STEM Career Aspirations Among Portuguese Secondary School Students

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***Abstract*— The main objective of this study was to investigate the Science, Technology, Engineering and Mathematics (STEM) career interests of secondary school students in Portugal. Data were collected from a sample of 190 twelfth grade students, consisting of 106 females and 84 males, using the STEM Career Interest Survey. The results showed that interest in careers in engineering tended to be lower than interest in mathematics, science, and technology among secondary school students. The study also found a gender gap in students' interest in science, engineering, and technology careers. Female students were less interested in engineering and technology-related careers than their male counterparts, but more interested in science-related careers. These findings can inform education policy makers, curriculum developers, teachers, and researchers about the importance of STEM education in nurturing and cultivating students' interest in STEM fields.**

Keywords—career, interest, secondary students, STEM education

I. Introduction

Nowadays, an increasing number of occupations require a strong foundation in science, technology, engineering, and mathematics (STEM). Making informed decisions, both as individuals and as a society, increasingly relies on having a basic understanding of STEM. This encompasses understanding medical diagnoses, evaluating competing claims related to the environment, and effectively utilizing a wide range of computer-based applications in our daily activities [1]. The fourth industrial revolution brought enormous advances, such as artificial intelligence, augmented reality, quantum computing, big data, and analytics, but also numerous challenges. So, there is a pressing need to prepare students for the ever-evolving technological landscape of the fourth industrial revolution. This entails equipping students with a mastery of knowledge and skills in STEM-related fields, as well as fostering their interest in pursuing careers related to STEM [2].

However, there has been a noticeable decline in the enrolment of students in STEM fields of study in tertiary Education, especially in information and communication technologies (ICT); and engineering, manufacturing, and construction [3]. Recognizing this decrease as one of the most significant challenges for the future of Europe, there is a need to address the shortage of skilled individuals in these areas [4]. Moreover, although women constitute most of undergraduate students, on average across OECD countries, they are still under-represented in STEM. The shortage of STEM workers and the underrepresentation of both ethnic minorities and women have been extensively documented, as reported by UNESCO [5]. Even though gender gap was overcome in natural sciences, mathematics and statistics, other STEM fields remained critical, such as engineering and ICT [3, 6].

According to data from the International Labor Organization (ILO) [7], women constitute 38% of individuals holding STEM degrees, and they hold approximately 44% of the jobs in STEM fields, despite the fact that such jobs make up only 12% of total employment. The striking 24 percentage point gender gap in the number of STEM graduates in Portugal highlights the need for substantial progress.

Over the last decade, the Portuguese government and education policymakers have been working to strengthen STEM education by focusing on two key components: improving STEM curricula and teaching methods to make them both effective and engaging and promoting teacher education and professional development in STEM [8]. The national strategies have been aimed at 1) increasing the proficiency of all students and teachers in STEM, in order to improve the ability of students to address increasingly complex problems; and 2) increasing the number of students pursuing STEM careers and advanced studies by raising awareness of the importance of STEM and by stimulating interest in STEM subjects [8]. However, according to the General Directorate of Statistics for Education and Science data, in Portugal between 2016 and 2021, the post-secondary study paths chosen by students are social sciences, commerce and law, even though more than 50% of students choose science and technology at the end of the ninth grade [9]. In this context, the *Impulso Adultos* and *Impulso Jovens STEAM* programs, part of the ongoing Recovery and Resilience Plan (PRR 2021-2026) [10] were launched in Portugal, aiming to graduate over 18, 000 students through higher education in STEAM domains by the end of 2025, as compared to the total number of graduates in 2020. Additionally, they aim to qualify approximately 100,000 adults by the end of 2025, with the goal of increasing the percentage of higher education graduates among the population aged 30-34 to 50% by 2030, up from around 37% in 2020. This program also seeks to promote greater participation of female students in STEAM disciplines at the higher education level.

In this sense, understanding the factors that influence STEM subject choice is vital to encourage greater STEM participation and increase the number of STEM graduates and the prevalence of STEM skills in the labour force [11].

However, there is a notable scarcity of research examining the underlying causes of the declining interest in STEM among students, particularly when they are about to enter the tertiary level [12]. To fill this gap, it is imperative to develop a deeper comprehension of young individuals' perceptions regarding STEM careers. Consequently, the primary objective of this study is to offer an overview of the Portuguese context by investigating the level of interest in STEM careers among upper secondary students in Portugal, following educational reforms aimed at strengthening STEM education. Specifically, the study will focus on addressing the following research questions (RQ):

RQ1) What is the level of interest among secondary-school students in STEM careers?

RQ2) Do secondary-school students' interest in STEM careers differ across STEM fields?

RQ3) Does the interest in STEM careers among secondary-school students differ in terms of gender?

II. INTEREST IN STEM CAREERS

The "term interest describes the mind-set characterised by a need to give selective attention to something that is significant to a person such as an activity, goal or subject" (p. 69, [13]). Interest is one of the strongest predictors of STEM enrolment behaviour [13] and career orientation [14]. Furthermore, Gender represents a potential influential factor on students' STEM interests and career aspirations, with existing research indicating a tendency for male students to show more inclination towards STEM fields [15, 16]. On the other hand, female students often display a stronger interest in arts and education fields [15, 16]. This gender pattern is particularly noticeable in engineering, which tends to attract more male students [16], whereas females lean more towards medical/health and biology careers [17, 18].

In order to study the factors that influence interest in STEM careers, several instruments have been tested. Tyler-Wood et al. [19] developed two instruments, the STEM semantic survey and the STEM career questionnaire, which were validated using a sample encompassing junior high school students through to adults. The findings of their research demonstrate the efficacy of these instruments in gauging students' interest in STEM. However, it is important to note that while these surveys have been successful in measuring interest levels, they do not explicitly elucidate the factors that influence students' interest in pursuing STEM careers.

STEM Career Interest Survey (STEM-CIS) was developed by Kier et al. [20] to assess students' interest in STEM careers. The instrument was based on key aspects of the social cognitive career theory [21] (e.g., self-efficacy, outcome expectations, personal inputs, and contextual supports and barriers). STEM-CIS was used to gather data on the validity and interest of students residing in rural Southeastern America towards STEM careers. Additionally, research has been conducted in Turkey to test the STEM-CIS instrument validity and reliability of the STEM-CIS instrument using the confirmatory factor analysis (CFA) technique [22]. Several studies used this instrument to determine students' interest in STEM. Among them, Dönmez and Idin [23] applied it to 534 middle school students. The results indicate that middle school students' STEM career interests are influenced by factors such as self-efficacy, personal goals, outcome expectations, interest in science, contextual support, and individual inputs. The study also revealed that STEM career interest is not dependent on gender, but it does vary according to the students' grade level. Also, in Turkey, another study [24] applied this instrument to a larger sample (892 students) and determined that the interest of male students in STEM careers is more positive compared to the female students. Another study conducted by Ünlü and Dökme [25] utilized the STEM-CIS instrument to examine a sample of comparable size from various regions of the country. The findings indicated that students' interest in STEM careers varied significantly based on their gender, geographical location, and grade levels. However, no significant differences were observed in relation to their parents' educational status or family income levels.

A pivotal aspect involves identifying the factors that foster interest in STEM careers among high school students who are in the crucial stage of exploring their career interest [26, 27], as several studies focused on this particular period. For instance, Sadler et al. [28] conducted a retrospective cohort study to exemplify how the interests in STEM career of high school students change. The study findings by Robnett and Leaper [26] showed a gender difference in STEM-related career interest in high school and suggested that social identities and self-concepts play a substantial role in shaping the STEM career choices of young individuals. Ketenci et al [28] and Myint and Robnett [29] also reported gender differences choice on STEM career attainment. Kızılay and Yamak [30] employed the Career Interest Scale for STEM Fields [31] as data collection tool and revealed a gender disparity among high school students, in favour of male students.

III. METHODOLOGY

A. Design

The present study employed a descriptive survey model to investigate the STEM Career Interest of secondary school students in Portugal. Data were gathered using the STEM Career Interest Survey (STEM-CIS) [20].

B. Participants

A non-probabilistic (convenience) sampling approach was utilized to select participants from two 12th-grade classes attending the Chemistry subject during the academic year 2022/2023. The initial sample size consisted of 212 students, but after exclusions, the final sample included 190 students, representing 89.6% of the students. In terms of gender distribution, 44.2% (84 students) were male, while 55.8% (106 students) were female, with an average age of 17.2 years.

C. Instruments

The questionnaire, adapted for use in Portuguese, comprised four discipline-specific subscales: Science (S), Technology (T), Engineering (E), and Mathematics (M). Each subscale consisted of 10 items, resulting in a total of 40 questions answered on a 5-point Likert scale, ranging from 'strongly disagree' to 'strongly agree'.

D. Data analysis

The questionnaire results were analysed using Jamovi 2.2.5.0 software. To analyse the questionnaire's psychometric characteristics, an exploratory factor analysis was carried out using minimum residuals extraction. Reliability was examined by calculating *Cronbach's* alpha (α) in the

questionnaire and all subscales. To address RQ1 and RQ2, descriptive statistics were examined, and the average score was obtained for each subscale of the questionnaire. The normality assumption of the data was checked using the *Shapiro-Wilk* test. It was found that some subscales did not follow a normal distribution ($p \leq 0.05$), as a result, non-parametric tests (*Friedman* test and pairwise comparisons through *Durbin-Conover* test) were employed to determine differences in students' interests across the STEM fields. Regarding RQ3, to assess the effect of gender on STEM career interest within specific STEM fields, *independent samples t-tests* were used if the assumptions of normality (*Shapiro-Wilk* test) and equal variances (*Levene's test*) were met. Otherwise, the *Mann-Whitney U* test was employed. The effect size was calculated using Cohen's *d* value. The magnitude of the effect size was assessed independently of the d sign and can take on any value. Successively, the *d* values of 0.2, 0.5, and 0.8 are evaluated as representing small, medium, and large effects, respectively [32]. The statistical analyses used a confidence level of 95% ($p < 0.05$).

IV. RESULTS AND DISCUSSION

To assess the levels of STEM career interest among secondary-school students (RQ1), a descriptive analysis was performed. Table I displays the minimum (Min) and maximum scores (Max), along with the mean (M) and standard deviation (SD), obtained by students on the discipline-specific subscales of the STEM-CIS.

TABLE I. DESCRIPTIVE ANALYSIS OF THE SECONDARY-SCHOOL STUDENTS' STEM CAREER INTEREST

						Shapiro-Wilk	
Subscale	***N***	***M***	***SD***	***Min***	***Max***	***W***	***p***
Science	190	3.61	0.704	1.73	5.00	0.983	0.021
Mathematics	190	3.63	0.674	1.64	5.00	0.988	0.123
Technology	190	3.66	0.665	1.67	5.00	0.981	0.011
Engineering	189	3.31	0.810	1.00	5.00	0.976	0.002

The career interest of the secondary-school students was observed to vary across different areas, with technology, mathematics, science, and engineering ranking from the highest to the lowest in terms of preference.

Regarding RQ2, the *Friedman* test showed that the secondary-school students' STEM career interests displayed statistically significant differences in terms of STEM fields ($X^2_{(3)} = 37.3$; $p < 0.001$). To identify the specific STEM fields associated with this observed difference, a Post hoc *Durbin-Conover* test was performed. The results of this analysis are presented in Table II.

TABLE II. RESULTS OF THE PAIRWISE COMPARISONS (DURBIN-CONOVER TEST)

Subscale	***Subscale***	***Statistic***	***p***
Science	Mathematics	0.062	0.950
	Technology	1.471	0.142
	Engineering	4.475	< 0.001*
Mathematics	Technology	1.533	0.126
	Engineering	4.413	< 0.001*
Technology	Engineering	5.947	<0.001*

*p. <0.05

Based on the findings presented in Table II, no significant difference was observed between the career interest in science and the career interest in mathematics and technology among secondary-school students. However, a significant difference was detected in the interest levels of engineering fields compared to mathematics, technology, and science, favouring the latter areas.

In other studies that utilized the STEM-CIS to assess students' career interests across various STEM fields, it was found that interest in engineering careers tended to be lower when compared to mathematics, science, and technology [24, 33].This result is not surprising, as students typically receive limited (or none) education related to engineering in school [24], and a significant number of them are not familiar with careers in this field, resulting in an unclear vision about the field of engineering [34]. Furthermore, negative stereotypes associated with engineers, such as the perception that they are nerds or that they must be geniuses, contribute to this lack of knowledge [24, 33]. Consequently, pre-university students may face challenges in making informed decisions when considering engineering as a potential career path [34].

In order to attract students to STEM careers, such as engineering, there is a need to build better understanding of young people's perceptions of STEM as well as to develop appropriate programs, activities or interventions that will positively influence their perceptions of STEM [35, 36]. Research have demonstrated that effective teaching practices within and beyond the classroom, as well as after-school activities, play a significant role in shaping perceptions of STEM careers [35, 37]. Consequently, it is crucial to prioritize the enhancement of professional development opportunities for teachers, considering their influential role in shaping students' perceptions. Providing teachers with strategies to facilitate student learning of engineering concepts, such as the engineering design process, has the potential to enhance their ability to integrate engineering principles into the classroom, and may positively impact students' interest and engagement in engineering-related fields [34].

To evaluated if the interest in STEM careers among secondary-school students differ in terms of gender (RQ3), *independent sample t* test or *Mann-Whitney U* test were used, and its results are presenting in Table III. The assumptions of normality (*Sharipo-Wilk* test), and equal variances (*Levene's* test) were checked to all subscales. Thus, the science subscale presented normal distribution [$W_{(188)} = 0.987$; $p = 0.068$] and equal variances [$F_{(1,188)} = 0.927$; $p = 0.337$]. Similarly, the mathematics subscale presented a normal distribution [$W_{(188)} = 0.989$; $p = 0.158$] and equal variances [$F_{(1,188)} = 0.126$; $p = 0.723$]. However, the technology subscale violated the assumption of normality [$W_{(188)} = 0.983$; $p = 0.023$] and showed homogeneity of variances [$F_{(1,188)} = 0.659$; $p = 0.418$]. Lastly, engineering subscale violated the assumption of normality [$W_{(188)} = 0.972$; $p < 0.001$] and the assumption of equal variances [$F(1,188) = 6.12$; $p = 0.014$].

TABLE III. DESCRIPTIVE ANALYSIS OF THE SECONDARY-SCHOOL STUDENTS' STEM CAREER INTEREST

Subscale	*Gender*	*N*	*M*	*SD*	*df*	*t*	*U*	*p*	*Cohen' s d*
S	F	106	3.72	0.66	188	2.51	----	0.013 *	0.37
	M	84	3.47	0.74					
M	F	106	3.64	0.68		0.26	----	0.796	------
	M	84	3.62	0.67					
T	F	10	3.56	0.65		---	3505	0.012 *	-0.34
	M	84	3.78	0.67					
E	F	106	3.22	0.72		---	3465	0.012 *	0.21 ª
	M	84	3.43	0.89					

Note: M= Mean; SD= Standard Deviation; t = independent sample t test; U= Mann-Whitney; p.= level of significance; *p. <0.05; ª Rank Biserial correlation.

According to Table III, a statistically significant difference, in terms of gender, was observed in students' career interest across the fields of science [$t_{(188)} = 2.51$; $p = 0.013$], technology [$U_{(188)} = 3505$; $p = 0.012$] and engineering [$U_{(188)} = 3465$; $p = 0.012$]. The effect sizes indicated that the gender effect on career interest in science, technology, and engineering fields was of a small magnitude.

This study revealed that female students had less interest in the careers related to engineering and technology than male students. By other side, female students had more interest in the careers related to science than male students. These findings are consistent with other research studies that have identified a gendered pattern in STEM fields, indicating that females tend to prefer careers in medical/health and biology, while males are more inclined towards engineering and computer sciences [3, 6, 16, 17, 18].

These differences can be attributed to traditional perceptions of gender roles and identities as well as the cultural values sometimes associated with specific professions [26]. Many female students do not know much about the engineering field, and many are thought to be more interested in leading their careers on the way to serve for the society [38]. Concerns about not fitting the stereotypical image of a STEM professional and doubts regarding their own abilities to succeed in STEM fields contribute to women's apprehension [39]. Moreover, numerous female students perceive engineering as "difficult," "boring," and predominantly male-oriented, often associating it solely with construction work [40]. Consequently, these outdated and invalid stereotypes have a detrimental impact on females' interest and attitudes towards STEM fields and careers [41].

Other studies have indicated that female students tend to exhibit lower interest in engineering compared to their male counterparts, potentially due to the lack of sufficient role models who have pursued STEM careers [42]. The decision of a female student to pursue a STEM career can be influenced by the presence of female role models, such as teachers or relatives [25, 41, 42, 43]. According to Dubetz and Wilson [43], secondary school female students who participate in summer camp activities organized by universities and guided by female role models in science and mathematics exhibit a higher level of interest in STEM careers in higher education. Additionally, Ünlü and Dökme [25] stated that individuals who have family members with STEM careers have an increased likelihood of choosing STEM fields.

V. CONCLUSIONS

The main objective of this study was to explore the level of interest in STEM careers among upper secondary students in Portugal, using the STEM Career Interest Survey. However, there are some limitations. The low number of participants is a limitation that may affect the generalisability of the results. Quantitative research often focuses on identifying patterns and relationships but may not capture the nuances and complexities of individuals' experiences or perspectives. Therefore, the study may not have provided a complete understanding of the issues surrounding STEM career choice.

Despite these limitations, the results of the study provided an overview of the interest of Portuguese secondary school students in STEM careers, following educational reforms aimed at strengthening STEM education. The results showed a relatively low interest in engineering careers compared to mathematics, science, and technology among secondary school students. To attract students to STEM careers, especially engineering, it is imperative to develop effective interventions, aligned with ongoing initiatives, aimed at influencing their perceptions of STEM fields.

The results of the study also highlighted a gender gap in students' interest in science, engineering, and technology-related careers. To rectify this situation and bridge the gender gap, it is important to introduce STEM education initiatives within educational institutions and to extend them to other settings. To meet this need, it is therefore essential to prioritise the improvement of professional development opportunities for teachers, given their influential role in shaping students' perceptions.

The identified findings have valuable implications for various stakeholders in the education sector, including education policy makers, curriculum developers and teachers. These findings underline the importance of STEM education in fostering and nurturing students' interest in STEM fields, but Portugal can do more and better. As such, they can serve as an important guide for education policy makers in designing policies that promote and prioritise STEM education. Curriculum developers can use these findings to design and improve STEM curricula, ensuring that they are aligned with students' interests and address the gender gap in STEM career preferences. Finally, teachers can benefit from this knowledge by incorporating engaging STEM activities and promoting female role models to inspire and encourage students, particularly female students, to pursue STEM subjects.

Future research should consider conducting qualitative studies to obtain more detailed results. In addition, researchers could focus on variables other than gender, such as where participants live, what grade they are in, and what level of education their parents have. By examining these additional variables, researchers can explore how different factors influence the decision-making process regarding STEM careers.

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