEE women, perhaps because CCEEE courses have a lower cut-off grade than other STEM courses, meaning that CCEEE women do not require such a high grade to qualify.

CCEEE women received fewer recommendations for their field of study than non-CCEEE women from close family members or their pre-university teachers, suggesting that society in some way rejects the idea of women studying CCEEE; this is one area where progress should be made.

When asked "*Who completely approved of your choice of course?*" more CCEEE women than non-CCEEE women reported that pre-university teachers, close friends, and male

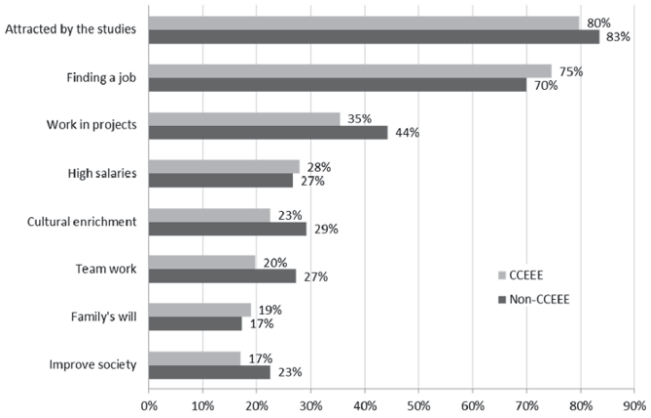

Fig. 1. Main motivations given by women for choosing their studies. The options given were: "Attracted by the studies", "Finding a job", "Possibility of working in projects", "High salaries", "Cultural enrichment", "Possibility of working as a team", "Family influence" and "Improve societal quality of life".

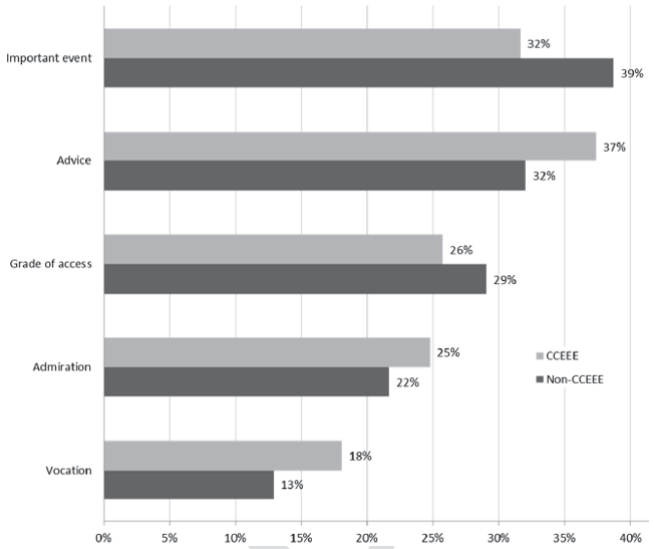

Fig. 2. Main factors given by women as contributing to their choice of studies. The options given were: "Vocation", "Advice from family or teacher or because I had an inspirational model before university", "Due to an important event in my life", "Due to entrance exam grades" and "Admiring an engineer, an architect, or a scientific a historical personality".

classmates tended to discourage them from pursuing these studies—a further important factor that highlights once again that society rejects the idea that women should opt for CCEEE studies.

When asked for their personal opinion about how skilled they felt in comparison with their male colleagues on starting their studies, the results regarding women's capability in mathematics, physics, chemistry, informatics and graphic expression as compared with their male colleagues on commencement of their studies suggest that CCEEE women were regarded as less capable than were non-CCEEE women. This factor may also be regarded as sufficiently important to merit further in-depth study. However, no differences were found in either groups' level of self-confidence in embarking on technological studies.

It appeared that CCEEE women were more likely to feel discouraged than non-CCEEE women, perhaps due to societal pressure, as indicated by their reactions to the questions about dedication to study and academic results. For the question "*During your university years, what has been your perception of dedication of time to studies to achieve good results?*", CCEEE women selected responses such as "*This is not for me; I don't think I'll be successful*" more frequently than expected.

Far more CCEEE women alumnae were currently engaged in, or had had more experience in, professional activities related to their studies (72.02%) than non-CCEEE women (60.91%). The percentage of CCEEE women students who had never had or did not have paid employment was only 2.3%, while for non-CCEEE women it was more than three times higher (7.82%). For alumnae the results were similar, but with larger differences between both groups. Similarly, professional activity by close female relations (mother/progenitor, grandmother, aunt) had greater importance for non-CCEEE women than for CCEEE women. This finding can be explained by the current percentage of CCEEE women being far lower that non-CCEEE.

The perception of gender discrimination was greater in non-CCEEE women than in CCEEE women. CCEEE women perceived greater equality in certain job selection processes than non-CCEEE women. Further detailed research should determine whether gender discrimination is really lower in the CCEEE environment than in other spheres.

Figs. 1 and 2 present women's reasons for choosing their area of study, and the main factors they identified as contributing to their choice of studies, two items selected as being the most relevant to the present study. Their attraction to the studies stands out, as does the possibility of finding employment. Vocation (i.e., professional calling) and advice from family and teachers are the two most prominent reasons cited for their choice of studies.

B. Qualitative Analysis

The most cited reply to the open field question asking why women continue to be a minority in STEM courses, Table I, was the existence of social stereotypes (31.5%).

Reasons cited by over 5% of the respondents, which can therefore be considered as more relevant, were:

1) Social stereotypes (254 replies, 31.47%)
2) Immediate environment (117 replies, 14.5%)
3) Women do not like engineering (89 replies, 11.03%)
4) Lack of information in secondary school (70 answers, 8.67%)
5) Stereotypes in education (66 answers, 8.18%)
6) Lack of women role models (64 responses, 7.93%)
7) Discrimination by parents' choice of toys (60 replies, 7.43%)
8) Discrimination in the workplace (58 replies, 7.19%)
9) Engineering is difficult (47 replies, 5.82%)

In terms of social stereotypes, the reason most frequently given was that women perceive that they are regarded as being more suited to humanistic, psychological, social or literature

courses, whereas men are more suited to STEM and technology courses. Respondents indicated that in their immediate environment (family, school, and friends), they were encouraged from childhood to study other courses. They also cited a lack of encouragement in their childhood to learn and understand how things work (in school, the family and society in general); that curiosity, research, effort and personal challenge were not encouraged; that they were not encouraged to be engineers (the argument being that it was not for them); that engineering receives insufficient promotion among girls and that there is little education in technology. Finally, they commented that boys and girls are not educated in the same way, since girls are educated for motherhood.

Only three reasons received more than 10%*:* social stereotypes, the immediate environment and women not liking engineering. While the first two were to be expected, the third is surprising: that some women engineers or engineering students think that, in general, women do not like engineering. This answer is probably a consequence of the first two reasons: social stereotypes and the influence of the immediate environment from childhood lead some women to think that women do not like engineering.

Some of these reasons are reflected in Fig. 2. For example, the fact that vocation was the main factor contributing to the choice of studies shows the importance of social and educational stereotypes, the immediate environment, the lack of information in secondary school, the lack of female role models and discrimination in the selection of toys made by parents. All these factors contribute in a definitive way to awakening the sense of vocation. The second factor with the greatest impact on choice of studies - advice from family and teachers - is also closely related to social and educational stereotypes, and especially to the immediate environment. This suggests that the quantitative and qualitative results are aligned.

Finally, five reasons were cited 17 times (2% of answers), eight occurred no more than 25 times (3%), and 13 reasons no more than 33 times (4%).

C. Practical Suggestions

Given that the two main factors identified by respondents as being responsible for the low enrollment of women in engineering were social stereotypes (31.47%) and the immediate environment (14.5%), solutions based on the responses of all the women surveyed—not just CCEEE women—are proposed here:

1) *Mentoring between women*, particularly between high school girls and university students, in order to motivate and accompany scientific-technical vocations. This mentoring could establish a relationship that guides high school girls in the search for information, and helps awaken a technological vocation. The objectives of mentoring are different for those mentoring, those receiving mentoring, for the university community, and for secondary schools. For mentoring women, the objectives are: to support STEM (and CCEEE) vocations and to bring the university closer to pre-university girls; to show the availability of useful science and technology courses with attractive professional opportunities, and to provide resources and information about studies to empower girls in their choice of university studies. For the mentored girls, the objectives are to create bonds of gender solidarity and to favor their relational competencies and their capacity of leadership. For the university community and secondary schools, the objectives are: to raise community awareness of gender segregation; to demystify existing relationships between gender and STEM studies to break gender constraints when choosing a professional path, and encourage mentoring as a tool for the pre-university orientation of students. A pilot plan in this form is currently being carried out at the UPC.
2) *Integrate technological activities into pre-university curricula*, to prevent adolescent girls from being discouraged from studying engineering. Universities should organize activities to bring young students, especially in the 12-15 age group, into closer contact with technology. These activities would preferably not require extra effort from students. The aim is to make technology and information technology more attractive to women through their participation in experiments involving a knowledge of experimental sciences; this would increase women's confidence in their ability to take STEM studies. An example would be technological workshops bringing technology closer to young pre-university students in general and to women in particular. These workshops could be conducted by integrating them into technology subjects during school hours, or after school with or without the family participation (introducing a fun element into these activities usually helps to make them more attractive). Such activities help overcome prejudices over the difficulty of technology subjects, and let students see how technology improves the quality of life (an aspect which tends to appeal to women).
3) *Produce a TV series about a group of female engineers*. The storyline would focus not on their work in engineering *per se*, but rather on the environment in which the action took place. Some episodes could emphasize the social side of engineering, but the main goal would be to dismantle stereotypes through scripts designed for that purpose. The Catalan TV3 series "Merlí" has recently shown the effects of a TV series on college enrollment; it has had a great impact on young people and will be adapted in other countries. Merlí is a philosophy professor who motivates his teenage students of philosophy by applying it to their personal problems. An increase in enrollment has been seen this year in the four Catalonia university faculties that teach philosophy, even though philosophy is not exactly the most popular or fashionable course. In the three previous years, three of the schools had had a stable level of enrollment, while in the fourth school enrollment had fallen, so the increase may well be due to the series.
4) *Encourage female enrollment through affirmative action*, either by a significant reduction in tuition fees or by increasing the number of scholarships offered to this

group. In the medium- or long-term, these affirmative action measures should result in more women graduates and more women occupying important positions in engineering, business management, and research, who would also be female role models in engineering, and thereby reduce current social stereotypes.

5) *Include more science and engineering subjects in school curricula* to counteract the effect of the immediate environment. This would also solve the problem of the lack of information identified by 8.67% of the respondents. Affirmative action for girls could be carried out in this area, for example, by using the technological activities mentioned above. Acting on family and friends in the short term is difficult, but less so at the primary school stage. In any case, to avoid stereotyping it seems imperative to train primary school teachers appropriately, and it would probably also be necessary to rewrite some of the material used in class, which is peppered with stereotypes.

D. Comparison With Previous Research

The results presented here coincide with [7] and [8] regarding women's lack of confidence in their own capabilities. They also confirm the masculine view prevalent in society about the world of engineering (stereotypes), as cited in [9] and [10]. The impact of the immediate environment on the low enrollment of women in STEM studies also coincides with the results found in [1] and [12]. The negative attitudes of classmates found in [13] also appear in this study. However, in [6] it is stressed that women have role models, whereas in the present study it is a specific cause of low enrollment of women.

This work found similar conclusions to those presented by Hartman *et al.* [7], who compares groups of women enrolled in bio-engineering, biomedical engineering, chemical engineering, and civil/environmental engineering degrees, to those in degree courses in mechanical, electrical and computer engineering. He concludes that the choice of studies is related to perceived personal capability. In the present work, CCEEE women are found less likely than non-CCEEE women to regard themselves as more capable than men.

Expectations for outcomes did not differ greatly between women of different specialties in the Hartman study, whereas in the present work it appears that CCEEE women feel greater satisfaction than non-CCEEE women in this area. In the Hartman study the women who chose mechanical, electrical or computer engineering expressed greater satisfaction with their choice of course, whereas in this work no differences were identified between CCEEE women and non-CCEEE women when asked whether they would choose the same courses if they had to do their studies again. Finally, Hartman *et al.* [7] concludes that women starting chemical or civil/environmental engineering degrees have greater self-confidence, although there are no significant differences in their academic abilities. In the present work, in answer to the question about self-confidence when tackling technological courses, the responses show no significant differences in the level of self-confidence between either population.

E. Limitations of This Study

This study has some limitations:

1) Only alumnae who graduated in the last six academic years were surveyed. Some were still students after their graduation, but most were not. This may help to reflect current trends in women's opinions on the topic of this paper, but it does not necessarily represent the opinions of current students in general. However, as interesting as it may be to look at differences between recent graduate women and previous alumnae, the objective of this study is not to investigate the current state of opinion of all alumnae on their career difficulties. This may be an interesting area for future investigation.
2) The wording of the survey may be a limiting factor when looking at the precision of the results. However, a group test survey (on 153 students) was conducted prior to issuing the final survey, during which unclear questions were clarified, as explained in the Section IV. The survey was conducted in Spanish, the mother tongue of the respondents, or at least the language in which they were proficient, so there were no known language barriers.
3) Survey fatigue may have had a limited impact on the validity of the results, but it does not seem likely, as may be concluded from the long final open-ended answers. For the majority of the respondents, given the length of their answers, this provided them with the opportunity to fully express the difficulties they are facing in their careers.
4) For the identity of the respondents, the personal email sent from the school from which they graduated contained their personal data, checked by the school authorities, thereby ensuring that the recipients were bona fide members of the sample. The open nature of the survey may have given rise to duplicate responses or other inappropriate answers, as no further verification was made when receiving the answers. However, great care was taken to send the survey only to the appropriate recipients, and after a detailed review of the 1,167 answers received, no incoherent data were detected, particularly for the final open-ended question.

VII. Conclusion

The low number of women doing STEM degree courses has been a concern for policy makers and has given rise to much research and many national policies. Despite these policies, in some areas such as CCEEE the number of women has not only failed to increase, but in some cases has even fallen. A deep knowledge of what motivates female students to enroll in STEM studies, and a knowledge of the stereotypes they face when choosing their studies, is required to implement effective policies.

This paper reports a quantitative and a qualitative exploratory study to determine: (1) whether a stereotype (description of an attitude or behavior) for women taking STEM studies does or does not exist; (2) whether this stereotype differs between women taking CCEEE and non-CCEEE degrees, and (3) what differences may exist between the

motives for the enrollment of CCEEE women graduates and those of other STEM women graduates.

The quantitative results reveal that (1) a stereotype exists for women taking STEM studies, and (2) there is a different profile for the women undertaking CCEEE studies and those who study non-CCEEE courses. From the qualitative results, (3) the women surveyed consider social stereotypes (31.47%) and the immediate environment (14.5%) to be the main reasons for the low enrollment of women in STEM studies, followed by the third reason (11.03%), which is that women do not like engineering subjects. These results suggest that a policy of awakening vocations for CCEEE studies should focus on these points in order to be really effective.

This exploratory study should be completed with further in-depth studies. Further research should concentrate on determining whether the differences detected are local, or whether similar differences exist in other parts of the world. In addition, policies aimed specifically at awakening vocation in future women CCEEE professionals should be put in place.

ACKNOWLEDGMENT

The authors would like to thank M. C. Martínez for her help and inspiration, as well as all the students and alumnae who took part in this survey, and the Institut de Ciències de l'Educació (ICE UPC) (www.ice.upc.edu) for assistance in the preparation of this paper.

REFERENCES

[1] H. Salmi, H. Thuneberg, and M.-P. Vainikainen, "How do engineering attitudes vary by gender and motivation? Attractiveness of outreach science exhibitions in four countries," *Eur. J. Eng. Educ.*, vol. 41, no. 6, pp. 638–659, 2016, doi: 10.1080/03043797.2015.1121466.

[2] L. J. Sax, "Women graduates of single-sex and coeducational high schools: Differences in their characteristics and the transition to college," Sudikoff Family Inst. Educ. New Media, Nat. Coalition Girls' Schools, Grad. School Educ. Inf. Stud., Univ. California, at Los Angeles, Los Angeles, CA, USA, Rep., 2009. [Online]. Available: http://www.ncgs.org/Pdfs/FINAL-REPORT.pdf

[3] B. Burchell, V. Hardy, J. Rubery, and M. Smith, "A new method to understand occupational gender segregation in European labour markets," Publ. Office Eur. Union, Luxembourg City, Luxembourg, Rep., 2014. [Online]. Available: http://ec.europa.eu/justice/gender-equality/files/documents/150119_segregation_report_web_en.pdf

[4] Y. A. Mlambo and R. O. Mabokela. "'It's more flexible': Persistence of women engineers in the academy," *Eur. J. Eng. Educ.*, vol. 42, no. 3, pp. 271–285, Mar. 2016, doi: 10.1080/03043797.2016.1158790.

[5] S. M. Lord, R. A. Layton, and M. W. Ohland, "Trajectories of electrical engineering and computer engineering students by race and gender," *IEEE Trans. Educ.*, vol. 54, no. 4, pp. 610–618, Nov. 2011.

[6] L. Beaman, E. Duflo, R. Pande, and P. Topalova, "Female leadership raises aspirations and educational attainment for girls: A policy experiment in India," *Science*, vol. 335, no. 6068, pp. 582–586, Feb. 2012.

[7] M. Hartman, H. Hartman, and J. Kadlowec, "Gender differences across engineering majors," in *Proc. ASEE Annu. Conf.*, Honolulu, HI, USA, Jun. 2007.

[8] J. K. Pinto, P. Patanakul, and M. B. Pinto, "Gender biases in hiring project managers: Perceptions of trust and likeability," *IEEE Trans. Eng. Manag.*, vol. 62, no. 3, pp. 325–334, Aug. 2015.

[9] J. J. Baroudi and M. Igbaria, "An examination of gender effects on career success of information systems employees," *J. Manag. Inf. Syst.*, vol. 11, no. 3, pp. 181–201, 1994.

[10] S. Barnard, A. Powell, B. Bagilhole, and A. Dainty, "Researching U.K. women professional in set: A critical review of current approaches," *Int. J. Gender Sci. Technol.*, vol. 2, no. 3. pp. 361–381, 2010.

[11] M. Hersh, "The changing position of women in engineering worldwide," *IEEE Trans. Eng. Manag.*, vol. 47, no. 3, pp. 345–359, Aug. 2000.

[12] D. M. Hatmaker, "Engineering identity: Gender and professional identity negotiation among women engineers," *Gender Work Org.*, vol. 20, no. 4, pp. 382–396, 2013.

[13] P. Molina-Gaudo, S. Baldassarri, M. Villarroya-Gaudo, and E. Cerezo, "Perception and intention in relation to engineering: A gendered study based on a one-day outreach activity," *IEEE Trans. Educ.*, vol. 53, no. 1, pp. 61–70, Feb. 2010.

[14] P. Pardo, M. D. Calvet, O. Pons, and M. C. Martinez, "Pioneer women in engineering studies: What can we learn from their experiences?" *Eur. J. Eng. Educ.*, vol. 41, no. 6, pp. 678–695, 2016, doi: 10.1080/03043797.2015.1121464.

[15] T. Hürsing, W. B. Korte, and E. Dasja. (2015). *'e-Skills in Europe'. Trends and Forecasts for the European ICT Professional and Digital Leadership Labour Markets (2015–2020)*. [Online]. Available: http://eskills-lead.eu/fileadmin/lead/working_paper_-_supply_demand_forecast_2015_a.pdf

[16] European Commission. (2013). *Women Active in the ICT Sector*. [Online]. Available: https://bookshop.europa.eu/en/women-active-in-the-ict-sector-pbKK0113432/

Noelia Olmedo-Torre received ~~a graduation~~ degree in telecommunications engineering and the Ph.D. degree in multimedia engineering from the Universitat Politècnica de Catalunya (BarcelonaTech), in 1991 and 2007, respectively. She is a Professor with the Department of Engineering Presentation, Barcelona East School of Engineering (formerly, the EUETIB). Her research interests are the social aspects of engineering education, innovation in higher education, professional competencies, assessment tools, the promotion of teaching and learning improvement and, in general, educational innovation that contributes to teaching quality.

Fermín Sánchez Carracedo was born in Barcelona, in 1962. He received the master's degree in industrial electronics from the E.A. SEAT, in 1981, and the B.S. degree in computer science and the Ph.D. degree in computer science from the Universitat Politècnica de Catalunya (UPC-BarcelonaTech), in 1987 and 1996, respectively. Since 1987, he has been a Lecturer with the Department of Computer Architecture, UPC-BarcelonaTech, where he has been an Associate Professor since 1997. His fields of study include computer architecture~~,~~ and innovation in education and education for sustainability.

M. Núria Salán Ballesteros received the metallurgical (chemistry) degree and the Ph.D. degree in materials science and metallurgical engineering from UPC-BarcelonaTech. She has been a Professor with the Department of Materials Science and Metallurgical Engineering since 1992. She has taught several degree and master subjects at the School of Industrial and Aeronautic Engineering of Terrassa. She is also leading a girls' mentoring program (M2m) as a pioneer experience in TECH universities, and she has organized an international traveling exhibition about the invisibility of women's tech ["(In)Visible ingenuity"].

David López was born in Barcelona, Spain, in 1967. He received the M.Sc. and Ph.D. degrees in computer sciences from the Universitat Politècnica de Catalunya (BarcelonaTech), Spain, in 1991 and 1998, respectively, and the M.A. degree in Asian studies with a major in East Asia ~~A~~rts and ~~S~~ocieties from the Universitat Oberta de Catalunya, in 2008.

Antoni Perez-Poch is the Deputy Director with the Education Sciences Institute, Universitat Politècnica de Catalunya (UPC-BarcelonaTech), and a Lecturer of Computer Science and Telecommunications with the School of Engineering Barcelona East. He is also the Director of the STEM Master Program ~~and~~ a postgraduate degree from the Fundació Politècnica de Catalunya that provides competence-based teaching training to lecturers at UPC-BarcelonaTech.

Mireia López-Beltrán received ~~a graduation~~ degree in mathematics from the Universitat de Barcelona, in 2002, and the Ph.D. degree in didactics of mathematics and experimental sciences from the Universitat Autònoma de Barcelona, in 2010. She has been a ~~s~~econdary ~~t~~eacher since 2002. Since 2013, she has been with the ICE, Universitat Politècnica de Catalunya, in the area of secondary teacher training.