Challenges of STEM Vocations in Secondary Education

Alba Ayuso, Noemi Merayo, Inés Ruiz, and Patricia Fernández

Abstract*—*Contribution: **There is a significant decline in technological vocations despite a huge increase in labor demand for professionals in these sectors. This technology-related problem has become a major concern for governments, organizations, and education systems. Students' motivation toward Science, Technology, Engineering, and Mathematics (STEM) may be due to the influence of their immediate environment, known role models and the involvement of families and teachers, as well as the search for more positive and inclusive perceptions of science and technology in our lives. The present study shows the perception and motivation of secondary students and teachers toward STEM and its importance in society.**

Background: **The low presence of students in STEM could be explained by the perception and knowledge of students and teachers toward technology. Studies show that students largely lose interest in STEM during secondary school education, and this leads to a decline in technological vocations that carries over to university and the labor market. Due to the economic and social impact of this loss, institutions are launching initiatives to support education and the development of digital competences, with special emphasis on the awakening technological vocations.**

Research Questions: **What is the motivation and perspective of students for STEM studies? Are teachers aware of students' perceptions? What are the actions taken by teachers to encourage secondary students toward STEM?**

Methodology: **This study follows a descriptive correlational design based on surveys (1562 students and 430 teachers) regarding issues that influence the perceptions of students and teachers toward STEM.**

Findings: **This study demonstrates a divergence between teachers' and students' perceptions of STEM-related skills and abilities. Indeed, teachers and parents/guardians need to encourage more young people to engage in STEM activities because of the great influence they have on their decisions. The search for new STEM referents that young people can identify with is another important finding. Furthermore, this study also reveals that technology should be linked to our daily lives and emphasize its role as a social good for society. Finally, integrating STEM subjects into the curriculum and encouraging technological vocations at all stages of education are of utmost importance.**

***Index Terms*—Science, technology, engineering, and mathematics (STEM), secondary school, secondary teachers, technological vocations.**

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This work involved human subjects or animals in its research. The authors confirm that all human/animal subject research procedures and protocols are exempt from review board approval.

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I. INTRODUCTION

TECHNOLOGY is acquiring great relevance in modern societies. On the one hand, societies are becoming digitalized at a dizzying and irreversible pace. On the other hand, it represents a growing employment and business niche, which makes it possible to speak of a 4th industrial revolution. The digital world is flooding our daily lives: institutional, academic, professional, even in personal relationships. But in addition, the coronavirus pandemic has further accelerated the need for digital technologies, that is, the application of methods to develop systems that are expressed in numbers or data and which allows certain processes to be automated.

This deep digitalization, process by which digital technology is embedded in society and the economy, makes visible the need for professional profiles aligned with artificial intelligence (AI), automation, cybersecurity, big data, cloud computing, or Internet of Things (IoT) [1]. Thus, the European Commission (EC) estimates that 45% of jobs in 2022 will be digital-related and this trend will continue to grow much more rapidly. Besides, LinkedIn estimates that the technology sector would need almost 150 million jobs in the next five years [2], with advanced computer and programming skills set to grow the most in the coming years [3]. But despite this growing trend, there is a significant shortage of ICT specialists. By way of example, 57% ICT companies reported difficulties filling vacancies during 2018 [4], in addition to the top ten hardest jobs to fill being Science, Technology, Engineering, and Mathematics (STEM) [5] and the skills gap in the cybersecurity sector is 2.9 million [3]. Consequently, this undersupply of ICT specialists has become a major concern for governments, organizations, companies, and educational systems.

In this regard, the pursuit of ICT professions requires training in mathematics, engineering, and technology, and this new social and economic scenario has highlighted new challenges for education in terms of digital skills and competences [3], [4], as, paradoxically, students choosing these disciplines are declining at an alarming rate, and education systems must adapt to the challenges of the 21st century. Digital skills are thus defined as skills in using digital devices, applications, software, and systems. However, digital competences go beyond this and involve a deeper, more confident and critical understanding of technology, encompassing social and emotional aspects of appropriate use of technology [3], [4]. These educational challenges are, therefore, observed in the latest international computer and information literacy study (ICILS) [6], where more than a third of students scored below the low performance threshold in digital skills. Furthermore, the EU, in its annual report on the Sustainable Growth Strategy 2021 [7], proposes to increase the acquisition of digital skills to 70% by 2025, with Member States ensuring that the percentage of students aged 13–14 with low digital skills is below 15% [7]. In fact, the Digital Education Action Plan (2021–2027) of the EU aims to reduce this gap through formal education [8]. This plan seeks to adapt the education and training systems to the digital age in a sustainable and effective way. These measures are necessary because the digital world has transformed society and economy, but the pandemic has revealed the need for an education system adapted to the digital age and has highlighted challenges regarding digital capabilities of educational institutions, teacher training, and digital skills levels [8]. Therefore, this initiative is working on fostering the development of a high-performing digital education ecosystem and enhancing digital skills and competences for the digital transformation [8]. Furthermore, STEM education is the main concern of the Organization for Economic Co-operation and Development (OECD) countries. Thus, public budgets for STEM education have increased in Belgium, Croatia, Latvia, South Africa, or United States [9]. Initiatives are being promoted to make STEM subjects more attractive to students. For example, New Zealand's "A Nation of Inquiring Minds" and "Futureintech" programmes bring technology professionals into schools [9]. In Ireland, developmental subjects in science are offered on a step-by-step basis, as well as courses for teachers to match the interests of secondary school students. Finally, countries, such as Portugal, have designed national competitions to encourage interest in STEM [9]. Besides, new training programs and teacher recruitment criteria are being introduced in some countries (Croatia, Korea, Norway, and Sweden) and new IT-based teaching methods in countries, such as the Czech Republic, Lithuania, Portugal, and Spain [9].

This educational and economic picture also applies to Spain, where although the number of companies hiring ICT specialists has grown the most in the EU, the number of university graduates has fallen [3]. In this regard, the latest official study of the Spanish University System (2021) shows that between the academic years 2010 and 2011 and 2019 and 2020, enrolment in Engineering and Architecture has fallen by 7.9% [10]. In fact, only around 8000 students graduate from computer science degrees and the latest report from the Ministry of Universities (2021) stated that only 9699 students were enrolled in computer science degrees in 2020 [10]. These numbers are insufficient for the more than 15 000 companies in need of ICT specialists. In line with this, a recent study in Spain [11] shows that there are more than 10 000 job vacancies in ICT and it is estimated that 1.25 million jobs will be created between 2017 and 2022. Despite this growing need, the latest PISA report reveals that Spain scored its worst in science and mathematics, eight points lower than OECD countries [12].

To understand this lack of STEM vocations, the literature suggests that students' motivation may be due to different factors. An important factor is the impact of their environment, such as family support, family referents in STEM jobs or the involvement of families and teachers to encourage them toward STEM [13]–[16]. Research conducted in [17] concluded that students with parents with STEM jobs are more likely to choose these disciplines and teachers can influence STEM career choices by giving students positive STEM-related experiences [18]. Indeed, some studies claim that family engagement plays an essential role in strengthening STEM education, as the family (especially, parents/guardians) is the most influential in children's educational and career decisions [19]. On the other hand, some studies also show the important impact of teachers on their academic behavior and emotions [20]. Moreover, some studies suggest that existing stereotypes about science and technology jobs are turning students away from these studies [21]. Parents and teachers should, therefore, help them to become aware of the career opportunities that science/technology education opens up, and it is important to convey a positive and inclusive image of technology, as we are facing a digitalized world and science/technology education should focus on new sources of interest and enjoyment [21].

Therefore, this study aims to investigate students' opinion and interest in STEM during compulsory secondary education (CSE) in the 3rd and 4th grades (aged 14–16) and to compare teachers' perceptions. This will make it possible to analyze the divergences in thinking between the two and see if they are aligned on the same perceptions. The Spanish education system, according to the Organic Law 3/2020, of 29 December [22], initially comprises the Infant Education stage, which is voluntary and is divided into two cycles from 0 to 3 years and from 3 to 6 years (three academic years each cycle). This is followed by Primary Education, the first level of compulsory education, with a duration of six academic years (from 6 to 12 years) and then secondary education, also compulsory and divided into four academic years (from 12 to 16 years). As part of post-CSE is the Baccalaureate, which is voluntary and consists of two academic years (between the ages of 16 and 18). The Baccalaureate is organized in a flexible way and consists of several modalities (Science, Humanities, Social Sciences, and Arts) that students are free to choose at the end of 4th CSE [23]. This article is organized as follows. Section II describes the methodology and sample. Section III shows teachers' and students' attitudes toward STEM. Section IV discusses the results and Section V provides the conclusions of the study.

II. Methodology and Sample Characterization

A descriptive, correlational, and explanatory quantitative design [24], [25] has been carried out with the purpose of understanding the motivation and perspective of students toward STEM disciplines, as well as describing and understanding the actions carried out by teachers to encourage students to opt for this type of disciplines. This type of design gives the opportunity to generalize the results widely, and to have more control over the phenomena.

A. InGenias Project

InGenias is a research project developed by the Higher Technical School of Telecommunications of the University of Valladolid (UVa) with the aim of promoting technological vocations among secondary school students by making university students and professors the protagonists in the promotion of these future vocations. Teams of female university professors/students go to secondary schools (urban and rural) to promote technological vocations (especially, among girls) showing a more social and human perspective of technology in society and how it can impact on the quality of life of citizens. Then, our proposal focuses on disseminating science and technology in an entertaining way by exhibiting experiments of a social and sustainable nature. Therefore, InGenias turns female university students and professors into role models for secondary school students and a source of inspiration in which they can see themselves reflected. In this way, InGenias responds to the needs of a society that is suffering a significant decline in technological vocations, especially among women. Indeed, many studies demonstrate the lower presence of female students and professionals in STEM areas, especially in engineering and technology, and institutions are aware of this problem and have proposed different strategies to alleviate this effect. This work has been carried out with experts in scientific dissemination to detect communication problems. In fact, the team of experts belongs to university entities in charge of scientific dissemination and communication tasks, such as the Scientific Culture and Innovation Unit, which act as intermediaries between the University and citizens with the aim of promoting scientific, technological, and innovation culture. The methodology of the InGenias project is as follows.

1) The first step is to establish contact with secondary schools to offer the activity. This contact starts in September to plan the visits from February to April.
2) Experts in science dissemination propose communication strategies with a special focus on making the presence of women in these sectors more visible. This training programme is aimed at dual teams attending secondary schools. In fact, a communication based on "elevator speech" strategies is proposed, so that in a few minutes, female professors and students can arouse the interest and curiosity of their target audience, using a language close to what secondary students use in their daily live.
3) In parallel, the project team is working on the development of prototypes and experiments related to technology and engineering. The differentiating feature of the experiments/prototypes lies in the fact that the students can build them themselves and that they are useful in their daily lives, promoting creative technology based on do it yourself (DIY). On the other hand, the project wants to instil in young people the idea that technology is at the service of society and people by developing prototypes with a social and sustainability component. An obstacle detection system, a digital Braille reader (e-book) for the blind, an automated greenhouse and a station that measures pollution levels have been developed.
4) Once the talks and the experiments/prototypes have been prepared, this scientific communication is disseminated to secondary schools (3rd and 4th CSE). These school years are crucial as students particularly lose interest in Technology and Engineering during secondary school.
5) In parallel, questionnaires designed to investigate their approach to STEM disciplines and compare their different views are sent to secondary school teachers and students.

B. Participants

In this research, a nonprobabilistic, purposive sample [25] was used with two groups: 1) a group of students and 2) a group of teachers. The study involved 1562 students aged between 13–18 years ($\mu = 14.96$; $\sigma = 1.018$ corresponding to 3rd and 4th CSE. According to the current Spanish education system, students in 3rd and 4th CSE are aged between 14 and 16. However, in this study, we have ages up to 18 years because they have repeated some grades. 49.7% were male (776 participants) and 50.3% female (786 participants). 59.8% of the participants (934) belonged to the 3rd CSE, 30.1% (470) belonged to the 4th CSE, 6.4% (100) belonged to 1st High School, and 3.7% (58) belonged to the 2nd High school. In the group of teachers, 432 teachers between 24 and 68 years of age participated ($\mu = 45.54$, $\sigma = 9.094$). Of the teachers, 27.5% were men (119) and 75.5% were women (313). Furthermore, 69.4% of the respondents have a STEM degree (300) compared to 30.6% who do not have a STEM degree (132). The years of teaching experience of the surveyed teachers ranged from 1 to 40 years ($\mu = 15.77$, $\sigma = 10.4251$).

C. Data Collection and Analysis Procedure

The questionnaires were designed *ad hoc*, based on a systematic review of the scientific literature in the framework of the InGenias project on STEM [14]–[20], [26], [27], which favored greater precision in the wording of the items. In fact, topics related to the influence and support of teachers and parents/guardians are drawn from [20] [26], and [27]. Questions regarding out-of-school activities were taken from [14]–[17] and those related to interest, abilities/skills or enjoyment from [16], [18], and [27]. Finally, the alignment of personal goals and values with STEM disciplines and those related to external motivation were extracted from [27]. Then, two types of questionnaires were designed: one for students and one for teachers. Both were carried out using Google Forms and were answered anonymously. The teachers' questionnaire includes a total of:

1) fifteen dichotomous response questions (yes or no).
2) two questions on a 10-point LIKERT scale.

On the other hand, the students' questionnaire includes:

1) twenty eight dichotomous questions (yes or no);
2) three LIKERT scale questions;
3) five open-ended questions as follows.
   a) Why do you think there are male and female toys, or that toys have no gender?
   b) What would you like to do when you grow up?
   c) Why do you think there are less women in STEM careers?
   d) What qualities do you think you need to have to study STEM disciplines?
   e) Mention a famous or well-known referent in a STEM.

The reliability of both questionnaires was tested in a pilot study with 400 students and 35 teachers participating. The results of this pilot study led to the conclusion to change some questions to better adapt them to the environment we wanted to assess. Subsequently, the questionnaires were redesigned as described in this study and their reliability was reassessed. Cronbach's alpha is used to determine the reliability of a questionnaire, i.e., the accuracy of its measurement [28], in order to assess the degree of correlation of the items of an instrument (questionnaire) [29]. Cronbach's alpha scores are considered good if they are above 0.6 [30]. In fact, for the teacher questionnaire, a reliability of between 0.671 and 0.707 was obtained for all variables using Cronbach's alpha coefficient, and for the student questionnaire variables, a reliability of between 0.682 and 0.726 was obtained, so it can be stated that the reliability obtained is good for both questionnaires.

The students' questionnaire was filled by the students (3rd and 4th CSE) of the secondary schools that participated in the InGenias project during the academic courses 2019–2020 and 2020–2021. This project is endorsed by the UVa in Castilla y Leon (Spain) and was applied in all the secondary schools that wanted to participate in the project. On the other hand, the teachers' questionnaire was sent to all secondary schools in Valladolid (Castilla y León) during the same academic courses (2019–2020 and 2020–2021), and the teachers who wanted to participate answered the questions anonymously. Regarding the teachers' surveys, 68% of the secondary schools in Valladolid to which the questionnaire was sent participated. Regarding students, 100% of the students to whom the questionnaire was sent participated, as a requirement for participation in the project was that all 3rd and 4th CSE students filled in the questionnaire during school hours.

All the participants' answers were collected and processed using the SPSS 24.0 statistical package [31] for Windows. In all tests, a confidence level of 95% was established and frequencies, means, and percentages were established according to each variable. In addition to the descriptive statistics, the tests performed were Chi-square, because all variables were dichotomous nominal variables, and in this way, it can be observed whether there is an association between each pair of variables. The Phi test was also performed to find out the strength between these two variables and, finally, Lambda to measure the intensity and check whether one variable can be used to predict another. A complementary qualitative analysis was carried out using word clouds. For the open-ended questions, a complementary content analysis was carried out using word clouds, which allowed us to gain insight into some of the students' responses.

TABLE I
DESCRIPTIVE STATISTICS BY FREQUENCIES OF STUDENTS' SCORES

Questions	Yes
Family encourages me to STEM activities	44%
Teachers encourage me to STEM activities	62.2%
I'd like to pursue higher education	91.9%
I'd like to pursue STEM studies	60.7%
I think special skills/qualities are needed to study STEM	60.4%
I think people who work in STEM are attractive/curious	66.7%
I have family members working in STEM	35.7%
I have friends or acquaintances working in STEM	26.9%
I have teachers working in STEM	26%
I don't know anyone who works in STEM	19.8%

III. RESULTS

The results will be divided into two different groups: 1) on the one hand, the results of the students' questionnaires will be shown and 2) on the other hand, the results of the teachers' questionnaires will be described. Finally, both results will be compared to find common conclusions.

A. Secondary Students' Results

Table I shows the descriptive statistics of the students' responses. In this table, it can be observed that teachers encourage students to pursue STEM activities (62.2%) more than their parents do (44%). Initially, students are interested in studying something related to technology or science (60.7%), as most of them find the people involved in it attractive and curious (66.7%). Table I also shows that 35.7% of the students have family members working in STEM-related jobs, 26.9% know a friend or acquaintance, and finally, 26% know a teacher. However, 19.8% of students stated that they do not know anyone in their environment who works in STEM.

To delve deeper into famous STEM referents identified by the students, they were asked an open-ended question and their answers are reflected in the word cloud in Fig. 1. First, it is important to note that 45% of students claim not to know any famous role models. Second, the word cloud shows that the most mentioned referents are Marie Curie, Albert Einstein, Stephen Hawking, Isaac Newton, and Bill Gates, some of them far from the technology sector. Focusing on that, students named Mark Zuckerberg, Steve Jobs, Elon Musk, or Jeff Bezos, although to a much lesser extent than the most named (between 75%–85% less). Finally, it is important to emphasize that, although not shown in Fig. 1, some students named scientific youtubers, such as *La hiperactina*, *Debora*

Fig. 1. Famous referents known to secondary school students.

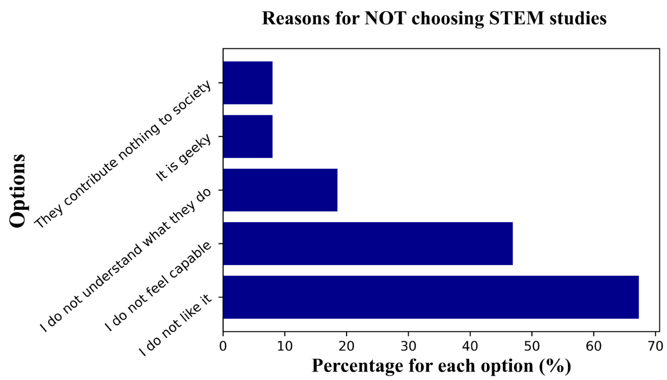

Fig. 2. Reasons for not choosing STEM studies.

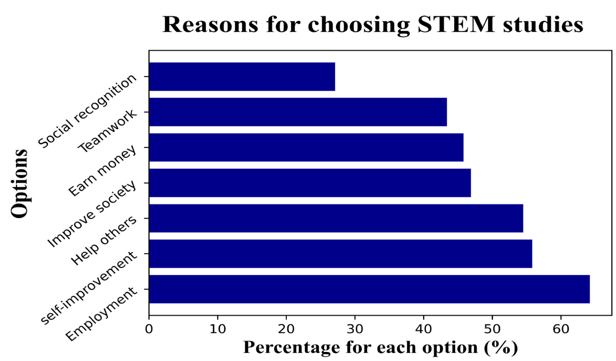

Fig. 3. Reasons for choosing STEM studies.

ciencia, *Nate gentile*, *Toro Tocho*, or *Dante GTX*, as famous referents.

Besides, Fig. 2 shows the most frequent reasons, ordered from highest to lowest, why students would not choose STEM studies: I do not like it (67.3%), I do not feel capable (46.9%), I do not understand what they do (18.5%), it is geeky (8%), and they contribute nothing to society (8%). In this way, Fig. 3 shows the reasons why students would choose STEM studies (from highest to lowest): employment opportunities (64.2%), self-improvement (55.8%), help others (54.5%), improve society (46.9%), earn money (45.8%), teamwork (43.4%), and social recognition (27.1%).

In addition to the above questions, the questionnaire asked them about the type of participation in STEM-related extracurricular activities. Specifically, for the question "I now frequently participate in STEM-related activities outside school hours," a mean of 3.55 was obtained ($\sigma = 2.675$). In the question "my parents/legal guardians currently encourage me to participate in STEM-related activities," an average of 6.60 is achieved ($\sigma = 2.942$). Finally, to the question "my teachers currently encourage me to participate in STEM-related activities," a mean of 4.53 was obtained ($\sigma = 2.781$).

TABLE II
CHI-SQUARE OF STUDENTS' VARIABLES

Questions	Chi-Square Value	Asymptotic significance
Family encourages me to STEM activities I'd like to pursue higher education	14.718	.000 <.050
Family encourages me to STEM activities I'd like to pursue STEM studies	66.010	.000 <.050
Teachers encourage me to STEM activities Do I like arts or STEM subjects?	7.194	.007 <.050
Teachers encourage me to STEM activities I'd like to pursue STEM studies	23.832	.000 <.050
I played with legos/uzzles/cars I'd like to pursue STEM studies	23.029	.000 <.050
I played with dolls Do I like arts or STEM subjects?	11.554	.001<.050
I do Sport Do I like arts or STEM subjects?	20.860	.000 <.050
I play videogames Do I like arts or STEM subjects?	19.931	.000 <.050

On the other hand, Table II describes the statistical results of all pair of variables in the student's questionnaire that had a significant result in Chi-square, i.e., obtained an asymptotic Chi-square significance of less than 0.05.

Besides, Tables III and IV show the statistical results of Lambda and Phi correlation for the variables of Table II. In this way, Table III reveals that there is an association between these pairs of variables, but, although this association exists, it is not possible to predict one variable by observing the other, since in all of them, the Lambda value is very low, regardless of which variable is the dependent variable or whether both variables are symmetrical. Regarding the Phi correlation value (in Tables III and IV), when it is positive, it means that if in one variable the result is positive (indicating yes), the same behavior will have the other variable. Thus, the Phi correlation values show that for all pairs of variables in Table III, this correlation strength is weak (as it is below 0.200), except the association of whether their parents/legal guardian encourage them to pursue STEM-related activities and whether they would like to study something STEM-related (0.207). In this case, there is a moderate strength between the two variables,

TABLE III
LAMBDA AND PHI CORRELATION OF FAMILY AND GUARDIAN ACTIONS AND STUDENT CHOICES

Questions	Lambda Value	Phi Corr. value
V1: Family encourages me to STEM activities V2: I'd like to pursue higher education	Sim.: .000 V1 dep.: .00 V2 dep.: .000	.132
V1: Family encourages me to STEM activities V2: I'd like to pursue STEM studies	Sim.: .033 V1 dep.: .063 V2 dep.: .000	.207
V1: Teachers encourage me to STEM activities V2: Do I like arts or STEM subjects?	Sim.: .000 V1: .000 dep.:.000 V2 dep.: .000	.068
V1: Teachers encourage me to STEM activities V2: I'd like to pursue STEM studies	Sim.: .0000 V1 dep: .002 V2 dep: .000	.128

Sim.= Symmetrical; dep.=dependent; V1: Variable 1; V2: Variable 2.

TABLE IV
LAMBDA AND PHI CORRELATIONS OF THEIR HOBBIES WHEN THEY WERE YOUNG AND STUDY PREFERENCES

Questions	Lambda Value	Phi Corr. value
V1: I played with legos/puzzles/cars V2: I'd like to pursue STEM studies	Sim.: 0.031 V1 dep.: .000 V2 dep.: .037	.122
V1: I played with dolls V2: Do I like arts or STEM subjects?	Sim.: .000 V1: .000 dep.:.000 V2 dep.: .000	.091
V1: I do Sports V2: Do I like arts or STEM subjects?	Sim.: .020 V1 dep: .037 V2 dep: .000	.116
V1: I play video games V2: Do I like arts or STEM subjects?	Sim: .057 V1 dep: .101 V2 dep: .000	.113

Sim.= Symmetrical; dep.=dependent; V1: Variable 1; V2: Variable 2.

which means that in many cases, those who attend STEM activities want to pursue STEM studies. For the rest of the pairs of variables, there is an association, albeit a weak one (value below 0.200), so there is a relationship between students whose parents encourage them to pursue STEM activities and that these same students to want to study at university (0.132). Finally, a weak association is also found between students who are encouraged by their teachers to pursue STEM activities and those who like Technology/Science (0.068) and want to continue studying something related to STEM disciplines (0.128). Furthermore, Table IV shows that correlation exists

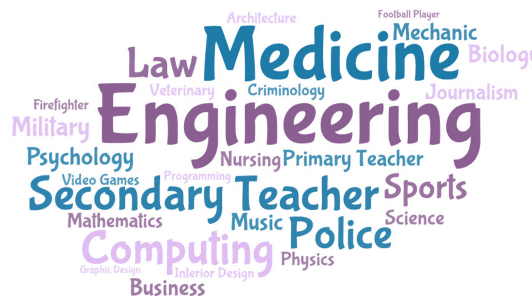

Fig. 4. Future careers enumerated by secondary school students.

for all pairs of variables, but is weak. Thus, there is a very diffuse association between what they played in their childhood and their current hobbies (sports, video games) or between their choice of their academic future and their preference for subjects.

Moreover, Tables III and IV also illustrate the Lambda results, where a value close to 0 means that there is no association and a value close to 1 means that there is a perfect association between the variables. In fact, Lambda gives three results depending on how the variables are considered: 1) symmetric; 2) asymmetric with the first variable as the dependent variable; or 3) asymmetric with the second variable as the dependent variable. In Table III, all Lambda results are close to 0, so there is no dependence. However, in Table IV, the results are close to 0 except for the last pair of variables, where it is observed that the result is higher. Therefore, playing video games (V1) is the dependent variable (0.101), which means that playing video games (as a hobby) is more predictive of liking STEM subjects (although only weakly as it is a very low result). In contrast, the variable they like arts or science-related subjects more (V2) (0.000) is not dependent, meaning that liking STEM subjects does not predict playing video games.

Finally, the possible studies/careers that they young people would like to pursue in the future were explored in more detail, by asking an open-ended question, for which the responses are shown in Fig. 4., where the most popular careers are Engineering, Secondary School Teacher, Medicine and Computer Science. Besides, according to the students' year, 49.35% of students in the 3rd CSE (14–15 years old) and 49.46% of students in the 4th CSE (15–16 years old) know what they want to do in their future, with very similar percentages.

B. Secondary School Teachers' Results

This section describes the results of the secondary school teachers' questionnaires, divided into STEM and non-STEM teachers. Table V shows the descriptive statistics for the affirmative responses of STEM and non-STEM teachers.

In general, the opinion on STEM studies is positive in both groups, with some differences in some questions. For example, the opinion on the importance of STEM studies because the today's/future society is digitalized is almost the same for non-STEM teachers (54.5%) and STEM teachers (52.3%). The same behavior is observed in the question concerning the importance of STEM disciplines for innovation, development,

TABLE V
DESCRIPTIVE STATISTICS BY FREQUENCIES

Questions	STEM teachers	Non-STEM teachers
STEM is important since society is digitalised	52.3%	54.5%
STEM helps improve quality of life and society	63.7%	53%
STEM promotes development/innovation/evolution	76.7%	77.3%
I guide towards STEM	79%	47.7%
I guide towards STEM by valuing job opportunities	8.7%	6.1%
I guide towards STEM working with universities	17.3%	12.1%
I guide towards STEM showing female referents	47%	21.5%
I guide towards STEM explaining STEM studies	58.7%	28.8%
STEM students should have a specific profile	78%	67.4%
STEM students should be logical minded	58.7%	48.5%
STEM students should have aptitude and skills	46%	49.2%
STEM students should be organized/methodical	29%	23.5%
STEM students should have interest	62.7%	48.5%
STEM students should be hard-working	43%	35.6%
STEM students should be curious	47.3%	30.3%

TABLE VI
CHI-SQUARE OF TEACHERS' QUESTIONS

Questions	Chi-square value	Asymptotic significance
I guide towards STEM studies I teach language and/or literature	17.252	.000 <.050
I guide towards STEM studies I teach geography/history	9.569	.002 <.050
I guide towards STEM studies I teach technology/programming	6.739	0.009 <.050
I guide towards STEM studies I teach foreign languages	17.094	.000 <.050
I guide towards STEM studies I teach maths/physics/chemistry	46.770	.000 <.050
I guide towards STEM studies I teach in 4th CSE	8.550	.003 <.050

and evolution, 77.3% for non-STEM teachers and 76.7% for STEM teachers. In contrast, the difference is greater on other issues, with 63.7% of STEM teachers believing that STEM studies are important for improving the quality of life and society, compared to only 53% of non-STEM teachers. The same behavior is observed when asked whether they guide students toward STEM studies, where a higher percentage of STEM teachers do so (79%) compared to non-STEM teachers (47.7%). Specifically, the actions taken by secondary school teachers to orient students toward STEM, from most to least frequent, are as follows: explaining what these studies consist of (58.7%), showing referents in these fields (47%), coordinating activities with the university (17.3%), and finally giving value to job opportunities (8.7%). Furthermore, 78% of STEM teachers believe that a specific profile is necessary to study STEM disciplines, compared to 67.4% of non-STEM teachers. In this respect, and in order of priority, teachers list the following skills/abilities: to be interested (62.7%), to be scientifically logical (58.7%), to have aptitudes/skills toward STEM (46%), to be curious (47.3%), to be hard working (43%), and to be organized/methodical (29%). Apart from the questions in Table V, a Likert-type question (0–10) was also included in the questionnaire, in which teachers were asked about the importance of STEM disciplines in the development of current and future society. The mean of the responses was relatively high for all teachers 9.03 ($\sigma = 1.160$), but the mean of the non-STEM teachers was 8.60 ($\sigma = 1.353$) while the result of the STEM teachers was higher, 9.22 ($\sigma = 1.008$).

On the other hand, Table VI shows the Chi-square results of the teacher's questionnaire. It can be observed that all pairs of variables have a significant Chi-square value, which means that they have obtained an asymptotic Chi-square significance of less than 0.05 and, therefore, there is an association between the variables.

Besides, Table VII describes the Lambda and Phi correlation results for the variables that appear in Table VI. This table reveals that there is an association between the subjects taught by teachers and orientation toward STEM studies, with teachers who teach STEM-related subjects being more likely to encourage students to choose STEM studies. However, one variable does not predict the appearance of the other in any pair of variables in Table VI, as Lambda has very low values. Indeed, values close to 0 mean that there is no prediction of one variable with respect to the other, and this is true for all three results covered by Lambda (symmetric variables, the first variable depends on the second, the second variable depends on the first). Regarding the strength of correlation (Phi value), a moderate correlation is observed in the orientation of students toward STEM studies and teachers who teach mathematics, physics, and chemistry (0.329), so this set of teachers tends to strongly guide students toward STEM studies. In this way, there is a moderate negative correlation between STEM orientation and language and literature teaching (−0.200), or foreign language teaching (−0.199), suggesting that these teachers do not guide students toward STEM studies. Interestingly, although there is an association between ICT, robotics, technology, programming, science literacy education, and STEM orientation, the strength of this association is weak (0.125). This result is explained by the fact that, in general, there are fewer teachers of these subjects in all secondary schools, with only 22.2% of teachers in our sample teaching one of these subjects. Finally, it is also important to note that there is an association between teachers who teach in the 4th CSE (15–16-years old) and those who

TABLE VII
LAMBDA AND PHI CORRELATION OF TEACHERS' QUESTIONS

Questions	Lambda value	Phi correlation value
V1: I guide towards STEM studies V2: I teach language and/or literature	Sim.: 0,033 V1 dep.: 0,045 V2 dep.: 0,000	-,200
V1: I guide towards STEM studies V2: I teach geography/ history	Sim.: ,012 V1 dep.: 0,015 V2 dep.: 0,000	,149
V1: I guide towards STEM studies V2: I teach technology/programming	Sim.: ,000 V1 dep.: ,000 V2 dep.: ,000	,125
V1: I guide towards STEM studies V2: I teach foreign languages	Sim.: ,027 V1 dep.: ,038 V2 dep.: ,000	-,199
V1: I guide towards STEM studies V2: I teach maths/physics/chemistry	Sim.: ,110 V1 dep.: ,000 V2 dep.: ,185	,329
V1: I guide towards STEM studies V2: I teach in 4th CSE	Sim.: ,060 V1 dep.: ,000 V2 dep.: ,099	,141

Sim.= Symmetrical; dep.=dependient; V1: Variable 1; V2: Variable 2.

guide students to STEM, and this correlation does not exist for teachers in other school years.

C. Joint Results of Students and Teachers in Secondary Schools

In this section, the responses of students and teachers are cross-referenced to analyze the differences in opinion and perception between the two. Fig. 5 shows the difference in the percentage of what students and teachers (STEM and non-STEM teachers combined) think about the skills needed to pursue STEM studies.

It can be observed that teachers' perceptions of the skills/abilities needed are higher than those of students. In fact, Fig. 5 depicts these skills/abilities from the highest to the lowest difference between the two perceptions (students and teachers), where the biggest difference appears in having a logical-scientific mindset (students = 6% versus teachers = 55.6%) and the smallest in being curious (students = 19.4%; teachers = 42.1%). In addition, in the students' section, it was stated that 62.2% of students think that their teachers encourage them to do STEM activities. However, the perception of teachers is higher than that of students, as on average, all teachers (STEM and non-STEM) feel that they guide their students by 67% (79% STEM and 47.7% non-STEM). If this analysis is done by school year, it can be found that 60.27% of the 3rd CSE students believe that their teachers

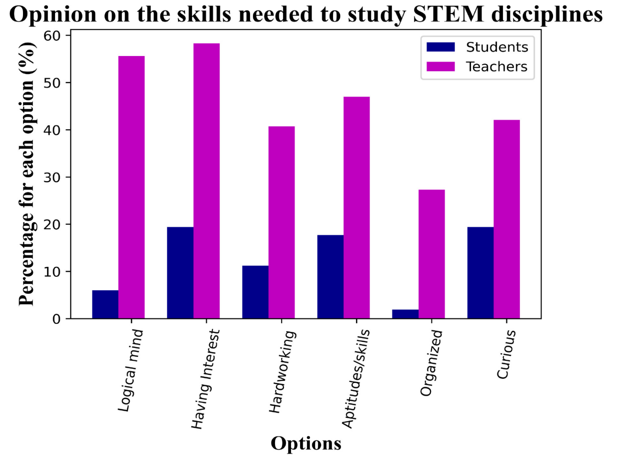

Fig. 5. Opinion on the skills needed to study STEM disciplines.

encourage them to do STEM-related activities, while 70.66% of teachers in the 3rd CSE say that they encourage students to do STEM activities. Another point to focus on is that 4th CSE, 64.89% of students perceive that their teachers encourage them to do STEM activities compared to 75.5% of their teachers (a significant difference). Therefore, it is observed that in general, many teachers in this school year (75.55%) carry out this type of actions, but students do not perceive it in the same way (64.89%). In addition, to the question "my teachers currently encourage me to participate in STEM-related activities" (0 not at all and 10 a lot), students report an average of 4.53, so this encouragement is medium–low. Finally, the disparity between students and teachers when it comes to perceiving STEM disciplines as a social good to improve the quality of life and society it is worth highlighting, as 63.7% of STEM teachers are aligned with this conception (compared to 53% of non-STEM teachers) while students' perception is lower, with 54.5% believing that technology helps people and only 46.9% believing that it has an impact on improving society.

IV. DISCUSSION

The discussion will be divided into two sections. The first section will talk about the first objective of this research, which is to investigate students' opinion and interest in STEM disciplines. The second section will describe the teachers' perception and the divergences found between teachers' and students' opinions.

A. Students' Opinion and Interest in STEM Studies

The first objective of understanding students' motivation for STEM studies has been addressed. This study has revealed that almost all students want to continue studying when they leave secondary school, and a high value would like their studies to be linked to technology or science, which is corroborated by Fig. 2, as the most named professions are Engineering, Secondary School Teacher, Medicine, and Computer Science. However, these data do not correspond to the decline in technological vocations, as in Spain, the latest official report of the Spanish university system has warned of a 7.9% drop in the number of young people enrolled in STEM disciplines, including Engineering and Computer Science [6], [11] and at the international level, the OECD indicates that STEM education is now the main concern of member countries [10]. Then, there is a point in secondary education where they lose motivation for these disciplines.

Therefore, and in line with the objective of finding out students' perception of STEM disciplines, one of the most important reasons given by students is that they do not see themselves as being able to complete higher education in these disciplines. This idea, together with the fact that some of the students do not understand what engineers/technologists do and a higher number do not like what they do, (also proven by other research studies [32], [33]) makes it essential to bring technology closer to the education system so that they feel empowered. In this regard, this study has found that there is a weak association between being a teacher of ICT, robotics, technology, programming and orientation toward STEM studies. Consequently, one of the main actions to be taken at the educational level would be to implement more subjects related to Robotics or Computer Science and that some of them would also be part of the educational curricula, since in the Spanish Curriculum, the subjects of Computer Science, Robotics, Technology, and Science Laboratory are optional and are taught in advanced courses, such as the 3rd and/or 4th CSE (14–16 years old) [34]. In fact, some countries already introduce subjects, such as Computer Robotics and Technology in their schools from basic education [35], [36]. Furthermore, not only should more subjects related to Robotics or Computer Science be integrated but teachers of these subjects should also guide students more toward STEM studies. Regarding improving the perception of their ability and interest in STEM subjects (another main objective of our research), students need to develop competences and have a flair for STEM subjects, as studies such as [37] "if students understand that they are competent at an activity and gain pleasure from the results, it is probable that they will develop and interest in that type of activity". Furthermore, other studies stress the importance of instilling a positive and inclusive image of science and technology, as the strong digitalization of society makes it coherent for education to promote science and technology to new sources of interest and entertainment, thus generating a new perspective more rooted in our daily lives. Then, in this context, it would be interesting to design competence-based teaching strategies that define the 2030 sustainable development goals (SDG), in particular SDG4 "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all," where ICT becomes relevant [38].

On the other hand, according to the objective of getting into students' motivation, the reasons given by students for choosing STEM studies in the future are diverse, but only half of them think that these careers are important for improving society and helping others, a relatively low percentage. It is, therefore, necessary to inculcate the more human side of technology and to show it as a social good for our society. This will motivate students more toward these disciplines, as studies indicate that helping others is one of the most globally valued characteristics for choosing a university degree [39]. In this sense, it is important, for example, to link ICTs to pandemic times such as COVID-19, as technology has positively impacted and helped social relations, education and health [40].

Regarding the objective related to students' motivation to study STEM, the results reveal that the main motivation among students to opt for STEM studies was employment opportunities, but only slightly more than half of them chose this option. This could lead one to think that it is crucial to orientate students by emphasizing their career opportunities, as nowadays, these disciplines are the most demanded in the labor market all over the world, according to studies such as that of the European Commission [4] which stated that during 2018, 57% of ICT companies reported difficulties in filling vacancies. Another reason why students would choose STEM-related studies is to earn a lot of money, a perception that is also observed in other studies where a high salary is an important reason for choosing a degree [41].

On the other hand, it is important to note that the perception of the abilities that a student studying STEM should have by teachers and students is very disparate (Fig. 5), so it is crucial to unify this perception, including educational actions that allow the development of this type of STEM competences. In this way, in countries such as Ireland, short courses are developed by teachers to suit the specific needs and interest of their students [9]. From the greatest to least difference in student and teacher perceptions, the abilities of being scientifically and logically minded, having an interest in STEM subjects, being hard-working/applied, having STEM skills, being organized/methodical and being curious should be encouraged. Some of these characteristics are part of the personality of each of them, and it is important to develop the personality to be successful and fulfilled in their future careers [42]. These differences in teachers' and students' perspectives on the skills needed to study STEM disciplines have not been explored in other studies. However, some research studies have shown that teachers and students have different perspectives on what attracts students [43]. Consequently, the results found in this study are new but not surprising. This study also confirms that there is an association between students who are encouraged by their teachers and parents/guardians to pursue STEM activities and those who would like to pursue STEM studies and like mathematics. These correlations are weak for teachers and moderate for parents, but nevertheless, several research studies have shown that participation in extracurricular activities increases positive perceptions of STEM studies (outreach or other activities based on the perspectives of new visions of science and scientists) [15], [17]. In fact, many studies claim that the impact of parents and teachers is very strong on young people's decisions [13]–[20], and this study has shown that, although there is an impact, there is not a very strong correlation, so increasing this involvement is of utmost importance. But in addition, it is also worth noting that the perception of a student is not high, as less than half, think that their parents/guardians motivate them to engage in such activities and just over half, think that their teachers motivate them. In fact, the response to the question "my teachers currently encourage me to participate in activities related to mathematics, technology, science and computer science," the students indicate an average of 4.5, i.e., they perceive this stimulation to engage in STEM-related activities as medium–low. This aspect should be reinforced, as many studies state that the impact of parents and teachers on young people is very relevant for their future [13]–[20]. To understand the reasons why they choose STEM studies, it is advisable to analyze their tastes and hobbies when they were children, as it has been found that there is a weak (not very decisive) association between what they play when they were young and the subjects they like when they grow up. Although the correlation is weak, it is important to consider as some research analyze the performance of toys that have the potential to develop STEM skills [44]. Moreover, other works propose the design and development of a smart toy (technological toys) for preschool children [45], [46].

In conclusion, it should be noted that some of the correlations presented are weak. However, some of them have been found to be important in other research, such as the importance of toys in fostering interest in STEM [44]–[46], or the involvement of families and teachers to encourage students toward STEM [13]–[16]. In fact, many studies affirm that the engagement of family and teachers plays an essential role in young people's future professional and personal choices [19], [20]. Therefore, these correlations should be reinforced by teachers and families to establish a positive perception of students toward STEM disciplines and increase technological vocations.

B. Teachers' Perception and Divergences Found Between Teachers' and Students' Opinions

The second objective of this research is to describe and analyze the actions taken by secondary teachers to encourage students to choose this type of studies, as well as to detect possible divergences in thinking between teachers and students or to observe whether they are aligned on the same perceptions.

It is interesting to understand how they perceive STEM disciplines. In this sense, about half of the teachers perceive STEM as important for the digitalization of society. However, this digitization is already very powerful; nowadays, the society is digitized and educating future generations in this concept and making them aware of this fact is fundamental for a good use and management of technology as a social good. Indeed, COVID-19 has meant that digitization has increased exponentially and that an education and training system suited to the digital age is essential [8]. In addition, the fact that only slightly more than half of teachers believe that technology is important for improving the quality of life and society, makes it necessary to align teachers with these ideas by reinforcing their training and providing them with resources so that they can adequately transmit the message to future generations. In this sense, some of the countries with the best results in Mathematics and Science competences in the PISA reports, such as Estonia, Finland, or Singapore, devote enormous efforts to the continuous training of their teachers in STEM disciplines [12], so Spain should look to the actions of these countries to improve their results.

For the second objective of our research work, concerning the understanding of the actions carried out by the teachers, it is interesting to note that there is a weak association between being a teacher of the 4th CSE (15–16 years old) and STEM orientation, while there is no such association in other academic years. Although this association is weak, it is important to highlight it, because it is known that children develop their vocational preferences at an early age [47], so these actions should be at an earlier age in secondary school.

In addition, many teachers steer students toward STEM studies, but students perceive this as a lower percentage, even more so in lower grades, such as the 3rd and 4th CSE, when they choose their academic future. It is also important to note the big difference between STEM and non-STEM teachers when it comes to encouraging students to pursue STEM studies. In this way, teachers of mathematics, physics, chemistry, biology, and/or geology are the ones who mostly encourage the study of STEM, in contrast to teachers of language and/or literature and languages, who hardly encourage STEM studies. These data show the need for teachers to reinforce their training to encourage STEM vocations, especially non-STEM teachers, for which it is important to promote the use of active methodologies [48] such as problem-based learning (PBL) or real-life challenge-based projects using technology [49], [50].

On the other hand, although the percentage of STEM teachers guiding students toward STEM studies is relatively high, there are no major achievements as the number of STEM vocations is currently decreasing. In the case of Spain, around 8000 students are graduating in university computer science degrees (2018–2019), which is significantly too few for the more than 15 000 companies that, according to EU estimates, hire or intend to hire ICT specialists [6]. Therefore, it is important to analyze the guidance actions that are carried out and whether their impact is adequate. In this sense, teachers' actions to encourage students toward STEM disciplines are summarized from highest to lowest as: showing role models, coordinating activities with the university and giving value to job opportunities, although in relatively low percentages (especially, for the last two). In particular, a very small number of teachers carry out activities coordinated with the University, which would be essential to promote, given that contact with the university can have a very positive impact, as some studies have shown [15]–[17]. In addition, recent research studies suggest [21] that existing stereotypes and prejudices about STEM jobs are misguided and are driving students away, so it is important to raise awareness among young people of the range of career opportunities that STEM studies open up [12].

Another important objective is to find commonalities and divergences between students' and teachers' opinions, thus studying students' and teachers' opinions on role models. Less than half of teachers show referents in these fields and a high percentage of students affirms that they do not know any famous referent, a fact that is corroborated in Fig. 1, where they hardly identify any referents in the technological field. This fact implies that teachers need to work on showing more recent models that connect with young people or modify the way in which they show these referents so that they are understood by students, as there is a great lack of female role models. In fact, it is important to note that some students nominated science youtubers, and some studies indicate their positive impact on secondary school students in learning processes and the acquisition of STEM competencies [51]. Other studies reflect the value of YouTube and channels dedicated to the dissemination of knowledge as an emerging informal medium for the popularization of science among youngest [52].

V. CONCLUSION

This research study has focused on obtaining an overview of students' perceptions of STEM vocations, as well as teachers' actions to increase STEM vocations, and finally the relationship between teachers' and students' opinion. For this purpose, a mixed methodology has been followed, using two questionnaires, one for 1562 students and the other for 432 teachers. On the one hand, the findings related to the first objective, which is to deepen the students' opinion and interest in STEM disciplines, will be described. The results suggested that students are not highly motivated to pursue Engineering/Technology related studies. It is, therefore, necessary to showcase modern STEM role models, as well as to promote nonformal learning and technological vocations outside the classroom, using complementary channels, such as science youtubers or science channels. Another fact is that many students do not understand the work of engineers/technologists and a large percentage do not like it, so it is necessary to introduce technology into the education system, showing that STEM studies are useful to help people and to improve society, as few students thought they could be useful in these fields. Regarding the conclusions focused on the second objective, related to the perception of teachers and the divergences found between the opinions of teachers and students, it can be said first that there is a strong divergence that should be minimized between teachers' and students' perceptions of abilities and skills related to STEM. Another key issue is that teachers and parents/guardians should be more aware of the need to promote STEM among young people, as this study has also confirmed that teachers guide more in 4th CSE toward STEM studies (15–16 years old) and do not do so to the same extent in other educational levels. This study also revealed that science and technology must be made more positively visible by linking it to our daily lives and its fundamental role as a social good and training. In this way, a stronger synergy should be created between university and secondary education to promote technological vocations among young people, fostering research and development of skills related to the world of work, as well as training teachers in the importance of STEM disciplines for the future. Finally, it has been concluded that there are weakly correlated variables (toys in childhood, teachers who encourage STEM activities...). However, these variables need to be considered, as many of them are mentioned in other studies as key elements, and their correlations need to be strengthened in the future to effectively foster future technological vocations.

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