Gender Gap in STEM: A Cross-Sectional Study of Primary School Students' Self-Perception and Test Anxiety in Mathematics

AQ1 Natalia Ayuso, *Member, IEEE*, Elena Fillola, Belén Masiá, *Member, IEEE*,
Ana C. Murillo, *Member, IEEE*, Raquel Trillo-Lado, Sandra Baldassarri, *Senior Member, IEEE*,
AQ2 Eva Cerezo, *Member, IEEE*, Laura Ruberte, M. Dolores Mariscal, and María Villarroya-Gaudó

Abstract*—*Contribution: **Significant gender differences are observed on primary school students' perception of self-efficacy and test anxiety in mathematics. Girls perceive themselves to be significantly worse than boys in mathematics and report higher test anxiety toward mathematics exams. Gender differences in self-efficacy become more pronounced as students grow up, and test anxiety increases for all students. However, the present study shows that teachers' do not perceive differences in self-efficacy in mathematics between boys and girls.**

Background: **The low presence of women in science, technology, engineering, and mathematics (STEM) might be explained by the attitude of young students toward mathematics. Different studies show that girls are less interested in STEM areas than boys during secondary school. A study on the reasons for this fact pointed out that the early years of education can provide a relevant insight to reverse the situation.**

Research Questions: **Is there any age-dependent gender difference in primary school students in aspects related to mathematics? Are teachers aware of students' perceptions?**

Methodology: **This work presents a study of over 2000 primary school students (6–12 years old) and 200 teachers in Aragón (Spain). The study consists of a survey on aspects that influence the experience of female and male students with mathematics and Spanish language for comparison purposes and teacher's awareness of students' perception.**

Findings: **The present study shows that during primary school, girls are more likely to experiment a negative attitude toward mathematics than boys as they grow up, and teachers may not perceive girls' situation.**

***Index Terms*—Mathematics, primary school, science, technology, engineering, and mathematics (STEM) studies, women in engineering.**

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Natalia Ayuso, Belen Masiá, Ana C. Murillo, Raquel Trillo-Lado, Sandra Baldassarri, Eva Cerezo, Laura Ruberte, M. Dolores Mariscal, and María Villarroya-Gaudó are with the School of Engineering and Architecture, University of Zaragoza, 50018 Zaragoza, Spain (e-mail: nayuso@unizar.es).

Elena Fillola is with the Department of Mathematics, University of Bristol, Bristol BS8 1TH, U.K.

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I. Introduction

The SCIENCE, technology, engineering, and mathematics (STEM) study areas are key to economic growth and innovation and have acquired special relevance in the ecosystem of the digital economy [1]. In this context, the scarce presence of women in these areas is especially visible and worrisome worldwide, especially in math-intensive fields, such as engineering and even more in computer engineering as different recent studies have shown [2]–[4].

Furthermore, even when girls do graduate from scientific fields, they are much less likely than boys to work as professionals in those fields. In the European Union, women were just 16.7% of those employed in the high and med-technological sector in 2016 [5]. In the United States, they accounted for one-fifth or less of those employed in some of these jobs, including 20.0% of software developers, 9.7% of computer network architects, and 7.8% of aerospace engineers [6].

According to the Organization for Economic Co-operation and Development (OECD), workers who have completed higher education in STEM areas are more successful in the labor market than other workers, even over those workers who have completed other university degrees: the employment rate for those with STEM higher education is 83.0% over the average 66.6%, and presents a lower unemployment rate of 9.4% over the average 17.9%, in 2016. Therefore, the lack of women accessing STEM studies reduces the number of females in professions with prestige and greater purchasing power and therefore deprives them of greater independence. Moreover, the fact that there are few women working in STEM disciplines is detrimental to society as a whole because the community lacks the views, ideas, creativity, work, and knowledge of half of the population. The seriousness of this situation has led institutions, such as the EU or the OECD to encourage the recruitment of women in these fields, and in 2016, the United

Nations established February 11th to be the International Day of Women and Girls in Science.

Almost 60% of female students at high school have no interest in studying engineering, while for male students this percentage is down to 35% [7]. A variety of reasons have been suggested for girls' lack of interest in STEM areas [3], [8], [9]. Both boys and girls report that little is known about the engineering profession [7], but girls hold fewer positive views than boys about the areas of computer science or information and technology [10]. Some causes have a clear social component, such as the stereotypes installed since childhood [11], the lack of family support, and the absence of references [7]. Stereotypes lead people to believe that the innate intelligence or brilliance required for mathematics or engineering fields are male attributes [12]. Teachers present implicit stereotypes toward gender differences in mathematical ability that are not present in other subjects or toward other factors such as race [13]. These stereotypes in a student's close environment may have an immediate effect on their interests at early ages [14], leading girls and women to avoid mathematics or engineering, and also causing people to subconsciously believe that women cannot be good in these fields.

Regarding reasons grounded in cognitive aspects, recent research is converging toward the notion that gender differences in STEM are not due to differences in absolute cognitive ability but rather to differences in the breadth of cognitive ability [15], [16]. A study compared gifted individuals and showed that those with higher mathematical skills relative to verbal skills are more likely to pursue STEM careers, while individuals with comparatively high mathematical and verbal abilities are more likely to purse a non-STEM career [9]. Therefore, as math-talented women tend to also have good verbal abilities, they are more likely to choose challenging non-STEM fields that are more practical or applied, as opposed to math-intensive fields that are more theoretical or mechanical [3]. Different works also confirm the importance of mathematics when choosing engineering as a career [17].

Herbert and Stipek [10] conducted a longitudinal study over 300 children from 5 to 10 years old in the United States to observe gender differences concerning math and literacy, including teachers' and parents' ratings. All participant children came from low-income families. The results show that starting at 7–8 years of age, girls rated themselves lower than boys at math, despite math achievements and teachers' ratings not showing gender differences. However, parents' ratings of children's competence strongly influenced children's self-perceived efficacy in math. According to research carried out in Spain following 1500 students for six years, from age 14 to 19 [18], girls tend to underestimate their competence in technology and mathematics even though they have better grades than boys. In contrast, boys tend to overestimate their skills in these same subjects. The research concludes that there is a clear gender gap in the perception of competences in subjects related to science, technology, and mathematics.

Besides perceived competence, Ramirez *et al.* [19] highlighted that anxiety negatively affects children's achievements in mathematics as early as the first and second grades (6–8 years old). The stress caused by math exams can negatively affect both results and interest in this subject. In this sense, emotions have been recognized as critically important to students' learning, motivation, academic achievement, and health [23], [24]. Positive activating emotions, as students' interest in a subject, are also related to academic achievements [19], [25], [26].

For primary- and elder-school students, the findings in PISA [21] 2012 and, for instance, of O'Keeffe *et al.* [22] showed that girls report higher levels of math anxiety than boys. Young *et al.* [20] showed that math anxiety disrupts and divides working memory resources and that individuals with higher levels of math anxiety have less working memory to focus on mathematical activities and several authors argue that students who experience mathematics anxiety generally avoid mathematics, mathematics courses, and career paths that require the mastery of some mathematical skills [27]–[30].

In addition, it was proven that teachers have a strong influence on the students' life, from academic achievements to emotions experimented in the classroom [31]–[33], with stronger influences exerted in younger students [34]. The teachers' attitude and interpersonal relations with students drive students' emotional experiences. Many works have analyzed the relationship between achievements in mathematics and teachers' emotions and attitudes [19], [35], as well as between teachers' attitude toward science and their pupils' attitude [36]. The gender of the teacher is also relevant in this relationship: female teachers with high levels of anxiety toward mathematics or negative attitudes toward science, lead female pupils to perform worse and have a worse opinion of science than male students or pupils with male teachers [34]–[36].

In light of the foregoing considerations, the present work intends to cover the gap found in previous studies, focusing on the evolution during primary school (6–12 years old) of aspects that influence the experience with mathematics of female and male students from any socioeconomic status. The work also considers teachers' awareness of children's autoperceptions because the regional evaluations show no relevant differences in mathematical competence by sex at the completion of primary education [37].

The remainder of this article is organized as follows. Section II presents methodology and sample. Section III investigates gender differences along with primary school regarding students' perceptions toward mathematics and teachers' awareness toward classroom climate. The results obtained are discussed in Section IV. Conclusions and future actions devised from present outcomes are given in Section V.

II. Methodology and Sample

A. Background

The present study analyzes 2137 questionnaires answered by primary-school students (48.7% female and 51.3% male) and 212 questionnaires filled in by their teachers (75.5% female and 24.5% male). The surveys were completed at schools that had carried out the outreach activity titled "*Una Ingeniera en Cada Cole*" ("A Female Engineer in Every

Fig. 1. Photographs taken during "A Female Engineer in Every School 2019" workshops. Left: "Augmented Reality" workshop participants coloring a human body page featured for an augmented reality app. Right: "How are images stored in computers?" workshop participants encoding/decoding simple images with pixel values.

School") from March to May 2018 [38]. This activity was founded after a group of female faculty members from the University of Zaragoza realized that activities to encourage high-school students to pursue engineering degrees were often ineffective, as the students had already chosen a study pathway. The need to direct activities to younger pupils was identified, and "A Female Engineer in Every School" started in 2016.

In these series of events, female engineers, both from academic and industry backgrounds, visit primary schools, when possible with some kind of personal link, so that children can see her as a close example. The engineers show their work to children through open and interactive workshops where students in groups are asked to build or design some technology-related project (see Fig. 1). The workshops are creative, collaborative, and open so that each group creates their own designs or suggests their solutions, encouraging students' effectiveness and self-perception. The workshops were shaped after research showing that girls tend to prefer working in small groups and learning through practical activities, and also that they feel more confident and obtain better results when teamworking and working in open problems [39]–[41].

The activity's focus depends on the area of expertise of the visiting engineer and the children's age group. Examples include "resistant structures with beautiful and tasty materials" [42], "a polyethylene thermocutter" [43], "how do we clean water?" [44], "augmented reality" [45], or "how are images stored in computers?" [46].

Before the activity with children, teachers were also involved through discussions about their opinions on STEM subjects, the education of their students, and the activity developed.

After 2016 and 2017 editions, the engineers realized that many primary school teachers were not aware of the lack of women in engineering studies. In addition, some teachers reported that many girls from the age of 9 started to show less interest in mathematics and technology than boys. Consequently, a new feature was added to the activity: a survey investigating the students' approach to mathematics, as it is often directly linked to STEM career choices. In addition, teachers' perceptions are also gathered and compared to students' ones, as teachers' beliefs can influence social interactions in the classroom life.

B. Questionnaires

Students were asked to fill in a questionnaire about cognitive test anxiety and self-perception, although the wording was simplified in an attempt to match the developmental level of the students participating (e.g., *S*6—I worry whenever I have a mathematics test. Instead of a more formal wording such as I have high anxiety levels when I have a cognitive evaluation on math-related topics). Teachers received a wider range of question topics, mostly to gather their preferences and strategies to teach different subjects and their thoughts about students' understanding of mathematics. The results of these questionnaires are the subject of this report. The questionnaires for both teachers and students had two parts as follows.

1) The first part gathered profiling information, such as gender, age, and previous studies in the case of the teachers. A survey was considered valid only if the first part was completed correctly.
2) The second part involved statements related to subjects, perceived ability of the students, and anxiety toward exams. Responses were given in the form of Likert-scale ratings.

The questionnaire for students comprised eight 1-item measures, questions *S*1–*S*8. Despite the questionnaire not being designed as a single scale, in questions *S*6–*S*8 (*S*6—I worry whenever I have a mathematics test; *S*7—I worry whenever I have a Spanish language test; and *S*8—I worry whenever I have a test, no matter the subject), where students' concern with exams can be the underlying factor, Cronbach's alpha yields a value of 0.8770, suggesting a good internal consistency. The teachers' questionnaire comprised seven 1-item measures, *T*1–*T*7.

For convenience and to maximize the number of participants, schools were given the choice to complete the surveys before or right after the activity or on a follow-up session. As the survey was focused on students' and teachers' perceptions, not on the activity, the moment the survey was completed did not affect the answers.

C. Sample Characterization

The survey was completed in 39 educational centers, 30 in cities, and nine in rural areas, both in public and private schools.

Teachers: Out of 156 teacher surveys received, 143 were considered valid for data analysis and 58.7% were from public schools. The respondents included 75.5% of women and 42.7% of the respondents took science-based studies before going to college (as opposed to a humanities-based or arts-based studies).

Students: 2148 student surveys were gathered, out of which 2137 were valid for the data analysis. Students were divided into stages according to their academic school years: the first stage for children in first and second years of primary school (ages 6–8), second stage for children in the third and fourth years of primary school (ages 8–10), and third stage for children in the last two years of primary school, fifth and sixth (ages 10–12). Table I comprises the student count and percentage for each stage, segregated by sex.

TABLE I
STUDENTS' COUNT BY STAGE AND GENDER

Stage	Girls (count)	Boys (count)	Total (count)	Girls (%)	Boys (%)	Total (%)
1st	152	175	327	7.1	8.2	15.3
2nd	381	360	741	17.8	16.8	34.7
3rd	509	560	1069	23.8	26.2	50
Total (count)	1042	1095	2137	48.7	51.2	100

TABLE II
ANOVA RESULTS FOR PREFERENCE AMONG SUBJECTS FOR THE STUDENTS' ANSWERS TO $S1$ (I PREFER SPANISH LANGUAGE TO MATH) AND $S2$ (I LIKE NATURAL SCIENCE BETTER THAN SOCIAL SCIENCE)

	S1			S2		
	F	(df_1, df_2)	p	F	(df_1, df_2)	p
Gender	37.88	(1, 2111)	0.0000*	2.40	(1, 2112)	0.1216
Stage	4.84	(2, 2111)	0.0008*	1.12	(2, 2112)	0.3251
Gender×Stage	0.24	(2, 2111)	0.7905	1.39	(2, 2112)	0.2505

F is the F-statistic, a measure of the ratio of the variance accounted for and the unexplained variance; df_1 and df_2 are the degrees of freedom for the effect of the factor (Gender, Stage, or the interaction) and the residuals, respectively; p is the associated p-value given the F-statistic and the degrees of freedom.

TABLE III
95% CONFIDENCE INTERVALS FOR THE STUDENTS' ANSWERS TO $S1$ (I PREFER SPANISH LANGUAGE TO MATH)

1st stage		2nd stage		3rd stage	
Boys	Girls	Boys	Girls	Boys	Girls
(2.91, 3.31)	(3.23, 3.66)	(2.66,2.94)	(3.12,3.39)	(2.70,2.92)	(3.12,3.35)

Out of all students, 48.8% were girls and 64.4% attended a public school. Note that these percentages are within less than 5% of the official statistics provided by the Regional Government [47] about primary-school students in the region, which confirms that the sample is an accurate representation of the relevant population for this study. The present results can also be generalized to the rest of Spain, due to the uniformity in student distribution around the country [48].

III. RESULTS

For every question, ratings in a five-point Likert scale with scores 1—never, 2—rarely, 3—sometimes, 4—very often, and 5—always, are collected. Questions are analyzed and discussed independently, using a two-way analysis of variance (ANOVA) to test whether our two factors (gender and stage) have an influence on the observed data. Significant effects are further analyzed by using a Tukey–Kramer *post hoc* analysis, which allows us to test pairwise comparisons. In all tests, a p-value below 0.05 is considered to indicate significance.

A. Students' Preferences and Perceptions Along Primary School

This section presents students' beliefs concerning math and Spanish language to highlight gender differences along the primary school years that can explain the scarce presence of women pursuing STEM studies: preferences, self-efficacy, and test-anxiety of math and language. In addition, the perceived usefulness of mathematics has been also considered as a factor that influences the students' experience of positive activating emotions [49].

1) Preference of Math Versus Spanish Language: Students' preference for math versus Spanish language was tested through question $S1$ (*I prefer Spanish language to math*). Both gender and stage had a significant effect on the answers while the interaction of both did not (see Table II). When looking into the *post hoc* tests, it shows that gender drives the main differences: from the second stage on, girls show a stronger agreement with the statement than boys. Looking at the 95% confidence interval for the mean rating of girls and boys in the second and third stages, those of the girls are above the neutral answer (3—sometimes), and those of the boys are below the neutral answer (see Table III), separated by gender and stage, suggesting that boys prefer math to Spanish language, whereas girls prefer the Spanish language to math, with a significant difference between genders.

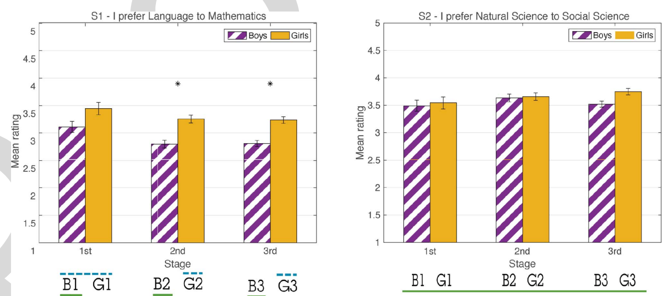

Fig. 2. Preference among subjects. Left: mean ratings for $S1$ (*I prefer Spanish language to math*). Right: mean ratings for $S2$ (*I prefer natural sciences to social sciences*). Error bars show standard error of the mean. Significant differences between both genders are marked with an asterisk. Girls' preference for Spanish language versus math is stronger than boys' preference from the second stage on, whereas no significant difference between genders is observed for natural versus social sciences. Below each graph, the results of the pairwise comparisons are shown for the corresponding question: items in the same group (i.e., marked by the same type of horizontal line) have no statistically significant differences between them. For each item, the letter refers to the gender (B: boys and G: girls), and the number to the stage. On the left, $B1$, $B2$, and $B3$ form one group (continuous line), while $B1$, $G1$, $G2$, and $G3$ form another group (dotted line). On the right, there is one single group comprising all six items (continuous line).

As an additional comparison to better put in context the findings from $S1$, the responses to $S2$ (*I like natural sciences better than social sciences*) were analyzed. $S2$ asks about the preference of natural versus social sciences, two distinct subjects in the Spanish primary school curriculum so students can differentiate them easily. There were no significant effects of gender or stage in the students' answers in this case (see Table II and Fig. 2).

The findings are summarized as follows.

1) From the second stage on, on an average, boys prefer math to Spanish language, whereas girls prefer Spanish language to math, with a significant difference between genders.
2) No difference between genders nor stage is observed, in contrast, for natural sciences versus social sciences.

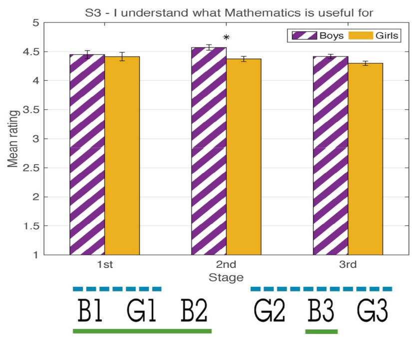

Fig. 3. Perceived usefulness of math, in the form of mean ratings for *S*3 (*I understand what mathematics is useful for*). Error bars show the standard error of the mean. Significant differences between both genders are marked with an asterisk. Only in the second stage, there is a significant difference between boys' and girls' answers. Below the graph, results for the pairwise comparisons are shown for the corresponding question (refer to the caption in Fig. 2).

TABLE IV
ANOVA Results for Perceived Usefulness of Mathematics for the Students' Answers to *S*3 (I Understand What Mathematics Are Useful for)

	S3		
	F	(df_1, df_2)	p
Gender	7.13	(1, 2116)	0.0077*
Stage	3.76	(2, 2116)	0.0235*
Gender×Stage	0.97	(2, 2116)	0.3800

2) Usefulness of Mathematics: Question *S*3 (*I understand what mathematics is useful for*) covers the understanding of math usefulness. It is assumed here that understanding its usefulness correlates with considering them useful. Since the first stage of education, mathematics is clearly perceived as being very useful (see Fig. 3). While both gender and stage have a significant effect on the answers (see Table IV), a look at the *post hoc* tests reveals that the only significant difference between boys and girls is found in the second stage, in which boys rate the usefulness of mathematics higher than girls. The interaction effect between gender and stage is nonsignificant (Table IV), indicating that there is no sign that boys' and girls' responses are influenced differently by the stage.

3) Self-Perceived Efficacy in Math Versus Spanish Language: Self-perceived efficacy in both math and Spanish language has been explored through questions *S*4 (*I am good at math*) and *S*5 (*I am good at Spanish language*).

Both for *S*4 and *S*5, a significant effect was found for gender (see Table V). The *post hoc* analysis reveals that in the first stage there is no significant difference between genders for any of the two questions, with differences between genders arising in the second and third stages. In the second stage, boys rate themselves significantly better at math than girls do ($p < 0.0001$); estimated means are $\mu_{B2} = 4.24$ versus $\mu_{G2} = 3.81$. This trend continues in the third stage, in which boys also rate themselves significantly better at math ($p < 0.0001$), with estimated means $\mu_{B3} = 3.96$ versus $\mu_{G3} = 3.60$. In Spanish language, the result is the opposite. Girls rated themselves significantly better than boys did in the second and third stages

TABLE V
ANOVA Results for Self-Perceived Efficacy for the Students' Answers to *S*4 (I Am Good at Math) and *S*5 (I Am Good at Spanish Language)

	S4			S5		
	F	(df_1, df_2)	p	F	(df_1, df_2)	p
Gender	41.24	(1, 2101)	0.0000*	13.60	(1, 2089)	0.0002*
Stage	19.86	(2, 2101)	0.0000*	28.87	(2, 2089)	0.0000*
Gender×Stage	1.84	(2, 2101)	0.1594	0.71	(2, 2089)	0.4927

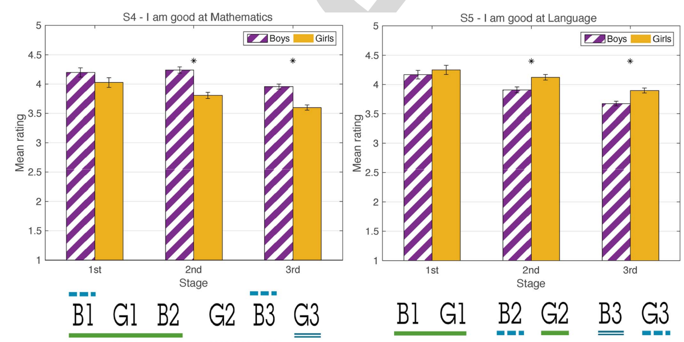

Fig. 4. Self-perceived efficacy. Left: mean ratings for *S*4 (*I am good at math*). Right: mean ratings for *S*5 (*I am good at Spanish language*). Error bars show the standard error of the mean. Significant differences between both genders are marked with an asterisk. From the second stage on, boys provide significantly higher ratings than girls in math, while the opposite happens for Spanish language. Below each graph, results for the pairwise comparisons are shown for the corresponding question (refer to the caption in Fig. 2).

($p = 0.0249$ for the second stage and $p = 0.0018$ for the third one); estimated means are $\mu_{B2} = 3.91$ versus $\mu_{G2} = 4.12$ and $\mu_{B3} = 3.67$ versus $\mu_{G3} = 3.90$. Fig. 4 shows estimated means for both questions, separated by gender and stage; significant differences are marked on the graphs.

A significant influence of the stage is found, as well for both questions (see Table V). The interaction effect between gender and stage is nonsignificant in both questions, indicating that there is no sign that boys' and girls' responses are influenced differently by the stage.

Additionally, there is a certain correlation between the self-perceived efficacy of children in a specific subject (e.g., math or Spanish language) and the preference of children for that subject. Specifically, the correlation between answers to *S*1 and *S*4 and answers to *S*1 and *S*5 has been tested for each gender group in the second and third stages. A weak correlation was found between the answers in all cases, with *p*-values allowing to assert that there is indeed a correlation (see Table VI). The sign of the correlation (negative for *S*1–*S*4 and positive for *S*1–*S*5) is indicative of this relationship between preference and self-perceived efficacy since *S*1 asks about the preference of language over math, *S*4 about self-perceived efficacy in math, and *S*5 about self-perceived efficacy in language.

4) Test Anxiety: Regarding students' concern about math and Spanish language tests, the answers to statements *S*6 (*I worry whenever I have a mathematics test*), *S*7 (*I worry whenever I have a Spanish language test*), and *S*8 (*I worry

TABLE VI
SPEARMAN CORRELATION COEFFICIENT (ρ) AND ASSOCIATED P-VALUE BETWEEN ANSWERS TO *S*1 AND *S*4, AND BETWEEN *S*1 AND *S*5, SEGREGATED BY GENDER GROUP AND STAGE, FOR STAGES WITH A SIGNIFICANT DIFFERENCE IN GENDER

		2^{nd} stage		3^{rd} stage	
		Boys	Girls	Boys	Girls
S1-S4	ρ	-0.2848	-0.3033	-0.3750	-0.3446
	p-val	<0.0001*	<0.0001*	<0.0001*	<0.0001*
S1-S5	ρ	0.2465	0.3533	0.3074	0.2680
	p-val	<0.0001*	<0.0001*	<0.0001*	<0.0001*

TABLE VII
ANOVA RESULTS FOR TEST ANXIETY FOR THE STUDENTS' ANSWERS TO *S*6 (I WORRY WHENEVER I HAVE A MATHEMATICS TEST), *S*7 (I WORRY WHENEVER I HAVE A SPANISH LANGUAGE TEST), AND *S*8 (I WORRY WHENEVER I HAVE A TEST)

	S6			S7			S8		
	F	(df_1, df_2)	p	F	(df_1, df_2)	p	F	(df_1, df_2)	p
Gender	53.40	(1, 2057)	0.0000*	3.87	(1, 2052)	0.0493	27.50	(1, 2064)	0.0000*
Stage	27.19	(2, 2057)	0.0000*	58.05	(2, 2052)	0.0000*	47.73	(2, 2064)	0.0000*
Gender×Stage	1.18	(2, 2057)	0.3081	0.06	(2, 2052)	0.9415	0.94	(2, 2064)	0.3903

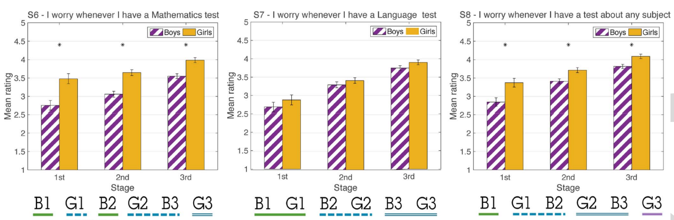

Fig. 5. Test anxiety. Left: mean ratings for *S*6 (*I worry whenever I have a mathematics test*). Middle: mean ratings for *S*7 (*I worry whenever I have a Spanish language test*). Right: Mean ratings for *S*8 (*I worry whenever I have a test, no matter the subject*). Error bars show the standard error of the mean. Significant differences between both genders are marked with an asterisk. Girls are significantly more worried than boys in math tests, while in Spanish language tests there is no significant difference between genders. Below each graph, results for the pairwise comparisons are shown for the corresponding question (refer to the caption in Fig. 2).

whenever I have a test, no matter the subject) were considered. Results are presented in Table VII, and the main findings are discussed next.

Gender has a significant effect on anxiety when facing a math exam ($F = 53.40, p < 0.0001$ in *S*6), but not when facing a Spanish language exam [$F(1, 2052) = 3.87, p = 0.0493$ in *S*7]. *Post hoc* tests for *S*6 show that in all three stages gender has a significant effect, with boys providing significantly lower ratings of test anxiety than girls ($p = 0.0017$ in the first, < 0.0001 in the second, and 0.0001 in the third stage). When looking at concern about exams, in general, gender again has a significant effect [$F(1, 2064) = 27.50, p < 0.0001$ in *S*8]; this significant difference is observed in all three stages ($p = 0.0191$ in the first, 0.0264 in the second, and 0.0126 in the third stage). These effects are illustrated in Fig. 5, and can be contrasted with test anxiety in engineering students, where gender differences are not observed [50].

The stage has a significant effect on all three questions regarding test anxiety (see Table VII), with students' anxiety increasing as stage increases (Fig. 5). *Post hoc* tests reveal that in *S*6 there is a significant difference only between the third stage and the other two ($p < 0.0001$) for both genders. This is also the case for girls in *S*8, whereas for boys, the three stages are significantly different: they experiment a larger increase in concern than girls, for whom the values were higher to begin with. In *S*7, all three stages are significantly different from each other for both genders.

The interaction effect between the gender of the student and the stage at which they are is nonsignificant for all three questions *S*6–*S*8 (Table VII), indicating there is no sign that boys' and girls' responses are influenced differently by stage. Furthermore, considering students' preferences, gender differences are maintained for learners without preference between math and Spanish Language. According to student's answers, out of the girls with no preference between math and Spanish language, 32.3% have a higher perceived self-efficiency in the Spanish language versus a 20.2% with higher self-efficiency in math. In the case of boys, only 17.1% of them have a higher self-efficiency in Spanish language versus a 37.8% in math. From these outcomes, it can be concluded that the general beliefs of boys and girls are kept also in learners that do not show any preference between Spanish language and math. In this group, it is also observed that 16.2% of the girls without preference are more worried about math and 12.6% about Spanish language, while 11.6% of the boys have higher anxiety about math versus 20.1% in Spanish language.

B. Relationship Between Teachers' Perception and Students' Beliefs

In order to determine, the teachers' consciousness of students' self-perceived efficacy in math and the perceived usefulness of math, teachers answered *T*6 (*I think my students understand the usefulness of mathematics*) and *T*7 (*I have noticed that girls think they are worse than boys in mathematics*).

Almost 50% of teachers consider that their students "very often" (41.13%) or "always" (9.93%) understand the usefulness of mathematics. However, almost 85% of students admit that they do very often (27.7%) or always (56.7%). It seems there may be a disconnection between students' and teachers' perceptions. However, the question posed to the students does not ask if they believe mathematics is useful, but rather if they understand what they are useful for; this nuance may be the cause of the disconnection. Teachers' perception is likely related to the fact that mathematics is more often tied to negative emotions like test anxiety rather than positive ones like the enjoyment of the subject. In fact, Muis *et al.* [49] recommended that teachers highlight the importance and usefulness of mathematics in order to help students' positive activating emotions.

Moreover, more than 50% of teachers think that girls "never" consider themselves worse than boys in mathematics when only 54.9% of the girls consider themselves very often or always good in mathematics as opposed to 71.5% of the boys. This means a gender difference of 16.6% that increases to 21.3% when focused on the second and third stages. The present result shows that teachers are mostly unaware of gender differences disadvantaging female students in children's self-perceived efficacy in mathematics.

IV. Discussion

Having found significant differences among primary school students in the previous section, this section highlights the implication of these quantitative results on the choice of subsequent studies and the potential effect on women's interest in STEM studies.

Mathematics has been chosen as the main subject to be analyzed, as it is the one most related to engineering studies throughout the Spanish Primary School Curriculum. Other subjects, such as natural science, contain relevant sections at certain levels (e.g., electricity in the last two courses of primary school) but are overall less related. The present study analyzes three factors identified in the literature as influencing the learning of mathematical concepts: 1) perceived usefulness of math; 2) self-perceived efficacy; and 3) test anxiety in math. Spanish language is also analyzed in order to compare tendencies between "engineering-related subjects" and "nonengineering-related subjects." First, looking into students' preferences, it can be observed that from the second stage on, on average, boys prefer math to Spanish language, whereas girls prefer Spanish language to math, and there is a significant difference between genders. In contrast, no difference between genders nor stage is observed in their preference for natural sciences versus social sciences.

Second, students' perceived usefulness of math was analyzed through the statement *I understand what math is useful for*. No gender differences were observed (Fig. 3 and Table IV). Throughout primary school, both girls and boys perceive math as very useful. However, teachers' perception of students' understanding underestimated students' ratings. This mismatch may be due to students usually exhibiting negative emotions as test anxiety toward mathematics.

Third, the statements *I am good at math* and *I am good at Spanish language* allowed an investigation of the self-perceived efficacy of children in math and Spanish language (Fig. 4 and Table V). Notable findings include that from the second stage on, boys have a better self-perception than girls in math, whereas girls have a better self-perception in Spanish language. The trend becomes more pronounced as students grow up, i.e., girls rate themselves significantly lower in math in the third stage than in the second stage, and boys behave similarly for Spanish language. These results are consistent with precedent works that establish using explicit measures that during primary school girls rate themselves lower than boys in math [51] but not in reading or writing [52]. Besides, a study with Singaporean primary-school students (math achievements of students in Singapore is outstanding without significant differences between genders) found higher implicit math self-concept in boys than girls [53]. Their findings suggest that even before young children's math achievement becomes affected, their understanding of themselves in relation to math is already beginning to be affected by sociocultural factors or stereotypical behaviors that may be prevalent in their community (i.e., gender differences in math self-concepts).

In addition, the results of the survey show that there is a correlation between children self-perceived efficacy in a specific domain (math or Spanish language) and children preferences for that domain with respect to other domains; i.e., if a child considers her or himself good at mathematics and not so good at Spanish language, then that child will likely prefer math to Spanish language. Besides, girls prefer Spanish language to math while boys prefer math to Spanish language (see Section III-A1 for more details).

Regarding teachers' perception on students' self-perceived-efficacy in mathematics, they apparently do not perceive such large gender differences. It has been shown that gender stereotypes in students' ability in mathematics exist in teachers even for very young students [13], and these are maintained throughout the education system with similar stereotypes held by high school teachers [54]. This stereotype is also present in their students, as 54.9% of the girls versus 71.5% of the boys consider themselves good in math always or "almost always." This difference increases to 21.3% at the ages from 8 to 10 years old. However, the results of this work show that teachers are not explicitly aware of their female students' lack of confidence, with more than 50% of the teachers believing that girls never consider themselves worse than their male colleagues. This result may also imply that teachers are not self-aware of their own stereotypes or the influence they have on their students. The disconnection between teachers' views of students and students' self-perception is potentially due to the fact that exam results show no significant difference in math performance between male and female students [37], [55].

Teachers' opinions of individual students also have an influence over those pupils. Rosenthal and Jacobson [34] showed that when teachers believe a student will show a strong intellectual development that student's performance increases highly irrespectively of her or his actual previous skills, especially in the early primary school years. The same study also showed that for those students, female pupils showed higher development in reasoning and male in verbal skills, the areas most affected by stereotypes.

Finally, gender differences also arise regarding test anxiety (Fig. 5 and Table VII). There is a significant difference in self-reported anxiety in math exams between boys and girls, with girls reporting higher anxiety scores. Interestingly, this trend is not found in Spanish language exams, where there is no significant effect of gender in self-reported anxiety for the first, second, and third stages. Additionally, self-reported test anxiety increases as students progress through primary school, particularly in the third stage with respect to the other two. Anxiety has been argued to be a mediating variable of stereotype threat. The stereotype threat theory (STT) [56] states that if negative stereotypes are present regarding a specific group, group members are likely to become anxious about their performance, which may hinder their ability to perform to their full potential. Stereotype threat has been found to be a contributing factor to longstanding racial and gender gaps in academic performance [57]. It has been extensively studied [58] and has been found not only in the laboratory but also in classroom settings [59]. Strong math-gender stereotypes have been found to correlate with stronger math self-concepts for boys and weaker math self-concepts for girls [53]. As stated, teachers have shown stereotypes toward gender in numerous occasions [13], [36]. Therefore, for girls, the development of a math self-concept that supports high math achievement may require opposing the effects of having acquired the societally stereotypical connection between math and boys [60]. Once stereotypes are internalized, students may begin to devalue particular school subjects; not because they have experienced difficulties with those subjects in the past, but because the stereotypes connote that they may experience difficulties in the future [61]. If explicit perceptions of academic discipline are at odds with one's identity they discourage students from choosing and identifying themselves with the field [62], [63]. Even if young girls excel in primary-school mathematics, as in Singapore, the stereotype that math is for boys might bias girls not to pursue mathematics in the long run, affecting girls educational interests and career choices in the future [45], [64], [65] and contributing to female underrepresentation in STEM fields.

There are many outreach activities for high-school students, such as Girls' Day [7] or Technovation Challenge [66], which have been running during more than ten years without strong effects. Findings support that girls become less interested in STEM topics when they move from the primary to secondary school [67], and that teachers have a stronger influence over their students in the younger years [34]. The effect of teachers paired with their implicit stereotypes and the unawareness of girls' self-perceptions indicates a potential area for development. It is a strongly suggested that changing teachers' perceptions of students' and girls' mathematical ability will lead to an increase in females' self-perception in this subject. Moreover, these facts together with the present study imply that interventions should focus on changing teachers' and students' beliefs and attitudes about math in primary school stages, when interventions may be most effective due to the malleability of stereotypes and students' emerging self-concepts [53].

V. Conclusion and Future Actions

The lack of women's presence in STEM studies is a global problem, receiving considerable attention in the last years. Recent studies have shown that girls become less interested than boys in STEM topics during adolescence; therefore, this work has analyzed through a large-scale study comprising more than 2100 students, 212 teachers, and a total of 17 520 answers, gender differences that may arise during early stages of education (i.e., throughout primary school). Math subject is the main focus of the study since it has been identified in the literature as highly correlated with the lack of female students in STEM university degrees. Gender and educational stage's influence in math perception are analyzed, in terms of perceived usefulness, preference with respect to another subject, self-perceived efficacy, and test anxiety. Whenever appropriate, these aspects are compared to similar perceptions for Spanish language subject in order to have a relative measure as opposed to an absolute one.

Results show remarkable differences between genders, with girls presenting a lower perceived self-perceived efficacy in math than boys and significantly higher test anxiety. These trends increase along educational stages as students grow up.

These findings suggest that girls are less likely to experience positive activating emotions during the mathematics learning process at primary school, often due to their teachers' unintended influence. This early childhood experience may affect girls' attitude toward mathematics at the high school level, increasing the anxiety levels in many girls. Consequently, it is more likely for them to avoid studies with mathematical requirements, such as STEM degrees. Primary-school teachers are not aware of this situation or of their implicit bias, so it cannot be expected that they accomplish actions to reverse the situation. Potential unawareness of the teachers can lead to difficulties in reversing this issue.

From these findings, the following recommendations in order to promote more women in STEM emerge. It is necessary, particularly during the early stages of education (i.e., primary school) to:

1) work on teachers' awareness of girls' lack of self-confidence toward mathematics;
2) accomplish actions in order for students, especially girls, to experience positive activating emotions toward mathematics;
3) give explicit messages about the value of mathematics in a real-world context.

To summarize, it is essential to make teachers aware of the problem and of their actions very powerful effects, and how they may influence students' beliefs. Schools have to actively promote gender balance in all areas, making all stakeholders work in the same direction. The authors will continue organizing and promoting "A Female Engineer in Every School," as it is an activity that can help close the gender gap in STEM.

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References

[1] *Education at a Glance 2018*. Paris, France: OECD Publ., 2018, p. 460.

[2] C. Botella, S. Rueda, E. López-Iñesta, and P. Marzal, "Gender diversity in STEM disciplines: A multiple factor problem," *Entropy*, vol. 21, no. 30, pp. 1–17, 2019.

[3] M. T. Wang and J. L. Degol, "Gender gap in science, technology, engineering, and mathematics (STEM): Current knowledge, implications for practice, policy, and future directions," *Educ. Psychol. Rev.*, vol. 29, no. 1, pp. 119–140, 2017.

[4] M. Klawe, T. Whitney, and C. Simard, "Women in computing–take 2," *Mag. Commun. ACM Inspiring Women Comput.*, vol. 52, no. 2, pp. 68–76, 2009.

[5] *Employment in Technology and Knowledge-Intensive Sectors at the National Level, by Sex (From 2008 Onwards, NACE Revision 2)*, Eurostat, Brussels, Belgium, 2017.

[6] *Current Population Survey, Household Data Annual Averages 2016*, Bureau Labor Stat., Washington, DC, USA, 2017.

[7] P. Molina-Gaudó, S. Baldassarri, M. Villarroya-Gaudó, and E. Cerezo, "The 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.

[8] J. C. Blickenstaff, "Women and science careers: Leaky pipeline or gender filter?" *Gender Educ.*, vol. 17, no. 4, pp. 369–386, 2005.

[9] M. T. Wang, J. S. Eccles, and S. Kenny, "Not lack of ability but more choice: Individual and gender differences in choice of careers in science, technology, engineering, and mathematics," *Psychol. Sci.*, vol. 24, no. 5, pp. 770–775, 2013.

[10] J. Herbert and D. Stipek, "Are computer science and information technology still masculine fields? High school students' perceptions and career choices," *Comput. Educ.*, vol. 51, no. 2, pp. 594–608, 2008.

[11] D. I. Miller, A. H. Eagly, and M. C. Linn, "Women's representation in science predicts national gender-science stereotypes: Evidence from 66 nations," *J. Educ. Psychol.*, vol. 107, no. 3, pp. 631–644, 2015.

[12] S. Leslie, A. Cimpian, M. Meyer, and E. Freeland, "Women are underrepresented in disciplines that emphasize brilliance as the key to success," *Sci.*, vol. 347, no. 6, pp. 262–265, 2015.

[13] J. Robinson-Cimpian, S. Theule Lubienski, C. Ganley, and Y. Copur-Gencturk, "Teachers' perception of students' mathematics proficiency may exacerbate early gender gaps in achievement," *Develop. Psychol.*, vol. 50, no. 4, pp. 1262–1281, 2014.

[14] L. Bian, S. L. Leslie, and A. Cimpian, "Gender stereotypes about intellectual ability emerge early and influence children's interests," *Science*, vol. 355, no. 6323, pp. 389–391, 2017.

[15] G. Park, D. Lubinski, and C. P. Benbow, "Contrasting intellectual patterns predict creativity in the arts and sciences: Tracking intellectually precocious youth over 25 years," *Psychol. Sci.*, vol. 18, no. 11, pp. 948–952, 2007.

[16] J. M. Valla and S. J. Ceci, "Breadth-based models of women's underrepresentation in STEM fields: An integrative commentary on Schmidt (2011) and Nye et al. (2012)," *Perspect. Psychol. Sci.*, vol. 9, no. 2, pp. 219–224, 2014.

[17] E. A. P. Cass, Z. Hazari, J. Cribbs, P. M. Sadler, and G. Sonnert, "Examining the impact of mathematics identity on the choice of engineering careers for male and female students," in *Proc. Frontiers Educ. Conf.*, 2011, pp. 1–5.

[18] M. Sainz and J. Müller, "Gender and family influences on Spanish students' aspirations and values in stem fields," *Int. J. Sci. Educ.*, vol. 40, no. 2, pp. 188–203, 2018.

[19] G. Ramirez, E. A. Gunderson, S. C. Levine, and S. L. Beilock, "Math anxiety, working memory, and math achievement in early elementary school," *J. Cognition Develop.*, vol. 14, no. 2, pp. 187–202, 2012.

[20] C. B. Young, S. S. Wu, and V. Menon, "The neurodevelopmental basis of math anxiety," *Psycol. Sci.*, vol. 23, no. 5, pp. 492–501, 2012.

[21] *The ABC of Gender Equality in Education: Aptitude, Behaviour, Confidence (PISA)*. Paris, France: OECD Publ., 2015, p. 180.

[22] L. O'Keeffe, L. White, D. Panizzon, K. Elliott, and A. Semmens, "Mathematics anxiety: Year 7 and 8 student perceptions," in *Proc. 41st Annu. Conf. Math. Educ. Res. Group Australasia (MERGA)*, 2018, pp. 607–614.

[23] A. Efklides and S. Volet, "Feelings and emotions in the learning process," *Learn. Instruct.*, vol. 15, no. 5, pp. 377–515, 2005.

[24] E. A. Linnenbrink, "Emotion research in education: Theoretical and methodological perspectives on the integration of affect, motivation, and cognition," *Educ. Psychol. Rev.*, vol. 18, no. 4, pp. 307–314, 2005.

[25] P. A. Schutz and R. Pekru, Eds., *Emotion in Education* (A Volume in Educational Psychology Series). Burlington, VT, USA: Elsevier, 2007, p. 368.

[26] S. Shukajlow and K. Rakoczy, "The power of emotions: Can enjoyment and boredom explain the impact of individual preconditions and teaching methods on interest and performance in mathematics?" *Learn. Instruct.*, vol. 44, pp. 117–127, Aug. 2016.

[27] R. Hembreee, "The nature, effects, and relief of mathematics anxiety," *J. Res. Math. Educ.*, vol. 21, no. 1, pp. 33–46, 1990.

[28] H. Ho *et al.*, "The affective and cognitive dimensions of math anxiety: A cross-national study," *J. Res. Math. Educ.*, vol. 31, no. 3, pp. 362–380, 2000.

[29] T. M. Beasley, J. D. Long, and M. Natali, " A confirmatory factor analysis of the mathematics anxiety scale for children," *Meas. Eval. Counseling Develop.*, vol. 34, no. 1, pp. 14–26, 2001.

[30] M. H. Ashcraft and K. S. Ridley, " Math anxiety and its cognitive consequences—A tutorial Rev.," in *Handbook of Mathematical Cognition*. New York, NY, USA: Psychol. Press, 2005, pp. 315–327.

[31] T. Mainhard, S. Oudman, L. Hornstra, and R. J. Bosker, "Student emotions in class: The relative importance of teachers and their interpersonal relations with students," *Learn. Instruct.*, vol. 53, no. 1, pp. 109–119, 2018.

[32] E. S. Becker, T. Goetz, V. Morger, and J. Ranellucci, "The importance of teachers' emotions and instructional behavior for their students' emotions—An experience sampling analysis," *Teach. Teacher Educ.*, vol. 43, pp. 15–26, Oct. 2014.

[33] F. Cubukcu, "The significance of the academic emotions," *Procedia Soc. Behav. Sci.*, vol. 70, pp. 649–653, Jan. 2013.

[34] R. Rosenthal and L. Jacobson, "Pygmalion in the classroom," *Urban Rev.*, vol. 3, pp. 16–20, Sep. 1968.

[35] S. L. Beilock, E. A. Gunderson, G. Ramirez, and S. C. Levine, "Female teachers' math anxiety affects girls'math achievement," *Proc. Nat. Acad. Sci. USA*, vol. 107, no. 5, pp. 1860–1863, 2010.

[36] E. Denessen, N. Vos, F. Hasselman, and M. Louws, "The relationship between primary school teachers and students attitudes towards science and technology," *Educ. Res. Int.*, vol. 2015, Feb. 2015, Art. no. 534690. AQ5

[37] Gobierno de Aragón, "Report of diagnostic evaluation results. Course 2017/18," Departamento de Educación, Cultura y Deporte, Evaluación Educativa Aragón, 2018. Accessed: Jun. 18, 2020. [Online]. Available: http://evalua.catedu.es/evaluacion/wp-content/uploads/InformeGeneral2017_2018.pdf AQ6

[38] E. Cerezo *et al.*, "A female engineer in every school," in *Proc. 21st Int. Conf. Human Comput. Interact. (Interacción)*, Palma, Spain, 2018, p. 2.

[39] A. J. Little and B. A. León de la Barra, "Attracting girls to science, engineering and technology: An Australian perspective," *Eur. J. Eng. Educ.*, vol. 34, no. 5, pp. 439–445, 2009.

[40] A. G.-V. Muñoz-Repiso and V. B. Gómez-Pablos, "Evaluación de una experiencia de aprendizaje colaborativo con Tic desarrollada en un centro de educación primaria," *Revista Electrónica de Tecnología Educativa (EDUTEC)*, vol. 51, pp. 1–12, Mar. 2015.

[41] A. García-Varcárcel, V. Basilotta, and C. López, "ICT in collaborative learning in the classrooms of primary and secondary education," *Comunicar*, vol. 21, no. 42, pp. 65–74, 2014.

[42] D. Llewellyn, S. Pray, R. DeRose, and W. Ottman, "Engineering encounters: Building a spaghetti structure," *Sci. Children*, vol. 54, no. 2, pp. 70–75, 2016.

[43] Laughing Squid. (May 2, 2016). *How to Build a Simple DIY Plastic Foam Cutter Using a Nine-Volt Battery and Some Wire*. Accessed: Jun. 18, 2020. [Online]. Available: https://laughingsquid.com/diy-plastic-foam-cutter/

[44] Water Filter Mag. (Feb. 2, 2020). *DIY Water Filtration System—Basics & Tips for Beginners*. Accessed: Feb. 3, 2020. [Online]. Available: https://www.waterfiltermag.com/diy-water-filter/

[45] Imascono. (Feb. 1, 2019). *Educational Augmented Reality App for Kids*. Accessed: Jun. 18, 2020. [Online]. Available: https://imascono.com/portfolio-item/augmented-reality-kids-chromville

[46] (Mar. 8, 2019). *CS Unplugged*Accessed: Jun. 18, 2020. [Online]. Available: https://csunplugged.org/en/topics/image-representation/

[47] I. A. E. (Aragonese Insitute of Statistics), Educación y Formación: Indicadores de la enseñanza no universitaria. (1.3 y 1.4), 2018. AQ7

[48] B. Flyvbjerg, *Qualitative Research in Practice*, C. Seale, G. Gobo, J. F. Gubrium, and D. Silverman, Eds. London, U.K.: Sage, 2004, pp. 420–434.

[49] K. R. Muis, C. Psaradellis, S. P. Lajoie, I. D. Leo, and M. Chevrier, "The role of epistemic emotions in mathematics problem solving," *Contemporary Educ. Psychol.*, vol. 42, pp. 172–185, Jul. 2015.

[50] M. Alves, C. S. Rodrigues, A. M. A. C. Rocha, and C. Coutinho, "Self-efficacy, mathematics' anxiety and perceived importance: an empirical study with Portuguese engineering students," *Eur. J. Eng. Educ.*, vol. 41, no. 1, pp. 105–121, 2016.

[51] J. Herbert and D. Stipek, "The emergence of gender differences in children's perceptions of their academic competence," *J. Appl. Develop. Psychol.*, vol. 26, no. 3, pp. 276–295, 2005.

[52] F. Pajares, M. D. Miller, and M. J. Johnson, "Gender differences in writing self-beliefs of elementary school students," *J. Educ. Psychol.*, vol. 91, no. 1, pp. 50–61, 1999.

[53] D. Cvencek, M. Kapur, and A. Meltzoff, "Math achievement, stereotypes, and math self-concepts among elementary-school students in Singapore," *Learn. Instruct.*, vol. 39, pp. 1–10, Oct. 2015.

[54] C. Riegle-Crumb and M. Humphries, "Exploring bias in math teachers' perceptions of students' ability by gender and race/ethnicity," *Gender Soc.*, vol. 26, no. 2, pp. 290–322, 2012.

[55] J. Hutchison, I. Lyons, and D. Ansari, "More similar than different: gender differences in children's basic numerical skills are the exception not the rule," *Child Develop.*, vol. 90, no. 1, pp. e66–e79, 2019.

[56] C. M. Seele, "A threat in the air. How stereotypes shape intellectual identity and performance," *Amer. Psychol.*, vol. 52, no. 6, pp. 613–629, 1997.
[57] C. M. Steele and J. Aronson, "Stereotype threat and the intellec-tual test performance of African Americans," *J. Personal. Soc. Psychol.*, vol. 69, no. 5, pp. 797–811, 1995.
AQ8 [58] R. Pennington, D. Heim, A. R. Levy, and D. Larkin, "Twenty years of stereotype threat research: A review of psycho-logical mediators," *Procedia Soc. Behav. Sci.*, vol. 190, pp. 211–219, 2015.
[59] J. Keller, "Stereotype threat in classroom settings: The interactive effect of domain identification, tasl difficulty and stereotype threat on female students' math performance," *Brit. J. Educ. Psychol.*, vol. 77, pp. 323–338, Jun. 2007.
[60] B. A. Nosek, M. Banaji, and A. Greenwald, "Math=male, me= female, therefore math # me," *J. Personal. Soc. Psychol.*, vol. 83, no. 1, pp. 44–59, 2002.
[61] E. M. Skaalvik and R. J. Rankin, "Math, verbal, and general academic selfconcept: The internal/external frame of reference model and gender differences in self-concept structure," *J. Educ. Psychol.*, vol. 82, no. 3, pp. 546–554, 1990.
[62] S. Cheryan, A. Master, and A. N. Meltzoff, "Cultural stereotypes as gatekeepers: Increasing girls' interest in computer science and engineering by diversifying Stereotype," *Frontiers Psychol.*, vol. 6, pp. 1–8, Feb. 2015.
[63] P. M. Frome, C. J. Alfeld, J. S. Eccles, and B. L. Barber, "Why don't they want a male-dominated job? An investigation of young women who changed their occupational aspirations," *Educ. Res. Eval.*, vol. 12, no. 4, pp. 359–372, 2006.
[64] S. D. Simpkins, P. Davis-Kean, and J. S. Eccles, "Math and science motivation: A longitudinal examination of the links between choices and beliefs," *Develop. Psychol.*, vol. 42, no. 1, pp. 70–83, 2006.
[65] E. S. Weisgram, R. S. Bigler, and L. S. Liben, "Gender, values, and occupational interests among children, adolescents, and adults," *Child Develop.*, vol. 81, no. 3, pp. 778–796, 010.
[66] (2019). *Technovation Challenge Website*. Accessed: Jun. 18, 2020. [Online]. Available: https://technovationchallenge.org
[67] *Why Europe's Girls Aren't Studying STEM*, Microsoft, Redmond, WA, USA, 2017.

AQ9 **Natalia Ayuso** (Member, IEEE) received the Ph.D. degree in 2010.

She is an Associate Professor with the Department of Computer Science, Universidad de Zaragoza, Zaragoza, Spain. Her research interests focus on electromagnetic field propagation in challenging environments as caves, tunnels, or mines for subsurface location and communication in constrained sceneries for robotics as well as in wireless sensor networks in confined environments.

Dr. Ayuso is a member of AMIT (Spanish Association of Women Researchers and Technologists).

Elena Fillola was born in Zaragoza in 1999. She is currently pursuing the M.Eng. degree in engineering mathematics with the University of Bristol, Bristol, U.K.

She is Outreach Representative for the Society of Women in Engineering, University of Bristol, Bristol, U.K. She has an interest in modeling and data science.

Dr. Fillola is a member of AMIT (Spanish Association of Women Researchers and Technologists).

Belén Masiá (Member, IEEE) received the Ph.D. degree in 2013.

She is an Assistant Professor with the Department of Computer Science, Universidad de Zaragoza, Zaragoza, Spain. Her research focuses on computational imaging, applied perception, and virtual reality.

Dr. Masiá is also a recipient of the Eurographics Young Researcher Award in 2017 and the NVIDIA Graduate Fellowship in 2012. She serves as an Associate Editor for the *ACM Transactions on Graphics*. She is a Eurographics Junior Fellow and a member of AMIT.

Ana C. Murillo (Member, IEEE) received the Ph.D. degree in computer science from the University of Zaragoza, Zaragoza, Spain.

She is currently an Associate Professor with the Department of Computer Science and Systems Engineering, Universidad de Zaragoza. Her research interests include scene understanding and visual recognition for robotics and other embedded systems.

Dr. Murillo is a member of the Aragonese Professional College of Engineering in Computer Science and AMIT (Spanish Association of Women Researchers and Technologists).

Raquel Trillo-Lado received the Ph.D. degree in 2012.

She is an Associate Professor with the Department of Computer Science and Systems Engineering, University of Zaragoza, Zaragoza, Spain. Her research interests include digital data management and keyword search on structured data sources.

Dr. Trillo-Lado is a member of SISTEDES, SERI, the Aragonese Professional College of Engineering in Computer Science, and AMIT.

Sandra Baldassarri (Senior Member, IEEE) received the Ph.D. degree in computer science engineering from the University of Zaragoza, Zaragoza, Spain, in 2004.

She is an Associate Professor with the Computer Science Department, University of Zaragoza. Her research interests include virtual humans, affective computing, multimodal interfaces, tangible and natural interaction, and their application in educational fields.

Dr. Baldassarri is a member of AMIT (Spanish Association of Women Researchers and Technologists). She serves as an Associate Editor for IEEE ACCESS.

Eva Cerezo (Member, IEEE) received the Ph.D. degree in computer science in 2002.

She is an Associate Professor with the Computer Science Department, University of Zaragoza, Zaragoza, Spain. She leads the AffectiveLab, Tokyo, Japan, a research group that focuses on affective multimodal human computer interaction, tangible tabletops, and virtual humans. She has authored more than 80 international publications.

Dr. Cerezo is the Head of the Executive Board of the ACM SIGCHI Spanish Local Chapter and a member of AMIT (Spanish Association of Women Researchers and Technologists).

Laura Ruberte received the Ph.D. degree in 1985.

She is an Associate professor with the Department of Analytical Chemistry, Universidad of Zaragoza, Zaragoza, Spain. Her research focuses on chemical analysis.

Dr. Ruberte is a member of SEQA (Spanish Society of Analytical Chemistry) and AMIT (Spanish Association of Women Researchers and Technologists).

M. Dolores Mariscal is an Associate Professor with the Department of Science and Technology of Materials and Fluids, University of Zaragoza, AQ10 Zaragoza, Spain.

Dr. Mariscal is a member of AMIT (Spanish Association of Women Researchers and Technologists).

María Villarroya-Gaudó received the Ph.D. degree from the Department of Electronics Engineering, Autonoma University of Barcelona, Bellaterra, Spain, in 2005.

She is an Associate Professor of computer architecture and technology with the Department of Computer and Systems Engineering, Universidad de Zaragoza, Zaragoza, Spain. Her research interests include memory hierarchy and heterogeneous systems.

Dr. Vilarroya-Gaudó is a member of the Spanish Society of Computer Architecture (SARTECO) and the President of AMIT-Aragón (Asociación Mujeres Investigadoras y Tecnólogas en Aragón).