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The Impact of STEM Activities on the Interest and Aspirations in STEM Careers of 12th-Grade Portuguese Students in Science and Technology Curriculum

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ABSTRACT

Social cognitive career theory posits that career interests and decisions are influenced by individual, contextual, and behavioural factors. This research aims to assess the impact of Science, Technology, Engineering, and Mathematics (STEM) activities on students' interest and aspirations in STEM careers. Additionally, the study aims to explore the critical factors that might shape students' STEM career aspirations. The research used a quantitative approach, with pre- and post-test measures for a cohort of 191 Portuguese secondary school students, using the Career Interest Questionnaire (CIQ). The results showed that STEM activities increased the intentions of non-STEM students to pursue educational opportunities that could potentially lead to a scientific career. Males, in contrast to females, showed a significant increase in their intentions to pursue educational opportunities that could eventually lead to a scientific career. Furthermore, gender along with the personal goals and positive perceptions of STEM careers were identified as significant predictors of the students' STEM career aspirations. These results highlight the critical role of STEM education in developing and sustaining students' interest in STEM careers. Integrated STEM activities should be developed in the early stages of education to enhance students' confidence in STEM and mitigate the gender gap.

Keywords: career, integrated STEM activities, interest, secondary students

INTRODUCTION

In response to the shortages in Science, Technology, Engineering, and Mathematics (STEM) skills and competencies, numerous European countries have implemented significant systemic changes in STEM education throughout all educational stages, particularly in secondary school education, in the past two decades (Boiko et al., 2019). In Portugal, there has also been an increase in STEM education initiatives, both in formal and informal learning settings, with the aim of promoting STEM integration, fostering context-based STEM learning, and developing students' interest in studies and careers in these areas (Baptista et al., 2023). Despite those efforts, a decreasing interest in pursuing STEM careers is a cause for concern, especially during a period when society is increasingly dependent on intricate technologies and scientific advancements (Kaleva et al., 2023). This emphasizes the significance of involving demographics that have been underrepresented in STEM fields such as women (UNESCO, 2017; Wang and Degol, 2017) and students from the low socio-economic family backgrounds (Chachashvili-Bolotin et al., 2016). Therefore, we need deeper insights into the factors influencing students' decisions to pursue a STEM career (Boiko et al., 2019; Christensen et al., 2015). Guzey et al. (2016) added another aspect that needs further development in literature that is the relationship between gender and interest in STEM after participation in a STEM program.

To examine the factors that influence students to pursue degrees and careers in STEM-related fields, many recent studies based on the Social Cognitive Career Theory (SCCT) (Lent et al., 1994) have focused on self-efficacy (e.g., Kaleva et al., 2023; Mohtar et al., 2019), and less emphasis has been placed on environmental/contextual factors (Halim et al., 2021; Woo et al., 2023). Therefore, in addition to the main constructs, other factors such as family, teachers, peers and school-related factors should be considered as sub-constructs (Bahar and Adiguzel, 2016).

This article describes data collected within the context of students' participation in STEM activities using the Career Interest Questionnaire (CIQ). The CIQ was constructed as a brief, easy-to-use instrument for elementary through high school aged students that measures interest in careers in broad science areas (Tyler-Wood et al., 2010). It is a useful tool for providing empirical evidence to document the impact of technology-enhanced science education programs (Peterman et al., 2016). The subscales of the CIQ document students' perceptions of being in an environment that is supportive of science careers (four items, referred to as *Support*), students' intent to pursue educational opportunities that would lead to a science career (five items, referred to as *Intent*), and the perceived importance of science careers overall (three items, referred to as *Importance*) (Peterman et al., 2016; Christensen and Knezek, 2017). Furthermore, according to Peterman et al. (2016) this instrument can be useful for distinguishing the interests of boys and girls. The aim of the research was to determine the effect of STEM activities on the interest and aspirations in STEM careers of twelfth grade students. This study attempts to answer the following research questions (RQ):

RQ1: Were there significant short-term changes in students' interest in STEM careers after participating in the integrated STEM activities?

RQ2: To what extent did participation in integrated STEM activities influence gender-based differences in interest toward STEM careers among secondary school students?

RQ3: Did Portuguese secondary school students' career aspirations align with their interests in STEM careers?

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

The theoretical framework of this study is SCCT which was developed by Lent et al. (1994) based on Bandura's (1986) social cognitive theory. SCCT was chosen for this study because it specifically focuses on career development as a process that students go through in developing their interests, choices, and behaviours, together with the impact of contextual and environmental influences of barriers and supports (Lent et al., 1994; Woo et al., 2023). Moreover, SCCT provides a relevant theoretical view of STEM career interest and choice and has been applied in several STEM-related studies (Bahar and Adiguzel, 2016; Chachashvili-Bolotin et al., 2016; Ciftci et al., 2020; Mohtar et al., 2019).

According to the SCCT, career interests, choices, and educational and occupational success are influenced by individual, contextual, and behavioral factors (Lent et al., 1996). More specifically, self-efficacy, outcome expectations and goal orientation are major constructs that affect career preferences (Lent et al., 1994; Bahar and Adiguzel, 2016). In this sense, people develop goals to pursue academic and career-relevant activities that are consistent with their interests, as well as with their self-efficacy and outcome expectations (Sheu et al., 2010). Self-efficacy refers to an individual's belief in his or her ability to perform tasks and influence events that affect his or her life (Bandura, 1986). In addition, self-efficacy promotes favourable outcome expectations – beliefs about the successful consequences of certain actions – (Chachashvili-Bolotin et al., 2016) and it is an important factor influencing students' careers interests (Tang et al., 2008). Therefore, students tend to develop interests in academic subjects at which they possess strong self-efficacy and consequently positive outcome expectations (Chachashvili-Bolotin et al., 2016). For instance, STEM career-related interests, along with high self-efficacy and positive outcome expectations regarding science pursuits, are likely to promote the choice of science-relevant activities in school and work contexts (Kaleva et al., 2023).

In addition to the major constructs (i.e., self-efficacy, outcome expectation and goals), SCCT also considers other factors, to explain how individuals make career-related decisions, namely personal inputs, contextual factors, and interests (Lent et al., 1994). Personal inputs are immutable personal traits, such as gender, race, and ethnicity that contribute to one's feelings of high or low self-efficacy. Contextual supports and barriers are external factors or individuals such as people (e.g., family, teachers, and peers) and school-related factors (e.g., learning experiences, courses, competitions/fairs) that either facilitate or hinder high self-efficacy or the setting of academic or career goals.

Previous research has identified numerous significant factors that impact students' interest in pursuing STEM careers, including their own self-motivation, the influence of parents or family members, the availability of high-quality science and mathematics courses at school, and the presence of an inspiring teacher (Halim et al., 2018; Christensen et al., 2015). In guiding career development, SCCT recognises that contextual factors, such as inside-of-school learning experiences and family influences, have the power to influence STEM career interests and either facilitate or limit individuals' unique choices (Lent et al., 1994; Halim et al., 2021; Woo et al., 2023).

For learning experiences inside-of-school, research suggest that integrated STEM instruction may support increased interest among students (Honey et al., 2014). Integrated STEM approaches often provide students with interesting and challenging problems; therefore, they may become more interested in learning about STEM fields. Additionally, these approaches provide students with career prospects, which may increase their interest in pursuing a STEM career (Batdi et al., 2019). For example, Guzey et al. (2016) found that students who were taught using an engineering design-based science programme showed a greater interest in STEM after the instructional phase than before the programme was implemented. Chachashvili-Bolotin et al. (2016) conducted a study on the factors that influence students' interest in pursuing STEM fields in tertiary education. Their results showed that STEM learning experiences are positively associated with students' interest in pursuing STEM fields in tertiary education, as opposed to non-STEM fields. Thus, it can be argued that students' intention to pursue STEM fields is influenced by direct classroom instruction that provides students with satisfying learning experiences that can inspire or prepare students for a STEM career (Woo et al., 2023; Chachashvili-Bolotin et al., 2016).

Parental and familial support (social influences) has been posited as a pivotal influence on students' interest in STEM fields (Archer et al., 2012). Bahar and Adiguzel (2016) conducted a comprehensive investigation into the determinants of STEM-related degree and career interests among American and Turkish students. Their research uncovered that self-efficacy emerged as a significant predictor for American students' interest in STEM, while the influence of parents was particularly pronounced among Turkish students. This finding aligns with the study by Christensen et al. (2015), which highlighted the substantial role of the family in shaping students' inclinations towards STEM careers. Parents and families, as the nearest and most immediate sources of inspiration for students, hold the capacity to shape students' perceptions of STEM careers and their self-efficacy (Mohtar et al., 2019). This influence may manifest indirectly, through the provision of support, encouragement, and role modelling, or directly, through the sharing of knowledge and career guidance (Plasman et al., 2021).

Another influencing factor reported in previous studies is students' perceptions of a STEM career. Franz-Odendaal et al. (2016) found that factors influencing students' perceptions of their interest in STEM careers include their own perceptions of STEM careers, classroom culture, and self-efficacy in STEM-related fields. Similarly, the findings of Mohtar et al. (2019) showed that students' interest in life science-based careers is influenced by their self-efficacy and perceptions of the careers. On the other hand, negative views of STEM careers or lack of awareness of the skills required for different STEM careers may hinder students' interest in these fields during their formal schooling (Wyss et al., 2012). Thus, it can be argued that students tend to follow careers with which they are familiar (Franz-Odendaal et al., 2016) and that students' positive perceptions of a STEM career positively influence their career choices.

Gender is another significant factor that shapes interest in STEM fields and attitudes towards STEM careers (Boiko et al., 2019; Chachashvili-Bolotin et al., 2016). Although women constitute most of undergraduate students, on average across OECD countries, they are still under-represented in STEM (UNESCO, 2017). According to data from the International Labor Organization (2020), women constitute 38% of individuals holding STEM degrees. Research shows that gender influences career choices among students, particularly in Computing and Engineering, where boys are three times more likely to pursue careers than girls (Boiko et al., 2019). Consequently, gender inequality remains a prominent concern within STEM careers (Ciftci et al., 2020). Wang and Degol (2017) have ascertained that the underrepresentation of female students in STEM education is attributed to factors such as lifestyle values, work-life balance preferences, beliefs regarding field-specific abilities, and the presence of gender-related stereotypes and biases. To address this situation, Chauke (2022) emphasizes the pivotal role of parental education and their knowledge of STEM education in fostering the engagement of both male and female students in STEM fields. Additionally, the findings of the study conducted by Chachashvili-Bolotin et al. (2016) reveal that the enrolment in advanced science courses during secondary education diminishes the gender gap and mitigates the influence of family background on students' inclination to pursue STEM domains.

Based on the identified factors, the current research uses SCCT to explore meaningful factors that may influence students' interest and aspirations in STEM careers. For this purpose, a set of integrated STEM activities were incorporated into the 12th grade chemistry curriculum (STEM learning experiences) and their impact on students' interest in STEM careers was assessed using the CIQ. In order to investigate accurate predictors of students' STEM career aspirations, the CIQ dimensions (*Support, Intent*, and *Importance*) and the gender variable were used as independent variables. More specifically, the *Support* dimension, which documents the students' perceptions of being in an environment that is supportive of science careers, is closely related to the contextual supports and barriers of the SCCT. The *Intent* dimension, which documents the students' intent to pursue educational opportunities that would lead to a science career, could be associated to personal goals, which is a

Aims	Theories	Methods
To promote students' competence development in terms of STEM contents.	*Didactic axis* Achieving the aims considering the students' representations about the STEM contents. Students used technologies, namely educational animations and the Internet searches to explore the topic, they followed the engineering design process to develop the protype of an industry that entailed a crude oil distillation column, and they resorting to knowledge about distillation of crude oil (hydrocarbons and intermolecular forces)	Students followed the engineering design process, which involved imagining the industry, developing plans, constructing a model, creating a protype, and testing and refining the protype.

Figure 1. Dimensions of integrated STEM education framework used in designing the sequence of STEM activities (adapted from Ortiz-Revilla et al., 2022)

major construct in SCCT. The *Importance* dimension, which measures the perceived importance of science careers overall, has been identified, in several studies, as an important factor that could influence students' interest in pursuing a STEM career (Franz-Odendaal et al., 2016; Mohtar et al., 2019). Finally, gender is a SCCT subconstruct that is used to explain how individuals make career-related decisions (Lent et al., 1994).

RESEARCH METHODOLOGY

Design

This study followed a quantitative approach with pre- and post-test measures for a group of participants, with the aim of determining whether the implementation of integrated STEM activities had an impact on their interest in STEM careers. Information was collected using the CIQ, which measured interest in STEM careers according to the time of application (pre- and post-test) (Tyler-Wood et al., 2010).

Participants

A non-probabilistic (convenience) sampling approach was used to select 191 students from two 12th-grade classes attending the chemistry subject during the academic year 2022/2023. In terms of gender distribution, 44.5% (85 students) were male and 55.5% (106 students) were female. The average age of the students was 17.2 years.

Procedure

The students were involved in a sequence of STEM activities in their chemistry lessons on the topic of *Fossil Fuels*, which is part of the Year 12 chemistry curriculum. The STEM activities were carried out by five chemistry teachers who had taken part in professional development program. The sequence of activities and their implementation with the students was therefore planned by the three authors together with the teachers, based in the theoretical framework on integrated STEM education (Ortiz-Revilla et al., 2022), which comprises three dimensions: aims, theories and methods (**Figure 1**).

To carry out the activities, the teachers organised the pupils into groups of 4 or 5, during six 90-minute lessons. To introduce the sequence, the teachers began by exploring the importance of crude oil in societies. Specifically, in this introductory phase, teachers conducted a brainstorming session to gather students' ideas by posing questions such as: What would life be like without oil? How important is oil in our daily lives? And for society in general? How is crude oil extracted from nature? After this initial exploration of students' ideas and the connection of the topic to society, to understand the compounds acquired through crude oil distillation, the students researched the topic online and used educational animations. Following this, they developed a prototype of an industry that entailed a crude oil distillation column. During this process, students engaged in the engineering design process, which involved imagining the industry, developing plans, constructing a model, creating a prototype, and testing and refining the prototype. In addition, as the students developed their prototype, the teachers introduced questions that helped the students improve their plans, models, and prototypes. These questions were associated with catalytic cracking and its importance in the crude oil refining industry, as well as the production of petrol used in combustion engines. During the development of the refinery prototypes, the students watched videos about this type of industry, had access to games about hydrocarbons and consulted various websites on the internet, some of which included Portuguese legislation regulating this type of industry.

Instruments

The CIQ is a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) instrument composed of 12 items over three subscales or dimensions (*Support, Intent*, and *Importance*). Tyler-Wood et al. (2010) validated the CIQ with a population of 60 middle school students. The authors' use of exploratory factor analysis on the survey provides strong implications that these items are effective in measuring interest in STEM. Cronbach's alpha for the CIQ typically ranges from .70 to .93 across subscales (Tyler-Wood et al., 2010).

Regarding the instrument's validation, it achieved adequate psychometric properties. An exploratory principal component factor analysis was performed, and Cronbach's alpha was determined to ensure the construct validity and reliability of the instrument in the sample of 191 students. The results showed that the sample adequacy was good (KMO = .862); through Barlett's test of sphericity ($p < .001$), the fit of the variables or dimensions of the CIQ was also guaranteed by the factor analysis. To confirm the structure between the variables under study and validate the correlated factor groups, an exploratory factor analysis was performed. The extraction method of *Unweighted Least Squares* with *Varimax Rotation* was applied. The 12 items were analysed through a single-factor analysis, and no conflicting factor was detected. On the other hand, the three dimensions contribute to 65.8% of the explained variance. The overall reliability of the instrument was acceptable ($\alpha = .893$), achieving the same evaluation in all its dimensions (α [*Support*] = .829; α [*Intent*] = .909; α [*Importance*] = .777).

The survey battery adapted for the Portuguese context included the 12 items of the CIQ, but also introduced an additional question aimed at measuring students' inclination to pursue different STEM careers. Participants were given the opportunity to express their career aspirations by selecting one option from the following career-oriented question: "I intend to pursue a career in:

(1) science,
(2) technology,
(3) engineering,
(4) mathematics, and
(5) other".

The survey also included demographic questions, including the gender of the respondents.

The survey was conducted in person under the supervision of the teachers. Prior to the administration of the questionnaire, the participants were provided with a brief description of the purpose of the study and an informed consent process. The questionnaire was completed by the participants in approximately 10 minutes.

The pre-test was administered to the students at the beginning of the academic year (September) with the objective of determining their pre-existing interest in pursuing a career in a STEM field. The post-test was administered to the students after they had participated in the integrated STEM activities (May). The pre- and post-tests were matched using the students' identification numbers.

Data Analysis

The questionnaire results were analysed using Jamovi 2.2.5.0 software. Four mean scores were calculated from the CIQ data. The mean scores for the *Support, Intent, Importance* subscales were calculated by summing the ratings for each subscale and dividing by the total number of items included in the subscale. The total CIQ mean was calculated by summing all the ratings given in the questionnaire and then dividing the sum by 12, which is the total number of items that were rated.

The normality assumption of the data was checked using the Shapiro-Wilk test. It was found that the data did not follow a normal distribution ($p \leq .05$), so non-parametric tests were employed.

To assess the effect of gender and career aspirations on the CIQ scores, the Mann-Whitney U test was employed. To determine whether the implementation of integrated STEM activities had an impact on the students' interest in STEM careers, pairwise comparisons were made between the pre- and post-test scores for each of the CIQ subscales and the total CIQ. For this purpose, the Wilcoxon test was used, controlling for family-wise error across the tests at the .013 level using the Holm's sequential Bonferroni procedure.

Finally, a binary logistic regression analysis was performed to investigate the correlation between students' interest in STEM and their career aspirations. Specifically, the aim was to determine whether students' scores on the CIQ subscales (i.e., *Support*, *Interest*, and *Importance*) and gender could accurately predict students' STEM career aspirations. In this analysis, the CIQ subscales scores were independent continuous variables, gender was a dichotomous variable, and career aspirations (STEM or non-STEM) was the dependent binary variable. STEM career aspirations were coded into an ordered dichotomous variable, such that students interested in a STEM career were coded as 1 and those who were not interested in a STEM career were coded as 0. Before running the binary logistic regression, the variance inflation factor (VIF) for multicollinear relationships among independents variables and tolerance were verified. All the VIFs were less than 1.5, therefore multicollinearity was not a concern (Thompson et al., 2017), and all the tolerances were greater than .6. Unstandardised coefficients were reported in addition to odds ratios, indicating the effect of the predictor on the dependent variable (STEM career aspirations), such that the relative effect on the odds of the event occurring (choosing a STEM career) could be compared across the predictors, regardless of the units of each predictor variable.

Table 1. Mean and standard deviation for the pre-CIQ (N = 191)

Subscale	Mean	Standard deviation	Shapiro-Wilk	
			W	p
Support	3.54	1.065	.915	< .001
Intent	3.07	1.094	.962	< .001
Importance	3.90	.771	.938	< .001
CIQ total	3.50	.805	.984	.032

Table 2. Pre-CIQ analysis by gender

Subscale	Gender				Mann-Whitney U test		Effect size
	Female (N = 106)		Male (N = 85)		U	p	
	Mean	Standard deviation	Mean	Standard deviation			
Support	3.72	1.019	3.32	1.085	3,613	.017	.198
Intent	3.17	1.114	2.94	1.062	4,030	.209	--
Importance	3.95	.769	3.84	.772	4,047	.225	--
CIQ total	3.59	.802	3.37	.797	3,880	.099	--

Table 3. Pre-CIQ analysis by student's career aspirations

Subscale	STEM (N = 134)		Non-STEM (N = 57)		Mann-Whitney U test		Effect size
	Mean	Standard deviation	Mean	Standard deviation	U	p	
Support	3.73	1.014	3.10	1.058	2,457	< .001	.357
Intent	3.37	1.042	2.37	.876	1,793	< .001	.531
Importance	4.09	.612	3.46	.923	2,250	< .001	.411
CIQ total	3.73	.721	2.95	.734	1,758	< .001	.540

RESULTS

Pre-Test

For the pre-CIQ (**Table 1**), mean ratings ranged from 3.07 to 3.90 across the subscales. *Importance* ratings were the highest of the three subscales.

To determine whether students' STEM career interest, as reflected via individual subscales, was affected by gender, a Mann-Whitney U test was performed, and its results are presented in **Table 2**.

According to **Table 2**, a statistically significant difference in terms of gender was observed in the *Support* subscale [$U_{(189)}$ = 3,613; p = .017]. Therefore, female students had a greater perception of being in an environment that is supportive of science careers. The effect sizes indicated that the gender effect was of a small magnitude.

A second subset of analyses, presented in **Table 3**, was carried out to assess whether pre-CIQ scores, as reflected via the individual subscales, were affected by career aspirations, using the Mann-Whitney U test.

As expected, students with STEM career aspirations scored higher on all CIQ subscales. According to the Mann-Whitney test, statistically significant differences were observed in all subscales. Thus, students with STEM career aspirations had a greater interest in STEM careers, they had a higher perception of being in a science-oriented career environment, they had intentions to pursue educational opportunities that would lead to a science career, and they had a higher perception of the importance of science careers.

Post-Test

For the post-CIQ (**Table 4**), mean ratings ranged from 3.12 to 3.90 across the subscales. *Importance* ratings did not change with the implementation of integrated STEM activities and remained the highest of the three subscales.

To determine whether students' STEM career interest, after the implementation of integrated STEM activities, was affected by gender, a Mann-Whitney U test was used, and its results are presented in **Table 5**.

Based on the results presented in **Table 5**, no statistically significant differences in terms of gender were observed on the CIQ subscales following the implementation of integrated STEM activities.

In order to assess whether CIQ scores, after the implementation of integrated STEM activities, were affected by career aspirations, a Mann-Whitney U test was performed, and its results are presented in **Table 6**.

Table 4. Mean and standard deviation for the post-CIQ (N = 191)

Subscale	Mean	Standard deviation	Shapiro-Wilk	
			W	p
Support	3.57	1.033	.918	< .001
Intent	3.12	1.037	.969	< .001
Importance	3.90	.788	.938	< .001
CIQ total	3.52	.773	.985	.043

Table 5. Post-CIQ analysis by gender

Subscale	Gender				Mann-Whitney U test	
	Female (N = 106)		Male (N = 85)			
	Mean	Standard deviation	Mean	Standard deviation	U	p
Support	3.70	1.013	3.40	1.040	3,813	.063
Intent	3.21	1.064	3.01	.998	4,064	.244
Importance	3.95	.770	3.83	.786	4,049	.227
CIQ total	3.61	.791	3.41	.741	3,903	.112

Table 6. Post-CIQ analysis by student's career aspirations

Subscale	STEM (N = 135)		Non-STEM (N = 56)		Mann-Whitney U test		Effect size
	Mean	Standard deviation	Mean	Standard deviation	U	p	
Support	3.73	1.009	3.16	.987	2,462	< .001	.349
Intent	3.37	1.006	2.52	.856	1,970	< .001	.479
Importance	4.09	.610	3.43	.931	2,142	< .001	.433
CIQ total	3.73	.704	3.01	.698	1,798	< .001	.524

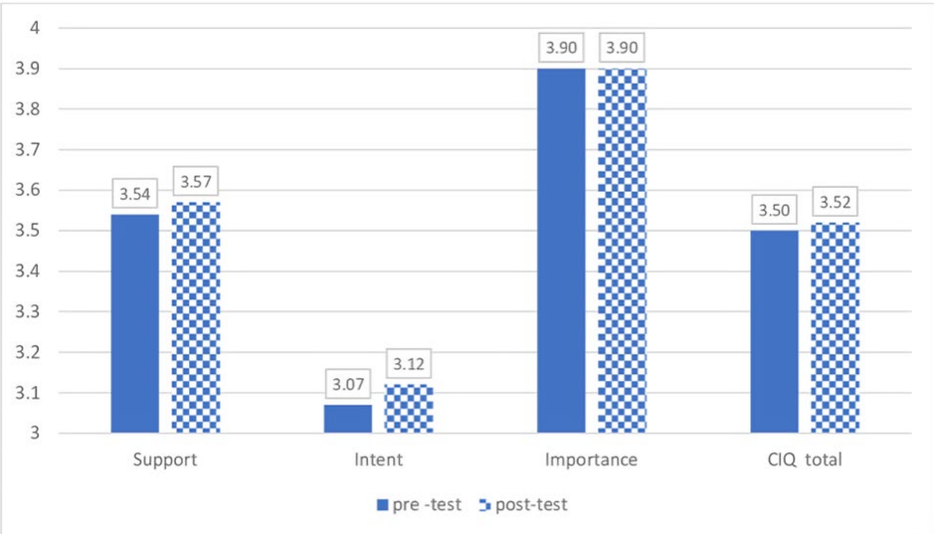

Figure 2. Pre- and post-CIQ mean scores of different subscales

Students with STEM career aspirations continued to score higher on all CIQ subscales. According to the Mann-Whitney test, statistically significant differences were observed in all subscales.

Comparison of Pre- and Post-Test

To compare pre- and post-test scores, four pairwise comparisons were conducted for each of the CIQ subscales and CIQ total using the Wilcoxon test, with for family-wise error control across the three tests at the .013 level according to Holm's sequential Bonferroni procedure. **Figure 2** summarises the pre- and post-test results for each CIQ subscale and CIQ total. The comparison of results showed a statistically significant difference on the *Intent* subscale [$W_{(190)}$ = 12.00; p = .002]. Therefore, following the implementation of integrated STEM activities, students' intention to pursue educational opportunities that would lead to a scientific career was higher.

Figure 3 summarises the pre- and post-test results for each CIQ subscale by gender. The comparison of results for the male gender showed a statistically significant difference on the *Intent* subscale [$W_{(84)}$ = 2.50; p = .017]. Therefore, following the implementation of integrated STEM activities, male students' intention to pursue educational opportunities that would lead to a scientific career was higher. The comparison results for the female students did not show significant differences on any of the CIQ subscales.

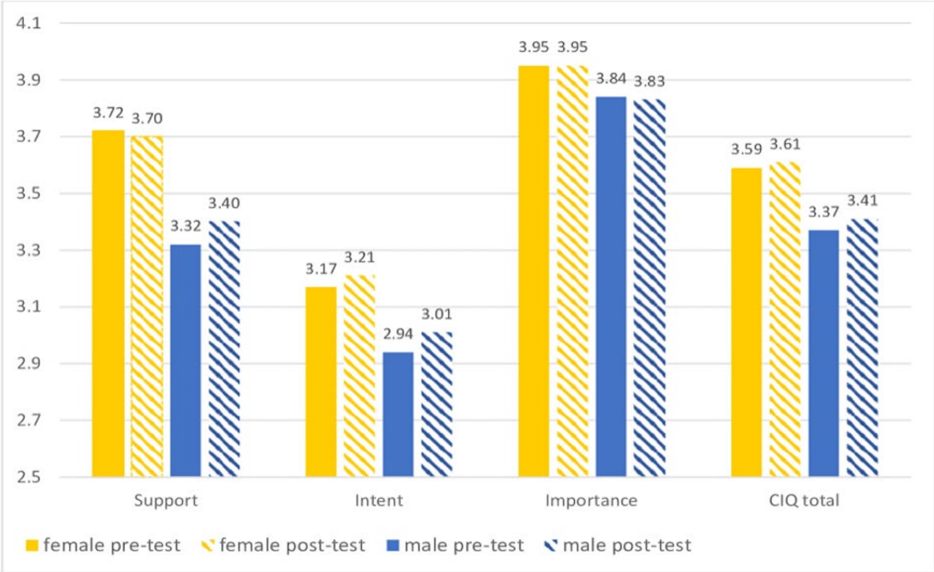

Figure 3. Pre- and post-test mean scores of different subscales by gender

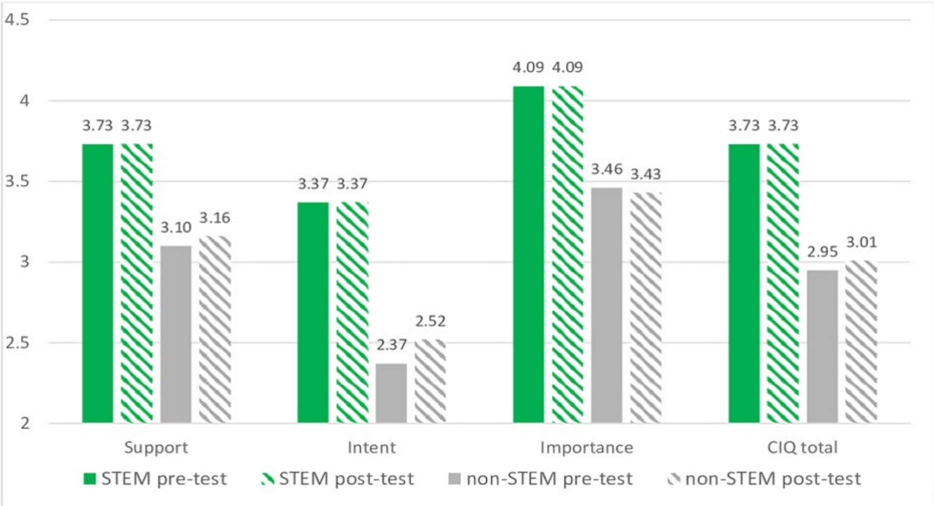

Figure 4. Pre- and post-test mean scores of different subscales by student's career aspirations

Table 7. Logistic regression analysis of CIQ subscales scores and gender on STEM career aspirations

	β	Standard error	Wald test	p	Odds ratio	95% confidence interval [lower-upper]
Gender	1.691	.422	4.005	< .001	5.423	2.371 – 12.40
Support	.155	.216	.720	.471	1.168	.766 – 1.782
Intent	.667	.251	2.659	.008	1.948	1.192 – 3.185
Importance	.950	.297	3.199	.001	2.585	1.444 – 4.625

Figure 4 presents the pre- and post-test results of each subscale of the CIQ based on student's career aspirations. The mean scores of the three subscales remained constant for students with STEM career aspirations. However, minor fluctuations were observed in the subscales scores mean of students without STEM career aspirations, primarily in the *Intent* subscale.

A binary logistic regression analysis was used to determine whether the CIQ subscales (i.e., *Support, Interest, and Importance*) and gender, could accurately predict students' STEM career aspirations. For this purpose, gender and students' mean post-scores on the CIQ subscales, were examined in relation to STEM career aspirations.

Based on the findings presented in **Table 7**, the model with the gender and CIQ's subscales was significant [$\chi^2_{(4)} = 57.4$; $p < .001$, $R^2_{Negelkerk} = .370$]. The gender (OR = 5.42; CI $_{95\%}$ = 2.37 – 12.40), the *Intent* (OR = 1.95; CI $_{95\%}$ = 1.19 – 3.18) and *Importance* (OR = 2.58; CI $_{95\%}$ = 1.44 – 4.62) subscales were significant predictors of students' STEM career aspirations. Thus, the odds of having STEM career aspirations, after completed integrated STEM activities, increased by a factor of 5.42 for male students when compared to female students. Also, the odds of having STEM career aspirations, after completed integrated STEM activities, increased by a factor of 1.95 for every one unit of increase in *Intent* scores. Finally, the odds of having STEM career aspirations, after completed integrated STEM activities, increased by a factor of 2.58 for every one unit of increase in *Importance* scores.

DISCUSSION

This study aims to assess the level of interest among secondary school students in STEM careers, with specific regard to the impact of gender, following their participation in integrated STEM activities. Furthermore, the research investigates the relationship between students' interest in STEM careers and their inclination towards pursuing a career in STEM.

Regarding RQ1. Were there significant short-term changes in students' interest in STEM careers after participating in the integrated STEM activities? The results of the pre- and post-test comparison indicate that, overall, there was a slight and non-significant increase in the interest in STEM careers of secondary students (as measured by the CIQ total) after they participated in integrated STEM activities. While previous studies have shown that school-related factors, such as classes, curriculum, course materials, and instructional techniques, can enhance students' interest in STEM fields (Bahar and Adiguzel, 2016; Honey et al., 2014), it's possible that the integrated STEM activities in this study may not have been a substantial enough intervention to significantly impact the students' interest in STEM careers. This could be attributed to the relatively short duration of the implementation or the fact that these activities were introduced at an age when students already had well-established interests in specific study areas. This hypothesis finds support in the analysis presented in **Figure 4**, which demonstrates that the interest of students, both those with STEM and non-STEM career aspirations, remained relatively stable after participating in the integrated STEM activities. However, when analysing the pre- and post-test comparisons of the individual dimensions within the CIQ, it becomes evident that the integrated STEM activities had an impact on the *Intent* dimension. This effect is further confirmed by the findings presented in **Figure 4**, which highlights the *Intent* dimension as the one displaying the most substantial change among students with non-STEM career aspirations. In contrast, students with STEM career aspirations exhibited stability across all dimensions of the CIQ. Consequently, the introduction of integrated STEM activities led to an increased intention among non-STEM students to pursue educational opportunities that could potentially lead to a scientific career. This suggests that integrated STEM activities exerted a positive influence on the intentions of students who initially had non-STEM career aspirations. This result aligns with previous research, which suggested that students' intentions to pursue STEM fields are influenced by direct classroom instruction that provides satisfying learning experiences, ultimately inspiring or preparing them for STEM careers (Chachashvili-Bolotin et al., 2016; Woo et al., 2023).

Regarding RQ2. To what extent did participation in integrated STEM activities influence gender-based differences in interest toward STEM careers among secondary school students? There were no disparities in the interest to pursue STEM careers after the integrated STEM activities (CIQ total), as revealed by the comparison of post-test results by gender. Remarkably, female students scored higher in all CIQ dimensions, both in the pre- and post-test. Despite literature indicating that gender differences exist in STEM career interest, particularly in engineering and computing (Boiko et al., 2019; UNESCO, 2017), this study found no such differences. This result may be attributed to the fact that the CIQ focuses on scientific careers in general rather than specific occupations (Tyler-Wood et al., 2010), and by the female students' higher perception of being in a science career-oriented environment. According to the pre-test, there was a gender discrepancy that favoured female students in the *Support* dimension. This category pertains to the assistance and encouragement provided by parents and family members to students in their academic pursuits, and it has been identified as a crucial influence on students' interest in STEM careers (Archer et al., 2012; Chauke, 2022; Christensen et al., 2015; Plasman et al., 2021). However, the implementation of integrated STEM activities had two distinct effects based on gender. First, it significantly impacted the *Intent* dimension for male students. After participating in integrated STEM activities, male students expressed a higher intention to pursue educational opportunities leading to a scientific career. Second, the perceived gender gap in the *Support* dimension was eliminated. After the implementation of the integrated STEM activities, male students' perception of being in an environment supportive of science careers increased, eliminating the gender gap that had previously existed. As the *Support* dimension of the CIQ is related to the support and encouragement given by parents and family members to students in their studies. It is plausible that male students, after engaging in integrated STEM activities that were meaningful to them, discussed their career prospects with their parents and family members and perceived a more supportive environment.

Regarding RQ3. Did Portuguese secondary school students' career aspirations align with their interests in STEM careers? Students with STEM career aspirations consistently scored significantly higher than their peers with non-STEM career aspirations on all dimensions of the CIQ, both at pre- and post-test. This suggests that students with STEM career aspirations had a greater interest in STEM careers. As they had a higher perception of being in a science-oriented career environment, a higher intention to pursue a science-oriented career, and a higher perceived importance of science careers than their non-STEM peers. This finding is consistent with the SCCT, which proposes that individuals employ personal inputs, contextual factors, and interests to make career-related decisions (Lent et al., 1994). Additionally, prior research has consistently emphasised the significance of interest in predicting the selection of subjects and courses (Maltese and Tai, 2011). The results of the binary logistic regression provided further evidence that confirmed the correlation between students' interest in STEM and their career aspirations. Gender, along with the *Intent* and *Importance* subscales, were identified as significant predictors of the students' STEM career aspirations. In terms of gender, this finding is mostly similar with prior research that found that gender have a statistically significant effect on STEM career aspirations (Boiko et al., 2019; Chachashvili-Bolotin et al., 2016). As a result, male students were more likely to choose STEM careers than female students, as found in the previous studies. This suggests that further efforts need to be made to increase female interest in STEM fields and careers. The literature suggests that the middle school period is crucial for career development (Wyss et al., 2012). Moreover, science gaps emerge in elementary schools and persist to remain unchanged in secondary schools (Morgan et al., 2016). Therefore, it is crucial to develop targeted intervention programmes at this stage to minimise these gaps in career aspirations. Other significant predictors were the *Intent* and *Importance* dimensions. Students with higher intent to pursue educational opportunities that would lead to a career in science were more likely to report STEM career aspirations than their counterparts with lower intent. This finding supports the SCCT, which posits that goal orientation is an important construct that influences career preferences (Bahar and Adiguzel, 2016; Lent et al., 1994). In this sense, people develop goals to pursue academic and career-related activities that are consistent with their interests, self-efficacy, and outcome expectations (Sheu et al., 2010). Regarding the *Importance* dimension, students with positive perceptions of STEM careers were more likely to be interested in STEM than those with negative perceptions of STEM careers. Previous studies already have indicated that students' positive perceptions of a STEM career positively influence their career choices (Franz-Odendaal et al., 2016; Mohtar et al., 2019; Wyss et al., 2012). However, it's worth noting that while many students may hold a positive view of STEM careers, they also perceive STEM studies as challenging and requiring a high level of education (Boiko et al., 2019). This underscores the importance of implementing science education efforts, as featured in this study, to demystify science and scientific processes. Such initiatives can enhance students' confidence in STEM and promote and sustain their interest in STEM careers.

FINAL REMARKS

This study has certain limitations that may affect the generalisability of its findings. Nevertheless, it provides an important foundation for future research efforts. The main limitation concerns the narrow focus of the study on a single group of participants, with a relatively small sample size of 191 individuals. The lack of a control group in the study design makes it difficult to attribute the observed results solely to the integration of STEM activities. It is therefore recommended that future research includes a quasi-experimental design with both experimental and control groups and a larger number of participants. It is also important to recognise that the CIQ items focus primarily on the domain of science, rather than encompassing the broader scope of STEM. This limited focus has implications for the generalisability of the results, as they are limited to career interests primarily within the domain of science, rather than across all four components of STEM.

However, it is important to emphasise that this study provided evidence that integrated STEM activities led to an increased intention among non-STEM students to pursue educational opportunities that could potentially lead to a scientific career.

In terms of gender, notable differences emerged in the intention to follow educational opportunities that could eventually result in a scientific career between male and female students who participated in STEM activities. Following the activities, males exhibited a substantial increase in their intentionality in contrast to females. Additionally, the results also provided further evidence to support the use of the CIQ as a reliable measure of students' interest in STEM careers. Gender, along with the personal goals (*Intent subscale)* and positive perceptions of STEM careers (*Importance subscale*), were identified as significant predictors of the students' current STEM career aspirations.

These findings emphasise the importance of STEM education in promoting and nurturing students' interest in STEM fields. Consequently, it is recommended that integrated STEM activities can be developed in the early stages of education. Early exposure to STEM concepts and hands-on experiences can ignite a passion for these fields and provide a solid foundation for more advanced learning in secondary school and beyond. By incorporating STEM education into the curriculum from an early age, educators can tap into students' natural curiosity and enthusiasm and encourage a diverse group of students to engage in STEM activities. This, in turn, fosters a more inclusive and equitable learning environment, ultimately leading to a broader representation of voices in these fields. This approach not only contributes to individual growth and achievement but also strengthens the overall workforce and future innovation in society, making it a crucial investment in our collective future.

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REFERENCES

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B. and Wong, B. (2012). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science. *American Educational Research Journal*, 49(5), 881–908. https://doi.org/10.3102/0002831211433290

Bahar, A. and Adiguzel, T. (2016). Analysis of factors influencing interest in STEM career: Comparison between American and Turkish high school students with high ability. *Journal of STEM Education: Innovations and Research*, 17(3), 64–69.

Bandura, A. (1986). *Social Foundations of Thought and Action: A Social Cognitive Theory*. Upper Saddle River (NJ): Prentice-Hall.

Baptista, M., Jacinto, H. and Martins, I. (2023). What is a good explanation in integrated STEM education? *ZDM Mathematics Education*, 55, 1255–1268. https://doi.org/10.1007/s11858-023-01517-z

Batdi, V., Talan, T. and Semerci, C. (2019). Meta-analytic and meta-thematic analysis of STEM education. *International Journal of Education in Mathematics, Science and Technology*, 7, 382–399.

Boiko, A., Nistor. A, Kudenko I. and Gras-Velazquez, A. (2019). *The Attractiveness of Science, Technology, Engineering and Mathematics Subjects. Results From Five Countries | September 2019*. Brussels: European Schoolnet.

Chachashvili-Bolotin, S., Milner-Bolotin, M. and Lissitsa, S. (2016). Examination of factors predicting secondary students' interest in tertiary STEM education. *International Journal of Science Education*, 38(3), 366–390. https://doi.org/10.1080/09500693.2016.1143137

Chauke, T. A. (2022). Gender differences in determinants of students' interest in STEM education. *Social Sciences*, 11(11), Article 534. https://doi.org/10.3390/socsci11110534

Christensen, R. and Knezek, G. (2017). Relationship of middle school student STEM interest to career intent. *Journal of Education in Science, Environment and Health*, 3(1), 1–13. https://doi.org/10.21891/jeseh.275649

Christensen, R., Knezek, G. and Tyler-Wood, T. (2015). A retrospective analysis of STEM career interest among mathematics and science academy students. *International Journal of Learning, Teaching and Educational Research*, 10(1), 45–58.

Ciftci, A., Topcu, M. S. and Erdogan, I. (2020). Gender gap and career choices in STEM education: Turkey sample. *International Journal of Progressive Education*, 16(3), 53–66. https://doi.org/10.29329/ijpe.2020.248.4

Franz-Odendaal, T. A., Blotnicky, K., French, F. and Joy, P. (2016). Experiences and perceptions of STEM subjects, careers, and engagement in STEM activities among middle school students in the maritime provinces. *Canadian Journal of Science, Mathematics and Technology Education*, 16(2), 153–168. https://doi.org/10.1080/14926156.2016.1166291

Guzey, S. S., Moore, T. J., Harwell, M. and Moreno, M. (2016). STEM integration in middle school life science: Student learning and attitudes. *Journal of Science Education and Technology*, 25(4), 550–560. https://doi.org/10.1007/s10956-016-9612-x

Halim, L., Abd Rahman, N., Zamri, R. and Mohtar, L. E. (2018). The roles of parents in cultivating children's interest towards science learning and careers. *Kasetsart Journal of Social Sciences*, 39(2), 190–196. https://doi.org/10.1016/j.kjss.2017.05.001

Halim, L., Shahali, E. and Iksan, Z. (2021): Effect of environmental factors on students' interest in STEM careers: The mediating role of self-efficacy. *Research in Science & Technological Education*, 41(4), 1394–1411. https://doi.org/10.1080/02635143.2021.2008341

Honey, M., Pearson, G. and Schweingruber, H. A. (eds). (2014). *STEM Integration in K-12 Education: Status, Prospectus, and an Agenda for Research*. Washington (DC): The National Academies Press.

International Labor Organization. (2020). How Many Women Work in STEM, *ILO*. Available at: https://ilostat.ilo.org/how-many-women-work-in-stem/. (Accessed 18 October 2023).

Kaleva, S., Celik, I., Nogueiras, G., Pursiainen, J. and Muukkonen H. (2023). Examining the predictors of STEM career interest among upper secondary students in Finland. *Educational Research and Evaluation*, 28(1–3), 3–24. https://doi.org/10.1080/13803611.2022.2161579

Lent, R. W., Brown, S. D. and Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior*, 45(1), 79–122. https://doi.org/10.1006/jvbe.1994.1027

Lent, R. W., Brown, S. D. and Hackett, G. (1996). Career development from a social cognitive perspective, in D. Brown (eds), *Career Choice and Development* (pp. 373–421). San Francisco (CA): Jossey-Bass.

Maltese, A. V. and Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students. *Science Education*, 95(5), 877–907. https://doi.org/10.1002/sce.20441

Mohtar, L. E., Halim, L., Rahman, N. A., Maat, S. M., Iksan, Z. H. and Osman, K. (2019). A model of interest in STEM careers among secondary school students. *Journal of Baltic Science Education*, 18(3), 404–416. https://doi.org/10.33225/jbse/19.18.404

Morgan, P. L., Farkas, G., Hillemeier, M. M. and Maczuga, S. (2016). Science achievement gaps begin very early, persist, and are largely explained by modifiable factors. *Educational Researcher*, 45(1), 18–35. https://doi.org/10.3102/0013189X166331

Ortiz-Revilla, J., Greca, I. M. and Arriassecq, I. A. (2022). Theoretical framework for integrated STEM education. *Science & Education*, 31, 383–404. https://doi.org/10.1007/s11191-021-00242-x

Peterman, K., Kermish-Allen, R., Knezek, G., Christensen, R. and Tyler-Wood, T. (2016). Measuring student career interest within the context of technology-enhanced STEM projects: A cross-project comparison study based on the career interest questionnaire. *Journal of Science Education and Technology*, 25(4), 833–845. https://doi.org/10.1007/s10956-016-9617-5

Plasman, J., Gottfried, M., Williams, D., Ippolito, M. and Owens, A. (2021). Parents' occupations and students' success in STEM fields: A systematic review and narrative synthesis. *Adolescent Research Review*, 6, 33–44. https://doi.org/10.1007/s40894-020-00136-z

Sheu, H., Lent, R. W., Brown, S. D., Miller, M. J., Hennessy, K. D. and Duffy, R. D. (2010). Testing the choice model of social cognitive career theory across Holland themes: A meta-analytic path analysis. *Journal of Vocational Behavior*, 76, 252–264. https://doi.org/10.1016/j.jvb.2009.10.015

Tang, M., Pan, W. and Newmeyer, M. D. (2008). Factors influencing high school students' career aspirations. *Professional School Counseling*, 11(5), 285–295. https://doi.org/10.5330/PSC.n.2010-11.285

Thompson, C. G., Kim, R. S., Aloe, A. M. and Becker, B. J. (2017). Extracting the variance inflation factor and other multicollinearity diagnostics from typical regression results. *Basic and Applied Social Psychology*, 39(2), 81–90. https://doi.org/10.1080/01973 533.2016.12775 29

Tyler-Wood, T., Knezek, G. and Christensen, R. (2010). Instruments for assessing interest in STEM content and careers. *Journal Technology Teacher Education*, 18(2), 341–363.

UNESCO. (2017). *Cracking the Code: Girls' and Women's Education in Science, Technology, Engineering and Mathematics (STEM)*. Paris: UNESCO.

Wang, M. T. and Degol, J. L. (2017). Gender gap in science, technology, engineering, and mathematics (STEM): Current knowledge, implications for practice, policy, and future directions. *Educational Psychology Review*, 29, 119–140. https://doi.org/10.1007/s10648-015-9355-x

Woo, H., Heo, N., Jang, H. and Jang, Y. (2023). Parental and school factors on American high school students' academic and career intentions in STEM fields. *International Journal for Educational and Vocational Guidance*, 23, 19–42. https://doi.org/10.1007/s10775-021-09498-9

Wyss, V. L., Heulskamp, D. and Siebert, C. J. (2012). Increasing middle school student interest in STEM careers with videos of scientists. *International Journal of Environmental and Science Education*, 7(4), 501–522.

