

## The Vision of Future Generations towards STEM Education: Impact of a Tech Summer Camp

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### ABSTRACT

STEM professions, which encompass science, technology, engineering, and mathematics, are crucial for the labor market and society. The demand for these professions has increased in recent years due to the pervasiveness of technology in daily life. Thus, fostering a positive attitude toward STEM among children and young is essential. This study aims to analyze the attitudes of boys and girls aged 9 to 17 toward STEM education after attending a series of courses at a Tech Summer Camp. It also examines whether attitudes differ by sex and age. A cross-sectional quasiexperimental pretest-post-test design with a quantitative methodology was used to collect and analyze data. Unlike findings from Spanish schoolchildren, our sample displayed more positive attitudes toward STEM education with increasing age. However, younger participants showed the greatest improvement in their perception of the usefulness of science, attributable to their experiences at the Tech Summer Camp. Regarding sex, no significant differences were observed across most dimensions, except in usefulness and liking, where females excelled. There is a clear need to promote such activities at an early age, particularly for girls. The study confirms that attending technology-focused camps in an informal educational setting enhances attitudes toward STEM education, especially among younger children.

**Keywords:** STEM education, informal learning, attitudinal measurement

### INTRODUCTION

STEM education equips students with essential twenty-first-century skills by immersing them in real-world applications and enhancing their abilities to tackle complex challenges, fostering critical and analytical thinking, collaborative skills, peer-to-peer communication, problem-solving capabilities, and independent learning (Capraro et al., 2013; Garibay, 2015). It emphasizes problem-solving with direct applications in the real world and is acknowledged as crucial for developing the inquisitive, cooperative, creative, reflective, and critical faculties necessary in today's citizens (Greca et al., 2021).

Despite the growing emphasis on digital competence in education policies (European Commission, 2020), the integration of STEM skills in early education remains inconsistent. While numerous studies have demonstrated the potential of informal programs to enhance STEM attitudes (Mohr-Schroeder et al., 2014; Roberts et al., 2018;

Xia et al., 2024), there is still limited evidence on how intensive, context-specific interventions, such as university-hosted technology summer camps, impact younger learners' attitudes and identities toward STEM disciplines. This gap is particularly evident in Southern European contexts, where access to extracurricular STEM opportunities is less widespread (Toma & García-Carmona, 2021).

Recent international evidence also supports this view, showing that authentic, problem-based STEM experiences are key drivers of engagement and skill development (Roberts et al., 2018; Xia et al., 2024). Moreover, research underscores the significant relationship between early interest in STEM fields and subsequent career choices, indicating that initial exposure to STEM education can profoundly influence the decision to pursue STEM-related careers later on (Holmes et al., 2017; Jannini et al., 2024; Mohr-Schroeder et al., 2014; Nugent et al., 2010). A recent meta-analysis of informal STEM programs in North America also confirms that well-designed interventions significantly enhance students' attitudes, self-efficacy, and interest, with especially strong effects among primary and middle school students (Xia et al., 2024).

This evidence underscores the importance of establishing a foundation for early learning and interest in STEM through initiatives that allow children to solve genuine real-world problems in collaborative settings. These environments mimic the real-life situations encountered by STEM professionals, helping students see the practical importance of their studies for both personal growth and societal benefit. By providing opportunities to engage with STEM professionals and authentic tools, informal summer camps have been shown to deepen conceptual understanding and help students connect formal school learning with practical applications (Roberts et al., 2018).

However, in Spain, the implementation of STEM education faces significant challenges. Schools struggle to develop effective STEM curricula due to insufficient teacher training (Toma & García-Carmona, 2021), rigid class schedules, high student-to-teacher ratios, limited resources, and a dense curriculum that barely accommodates technological training. These obstacles underscore the necessity of enhancing and supporting STEM education experiences, particularly for primary and secondary students, beyond traditional school settings. As Nugent et al. (2010) and Jackson and Mohr-Schroeder (2018) suggest, informal educational settings provide unique opportunities for students to engage more deeply with STEM activities and concepts. These settings allow for prolonged interaction with specific STEM applications, often impractical in more formal or time-restricted educational environments. Technology summer camps are pivotal venues for nurturing future STEM professionals by offering innovative and entrepreneurial spaces. These camps provide collaborative learning environments where students can advance their skills and knowledge in realistic contexts.

To address these challenges and strengthen STEM education, we conducted a study at the summer technology camp of an engineering school within a university in Spain. The study involved boys and girls aged 9 to 17 and examined whether attitudes toward STEM disciplines changed after participating in courses in an informal, non-curricular educational setting.

## **LITERATURE REVIEW**

### **Informal Learning Environments in STEM Education**

Informal education programs offer students genuine learning experiences that allow them to forge valuable connections between STEM subjects by engaging in hands-on projects (Hurst et al., 2019; Meyers et al., 2013; Nugent et al., 2015). Research demonstrates that such learning environments significantly boost student interest in STEM education (Mohr-Schroeder et al., 2014; Roberts et al., 2018) and enhance engagement with STEM subjects in secondary education (Barker et al., 2014; Sha et al., 2015). Furthermore, participation in STEM-focused summer technology camps positively influences classroom learning (Kitchen et al., 2018; Hussim et al., 2024; Rogers & Portsmore, 2004).

Significantly, studies by Jackson and Mohr-Schroeder (2018) and Morris (2016) indicate that experiences in informal activities are crucial for fostering academic interest and motivation in STEM fields (Lent et al., 2000). At technology summer camps, students collaborate and engage in creative processes that transcend typical curricular objectives. These camps enrich STEM education by promoting active science and engineering practices (Vossoughi & Bevan, 2014) in an environment that supports teamwork, trial and error, and reflective thinking. Participants are encouraged to experiment with new ideas and synthesize elements to create innovative products (Simarro et al., 2016), thereby applying the scientific method in practice. This approach develops problem-solving skills through a design process that emphasizes reflection, learning from mistakes, and the use of diverse materials and technological tools to foster creativity in a fun, feedback-rich setting.

Informal learning environments sustain long-term interest in STEM education by offering alternative and inclusive learning spaces (Anand & Dogan, 2021). Moreover, participation in these programs is linked to students' expectations of success in future educational pursuits (Mahoney et al., 2005; Morris, 2016), increased

interest in pursuing careers in STEM fields (Price et al., 2018), and enhanced self-efficacy in STEM-related subjects (Dabney et al., 2012).

A distinctive feature of these programs is that participation is often a choice made by the students or their parents (Vandell et al., 2005). This decision is influenced by the perceived benefits of the camp experience and the opportunity to develop social and communication skills. Engaging in STEM-focused informal education programs not only cultivates students' beliefs in their abilities and interest in STEM fields (Dabney et al., 2012; Morris, 2016) but also serves as an important predictor of their well-being and future achievements (Meier et al., 2018).

## Sex Gap

Research on the declining attitudes toward STEM education, particularly among females, is gaining attention due to its implications for academic and career choices. Data indicate a consistent disparity in STEM aspirations between boys and girls, with girls less inclined to pursue STEM pathways (Nguyen et al., 2025; Sáinz, 2020). Notably, women constitute less than one-third of the workforce in science and engineering (SE) (National Science Foundation, 2021).

This underrepresentation is multifaceted. Numerous studies suggest that implicit biases, fueled by pervasive cultural stereotypes that portray science as predominantly male, influence students' behaviors and choices (Kim et al., 2018; Oon et al., 2020; Sharaby, 2021; Crittenden et al., 2023). Both sexes maintain and demonstrate such stereotypes (Blazev et al., 2017). According to Cheryan et al. (2017) and Grewe (2025), while boys might feel compelled to engage in science due to its stereotypical masculine perception, girls may withdraw from it to affirm their gender identity. Additional factors contributing to girls' apparent disinterest in STEM include the lack of female role models, teaching methods that fail to engage girls, and a diminished sense of acceptance or familial support (UNESCO, 2019).

Recent studies have also highlighted the role of the "hidden curriculum" in perpetuating gender stereotypes, particularly in the field of information and communication technologies. For instance, Papadakis et al. (2018) found a persistent underrepresentation of women in computer science in Greece, despite decades of initiatives to promote gender equity. This underrepresentation is not only a reflection of societal norms but is also reinforced by educational practices and materials. In a complementary study, Papadakis (2018) conducted a content analysis of Greek computer science textbooks and revealed that both language and imagery systematically underrepresent women, portraying men as the primary actors and experts in technology. Such findings underscore how formal and informal educational contexts can shape students' self-perceptions and career aspirations, discouraging girls from identifying with STEM pathways. Addressing these hidden messages is crucial, as informal learning spaces such as summer camps can act as counterbalances by fostering inclusive environments where girls can see themselves as competent and valued members of the STEM community.

From an early age, girls may doubt their fit or ability to succeed in STEM due to its male-dominated image, questioning their potential as scientists, engineers, or technologists and their recognition by others in these roles (Archer et al., 2017; Ryu et al., 2019). Informal education programs play a crucial role in enhancing girls' science identity by integrating school science with their daily lives, helping them envision themselves as part of the STEM community (Chan et al., 2020; Hughes et al., 2020; Kitchen et al., 2018; Ryu et al., 2019; Todd & Zvoch, 2019).

Interestingly, STEM-focused informal education programs benefit girls more than boys, as they show increased interest in STEM fields after participation (Broder et al., 2023; Dabney et al., 2012; Price et al., 2018). These programs also foster internal and external recognition of girls as capable individuals in scientific, engineering, or technological domains, thereby cultivating their identities in these fields (Calabrese Barton et al., 2013; Hughes & Roberts, 2019; Nation & Muller, 2023; Talafian et al., 2019). Informal educational spaces provide opportunities for girls to meet role models and be acknowledged for their scientific contributions, away from the formal classroom's stereotypical constraints (Calabrese Barton et al., 2013; Hughes et al., 2020; Ryu et al., 2019; Todd & Zvoch, 2019).

Given these insights, this study aims to analyze the attitudes of boys and girls aged 9 to 17 toward STEM education and the change in these attitudes after participating in courses at a Technology Summer Camp. It also examines whether attitudes and changes in attitudes differ according to sex and age.

There are several differences between this study and others analyzed. The courses taken by the students were weekly, lasted 30 hours, and focused exclusively on the course subject. In this sense, the courses were highly intensive in terms of hours and technical content and were always adapted to the profile of the students. They are conducted in an engineering school, using classrooms and laboratories, which served as additional motivation for the attendees. The instructors who taught these courses are mostly university students in their disciplines, who usually carried out their teaching with great passion. Moreover, as these were summer courses, the sample of Tech Summer Camp attendees differed significantly from that of other studies conducted in schools. The

students who attended were typically those with an interest in the course disciplines, especially the older participants (14 to 17 years old), who, due to their age, could stay at home alone.

Therefore, analyzing this sample and their attitudes toward STEM education is relevant before starting the Tech Summer Camp course. However, checking the change in their attitudes toward STEM education after attending the course is even more relevant. The analysis employs statistical techniques commonly used for this type of study, including clusters analysis to define the attendees' profiles, and Sankey plots to represent changes in the sample across profiles.

Based on this goal, we propose the following working hypotheses:

**Hypothesis 1:** Significant differences exist in attitudes toward STEM education and its dimensions based on sex.

**Hypothesis 2:** A statistically significant correlation exists between attitudes toward STEM education areas and dimensions and age, which varies by sex.

**Hypothesis 3:** Participation in the Tech Summer Camp program enhances overall attitudes toward STEM and improves scores across the four dimensions of the scale.

**Hypothesis 4:** There are different profiles of students according to their scores on the dimensions of the scale.

### **Tech Summer Camp Description**

The Tech Summer Camp is an informal education initiative held annually at an engineering school of a mid-sized university in Spain since 2014. The camp, aimed at young people aged 9 to 17, takes place outside the academic year, from June to July, and focuses on developing STEM (science, technology, engineering, and mathematics) skills in a fun and creative environment. It emphasizes promoting STEM careers among women and fostering gender equity.

In the summer of 2021, two types of Tech Summer Camp were offered: one in person and one virtual. The camp received 810 registrations from 649 students (424 boys and 225 girls), reflecting a female participation rate of 35%. Of the 810 registrations, 150 were for the virtual campus and 660 for the on-campus program, which was selected for analysis. The program offered 23 courses, including programming, engineering challenges, new technologies, mechatronics, bioengineering, entrepreneurship, and multimedia editing. Students could enroll weekly, with options ranging from one to four consecutive weeks. The camp is fee-based, though scholarships funded by private companies were available for low-income students, representing only 1.5% of total attendees.

The camp provides a real-life STEM education experience using the university's extensive resources, including teaching and research laboratories. The curriculum is divided into age groups, with younger students (9 to 13 years old) and older students (14 to 17 years old) offered specific courses. Some courses are shared between both groups, while others are exclusive to one group or the other.

Courses cover various subjects, such as website and mobile application development, video game development (2D and 3D), renewable energies, mechanical and electronic engineering, cybersecurity, artificial intelligence, robotics, drones, science in the kitchen, and smart city Internet of Things (IoT), among others. Each course spans five days, from Monday to Friday, with six hours of instruction daily, from 8:30 a.m. to 2:30 p.m. Senior students have a 45-minute break, while junior students have two 30-minute intervals.

The Tech Summer Camp courses at the School of Engineering emphasize a creative, enjoyable, and progressively enhancing learning environment, utilizing key teaching strategies tailored to foster collaboration, autonomy, and interdisciplinary learning among students. Classes are small, with activities structured around teamwork and project-based learning, spanning short- to long-term objectives. Projects often require knowledge across multiple STEM disciplines, and students have scheduled access to advanced laboratories for practical, hands-on experience. The courses are taught by young STEM instructors (mainly engineering students), including a significant representation of women, which helps break gender stereotypes and provides relatable mentorship to the students. This educational approach ensures personalized attention and adapts to individual learning styles, building a dynamic, supportive, and effective learning community.

### **METHODS**

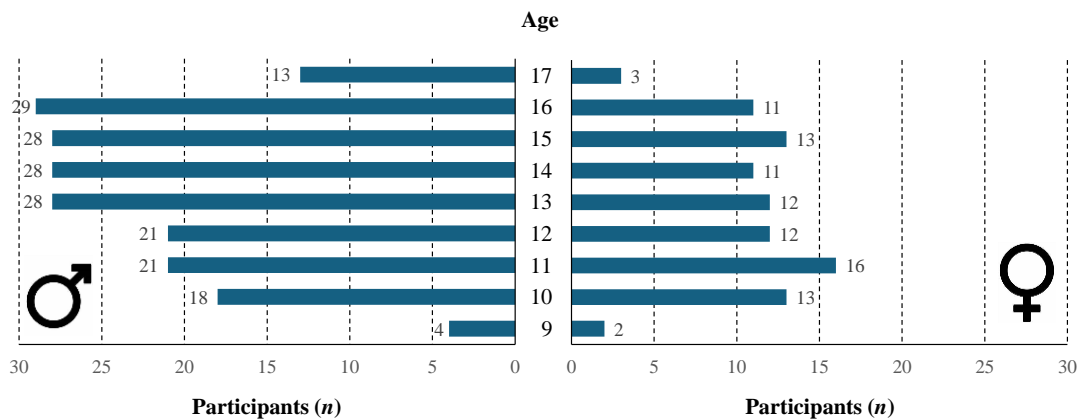
The research was conducted using an ex post facto design and a quantitative methodology. A questionnaire (Martín-Carrasquilla et al., 2023) called ACESTEM was used to measure attitudes toward science, technology, engineering, and mathematics in STEM education, aligned with the study objectives.

The aim was to measure not only the attitudes toward STEM education of the young people attending the Tech Summer Camp but also the change in these attitudes that occurred after attending the course, given that it was taught in an engineering school by instructors who were themselves STEM students. For this reason, the survey was administered to participants when they arrived at the camp and at the end of the course. Thus, the

design was strictly quantitative, based on PRE- and POST-administration of the attitude scale, and the analysis examined both changes in participants' responses and differences according to gender, age, and attitudinal profiles.

## Participants

The sample analyzed in this article consists of 283 surveys from students (190 boys and 93 girls) between 9 and 17 years old. These students attended an in-person Tech Summer Camp at a private mid-sized university in Madrid, Spain, during the summer of 2021. In terms of sex distribution, there were significantly fewer girls, constituting 33% (93 girls), compared to boys, who made up 67% (190 boys) of the participants. As illustrated in **Figure 1**, the sex disparity among attendees become more pronounced starting from age 12.



**Figure 1.** Distribution of the sample by age and sex

Each survey in the sample included responses to the ACESTEM questionnaire, administered twice: once on Monday at the start of the course (PRE) and again on Friday at the end of the week upon completion (POST). This repeated measure aimed to assess whether participation in the camp influenced any changes in the students' attitudes toward science, technology, engineering, and mathematics.

## Instruments

The ACESTEM scale, developed by Martín-Carrasquilla et al. (2023), measures attitudes toward science within STEM education. An exploratory factor analysis conducted on a sample of 408 students (210 girls and 198 boys) revealed a four-factor structure—Liking Science, Professional Interest in Science, Self-efficacy, and Perceived Usefulness of Science—with 24 items and a McDonald's Omega reliability coefficient of 0.909. A subsequent confirmatory factor analysis (CFA) on a different sample of 295 students (114 girls and 181 boys) upheld this four-factor structure and demonstrated satisfactory fit indices with a McDonald's Omega of 0.917, resulting in a refined scale of 21 items.

The finalized version of the questionnaire encompasses four dimensions:

- Liking STEM Studies: Reflects the pleasure or enjoyment of engaging in or learning about STEM-related activities.
- Professional Interest in STEM Studies: Indicates a desire to pursue further STEM education or a career in a STEM-related field.
- Perceived Usefulness of STEM Studies: Assesses the social significance attributed to STEM and scientists of both sexes.
- Self-efficacy: Measures beliefs and perceptions regarding one's capability to understand, learn, and engage with STEM subjects.

The questionnaire completed by the children consists of two parts: the first gathered socio-demographic data, and the second contained all the items related to the dimensions of the scale. The responses to these items were recorded using a five-point Likert scale, ranging from "Strongly Disagree" to "Strongly Agree".

## Procedure

The sampling procedure involved all course instructors at the Tech Summer Camp initiating the week by requesting participants to voluntarily complete the ACESTEM online questionnaire on Monday morning. At the week's end, instructors again asked participants to complete the questionnaire voluntarily. During the summer of 2021, the camp received 810 registrations over four weeks, 150 of whom attended the virtual camp and 660 the

in-person camp. Participants were asked to create a unique identifier using a combination of their birth date (day and month) and the last four digits of their mobile phone number to maintain anonymity while tracking changes in STEM attitudes. Those without a mobile phone used the code 0000.

A rigorous screening of the survey data ensured that only those who completed the PRE-survey at the beginning and the POST-survey at the end of the week were included in the analysis. Of the 660 registrations for the in-person camp, those from the first week (175) were discarded because the teachers forgot to distribute the PRE survey in class. After this, any cases in which the anonymized codes between the PRE and POST responses did not match were eliminated, as were responses from the same participant over several weeks. In such cases, only PRE- and POST-responses from the participants' first week were kept. Regardless of whether attendees participated in multiple courses across different weeks, only one PRE- and POST-response per individual was considered, corresponding to the week in which they participated for the first time. The analysis also differentiated responses using additional characteristics such as sex, course attended, and age when necessary. Ultimately, 283 valid samples were identified, each matching PRE- and POST-responses using the same code. The sex distribution within these valid samples was 67% boys and 33% girls, closely reflecting the overall camp participation rate of 35% female attendance that summer. We compared sex, age, and week between matched and unmatched respondents and found no substantial differences. Although unobserved factors cannot be entirely ruled out, the available evidence suggests limited attrition bias.

### **Ethical Considerations**

All participants in the Tech Summer Camp or their legal guardians completed a registration form upon arrival. This form provided detailed information about their rights under Regulation (EU) 2016/679 and Organic Law 3/2018 of 5 December concerning the Protection of Personal Data and Guarantee of Digital Rights. Additionally, participants could authorize the capture and distribution of their images, allowing the university to send them information about academic programs and to permit future contact for research purposes. This research would investigate whether participants opted for STEM-related studies in subsequent courses.

All participants completed both the PRE-and POST-surveys voluntarily and anonymously (research participants could not be identified at any time), ensuring their responses remained confidential and their privacy protected by security measures for accessing university accounts. Parents or legal guardians authorized their children's participation with full autonomy, and minors participated freely. There was no coercion or dependence on the researchers. The dignity of the research participants was always respected.

Although formal approval from the university's ethics committee was not obtained due to administrative circumstances, all ethical procedures were followed in compliance with the university's regulations at the time and the EU General Data Protection Regulation (GDPR). Parental consent was obtained for all minors involved, and data were collected anonymously, ensuring participant confidentiality. The study adhered to internationally recognized ethical standards for research involving human participants, including the Declaration of Helsinki.

### **Data Analysis**

To analyze the average levels of the variables across different groups defined by sex and to observe changes over time, Student's *t*-test was applied for both independent and related samples, as well as Welch's *t*-test for independent samples. Pearson's *r* test was also employed to examine the relationships between variables (Rovai et al, 2014). Concurrently, after observing deviations from normality in the distributions and primarily upon detecting issues of heteroscedasticity, non-parametric tests, including the Mann–Whitney *U*, Wilcoxon, and Spearman's  $\rho$  (rho) (Corder & Foreman, 2009), were utilized to confirm the findings of the parametric tests. Furthermore, effect size measurements were calculated using Cohen's *d* (Cohen, 1992), and rank-biserial correlation for nonparametric analyses (Kerby, 2014). All statistical analyses were conducted using Jamovi software version 1.6.23.0. Statistical significance was set at  $p < .05$ .

To verify the existence of profiles among participants, clustering was used, choosing the optimal number of clusters using the silhouette and sum-of-square metrics and using the elbow -method (Kaufman & Rousseeuw, 1990), and Sankey diagrams were used to analyze the evolution of students' STEM attitudes after the Tech Summer Camp experience.

## **RESULTS**

After the data for the study were collected, they were analyzed, and the results corresponding to the hypotheses are outlined below:

**Hypothesis 1:** Significant differences exist in attitudes toward STEM education and its dimensions based on sex.

Upon entering the Tech Summer Camp, girls scored higher across various dimensions and had a higher overall attitude toward STEM. However, these differences were minimal and not statistically significant ( $p > .05$ ), with effect sizes ( $d < 0.13$ ), as shown in **Table 1**. Upon completion of the summer program, the differences remained statistically insignificant ( $p > .05$ ), and the trend still slightly favored girls ( $d < 0.21$ ). However, there was an exception in the perceived usefulness dimension, where statistically significant differences were observed ( $t = 2.38, p < .05$ ), with an effect size of  $d = 0.30$ , which falls between low and moderate. In this dimension, the average score for girls was higher than for boys. All results were confirmed by nonparametric tests.

When analyzing the level of change between the PRE-and POST-test according to sex, no significant differences were found ( $p > .05; d = 0.32$ ) in the general attitude. The only dimension showing differences was the level of change in liking ( $d = 0.26$ ), with females exhibiting a higher level of change, as detailed in **Table 1**. Although the assumption of homogeneity of variances was met, the Mann–Whitney  $U$  test indicated that this result was not statistically significant ( $p > .05$ ).

**Table 1.** Differences in attitude toward STEM education areas by gender in 2021

	Group	Mean	SD	Student's $t$ Welch $t$ Mann Whitney $U$	Cohen's $d$ Rank-biserial correlation	Prev.	
PRE	STEM Attitude (TOTAL)	Female ( $n = 93$ )	3.98	0.570	0.397	0.0503	
		Male ( $n = 190$ )	3.95	0.560	0.395 8461	0.0501 0.0423	
	Liking	Female	4.10	0.720	0.411	0.0520	
		Male	4.06	0.738	0.415 8559	0.0679 0.0312	
	Professional Interest Pre	Female	3.77	0.845	-0.419	-0.0530	
		Male	3.81	0.834	-0.417 8481	-0.0529 0.0401	
	Self-efficacy	Female	3.73	0.701	0.831	0.1052	
		Male	3.65	0.712	0.836 8440	0.1055 0.0448	
	Usefulness	Female	4.28	0.608	0.957	0.1211	
		Male	4.21	0.524	0.909 7867	0.1179 0.1096	
POST	Attitude	Female	4.13	0.529	1.272	0.1611	
		Male	4.03	0.597	1.325 8018	0.1644 0.0877	
	Liking	Female	4.30	0.605	1.619 h	0.2051	
		Male	4.16	0.764	1.751 8059	0.2129 0.0831	
	Professional interest	Female	3.94	0.819	0.418	0.0529	
		Male	3.90	0.888	0.429 8618	0.0536 0.0194	
	Self-efficacy	Female	3.70	0.819	-0.125	-0.0158	
		Male	3.71	0.794	-0.123 8670	-0.0157 0.0135	
	Usefulness	Female	4.48	0.480	2.381* h	0.3015	
		Male	4.31	0.593	2.557* 7345*	0.3121 0.1643	Female
CHANGE	Attitude	Female	0.1500	0.281	1.82	0.230	
		Male	0.0779	0.328	1.92 7774	0.236 0.1154	
	Liking	Female	0.2007	0.466	2.08*	0.263	
		Male	0.0776	0.469	2.08* 7773	0.263 0.116	Female
	Professional interest	Female	0.1756	0.536	1.49	0.189	
		Male	0.0741	0.539	1.49 8115	0.189 0.077	
	Self-efficacy	Female	-	0.514	-1.14	-0.144	
		Male	0.0269		-1.21	-0.149	
	Usefulness	Female	0.2000	0.417	1.78	0.226	
		Male	0.0984	0.465	1.85 8059	0.230 0.083	

\* $p < .05$ ; \*\* $p < .01$ ; \*\*\*  $p < .001$ ; Prev = Prevalence: Highest Mean; PRE and POST= PRE-test; POST-test; CHANGE: difference between POST and PRE; h is a dimension where heteroscedasticity occurs.

**Hypothesis 2:** A statistically significant correlation exists between attitudes toward STEM education areas and dimensions and age, which varies by sex.

As shown in **Table 2**, upon entering the camp, the entire sample (without differentiating between males and females) displayed statistically significant correlations ( $p < .05$ ) between age and general attitude, liking, and interest, with all correlations being positive. For males and females, the relationship between age and interest was approximately  $r = .40$ , considered a moderate correlation and the strongest among the relationships analyzed. However, for females, the correlation between liking and age was not statistically significant ( $p > .05$ ).

**Table 2.** Pearson correlations (and rho Spearman) among the analyzed variables

Age	PRE	Liking Pre	Professional interest Pre	Self-efficacy Pre	Usefulness Pre
All (n = 283)	.234**	.197 *	.387 *	-.054	.042
	.224***	.166**	.407***	.073	.019
Male (n = 190)	.224**	.210**	.383***	-.075	.002
	.202**	.175*	.389***	-.111	-.041
Female (n = 93)	.270**	.185	.395***	.008	.134
	.278**	.161	.425***	.016	.063
	POST	Liking Post	Professional Interest Post	Self-efficacy Post	Usefulness Post
All	.171**	.179**	.331***	-.078	-.058
	.174**	.185**	.346***	.084	.082
Male	.162*	.211**	.330***	-.139	-.086
	.169*	.226**	.338***	-.152*	-.097
Female	.230*	.149	.350***	.039	.070
	.221*	.119	.377***	.052	.008
	CHANGE	Liking Change	Professional Interest Change	Self-efficacy Change	Usefulness Change
All	-.112	-.042	-.076	-.042	-.124*
	-.070	.004	-.072	-.004	-.086
Male	-.095	-.004	-.055	-.091	-.112
	-.050	.056	-.049	-.073	-.079
Female	-.0114	-.092	-.088	.051	-.115
	-.062	-.045	-.095	.137	-.055

\* $p < .05$ ; \*\* $p < .01$ ; \*\*\* $p < .001$

After the course, these relationships remained statistically significant ( $p < .05$ ) across the entire sample but decreased in magnitude. Similar to the start, at the course's end, the correlation of age with interest for both sexes was close to  $r = .40$ . Also consistent with the initial findings, the correlation between liking and age remained not statistically significant for females at the end of the course. It is noted that there was no statistically significant relationship between age and the level of change ( $p > .05$ ); however, the trend was negative, indicating that older participants showed less change. This pattern held for both boys and girls.

When analyzing the relationship of changes in dimensions with age, it was only significant for perceived usefulness, and this relationship was negative ( $p < .05$ ,  $r = -.124$ ), suggesting that younger individuals exhibited more change in perceived usefulness than their older counterparts.

The results were confirmed by Spearman's nonparametric rho test in all cases.

**Hypothesis 3:** Participation in the Tech Summer Camp program enhances overall attitudes toward STEM and improves scores across the four dimensions of the scale.

The data analysis presented in **Table 3** revealed statistically significant improvements in the overall STEM attitude when comparing the PRE- and POST-assessments ( $p < .001$ ). The mean scores were higher in the POST-assessment, and the magnitude of change was considered low to moderate (Cohen, 1992), with a Cohen's  $d$  value of 0.32. Upon examining the level of change within the different dimensions of the scale, statistically significant differences were noted in all dimensions except for self-efficacy ( $p > .05$ ). The greatest change was observed in the perceived usefulness dimension, with a Cohen's  $d$  of 0.29, indicating that participants notably altered their perceptions in this area. All results obtained with Student's  $t$ -tests were confirmed by the nonparametric Wilcoxon  $W$  test.

**Table 3.** Student's *t*-test to compare means according to time of application

n = 283	Group	Mean	SD	Student's <i>t</i> <i>W</i> Wilcoxon	Cohen's <i>d</i> Biserial Rank correlation	Prev.
STEM Attitude (TOTAL)	Post	4.07	0.576	5.43*** 9646***	0.323 0.404	Post
	Pre	3.96	0.557			
Liking	Post	4.20	0.718	4.216*** 8323***	0.2511 0.345	Post
	Pre	4.09	0.714			
Professional Interest	Post	3.91	0.865	3.350*** 9102***	0.1995 0.265	Post
	Pre	3.80	0.828			
Self-efficacy	Post	3.71	0.801	0.856 10639	0.0510 0.100	
	Pre	3.68	0.709			
Usefulness	Post	4.37	0.563	4.908*** 6216***	0.2922 0.400	Post
	Pre	4.23	0.554			

\* $p < .05$ ; \*\* $p < .01$ ; \*\*\* $p < .001$ ; Prev = Prevalence: Highest Mean

**Hypothesis 4:** There are different profiles of students according to their scores on the dimensions of the scale.

Clustering was applied to analyze this hypothesis, allowing elements of the sample that behaved similarly in the dimensions analyzed to be grouped. In this study, participants with similar ratings of the four dimensions in the survey were grouped.

The first step was to decide on the optimal number of clusters, the lowest number that allowed for good grouping by similar profiles. According to the silhouette and sum-of-square metrics and using the elbow method (Kaufman & Rousseeuw, 1990), the optimal number of clusters for this dataset was between three and five. Thus, a k-means clustering algorithm where  $k = 3$  was carried out to prioritize interpretability.

**Table 4** presents each cluster's scaled centroids or average values, rounded to two decimals (PRE survey). The centroid of a cluster is the center of that group, calculated as the arithmetic mean of all points in that cluster.

**Table 4.** Centroids for each cluster at each dimension (PRE survey)

	Liking	Professional interest	Self-efficacy	Usefulness
Cluster High (C0)	0.91	0.90	0.77	0.87
Cluster Low (C1)	0.50	0.43	0.49	0.66
Cluster Medium (C2)	0.76	0.65	0.65	0.82

The hypothesis put forward in this study was fulfilled since the results of the k-means clustering analysis (**Table 4**) revealed three distinct clusters of students with varying ACESTEM scores:

- Cluster High (C0) consisted mostly of students with high ACESTEM scores across all dimensions.
- Cluster Low (C1) predominantly comprised students with low ACESTEM scores in all dimensions.
- Cluster Medium (C2) was composed mainly of students with medium ACESTEM scores in all dimensions.

It is possible to see in **Table 5** that the age and sex distribution of each cluster were calculated with the PRE- and POST-survey answers to characterize the clusters. Analyzing this table, we can see the impact of the Tech Summer Camp. In the PRE, the most numerous cluster was Cluster Medium (126 students) while in the POST the most numerous cluster was Cluster High (127 students). The least numerous cluster in PRE and POST was Cluster Low (53 and 43 students respectively).

**Table 5.** Age and sex distribution of each cluster: Number (percentage)

	PRE					POST				
	Total	AGE		SEX		Total	AGE		SEX	
		Junior*	Senior*	Male	Female		Junior	Senior	Male	Female
C0 – High	104	31 (29.8%)	73 (70.2%)	64 (61.5%)	40 (38.5%)	127	44 (34.6%)	83 (65.4%)	78 (61.4%)	49 (38.6%)
C1 – Low	53	29 (54.7%)	24 (45.3%)	35 (66.0%)	18 (34.0%)	43	21 (48.8%)	22 (51.2%)	29 (67.4%)	14 (32.6%)
C2 – Medium	126	61 (48.4%)	65 (51.6%)	91 (72.2%)	35 (27.8%)	113	56 (49.6%)	57 (50.4%)	83 (73.5%)	30 (26.5%)

\* Junior: 9 to 13 years old, Senior: 14 to 17 years old; PRE and POST = Pre-test; Post-test

When analyzing the clusters by age in **Table 5**, the High Cluster (C0) predominantly consists of seniors, both in the PRE (70.2%) and POST (65.4%) responses, with an increase in the number of seniors in the POST responses. The Low Cluster was the smallest, and its numbers decreased from PRE to POST. This cluster was also more balanced; in the PRE responses, 54.7% are juniors, and 45.3% are seniors, while in the POST responses, seniors make up the majority with 51.2%, and juniors account for 49.6%. It is important to note that in the overall sample of 283 students, 42.8% were juniors, and 57.2% were seniors.

When analyzing the clusters according to sex in **Table 5**, in all clusters, both PRE and POST, the highest percentage was male, which is expected given that 67.1% of the entire survey sample were male and 32.9% were female. However, as shown in **Table 6**, women were primarily distributed in the High Cluster in both PRE (43%) and POST (52.7%) responses or the Medium Cluster (37.6% in PRE and 32.3% in POST). Women in the Low Cluster were a minority (19.4% in PRE and 15.1% in POST). Conversely, males were mainly found in the Medium Cluster in the PRE (47.9%) and POST (43.7%) responses, although their representation in the High Cluster increased from 33.7% in PRE to 41.1% in POST. The Low Cluster had the fewest males.

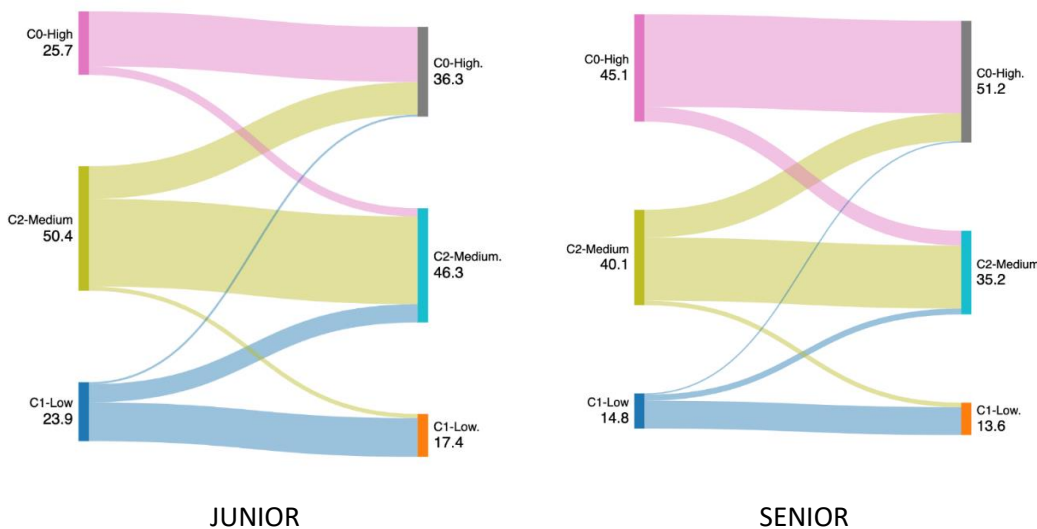
**Table 6.** Probability of belonging to a cluster as a function of age and sex

	AGE				SEX			
	PRE		POST		PRE		POST	
	Junior	Senior	Junior	Senior	Male	Female	Male	Female
C0 – High	25.7%	45.1%	36.3%	51.2%	33.7%	43.0%	41.1%	52.6%
C1 – Low	23.9%	14.8%	17.4%	13.6%	18.4%	19.4%	15.3%	15.1%
C2 – Medium	50.4%	40.1%	46.3%	35.2%	47.9%	37.6%	43.6%	32.3%

PRE and POST = Pre-test; Post-test

A Sankey diagram was used to analyze the evolution of students' STEM attitudes after the Tech Summer Camp experience. The Sankey diagram is a type of flowchart that allows visualization of flows and their quantities in proportion to each other between different nodes. The Sankey diagram of this study shows the transfer of students between clusters from PRE to POST, categorized by age and sex, providing an intuitive visualization of the effect of the camp on attitudes toward STEM studies. The order of the clusters ranges from higher attitudes (High Cluster) to lower attitudes (Low Cluster), arranged from top to bottom.

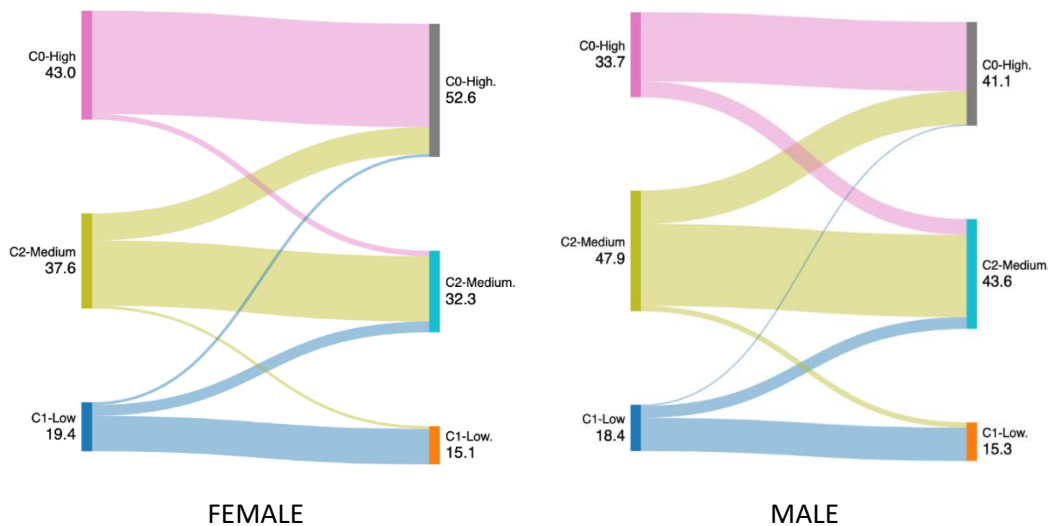
**Figure 2** illustrates the age-based evolution from PRE to POST. The predominant trend for both juniors and seniors was upward, indicating that the camp experience enhanced attitudes toward STEM. There were a few instances where students' attitudes toward STEM decreased due to the camp experience, albeit rare. However, seniors consistently exhibited higher STEM attitudes than juniors before and after the camp experience.



**Figure 2.** Sankey diagram of PRE–POST cluster flow by junior and senior students

**Note:** For further details on the interpretation of the data in **Figure 2**, please refer to the Supplementary Material.

**Figure 3** depicts the evolution based on sex. While there was an overall upward trend in both male and female cases, indicating a positive shift in attitudes toward STEM, there was also a slight downward trend in females and a more noticeable shift from the High to Medium Cluster in males. Notably, attitudes toward STEM were generally higher among females.



**Figure 3.** Sankey diagram of PRE–POST cluster flow by female and male students

**Note:** For further details on the interpretation of the data in [Figure 3](#), please refer to the Supplementary Material.

## DISCUSSION

Various studies recognize that attitudes play a crucial role in developing interest and engagement in STEM-related issues, suggesting that enhancing motivation and interest in STEM education can increase the likelihood of students (especially female students) considering a future STEM career (Denessen et al., 2015). Consequently, this study explored whether attitudes toward STEM education significantly varied based on sex, age, and educational stage and sought to identify patterns of student attitudes toward STEM fields. The hypotheses formulated will be discussed, considering the results obtained.

**First Hypothesis:** This hypothesis posited that there would be statistically significant sex differences in attitudes toward STEM education and its dimensions. The analyses conducted in this study revealed no significant differences in attitudes by sex; however, there was a tendency to favor girls. This partially aligns with recent findings from informal STEM programs, which report that girls benefit equally or even more than boys when interventions emphasize collaboration and the social impact of STEM fields (Roberts et al., 2018; Türkoğuz & Kayalar, 2021; Yıldız & Ecevit, 2024; Xia et al., 2024). Research on sex in this area has shown mixed results; some studies suggest boys generally display more positive attitudes toward science (DeWitt & Archer, 2015; Tytler, 2014), while others find more favorable attitudes among girls (Chetcuti & Kioko, 2012), and still others report no observable differences (Jerrim & Schoon, 2014; Toma & Greca, 2018).

Interestingly, after the course, the girls' mean scores exceeded those of boys, specifically in the dimension of perceived usefulness. Sáinz and Müller (2017) note that girls often value achieving goals related to caregiving and emotional expression more than boys, who prioritize power and decision-making. This result may explain why the usefulness dimension, particularly when linked to the socioemotional aspects of engineering presented at the camp, showed improvement among girls. Similar to other studies, many girls engage with STEM subjects when the context is realistically aligned with humanitarian or social relevance (McNees, 2004; Weber & Custer, 2005). This underscores the importance of designing informal learning experiences that highlight the societal relevance of STEM disciplines to engage female students effectively (Papadakis et al., 2018).

**Second Hypothesis:** Initially, there were statistically significant positive correlations between age, general attitude toward STEM education, and liking and interest. By the end of the camp, these relationships diminished in strength. The change in attitudes related to age remained significant only in the usefulness dimension, and notably, it was negatively correlated. Thus, the youngest students exhibited the most significant changes in their perception of STEM's usefulness. This finding reinforces the idea that early interventions may have a particularly strong effect on students whose attitudes are still forming (Xia et al., 2024).

The data from this study challenge established scientific literature (Gibson & Chase, 2002; Pell & Jarvis, 2001), which suggests that as students age, their attitudes toward STEM education shift toward disinterest. Contrary to this, Archer et al. (2013) found that while students' attitudes toward science are generally positive up to about age 10, they tend to decline during adolescence. However, the Tech Summer Camp findings reported in this article indicate that attitudes toward STEM education improved with age. In informal education settings, such as this camp, children's interests are prioritized (Anand & Dogan, 2021), and it is noteworthy that older

students applied more criteria to select courses that aligned with their interests. Furthermore, as boys aged, their desire to attend the camp increased, and they also tended to have more knowledge that connected science with technology and engineering. Older boys were more autonomous and capable of making decisions, allowing them more control over their educational choices, including attending the camp. As Vandell et al. (2005) note, this voluntary participation underscores students' genuine interest and intrinsic motivation to engage in STEM activities, fostering a more inclusive and responsive learning environment. Lent et al. (2000) suggest that as adolescents approach adulthood, they are more likely to develop interests and feel competent in these fields, which may influence their decision to attend a tech summer camp. Moreover, involvement in camp activities enhanced interest in science, technology, engineering, and mathematics. According to Dabney et al. (2012), participants not only viewed themselves as capable in these fields but also have positive expectations about the outcomes, seeing the potential for fulfilling results from engaging in these areas, which may have motivated them to choose to attend the camp and pursue STEM-related education.

However, contrary to the assertions made by Dabney et al. (2012) and Price et al. (2018), no significant increase was observed in girls compared to boys, which can be attributed to the higher-than-usual ACESTEM attitudes among girls who attended the camp.

Third Hypothesis. There was an observable increase in positive attitudes toward STEM education from the PRE- to POST-camp assessment, except in the dimension of self-efficacy, which remained unchanged. The most significant changes were seen in general attitude and perceived usefulness. This result supports the findings of Mohr-Schroeder et al. (2014) and Xia et al. (2024), who argue that authentic learning experiences provided by innovative camp programs enable students to establish valuable connections between different STEM areas, enhancing their future interest in STEM studies. This scenario benefits secondary education, as Barker et al. (2014) and Sha et al. (2015) demonstrate. Camp programs offer a rich, hands-on environment that improves students' attitudes toward STEM education, fostering creativity, collaboration, and critical thinking while increasing interest in STEM subjects. These programs are crucial in cultivating a long-term interest in these fields and promoting academic and career success among young people.

Although significant improvements were observed across all attitudinal dimensions except self-efficacy, this lack of change is consistent with previous research. Self-efficacy is a relatively stable construct that does not tend to shift substantially during short interventions, as its development typically requires prolonged mastery experiences and individualized feedback. In the context of this Tech Summer Camp, most older students attended voluntarily, suggesting profiles already characterized by strong interest in STEM and, likely, relatively high initial levels of self-efficacy, which may have produced a ceiling effect. Furthermore, the program's design appears more conducive to enhancing interest and perceived usefulness than to strengthening personal perceptions of competence, which generally require clearly identifiable individual achievements. Taken together, these factors help explain why self-efficacy remained stable while the other attitudinal dimensions showed significant improvement.

Fourth Hypothesis. Three distinct attitude profiles were confirmed: high, medium, and low. The least prevalent profile was the low one, indicating that most participants arrived at the camp with either high or medium attitudes toward STEM. Given that the camp is a summer activity, participants typically chose based on their interests. Seniors predominantly belonged to the high cluster, while juniors were mostly in the medium cluster. This scenario is reasonable as younger participants often engage in summer activities due to the need for supervision while parents work, whereas seniors, despite having more independence, opt for the camp due to their strong STEM attitudes. Across all age groups, participation in the on-campus experience generally enhanced attitudes toward science, with juniors showing a greater improvement. This result may be because juniors often attended at their parents' initiative rather than by their own choice.

Furthermore, the prevalence of the low cluster was similar between males and females. However, females are more represented in the high cluster, whereas males tended toward the medium cluster, contrary to the samples of most studies related to attitudes toward STEM education, where female attitudes were typically lower. Overall, the Tech Summer Camp experience positively influenced the attitudes of both sexes, though a notable proportion remained in the middle cluster. Nonetheless, the fact that students in the low-attitude profile also improved, particularly younger ones, highlights the potential of these programs to engage learners who might otherwise feel disconnected from STEM (Roberts et al., 2018).

## **CONCLUSION**

Based on the results obtained from the Tech Summer Camp, several important educational implications can be drawn. Firstly, while no significant sex differences were observed in attitudes toward STEM education, there was a slight trend favoring girls, particularly in the perceived usefulness dimension. This observation suggests that programs emphasizing the social and humanitarian relevance of STEM fields can be especially effective in increasing girls' interest in STEM.

Regarding age, a negative correlation was found in the usefulness dimension, indicating that younger students experienced greater changes in their perception of STEM's usefulness. These findings are valuable for designing intervention programs that foster interest in STEM from early education, capitalizing on the greater flexibility of attitudes in younger students.

Another relevant finding is that, although overall attitudes toward STEM improved after the camp, self-efficacy showed no significant changes. This result suggests that activities focusing on problem-solving and skill development should be implemented to strengthen students' confidence in their STEM abilities and achieve a deeper impact on this dimension.

Finally, three attitude profiles toward STEM were identified (high, medium, and low), with the low profile being the least prevalent. This pattern highlights that students who participate in activities like the summer camp generally have relatively positive attitudes toward STEM. However, the presence of these distinct profiles indicates the importance of differentiated approaches to engagement: while many students are predisposed to positive attitudes, others may require additional support to develop a sense of belonging and competence in STEM contexts.

One limitation of the study is the sample used, as the students came from a summer technology camp organized at an engineering school, which restricts the generalizability of the results to broader populations. Furthermore, the intervention was limited to a few weeks in a single summer, so the findings only reflect short-term changes in attitudes toward STEM, without allowing for an assessment of their sustainability over time. Although the ACESTEM instrument is suitable for assessing attitudes toward STEM, its application in a short extracurricular program may be conditioned by contextual factors, such as the voluntary nature of participation and the informal learning environment.

Another limitation related to the sample is its lack of socioeconomic diversity. Although the participants came from different educational centers, they all had the necessary resources to attend the camp, which could skew the results toward students with greater family support. Furthermore, although gender balance was ensured, other relevant socioeconomic variables, such as parental occupation or work dedication, which could have influenced attitudes toward STEM, were not considered.

Among the strengths, it is noteworthy that the results differ from those typically found in school contexts: female participants showed more positive attitudes toward STEM from the start of the camp, in contrast to what has been reported in other studies. Furthermore, the Tech Summer Camp program offers authentic learning experiences in multiple STEM areas, allowing students to link their interests to practical, real-world applications.

Future research should expand the sample to include students from more diverse backgrounds, both in formal and extracurricular programs, and validate the instruments in these different settings. It would also be relevant to analyze the long-term impact of similar initiatives in order to assess the sustainability of the interest generated and the development of STEM skills. Finally, it is worth exploring strategies that strengthen students' self-efficacy, as this dimension did not show significant changes in the present study.

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## Ethical Statement

All participants at the Tech Summer Camp, or their legal guardians, completed a registration form upon arrival. This form provided detailed information about their rights under Regulation (EU) 2016/679 and Organic Law 3/2018 of 5 December concerning the Protection of Personal Data and Guarantee of Digital Rights.

## Competing Interests

The authors have no conflict of interest to declare.

## Author Contributions

*Yolanda González-Arechavala* – conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, supervision, validation, visualization, writing – original draft, writing – review & editing; *Olga Martín-Carrasquilla* – conceptualization, formal analysis, investigation, methodology, project administration, resources, supervision, validation, visualization, writing – original draft, writing – review &

editing; Isabel Muñoz-San Roque – conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, supervision, validation, visualization, writing – original draft, writing – review & editing, María José Medina-Hernández - Data curation, Formal analysis, Methodology, Visualization, Writing – original draft.

## Artificial Intelligence (AI) Disclosure

During the preparation of this work, the authors used ChatGPT to assist in the translation process during the revision process. After using this tool/service, they reviewed and edited the content as needed and assume full responsibility for the content of the published article.

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## SUPPLEMENTARY MATERIAL: SANKEY DIAGRAM

### Sankey Diagrams: Origin, Development, and Application

Sankey diagrams originated in the late 19th century and are named after Irish Captain Matthew Henry Phineas Riall Sankey, who first used them in 1898 to illustrate the energy efficiency of a steam engine. In his graphic representation, Sankey used arrows whose thickness was proportional to the amount of energy transferred, allowing for a clear visualization of the energy system's losses and gains.

Since then, this form of visualization has expanded and been refined, being adopted in various scientific, technical, and industrial fields. A classic reference on its historical development is the work of Schmidt (2008), who analyzed the evolution of the diagram from its initial application in mechanical engineering to its contemporary use in resource management, sustainability, and the analysis of material and energy flows.

### Concept and Analytical Usefulness

A Sankey diagram is a visual representation of flows—of energy, materials, money, or resources—in which the width of the arrows or lines is proportional to the magnitude of the flow represented. This principle of proportionality makes the diagram a particularly effective tool for visualizing the distribution, transformation, and loss of resources within a system.

Thanks to their capacity for visual synthesis, Sankey diagrams allow us to identify relationships, proportions, and imbalances that might go unnoticed in tabular or numerical representations. For this reason, their use has spread to fields such as engineering, economics, sustainability, environmental management, and complex data visualization (Schmidt, 2008). In recent years, their application has also expanded to the social sciences, education, and digital humanities, where their potential as a tool for interpretive analysis and scientific communication is increasingly recognized.

### Application in the Present Study

In the context of the present study, the Sankey diagram was used to visualize changes in attitudes toward STEM (Science, Technology, Engineering, and Mathematics) studies before and after the Tech Summer Camp. The diagram represents the transfer of students between different clusters, which group high, medium, and low levels of attitude toward STEM disciplines, from the PRE phase (the start of the program) to the POST phase (the end of the camp), categorizing the information by age and gender.

This representation provides a clear and intuitive visualization of the educational program's effect, showing how some students transitioned from clusters with less favorable attitudes to others with more positive attitudes after participating in the camp. The clusters are presented vertically, from the “High Cluster” (most favorable attitudes) to the “Low Cluster” (least favorable attitudes), making it easy to track the direction and magnitude of the changes observed.

The use of the Sankey diagram in this context allows for a concise and visual interpretation of the evolution of the groups studied, highlighting patterns of change and general trends that complement the quantitative statistical analysis. Consequently, this tool contributes to a deeper understanding of the educational impact of the Tech Summer Camp and to a more effective communication of the results obtained.

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