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Breaking Barriers to Unleash STEM Futures by Empowering Girls Through Mentorship in Summer Camps

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Abstract: The underrepresentation of women in science fields limits their potential in solving current global challenges. As a lighthouse to close this gender gap, role models are crucial for girls to build their science identity, even in their early years. Therefore, we describe a combined mentoring intervention taking place during scientific summer camps for girls. In these camps, young girls lived for a week undertaking an intensive program conducting cutting-edge research and in close contact with female mentors and other girls within a community of practice. They were mentored in small groups, but there were also chances for participating in talks, entrepreneurial workshops, and social activities all together. On the last day, the girls presented their research results, sharing their perceptions about the camp and their concerns regarding the role of women in science in an open-door final conference. By means of a mixed-method assessment conceptualization, the aim of this study is to provide evidence supporting the impact of non-formal education settings to effectively enhance girls' science potential by using inspiring female scientists acting as mentors and role models. Furthermore, the study intends to shed light on what were regarded to be the key factors of the camp design that had such an impact on the participating girls. In particular, the findings demonstrate that the participating girls improved their attitudes towards STEM after the camp, highlighting how role models, in several roles, were key to empowering them in science through the building of a gender-responsive and inclusive community. Finally, the paper also discusses the key elements of the intervention based on the lessons learned and its transferability to different educational contexts in order to expand the beneficial effects of a gender-sensitive science education to build an inclusive future.

Keywords: mentorship; role models; STEM; gender gap; scientific summer camps

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1. Introduction

Although around half of Europe's population are women, there exists a very low proportion of women involved in STEM (Science, Technology, Engineering, Mathematics) and ICT (Information and Communication Technology) fields, which has provoked the establishment of a growing gender gap in these sectors (European Commission: Directorate-General for Communications Networks, Content and Technology, 2018). As active and committed educators and citizens, it is a requirement to be sensitized and more responsible for gender-equitable education. To this end, we should consider crucial issues such as archaic-rooted stereotypes, girls' relationships with science and science learning, the worrying drop-out rates of girls in STEM careers, and the underrepresentation of women in some STEM fields (Chavatzia, 2017; González-Pérez et al., 2022), with the consequent loss of inclusive perspectives and innovation capacity in our societies. Recent history has shown how the underrepresentation of the female perspective in the development of particular scientific advances can lead to biased and unsatisfactory solutions.

However, many recent reports have indicated a decline in STEM vocations among students (Archer et al., 2012; OECD, 2017; Jeffries et al., 2020), particularly among girls (Wade-Jaimes & Schwartz, 2019; Steegh et al., 2021). Despite having an interest in STEM fields or perceiving themselves as capable in science, many students lack the aspiration to pursue scientific careers (Jenkins & Nelson, 2005; Scholes & Stahl, 2022), with this trend being especially prominent among underrepresented groups in the field, such as women (Buccheri et al., 2011; Beckmann, 2021). This phenomenon is closely related to the way scientific identity is constructed (Vincent-Ruz & Schunn, 2018).

Scientific identity is a complex concept that has gained increasing relevance in science education research over the past 15 years (Carlone & Johnson, 2007; Lee, 2012; Rahm & Moore, 2016; Kim & Sinatra, 2018). It is generally understood as the way individuals perceive themselves as "science people" and how they are recognized by others in this regard. Moreover, it is not a fixed or singular construct; rather, it is a dynamic, flexible, relational, social, and context-dependent one (McDonald et al., 2019; Godwin et al., 2020; Dou & Cian, 2022), requiring an intersectional view to fully understand it (Avraamidou, 2020; Heeg & Avraamidou, 2021).

The diagnosis of scientific identity varies depending on whether measurement tools emphasize its value (centrality) or self-perception (typicality) (McDonald et al., 2019). For example, Young et al. (2013) developed a scale to assess the importance of science in a person's self-concept, directly valuing it as part of the person's identity. In contrast, other tools focus more on typicality, such as the work by Hazari et al. (2013), which asks whether a person considers themselves part of particular disciplines such as biology, chemistry, or physics—questions that assess typicality rather than the value of science, since participants must determine whether they align with the characteristics of that profile. Nadelson et al. (2015) emphasized that measuring professional identity requires asking questions that explore how well students' skills, knowledge, and attributes align with those of a "professionally identified" person. Starr (2018) suggested that when stereotypes about a group do not match an individual's self-concept, exploring typicality becomes even more relevant, as in the case of female students if they hold the stereotype that science is for men.

Following this reasoning, Carlone and Johnson (2007) argued that students from underrepresented groups in science are particularly vulnerable to exclusion or lack of recognition from the scientific community. In their qualitative analysis of scientific identity, they proposed that individuals with a strong scientific identity should feel (1) competent in acquiring the necessary knowledge in science, (2) confident in demonstrating their scientific skills in public settings, and (3) recognized by others, especially within the scientific community, for their competence and performance. Similarly, Herrera et al. (2012) suggested that competence, performance, and recognition interact with people's social and cultural identities, meaning that scientific identity is shaped both by perceived external recognition and by how science integrates into one's sociocultural context. Therefore, the scope of science education extends beyond acquiring knowledge and encompasses the construction of a scientific culture that students must integrate as part of their identity. It is crucial to explore how students connect with or distance themselves from this culture.

Encouraging scientific vocations, particularly among girls, represents a challenge that involves questioning how to foster inclusive scientific identities. In this regard, Finson (2010) concluded that the prevailing perceptions of science and scientists, as seen by students, are limiting. The stereotypical image of a scientist often includes being white, a man, working alone in a laboratory, and using test tubes. Holding onto these images of scientists may make it difficult for students to see themselves represented in the field (Archer et al., 2010; Zhai et al., 2014). Bian et al. (2017) raised concerns by reporting that girls begin to perceive themselves as less intelligent than boys as early as age 6. This, coupled with the view that science is reserved for privileged minds (Shimwell et al., 2021), can lead girls to dismiss science as a career option. Therefore, it is crucial to approach science education from a gender perspective, even at an early age (Speldewinde & Campbell, 2021; Castro-Zubizarreta & del Río, 2022; Mérida-Serrano et al., 2023).

Several factors contribute to this systemic gap. One significant factor is the lack of female role models in STEM fields, particularly in prominent positions in science and technology, which may discourage girls from pursuing science (Batty & Reilly, 2022; Costello et al., 2023). Additionally, ingrained societal stereotypes associate men with scientific and technological skills, while women are expected to focus on fields such as art or the social sciences (Cheryan et al., 2015), and gendered images of science are also often reinforced by teaching materials and resources (Kerkhoven et al., 2016). As such, recognizing the role of women in science is essential for inspiring more girls to pursue STEM careers (Damschen et al., 2005; Bloodhart et al., 2020; Hughes et al., 2021; Ladachart et al., 2024). Moreover, Esteban (2021) highlights that the lack of opportunities and resources for women interested in STEM represents a strong barrier to their engagement and development in the field. This includes limited access to educational programs and specialized training in science and technology, as well as a shortage of support and mentoring throughout their educational and professional journeys.

To face this issue, increasing efforts are being invested towards initiatives actively promoting scientific vocations among girls, including their families and the community in general terms, as indicated by Chavatzia (2017). In this line, STEAM education, which entails approaches integrating science, technology, engineering, humanities in a broad sense (arts), and mathematics, has emerged as an interdisciplinary strategy to enhance science education through a holistic view that connects science and humanities as a way to understand a complex reality through the development of transversal skills (Escalona et al., 2018). Therefore, STEAM education is nourished by inquiry-based learning, real contexts, and the promotion of critical thinking (Riley, 2012), as STEM education (Aguilera & Ortiz-Revilla, 2021), while accommodating the humanities view to enlarge its scope and integration aims (Taylor, 2016). This aligns with the recommendations from successful educational programs developed in the 1980s aimed at improving science education for women, which emphasized active learning strategies and hands-on instruction (Cole & Griffin, 1987). Studies have shown that girls respond positively to STEM approaches when they are linked to real-life applications and authentic contexts (Chapman & Vivian, 2016), inquiry-based learning (Patrick et al., 2009), or socially relevant topics connected to science (Sadler et al., 2007). However, it remains unclear whether these methodologies benefit only girls or other gender identities (Baker, 2003; Patrick et al., 2009; Lauer et al., 2013).

Since the term was coined at the Rhode Island School of Design (Yakman & Lee, 2012), integrating the "A" into STEM has been justified primarily by the need to foster skills such as creativity, innovation, and critical thinking—skills essential for both science and solving complex problems in a dynamic world (Riley, 2012). This argument sparked debate by suggesting that STEM disciplines lacked such capacities, while some reviewed interventions actually do so (Aguilera & Ortiz-Revilla, 2021). Moreover, incorporating the arts was expected to make traditionally STEM-related fields more attractive to a wider diversity of students, especially girls, who have historically been underrepresented in these fields (Castro-Zubizarreta et al., 2024). However, this may reflect stereotypical views, with the risk of reinforcing them. Providing a more holistic education suitable to face current global challenges and real-world problems is another of the given reasons for integrating the arts or humanities, although other authors argue that this is already present in STEM education itself (Aguilera et al., 2021).

In this regard, one might question the role of the "A" in STEAM approaches, as it has been interpreted in various ways. Some hold a narrow view, equating it with teaching visual arts, while others have expanded its scope to include disciplines such as the performing arts, digital arts, crafts, and even humanities or environmental studies (Perignat & Katz-Buonincontro, 2019; Aguilera & Vílchez-González, 2024). Beyond arts and crafts, the STEAM approach is often associated with emerging digital technologies, such as robotics or programming, though it remains debatable to what extent these approaches involve true disciplinary integration (Couso, 2017) or promote skills such as design thinking, which are becoming increasingly popular in classrooms, including early childhood education (Castro-Zubizarreta et al., 2024). There are also varying opinions in the literature on whether STEAM approaches represent an innovation over STEM or if they truly offer something new in the field of science education (Aguilera & Vílchez-González, 2024). The conceptualization of STEM/STEAM approaches is still evolving, and there are diverse perspectives on how they should be implemented and operationalized to demonstrate their potential as an effective strategy to improve science education (Miller & Knezek, 2013; Ortiz-Revilla et al., 2018, 2021).

In the particular case of this work, the designed intervention (i.e., the GEM scientific summer camp) might be considered a STEAM approach due to the integration of authentic research projects mentored by female scientists from a variety of fields of knowledge. In addition, all the activities conducted within the GEM camp shared a common focus on problem-solving from a social perspective (improving people's lives) and are aimed at fostering creativity, communication, collaboration, and entrepreneurial and digital skills in the participating girls. From this perspective, the approach applied within the GEM camp is very well aligned with current views of STEAM education.

In recent years, several educational initiatives have been implemented to address the gender gap in science. One effective approach has been exposing girls to female role models in science, which helps recognize the significant contributions of women in the field and aims to close the existing gender gap (González-Pérez et al., 2020). Mentoring, in this context, involves connecting girls with supporting figures to provide assistance for developing their science identity (National Academies of Sciences, Engineering, and Medicine, 2020; Guenaga et al., 2022). This not only encourages girls' entry into science but also contributes to their retention in the field (Drury et al., 2011).

While some mentoring effects can be observed immediately after a program ends, tracking long-term impact is necessary for assessing true efficacy. Wolf and Brenning (2023) proposed a logical model for evaluating mentoring experiences, focusing on short-term outcomes, such as students' acceptance and satisfaction with the program, as well as mentoring outcomes aimed at improving STEM career choices by offering support, reducing dropout risk, and increasing study satisfaction. In addition, they argue that tracking long-term effects is essential to understanding the true impact of the intervention, including the completion of STEM studies and successful entry into a STEM profession, or alternatively, by measuring expressed intentions.

In spite of the promising potential of mentoring, traditional mentoring models, such as those institutionally applied to higher education programs, tend to be less successful for women in terms of retention, career success, and self-reported career satisfaction, as reported in the review of Beck et al. (2022) and as discussed in the work of Nkrumah and Scott (2022). This phenomenon was referred to by Ziegler et al. (2021) as the "mentoring paradox". In contrast, models that foster a mentoring context among their collective participants (Mondisa et al., 2021) and that are specifically designed to match mentors with students and women in the profession have proven more effective in supporting their participation and achievement (Beck et al., 2022). Additionally, research suggests that combining academic, social, and support components can address the unique needs of underrepresented students in STEM (Nkrumah & Scott, 2022), such as girls, which are the target of the present study. In this regard, Stelter et al. (2021) highlight that the social and emotional support offered through mentorship is considered as a crucial factor contributing to positive outcomes for young people.

Close relationships with mentors during STEM-focused activities enhance mentees' scientific identity and self-efficacy in conducting research, which fosters greater interest and commitment to a STEM career (Stelter et al., 2021; Stoeger et al., 2021). These mentoring experiences in STEM can actively promote self-efficacy through the mentor-mentee relationship, but to be effective, mentors need proper training on how to nurture mentees' self-efficacy. In fact, Stelter et al. (2021) found that while mentors in STEM programs often have extensive knowledge in a specific STEM field, they may lack the skills, attitudes, and knowledge needed to establish an effective mentoring relationship with a young person. Thus, mentor training can enhance their understanding of their roles, clarify expectations, and improve the effectiveness of the mentoring process. In fact, well-prepared mentors can serve as effective role models for girls in STEM, as reported in various mentoring interventions (Stoeger et al., 2023; De Gioannis et al., 2023), with female mentors having an even greater impact, especially before leaving the college stage (Merritt et al., 2021; Germann et al., 2024).

In this context, an important question remains: who constitutes a role model for girls in science (Gladstone & Cimpian, 2021), and how is this image constructed both in the girls' perception and in the female scientists who could potentially serve as role models (Buck et al., 2008)? Additionally, many initiatives aimed at addressing the gender gap in science focus exclusively on girls and/or women (Sáinz et al., 2022). While some benefits have been reported when participation is restricted to girls (Marquardt et al., 2023; Fletcher et al., 2024), there is no consensus on whether this approach is necessary in all cases, or whether initiatives for boys or mixed-gender formats should be considered (Harackiewicz & Priniski, 2018; Master et al., 2021; Sáinz et al., 2022). Numerous events, conferences, and associations also aim to tackle the gender gap in STEM by providing various forms of support to encourage women's participation in science. For example, initiatives such as GSW (Global STEM Women) organize annual STEM Women Congresses (SWC) and publish reports on national efforts to promote STEM vocations among girls (SWC Annual Reports, https://www.globalstemwomen.org/swar, last accessed on 1 October 2024). Many of these initiatives are linked to non-formal education, leveraging its benefits for fostering scientific vocations and building science identity, but few of them can be easily transferred to the school context to extend their scope or include teachers or families as active participants (Donmez, 2021; Martín-Peciña et al., 2023).

Following this theoretical framework and as part of one of the multiple initiatives of the International Center for STEM Education (ICSE, https://icse.eu, accessed on 1 October 2024), we participated in a project aiming to encourage girls' potential in STEM and ICT subjects and to inspire them to choose careers and become entrepreneurs in these fields. This project, referred to as Empower Girls to Embrace their Digital and Entrepreneurial Potential (represented by the GEM acronym), is part of the innovation action founded by the European Union. In GEM, partners from higher education institutions of 11 European countries organized summer camps for girls, including a great diversity of activities to be piloted. Among other specific outcomes, it was expected that girls would increase their interest in the science field, become aware of their own potential and capacity to perform well in this field, and become concerned about gender stereotypes and their implications.

Thus, the aim was to make them feel confident to study or pursue careers in science and to consider themselves suitable for leadership positions. Based on all the previous considerations and in order to provide research evidence to shed some light on how to close the gender gap in STEM, we conducted a study to measure the impact of the GEM summer camp on the participating girls within the Spanish context. Furthermore, the perceptions of mentors and lecturers involved in the camp were explored. We present and discuss both results in order to explore which elements of this intervention were key to providing more inclusive and gender-sensitive STEM education and reinforcing science identity in girls.

2. Materials and Methods

2.1. Design of the Scientific Summer Camp

The core idea of these summer camps was to offer a positive experience to girls aimed at empowering them to embrace their STEAM, digital, and entrepreneurship potential. For that purpose, the intervention design was conceptualized to allow girls to:

- Become aware of the wide range of professional activities related to STEAM and led by women.
- Take part in a real research project guided by inspiring female mentors.
- Realize the empowerment feeling while designing, defending, and leading an entrepreneurship idea.
- Acquire digital skills related to the use of technical devices for data collection and data management.
- Develop creativity and decision-making skills related to their participation in a constructive project.
- Develop digital skills related to the use of ICT for the presentation and communication of research results.
- Develop their identity in scientific research and/or STEAM professional fields.

Considering these guidelines, each of the summer camps (2021 and 2022 editions) lasted five consecutive days during one week of July, when the academic year had come to an end. During these days, the participating girls lived an immersion experience conducting research with mentors involved in cutting-edge projects in groups of five to eight girls per project. Along with these research experiences, there were some scheduled time frames dedicated to social activities and workshops for the larger group each day of the camp. See this summer camp Learning Plan (https://icse.eu/wp-content/uploads/2023/02/Learning-Plan-Spain_2022.pdf, accessed on 1 October 2024) for a detailed description of the 2022 summer camp design and organization issues.

The research projects in which the girls were involved were articulated around meaningful topics related to current challenges, such as environmental issues, socio-scientific issues concerning digitalization, ICT potential, or health topics. In particular, some of these projects were related to biology, health, and natural sciences (BHN; six projects), and others focused directly on engineering, computer science, or technology (CEM; eight projects). Moreover, some of them, proposed for the first edition of the camp, had to do with social science and a gender perspective of society and science (SOC; three projects); see project details in Table 1. However, all the projects followed an inquiry-based learning approach and were conceived to foster girls' ownership and connection with real-life problems. Concerning the workshops included in the camp program, they were set mainly around transversal topics, such as digital tools, entrepreneurship skills, and science-arts interplay; all of them were offered by young female lecturers. Therefore, the overall design of the summer camp aligned with the STEAM concept explained above and understood that STEAM is not in opposition to STEM, but rather that it represents an extension of its scope.

Thus, the STEAM context was used in the present study to assess the attitudes of girls towards STEM.

Table 1. Research projects offered in each edition of the GEM summer camp.

Project's Title	Edition	Topic *
Z generation and the socialization in the digital era: gender-based attitudes and prevention of sexism	2021	SOC
Are young people now more sexist? New expressions of sexist attitudes	2021	SOC
Research from the gender perspective on issues of social intervention. When the personal matters	2021	SOC
Discover the secret life of waste and take care of your planet	2021	BHN
Fluid Mechanics: unraveling the mysteries of bubbles, drops, and other surface tension phenomena	2021	CEM
Towards inclusive and sustainable cities	2021	CEM
Acquiring data from social media for decision-making	2021	CEM
Smart networks for energetic transmission: caring about society and the environment	2021	CEM
Artificial Intelligence for a better world	2021	CEM
What do wetlands hide? Finding out cryptic biodiversity through digital images	2021 and 2022	BHN
Is pollination at risk? Study of the production and viability of pollen grains	2021 and 2022	BHN
Microbiological Zoo	2021 and 2022	BHN
Analyzing information with artificial intelligence techniques: application to medicine and protection of natural species	2021 and 2022	CEM
Histological study of the cellular response to cerebral ischemia	2022	BHN
What is essential is invisible to the eye: genes, proteins, microorganisms, and their role in human reproduction	2022	BHN
Talking to robots: Artificial intelligence to improve communication	2022	CEM
Artificial intelligence and machine learning for society	2022	CEM

* SOC = social science; BHN = biology, health, and nature; CEM = computers, engineering, and mathematics.

In this way, the GEM summer camp was aimed at empowering girls with valuable skills and knowledge, learning from inspiring role models to gain insight into the significance of these figures. The camp also introduced girls to the STEM and digital worlds of work with the aim of broadening their career prospects. Additionally, it was designed to foster entrepreneurial mindsets and develop transversal skills, such as critical thinking, communication, and teamwork, required to thrive in academic and professional settings.

2.2. Evaluation Concept and Research Instruments

Two types of questionnaires (for students and mentors/lecturers) were developed within the GEM consortium (GEM project consortium, 2019) and used during the summer camps. These instruments can be found at this link (https://icse.eu/wp-content/uploads/2023/02/Final-Report-on-the-European-GEM-summer-camps-Final-version-less-pictures.pdf, accessed on 1 October 2024). The Spanish verion, used in this experience, includes translation and some minor context adaptations.

The student pre questionnaire had three sections. Section 1: Anonymized data. This section was aimed at obtaining demographic Anonymized data. Anonymized data was needed regarding research ethics rules. In order to identify and pair the answers in the pre test and post test, a code was generated by the respondent following some basic instructions. This section also included information about their academic profile and the respondents' future work preferences (Appendix A). Section 2 was designed to identify the perceptions of the participants in relation to some science subjects (see Appendix A for a detailed description on the statements and the scale used). Section 3 included eight items in a 1 to 5 point Likert scale (from strongly disagree to strongly agree) and was intended to be the measurement of the intervention. Table 2 shows the items within this section.

Table 2. Student's pre-test and post-test items included in the questionnaires.

Code	Item ID	Statement
STEM_interest	1	I am interested in learning about STEM.
STEM_enjoy	2	I enjoyed learning STEM topics.
STEM_effort	3	Making an effort in my STEM subject(s) is worth it because this will help me in the work I want to do later on.
STEM_study	4	What I learn in my STEM subject(s) is worthwhile for me because I need this for what I want to study later on.
STEM_useful_everyday	5	STEM is useful in helping to solve the problems of everyday life.
STEM_easy	6	STEM is easy for me.
STEM_useful_world	7	STEM is helpful in understanding today's world.
STEM_job	8	It is important to know STEM in order to get a good job.
STEM_attitude	Average 1–8	

Note: Likert scale; from 1, completely disagree, to 5, completely agree.

The pre questionnaire also included a final section aimed at obtaining information about perceptions after the experience and about the summer camp using multiple-choice and open-ended questions (e.g., "Did you feel comfortable during the camp?", "Do you think differently about science since attending the summer camp?", "Which summer camp activity was your favorite? Why?").

During the week, we collected pre and post questionnaires from students and transcribed them into a formatted spreadsheet. We analyzed them using IBM SPSS Statistics software (version 27.0.1.0, IBM Corp., Armonk, NY, released 2020). In the first session with mentors, we surveyed girls using the pre-test questionnaire. Once the final conference finished, post questionnaires were distributed among girls and then collected for data processing.

In the case of the educators' (mentors or lecturers) questionnaires (only post; Appendix C), we used a Google Forms link sent to them just after the summer camp finished; data were downloaded and processed in a spreadsheet and analyzed using the same abovementioned software.

In this case, a questionnaire was developed, including different sections. The first section focused on the outcomes of each workshop or project, aiming to investigate which of the nine outcomes educators perceived as targeted in their own project or workshop. The second section gathered information about the educator's opinion as to what extent those outcomes were reached on a 1 to 5 scale, ranging from a small extent to a high extent, respectively. We included a final section with open-ended questions to gather feedback and suggestions for future summer camp editions.

For open-ended questions from post-questionnaires for both students and educators, we transcribed answers in a text processor to address the identification of categories/dimensions.

2.3. Selection of Participants and Research Sample

The dissemination campaign of the summer camp was spread through social media and the Spanish GEM website, including advertising panels, flyers, and a designed program. We also made strategic contact with teacher associations and other institutions involved in education (University of Jaén, Delegation for Education, the Regional Teacher Center, the Spanish Research Council, and the Spanish Foundation for Science and Technology), and used strategic channels to spread the message among schools, teachers, and society.

This campaign was effective in reaching girls interested in joining the camp: 93 and 82 for the first and the second editions, respectively. The number of applications reached these figures three days after the opening call, and at that point, it was closed as the maximum number of participants per edition was approximately 65 girls to ensure a low ratio of 5 to 8 girls per mentor.

As detailed in Table 3, the intended number of participants established was fulfilled, involving 65 and 62 girls aged 13 to 18 in the 2021 and 2022 editions, respectively. The application process was carried out using a Google Form template, where girls provided personal and contact information, wrote a motivation statement for joining the camp, and ranked the research projects available within the mentoring context in descending order of preference (from 1 to the total number of projects offered). The applications were accepted considering their motivation criteria through a "first come, first serve" basis and motivation statement evaluation. The rationale behind this criterion was that the primary goal of the initiative was to enhance the STEM potential of girls interested in science in order to prevent them from dropping out of this field and losing their valuable talent. As expected, from a voluntary-based intervention like this, applicants expressed their orientation to science in the motivation statement, which was simply reviewed to confirm the girl's interest, with no further evaluations conducted in this regard. The main selection criterion was a "first come, first serve" basis, as it was also considered a good reflection of the girls' motivation to join the camp. Additionally, to ensure a positive experience, the selected participants were assigned to one of the projects based on their preferences while maintaining the originally established girl-to-mentor ratio.

Table 3. Number of participants and questionnaires recovered.

Summer Camp Edition	**Participants**			**Questionnaires**			
	Girls	**Educators**		**Girls**		**Educators (Only Post Test)**	
		Mentors	**Lecturers**	**Pre Test**	**Post Test**	**Mentors**	**Lecturers**
2021	65	19	5	62	59	13	0
2022	62	13	9	55	55	12	6

Regarding mentors, there were 19 and 13 female researchers from the University of Jaén who joined the summer camp for the 2021 and 2022 editions, respectively. Therefore, the mentor-to-girl ratio was five and eight girls per mentor/project for the first and second editions, respectively, including the fact that some projects were led by more than one mentor. To select this group of female mentors, a call was announced through the dissemination channels of the University of Jaén. After an introductory meeting outlining the initiative's goals, those mentors willing to participate were selected, and subsequent meetings were arranged to prepare them for their involvement in the camp. As a result, mentors joining the camp were expected to share its vision and mission and to demonstrate a strong commitment to it. These female mentors were leaders of STEM research groups, as well as business leaders, and occasionally postdoctoral researchers or predoctoral students, with ages closer to those of the girls. This aimed to show the diverse academic and professional paths women could take in the STEM sector. These profiles also highlighted how the STEM sector is based on collaborative teamwork, as mentors opened their laboratories and workplaces to showcase the vivid life they had fostered. Additionally, these mentors usually shared social time with the girls, as well as workshops within the camp program, thus providing opportunities to build a strong mentoring relationship beyond the academic sphere. The number of lecturers leading the workshops amounted to five in the first camp edition and nine for the second. The participation of mentors and lecturers was acknowledged with accreditation and a modest financial reward. Detailed information on the qualifications and professional/academic backgrounds of each mentor and lecturer can be found at the camp Learning Plan (https://icse.eu/wp-content/uploads/2023/02/Learning-Plan-Spain_2022.pdf, accessed on 1 October 2024).

We collected the questionnaires from girls (pre and post test) and mentors/lecturers (post test), yielding 62 pre test questionnaires, 59 post test questionnaires, and 13 post test questionnaires from mentors and lecturers in the 2021 edition, and 55 student pre and post test questionnaires and 18 questionnaires from educators (mentors and lecturers) in the 2022 camp edition.

2.4. Data Analysis

To make sense of the responses retrieved from girls, we ran an analysis by item, and it offered a good picture of what happened in terms of the gains and the impact of this intervention. Similarly, the original simulation, grouping all items in a theoretical scale that we called STEM_attitude, was supported by an acceptable value of Cronbach's alpha (0.805, considering both camp editions) and enabled us to compare pre and post data as a whole using some statistics-based proofs. The statistical analysis carried out included non-parametric tests for paired data, corresponding to a final sample of 93 paired questionnaires, as described by Quesada et al. (2022), and setting a p-value below 0.05 as the threshold for statistical significance.

Additionally, the differences in the preferences of applicant girls between project categories were analyzed by means of non-parametric tests, comparing their preference for BHN, CEM, or SOC projects, considering both camp editions within the same edition and between them. For that purpose, the preferences for projects indicated by the applicants were expressed on a scale from 1 (higher) to 13 (lower preference) considering the number of projects offered for each camp edition. Notably, the first camp edition preference scale ranged to 13, as the lowest value, as this was the number of offered projects. In contrast, for the second edition, the lower preference value was 8, and for comparison analysis purposes, it was proportionately converted into a 1 to 13 scale.

3. Results and Discussion

3.1. An Insight into Girls' Preferences for Project Topics and Perceptions About Science Subjects

Table 4 illustrates the differences in the girls' preferences for the research projects offered by the mentors during both summer camp editions (see Table 1 for a description and categorization of projects). A significant difference was observed in the distribution of preferences for BHN (Biology, Health, Nature), CEM (Computing, Engineering, Mathematics), and SOC (Social Science) projects, indicating that the girls had different preferences for the three types of projects ($p < 0.001$). In both editions of the camp, the girls showed a stronger preference for CEM projects (5.86), followed by BHN projects (6.47), and lastly, SOC projects (6.95). This distribution of preferences for BHN and CEM projects was similar across both editions ($p = 0.425$ and $p = 0.106$, respectively). The preference for SOC projects could not be compared between the two editions, as no SOC projects were offered in the 2022 edition.

Research has consistently suggested that while girls are often enthusiastic about science in general, their specific interests within the STEM fields can vary significantly depending on factors such as social influences, exposure, and educational opportunities (Grimalt-Álvaro et al., 2022; Msambwa et al., 2024). The girls' greater preference for CEM projects (Computing, Engineering, and Mathematics) found in this study is particularly interesting and aligns with the literature showing that girls, particularly when exposed to engaging and relevant activities, can develop strong interests in these areas or increase those that they already have (Dou & Cian, 2022; Sultan et al., 2024). However, societal stereotypes often depict science fields, particularly computing and engineering, as more "masculine" or less accessible to girls than, as previously reported, those closer to biology or health issues (Kerger et al., 2011; Sikora & Pokropek, 2012; Ford et al., 2024; Jaoul-Grammare, 2024). According to the same studies, the second-highest preference for BHN projects aligns with previous research showing that girls tend to show more interest in biology and life sciences, which are often viewed as more traditionally feminine subjects. The fact that these projects received a slightly lower preference than CEM projects might suggest a shift in the traditional gendered division of scientific interests. As girls become more aware of the potential of STEM/STEAM careers, they may be drawn to fields that are perceived as more diverse and forward-thinking, even though biology and health-related projects remain highly appealing to them. The least interest in SOC projects is a somewhat surprising result, given that many studies find that girls tend to be drawn to subjects that intersect with social issues, cultural studies, and human-centered work (Ortega et al., 2025). However, this finding could be influenced by the camp's specific label as a "scientific" summer camp, which aroused the interest of those girls already interested in them before. These findings also reinforce the idea that the preferences of girls toward science-related projects are not static, thus creating more opportunities for girls to engage with a wide variety of scientific disciplines that could further increase their engagement and success in these fields.

Table 4. Differences between girls' preferences for research projects, categorized in terms of the main topic addressed, in the two summer camp editions.

Topic	N (2021/2022)	M (SD) Both Editions *	Pairwise Comparisons		M (SD) 2021 Edition **	M (SD) 2022 Edition **
			Compared ID	*p*-Value		
BHN—Biology, Health, Nature	93/82	6.47 (2.58)	CEM	0.007	6.38 (2.84)	6.58 (2.26)
CEM—Computers Engineering, Maths	93/82	5.86 (2.71)	SOC	0.000	5.57 (2.72)	6.18 (2.68)
SOC—Social Science	93/0	6.95 (3.90)	BHN	0.213	6.95 (3.90)	NA

* Hypothesis Test Summary—Friedman's Two-Way Analysis of Variance by Ranks. Null Hypothesis—REJECTED, the distributions of preferences for BHN, CEM, and SOC projects are not the same ($p < 0.001$). ** Hypothesis Test Summary—Independent-Samples Mann-Whitney U Test. The distribution of preferences for BHN ($p = 0.425$) and CEM ($p = 0.106$) projects is the same across both camp editions.

For the academic profile questions included in the pre test, the analysis comparing students' interest and perceived relevance concerning different school subjects demonstrated significant differences for maths, physics, and chemistry ($p < 0.001$). Thus, girls consider these subjects as relevant, but they feel they are not, at the same level, interested in them, although the average interest value was also acceptable (Figure 1a). A similar result, but with less significance, was found for biology ($p = 0.011$). In contrast, for science, which is not a school subject in the Spanish context, there were no significant differences between interest and relevance in this case ($p = 0.069$). Furthermore, as depicted in Figure 1a, there were significant differences between the perceived relevance of different subjects ($p < 0.001$), but when physics was excluded, it resulted in no significant difference between the relevance perceived for different subjects ($p = 0.684$) or the subject with less relevance value on average. Concerning interest, there were significant differences between subjects ($p < 0.001$) that disappeared when science and biology ($p = 0.126$) were excluded, with the subjects showing the highest interest value.

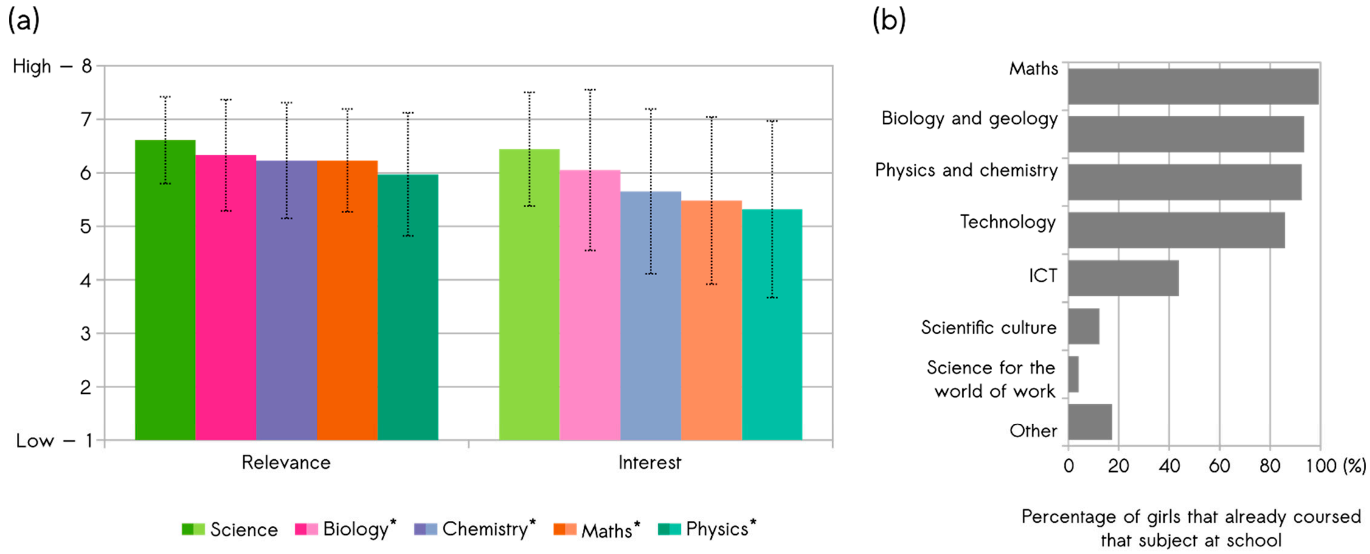

Figure 1. Girls' interest and perceived relevance of different scientific disciplines recovered from the pre test, the asterisks highlight significant differences ($p < 0.0$) between perceived relevance and interest (**a**) and information on subjects the girls followed at school before participating in the GEM summer camp (**b**).

These results suggest that the school context concerning each subject may have a negative impact on girls' interest in certain fields, despite them seeing their relevance (i.e., physics, maths, and chemistry) (Barmby et al., 2008; Kerger et al., 2011). However, girls show a high preference for these topics in out-of-school settings, as with the summer camp (see Table 4), including computer science, which is not a proper school subject in Spanish secondary education, although it is closely related to others (e.g., technology or robotics). In fact (see Figure 1b), almost all girls already took biology, chemistry, physics, and mathematics within the school context before participating in the camp (more than 90% of girls), followed by a significant percentage that also took technology (∼86%). In contrast, before joining the camp, a lower percentage of them enrolled in subjects regarding ICT (43.8%) and a few courses in which science was applied to the world of work (4.1%) or scientific culture (12.4%), which are also included in the Spanish curriculum for secondary education (Figure 1b). Therefore, this suggests that non-formal education is a promising context for girls to express and develop their interest in science topics that seem to be not so engaging within the school setting (Donmez, 2021).

As expected, due to the scientific nature of the camp, when the participating girls were asked about their future profession, several answers were related to jobs directly linked to technology or engineering ("*Chemistry engineering*" or "*Computer engineering*"), while others were more closely linked to life and health science ("*Medicine*" or "*Environmental Science*"). Interestingly, there were responses that indicated emerging professions that could fit within the STEAM view, such as "*Animate digital cartoons*", "*Graphic designer*", or "*Pilot*", suggesting that girls want to be part of the current world of work demanding transversal skills.

3.2. Impact of the Summer Camps on Participating Girls

According to the theoretical framework explained above, the impact of the GEM summer camp on girls was measured in terms of its effect on their STEM attitudes using a research instrument that aligned with approaches considering the items included to recover information about the value girls attributed to STEM (see Table 2). However, following the recommendations by McDonald et al. (2019), the typicality was also explored qualitatively, including an open-ended question in the post questionnaire regarding: "After attending the summer camp, do you see science differently? Please explain your answer".

In terms of the girls' STEM attitude before joining the camp, the results (as shown in Table 5) indicate that, on average, participants rated their attitude towards STEM above 4 points (4.22). This score was influenced by varying contributions from different items. When analyzing the pre-test data by item, we observed that the lowest ratings from participants were related to the perceived "ease" of science (3.80) and the importance of STEM for securing a good job (3.85). On the other hand, the highest ratings were given to the usefulness of STEM for understanding the world (4.57), their interest in learning about STEM (4.53), and whether it is worthwhile to make an effort with STEM to obtain the desired job (4.52).

Table 5. Statistics from responses to items on STEM_attitude comparing the pre-post questionnaires.

Code	Item ID	Pre-Test M (SD)	Post-Test M (SD)	Sign. (*p*-Value)
1. STEM_interest	1	4.53 (0.76)	4.53 (0.65)	0.886
2. STEM_enjoy *	2	4.16 (0.91)	4.40 (0.72)	0.009
3. STEM_effort	3	4.52 (0.73)	4.53 (0.66)	0.842
4. STEM_study	4	4.24 (1.02)	4.34 (0.83)	0.362
5. STEM_useful_everyday *	5	4.07 (0.74)	4.40 (0.67)	<0.001
6. STEM_easy *	6	3.80 (0.89)	4.06 (0.82)	0.009
7. STEM_useful_world	7	4.57 (0.63)	4.64 (0.59)	0.124
8. STEM_job *	8	3.85 (1.05)	4.14 (0.99)	0.001
STEM_attitude *	M 1–8	4.22 (0.56)	4.38 (0.50)	0.001

* $p < 0.05$ for significant differences.

Based on the analyzed data (see Table 5), we observed a significant overall improvement in participants' attitudes toward STEM (STEM_attitude, $p = 0.001$) after their participation in the camp. When analyzing the contribution of each item, we found that the most significant differences were related to the usefulness of STEM in solving everyday problems (item 5) and the importance of STEM knowledge for securing a good job (item 8). There were also notable gains in areas such as the enjoyment generated by STEM learning situations (item 2) and the perceived difficulty or ease of learning STEM (item 6). Although not significant, a slight improvement was noted in the relationship between the value of the STEM subjects at school and their potential positive impact on a future academic career (STEM_study). Finally, for items 1, 3, and 7, no significant improvements were detected. These items had the highest scores in the pre test, making it more difficult to detect meaningful gains and reflecting that girls were genuinely interested in STEM before joining the camp, as expected in the case of a non-compulsory initiative (Sultan et al., 2024).

A more detailed analysis of the data by project category (Figure 2) revealed an upward trend in most items after the girls participated in the summer camp, suggesting a positive impact on their perception and attitudes towards STEM. This also allowed for a meaningful comparison of the project impact on girls according to its categorization (i.e., BHN, CEM, or SOC).

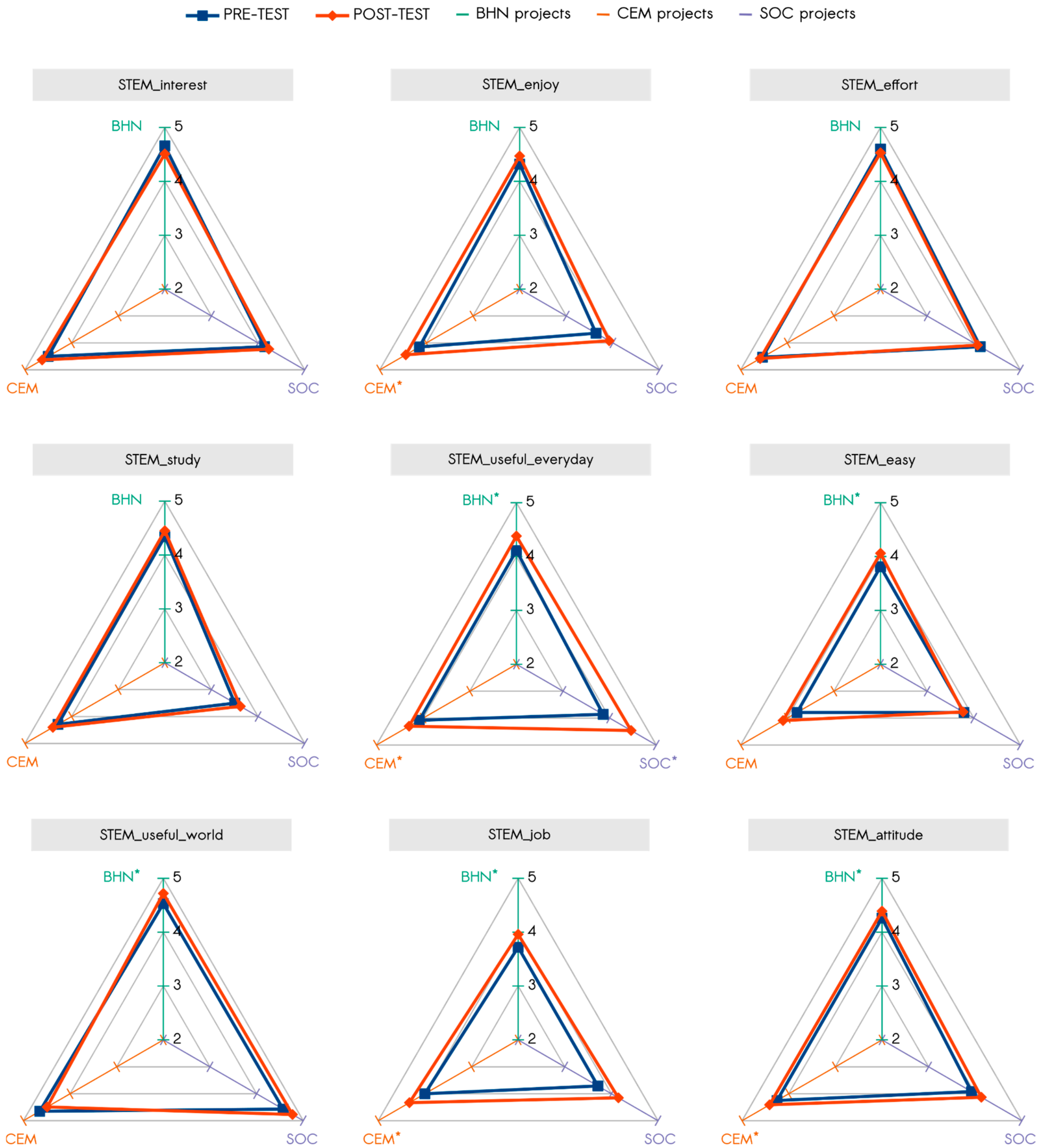

Figure 2. Spider graphs comparing the pre-post responses to each item included in the STEM_attitude theoretical dimension and splitting the sample by the category of the project in which girls participated (i.e., BHN: biology, health, and nature; CEM: computer science, engineering, and mathematics; SOC: social science). Note that the pre-post test differences showing statistical significance ($p < 0.05$) are pointed out with an asterisk.

Consistent with the overall results from Table 5, the STEM_interest (item 1), STEM_effort (item 3), and STEM_study (item 4) items showed no significant pre-post differences when considering project categories. However, for STEM_useful_world (item 7), which was already high in the pre-test, significant differences emerged when considering the BHN projects ($p = 0.016$), likely due to their direct connection to sustainability contexts that underscore the role of science in addressing major global challenges, as described by Romero-Ariza et al. (2021, 2023). Further examining the BHN projects specifically, significant improvements were observed in the perceived usefulness of science for solving everyday problems (5. STEM_useful_everyday, $p = 0.011$), the perceived difficulty of STEM (6. STEM_easy, $p = 0.034$), and the belief that studying STEM leads to better job prospects (8. STEM_job, $p = 0.028$). Regarding girls participating in CEM projects, they also showed significant improvements in item 5, STEM_useful_everyday ($p = 0.037$) and item 8, STEM_job ($p = 0.021$), and additionally in item 2, STEM_enjoy ($p = 0.025$). For girls involved in SOC projects, significant differences appeared again for item 5, STEM_useful_everyday ($p = 0.011$). Therefore, across all project categories, the girls improved their perception of the usefulness of science in solving everyday problems, an aspect that the literature identifies as crucial for fostering interest in STEM and building a strong scientific identity (Barmby et al., 2008; Kerger et al., 2011).

Finally, the dimension attitudes toward STEM (STEM_attitude) improved for all groups after the girls participated in the camp, with this improvement being significant for the BHN ($p = 0.013$) and CEM projects ($p = 0.025$). Although considerable gains were observed in the SOC projects, the small sample size, as only three SOC projects were offered and only during the first camp edition, made it difficult to achieve statistical significance.

According to these results, the girls believed that STEM is useful for understanding the world but not as much for solving everyday problems. This may suggest that they do not associate 'their problems' with scientific challenges, possibly dissociating science from their real-life experiences, which could make it seem less meaningful (Barmby et al., 2008). This is especially relevant in the case of girls, as science often has been seen as a field away from women's problems (Bebbington, 2002; Clark Blickenstaff, 2005). This finding is further supported by the open-ended responses, where many girls indicated the following when asked, "After attending the summer camp, do you see science differently? Please explain your answer." (extended information in Appendix B and Figure A1):

- "*I see science as more real and accessible*".
- "*I have found that what I have learned in this camp can be applied to my daily life in more ways than I thought*".
- "*I see science now not in such a complicated and complex way as I used to think it was. Moreover, I now see the myriad of forms it encompasses, not just the main ones that I had already taken into account*".
- "*I have realized even more how important science is in our daily lives*".

In line with the possible negative impact of some formal education approaches in science learning, also mentioned above, girls declared in the post test that some school settings may reduce their interest and motivation for science. Then, they highlighted that science was approached in the GEM summer camp from a different perspective, as more practical, real, and engaging ("*This is a different way of learning science than in school. It's practical, you enter a laboratory, meet people who work in the field, and especially, the opportunity to do real research*"; "*Here it's more dynamic. You use real-world examples, not just theory*"; "*[I see science now differently] because I wasn't interested in it at school*"; "*I see science from a practical point of view, which is not often the case at school, and that makes learning easier and more fun*"). Furthermore, looking at item 4, STEM_study ("What I learn in my STEM subject(s) is worthwhile for me because I need this for what I want to study later on"), its value was significantly lower than that of STEM_interest, probably indicating that, although they are interested in STEM, they do not see the relevance of the STEM content addressed at school to their future ($p = 0.003$).

In fact, although some girls had already declared to love science before joining the camp ("*I love science, that comes first, this is an opportunity to keep moving forward*"), their vision turned to a more useful ("*I have learned new uses and applications of science in everyday* *life that I was not aware of before*"; "*I think the GEM summer camp has helped me to see that work of this kind is very dynamic and can easily be applied in everyday life situations*"), meaningful ("*[Science] seems to me to be more necessary to have a better world*"; "*Science is something that I now see more passionately*"; "*I now see science as my future*"), and diverse ("*I now know different perspectives on science and what can be done from each of them*"; "*They help you see both science and the world of work that they offer us from different perspectives*") one. Furthermore, students also stated that they were aware of the scarcity of female role models in science ("*There are very few female role models in science and that is what is being promoted with this project, since we were little we do not see that there are scientific women and girls do not tend to follow this branch*") and that the camp encouraged them to be valued by highlighting their important role in scientific and social progress ("*What counts is how hard you work, what you have studied, how much you want to do your job, not your gender*"; "*I have understood how women have a key role in science even though sometimes it does not seem so*").

3.3. The Value of Role Models to Build Up a Community of Empowered Girls in Science

Drawing on previous evidence, the design concept of the GEM summer camp was based on the promotion of female role models to enhance girls' attitudes towards STEM (Bloodhart et al., 2020; Hughes et al., 2021; Guenaga et al., 2022; Ladachart et al., 2024). Thus, one of the main goals was to foster a more positive attitude towards STEM among the girls, and this was achieved through close collaboration with female leaders from cutting-edge research projects at University of Jaén. These mentors worked directly with the girls in small groups for a week on a project, and their involvement appears to have been crucial in inspiring the girls and improving their attitudes toward STEM, as reflected in the responses to the open-ended questions in the post-test questionnaire (see Table 6). In these questions, the girls were asked about the best aspects of the experience and how their views on science had changed after participating in the intervention.

Table 6. Quotations from participating students valuing the role of different participants in the camp.

Mentioned Role	Students' Quotations (Translated from Spanish)
Mentors	"*I liked the time with my mentor, because I did not know about the existence of things that she explained, the time with her seemed very short and I have learned a lot*". "*My mentor's enthusiasm for her work has given me a lot of positivity towards research*". "*Here you learn a lot, you make friends and the mentors are amazing*". "*I have learned a lot not only educationally but also morally thanks to the experiences of other women, mainly my mentor*". "*I liked talks about personal experiences and scientific careers*". "*The mentor was key for my daughter to get engaged in the camp and to think about a future job career related to architecture*".
Lecturers	"*The entrepreneurship talk has inspired me and given me the strength to make my way*". "*The talk about jewelry design was motivating and instructional*". "*Bioinformatics and the pollination project that we carried out in the laboratory, I learned many interesting things that gave me more knowledge*". "*Bioinformatics and immersion with mentors, I think they are interesting areas that will be very useful in my future*".
Other students	"*I loved when we went out to draw, because we were all together and we learned the importance of observation and curiosity*". "*We made new friends and were able to solve other problems and develop creativity*". "*It is a unique opportunity to interact with more people and learn*". "*I really liked the gymkhana since I met more girls, my project that taught me a lot about waste and the final conference in which I was able to learn about many topics*". "*I got really inspired by other older girls that also liked science, I felt reflected on them*".

In this context, the girls emphasized the importance of mentors. In fact, one of the most highly valued aspects was the mentoring sessions with the researchers, who were actively involved in research projects. The female mentors who participated in the camp were mostly young women from the region, with whom the girls could easily relate. The girls shared both research sessions and personal experiences related to women's careers. Similarly, the participating girls seemed to be inspired by the lecturers, who helped instill in them a sense of self-confidence and self-efficacy as professionals.

Furthermore, the girls' statements after their participation in the camp indicated that their peers could also have played a significant role as role models. Several girls mentioned that the older participants served as mirrors in which they could see themselves. This may be one of the reasons behind the effectiveness of girl-only interventions for empowering them in science (Marquardt et al., 2023; Fletcher et al., 2024), as they could enhance the value of each participant to inspire other girls. As a result, in this summer camp, role models extended beyond the mentors to include the lecturers and the girls themselves, fostering a community of empowered girls in science. This is in line with research reporting that the profile of a role model for girls in science can be diverse and challenge stereotypes associated with women and science (Drury et al., 2011; González-Pérez et al., 2020; Gladstone & Cimpian, 2021).

One of the most relevant findings of this study is that the design of the intervention facilitated the creation of a community and strengthened the sense of belonging to science. This sense of belonging is crucial to promoting inclusive science education (Vincent-Ruz & Schunn, 2018). According to the girls', mentors', and lecturers' quotations (see Table 7), the community built through the summer camp was one of the most noteworthy outcomes that also engaged families through their participation in the final GEM conference, considering their high impact on promoting scientific aspirations in girls (Chavatzia, 2017; Dou & Cian, 2021). The experience was rated very positively by the participating girls, who expressed a strong desire for more girls to attend the camp, describing it as a comfortable and safe space (Appendix B).

Table 7. Quotations from participating students and educators (mentors and lecturers) referring to the feeling of belonging to the summer camp and community building.

Participants	Quotations (Translated from Spanish)
Students	*"I have felt very supported by all the people here".* *"I have become more involved in science".* *"It is a unique experience that all girls with a passion for science should live".* *"I would strongly recommend it to my friends so they can experience the same as me".* *"Being a scientist seems like a dream to fulfill and women can do anything they dream of".*
Mentors	*"The organization, the atmosphere among all the participants, the close relationship between girls and mentors. At the end of the camp, the expressions of gratitude from girls and their families".* *"Motivation and curiosity have increased throughout the sessions. Those with leadership skills have been highlighted and fears or lack of confidence to try to overcome them have also been discussed".* *"The participants have carried out a small research project in all its stages, from the formulation of hypotheses to the communication of results. They have worked as a team, developing a potential that they themselves did not know they possessed".*
Lecturers	*"The community that was created by feeling part of a group with common interests and goals, the camp activities promoted that".*

Since the camp concluded, this community has been expanded internationally with the creation of the GEM network, the "1h4Girls in STEM" initiative as a series of online event to support girls in STEM education, and the adaptation of some summer camp activities as Learning Units for their transfer to formal education (information about these initiatives can be found at https://icse.eu/international-projects/gem/, accessed on 1 October 2024). This is crucial for reaching individuals who, for various reasons, do not regularly engage in non-formal education (Donmez, 2021; Dou & Cian, 2021). In that respect, two Learning Units have been produced, respectively, from both editions of the GEM summer camp that align with the principles of STEAM education: "Using sustainable architecture to improve people's lives" (https://icse.eu/wp-content/uploads/2023/02/GEM_ESP-Learning-Unit_Architects.pdf, accessed on 1 October 2024) and "Create and surprise, shaping your STEM entrepreneurial ideas" (https://icse.eu/wp-content/uploads/2023/02/GEM_ESP_Learning-Unit-_-Entrepreneurship.pdf, accessed on 1 October 2024).

3.4. Mentors' Perceptions About the Impact of the Summer Camp

As stated in the Materials and Methods section, the mentors involved in the GEM summer camp were asked about their perception of to what extent the learning goals proposed as desired achievements for the girls participating in their project were reached. These goals are indicated in Figure 3, showing that they were perceived as having been accomplished at a rate of more than 3.5 out of 5 in all cases.

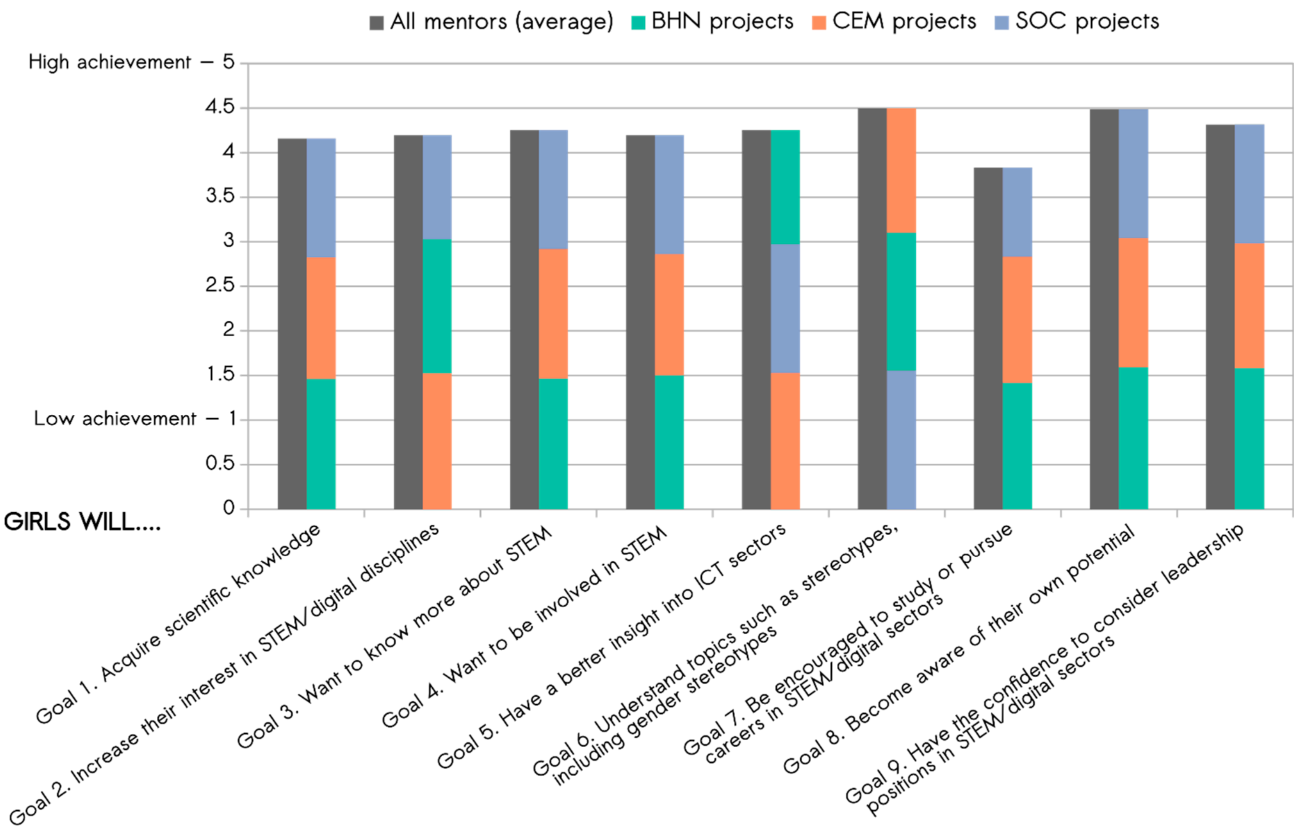

Figure 3. Chart graph showing the extent to which mentors perceived that girls achieved each of the established goals through their participation in the project (from 1, a low extent, to 5, a high extent). The results are depicted considering the total number of mentors (grey bar) and the proportion corresponding to BHN (green), CEM (orange), and SOC mentors (blue). Note that colors in the right bar for each goal (i.e., project categories) are sorted by the rate of the perception of goal achievement in a higher (bottom) to lower (up) manner. Thus, BHN mentors perceived that their projects were the most effective in reaching goals 1, 3, 4, 7, 8, and 9; the same applies to CEM mentors for goals 2 and 5 and to SOC mentors for goal 6.

As observed in Figure 3, the mentors offering BHN projects perceived that most of their established goals were fulfilled to a higher extent compared to those for the CEM or SOC mentors (goals 1, 3, 4, 7, 8, and 9). In contrast, CEM mentors perceived that, in their projects, girls reached goals 2 and 5, related to increasing their interest in the STEM/digital sector and knowing the ICT sector, respectively, to a greater extent compared to the remaining project categories. Finally, SOC mentors perceived that their projects were the most efficient in improving girls' understanding of gender stereotypes (goal 6). However, there were not significant differences in the perception of achieving each goal, either between camp editions or the category of the project offered (i.e., BHN, CEM, or SOC). This suggests that, despite the existence of goals perceived as slightly closer to some particular project categories, in general terms, the projects were perceived by mentors as an opportunity for girls to develop certain skills regardless of their nature or the main topic addressed. Therefore, it could be assumed that these skills are perceived as transversal as they are not related to goals attached exclusively to certain or specific kinds of projects that make sense in an intervention designed from a STEAM perspective (Aguilera & Vílchez-González, 2024). For example, SOC mentors perceived that their projects were more effective in giving a better insight into ICT sectors than BHN ones (see rates for goal 5 in Figure 3), highlighting that through a social science project, girls can presumably increase their knowledge about digital and technology fields provided that these issues are addressed in a meaningful context. The same applies to the development of leadership skills (goal 9) that could be fostered through BHN or CEM projects, although it can be initially seen as a goal specific to the entrepreneurial or business fields, traditionally linked to social science.

Accordingly, considering all mentors, the goals related to understanding gender stereotypes and becoming aware of their own potential and increasing self-confidence were those with higher rates of achievement (i.e., around 4.5 on average). This indicates that mentors perceived their projects as effective in addressing structural aspects directly related to filling the gender gap in science that go beyond the disciplinary boundaries (Archer et al., 2010; Cheryan et al., 2015). Perhaps it is this ability to empower, support, and guide individuals in expressing their own aspirations that defines an effective mentoring relationship (Pfund et al., 2016).

4. Conclusions

Within the framework of STEAM education, efforts to promote inclusive science and provide opportunities to develop scientific identities are growing (Hasti et al., 2022; Castro-Zubizarreta et al., 2024). Thus, the aim of this paper was twofold. Firstly, to present the main ideas and the pedagogical design of the GEM camp, in particular, the editions run in 2021 and 2022 in Spain. Secondly, this work presents the research results measuring some aspects of the intervention's impact on participants. Both aspects allowed us to develop a set of recommendations for designing STEAM education interventions that contribute to overcoming the gender gap and to boost girls' identities and talents in science.

Regarding the pedagogical design of the scientific camp, girls from secondary schools experienced, during the week, meaningful and inspiring activities guided by female researchers, entrepreneurs, and scientists (mentors) that acted as real role models representing successful women in different science and research fields. Mentors offered the female students different scenarios and opportunities to actively participate in their own research projects, providing them with an immersion experience in cutting-edge research topics within different scientific domains. The immersion in authentic research projects led by female scientists was complemented with workshops to develop creativity and entrepreneurial and digital skills in girls. In addition, participants had multiple opportunities to develop strong social ties, feeling part of a vivid community.

Regarding the impact of the GEM camp on participants, several instruments were designed to analyze the effects of those activities using a pre-post design along with some open-ended questions. Although this was a short-term intervention and the initial attitudes towards science among girls were already high, the interplay of hands-on experiences, mentoring relationships, and the creation of a supportive community was instrumental in shaping the girls' attitudes toward science. The research results show a positive impact on the participating girls, with different levels of significance in several items related to perceptions and beliefs about STEM and future professional orientation, as well as positive thoughts about the scientific and useful content of the activities developed during the summer camp. In particular, on average, all the participating girls experienced a significant improvement in their attitudes towards STEM and theoretical constructs that were charged by significant differences in items related to the perception of STEM enjoyment and easiness (STEM_enjoy and STEM_easy), but also to the perception of STEM as being useful for daily life problems (STEM_useful_everyday) and being important in order to get a good job (STEM_job). Although there were some different, concerning gains in significance according to the project category in which girls participated, the conception of STEM as being helpful and connected with the girls' daily life problems improved significantly regardless of the category of research the project was related to (i.e., BHN for biology, health, and nature; CEM for computers, engineering, and maths; and SOC for social science projects).

However, these findings are not exempt from limitations, as the camp's exclusive inclusion of female mentors and female students presents potential gender bias in responses, making it difficult to generalize the outcomes to mixed-gender settings. The absence of male participants prevents the exploration of how boys or men perceive and contribute to gender dynamics in STEM, limiting further understanding of the factors influencing the gender gap. Moreover, a bias may arise from interacting solely with women in STEM, limiting exposure to diverse viewpoints and complicating the assessment of the camp's impact on overall inclusion for other genders. In future camp editions, incorporating a more gender-diverse group of participants into the study would allow for the exploration of how these contexts and views contribute to gender dynamics in STEM, offering a more comprehensive understanding of the factors influencing the gender gap and how to promote gender inclusion more broadly.

Reviewing the post questionnaires immediately after the camp showed a short-term perspective, and a longitudinal study may be needed to track the sustainability of the observed effects. Thus, in light of this, conducting future, long-term follow-ups with participants would help assess the sustainability of the camp's impact on their attitudes toward STEM and their educational and career decisions, providing insights into whether the camp experience has a lasting effect on their trajectories.

The fact that participants already had a prior interest in science and often received support from their families could have introduced selection bias. As a result, the study's findings may not be generalizable to girls who do not share the same level of interest or support. Additionally, the high initial interest in science among participants makes it difficult to detect significant improvements in this dimension. Therefore, taking into account the girls' surrounding environment, such as family support and the type of school they attended, and developing specific initiatives to investigate the factors influencing the gender gap for those less interested in science, would provide a more nuanced understanding of the factors at play to bridge the gender gap in science.

Furthermore, if girls only experience one type of research project, it becomes difficult to determine whether their preferences for certain areas of STEM are authentic or simply the result of limited exposure. Although, in this case, there does not appear to have been a high influence of pre-existing gender stereotypes in the order of projects by preferences (see Table 4), expanding the number of projects in which girls can participate during the week would help them to explore their interests and aptitudes across various fields.

From the responsible position of educators and researchers, we should take part and take inclusive actions to bridge the gender gap in particular professions and work positions. Education certainly seems to be a privileged channel through which to encourage girls to actively participate in science, developing a positive science identity. As previously stated, this work intends to contribute to the delivery of gender-sensitive and inclusive STEAM education by sharing the main theoretical background, the educational design, and the results of the implementation of the GEM summer camp. The application of a pre-/post-research design allows us to provide some research evidence of the impact of the summer camp on girls' STEM identity and motivation to uptake a future career in STEM fields. Therefore, it is important to note that these results cannot be generalized to the entire girl population but are just limited to the girls participating in the summer camp. On the contrary, we aimed at an analytical generalization, and, in this sense, we tried to draw some design principles partly based on the specialized literature and the results confirmed by this study. However, more studies would be necessary to replicate the results and to further prove the suggested design principles for effective gender-sensitive educational interventions in STEM education. To this end, and based on the work conducted so far, we would like to highlight the key educational features and strategies that have been proven to be effective in improving girls' STEM identities. These might be taken as recommendations to develop gender-sensitive educational interventions:

- Create activities that make female scientists visible and provide opportunities to appreciate the great contributions of female professionals to the STEM fields. This is crucial to challenge stereotypes that associate STEM careers with men.
- Include hands-on activities that link science to real-life situations, showing the usefulness and relevance of science in our lives.
- Build strong mentoring relationships that offer opportunities to share both professional and personal experiences between female mentors and mentees. This provides girls with inspiring models, challenges wrong stereotypes, and fosters the development of STEM identities.
- Create inclusive learning environments where girls feel comfortable, safe, and empowered to explore their potential in science. In this regard, fostering a sense of belonging to a community is vital for promoting the inclusion and empowerment of girls in science.

This camp's intervention development within a non-formal educational context may limit the extrapolation of the results to formal educational settings. Therefore, it is important to emphasize the need to expand the reach of such initiatives to individuals who do not typically engage in non-formal education. In fact, although there have been many initiatives addressing the gender gap in science, few of them have prioritized teachers within the context of formal education, nor do they provide research evidence from science education to assess their impact or reach (https://www.globalstemwomen.org/swar, last accessed on 1 October 2024). In this regard, recent changes in legislation within formal education have been implemented to address gender biases in STEM fields from early stages. In the Spanish context, the Organic Law 3/2020 of December 29 (*LOMLOE*) highlights the importance of integrating gender equality as a cross-cutting issue (Article 19). This entails promoting an inclusive and equitable education that encourages girls and young women to actively engage in science, though achieving this goal remains a challenge.

In fact, in spite of these well-intentioned pedagogical principles guiding current educational legislation, gaps remain in teachers' ability to approach science through a gender perspective (Stephenson et al., 2022; Merayo & Ayuso, 2023). No educational stage, from high school to advanced professional careers, appears decisive in understanding the gender gap (Speer, 2023), suggesting that it may begin to emerge at earlier stages

(Evagorou et al., 2024). This recent report highlights inclusive methodologies aimed at eliminating gender barriers in science education and promoting the participation of all students. These approaches focus on boosting girls' self-efficacy, using gender-neutral language and activities, and embracing innovative pedagogical methods towards disciplinary integration (i.e., STEAM approaches), which connects learning to real-world issues, such as those promoted in the summer camp design concept. Aligned with the intervention design described in this paper, the same authors encourage participation in non-formal learning environments, the inclusion of female role models, and the development of transversal skills for success in science.

However, unlike non-formal learning environments, formal education faces the challenge of limited curricular flexibility, which makes it difficult to integrate innovative pedagogical approaches. Additionally, activities such as showcasing female role models, commonly found in non-formal settings, are constrained by the rigid structure of formal education. While resources and tools, such as the toolkits developed by projects, have been created to support teachers (e.g., *Hypatia*, *Girls Into Global STEM*, or *STING*), the lack of a unified approach at the national and regional levels limits their effectiveness. The successful implementation of inclusive methodologies requires a commitment at the institutional level to develop systemic strategies involving families, teachers, policymakers, and researchers. Consequently, there is not a single entity responsible for the gender gap in science, but what remains clear is that formal education must not be left out of the path toward inclusive science education.

Despite the general focus of this research on girls' attitudes towards science, these recommendations can also be beneficial and applicable to raising interest and science identity regardless of gender considerations (see Supplementary Material in Sáinz et al., 2022), thus improving gender-inclusive science education in a broad sense. However, it is this female half of the population that is at a greater risk of systematically distancing themselves from the scientific field, which poses significant limitations for both present and future science and society. In this regard, it is the need to expand and advance in the body of knowledge on how to improve science education towards the inclusion of different gender identities, exploring whether there are gender-sensitive pedagogies directly linked to science education. A matter as relevant as this requires measures as rigorous as evidence-based science education.

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Appendix A

This Appendix A includes the questions about the academic profile and the future job orientation asked in the students' pre-test questionnaire analyzed in this study. These questions were translated into Spanish, with minor adaptations to the national context, after the administration of questionnaires.

- Which of the following subjects do you study at school? Mark each subject by circling a Y (yes) or N (no).
  - Biology and Geology
  - Physics and Chemistry
  - Mathematics
  - Technology
  - Information and Communication Technologies (ICT)
  - Sciences applied to the world of work
  - Scientific culture
  - Other STEM/scientific/technological subjects
- What job would you like to have in the future?
- Choose one number between each adjective pair to indicate how you feel about the subject. Usually it is best to respond with your first impression, without giving a question much thought.
  - To me SCIENCE:
    1-means nothing to 7-means a lot
    1-is boring to 7-is interesting
  - To me MATHEMATICS:
    1-means nothing to 7-means a lot
    1-is boring to 7-is interesting
  - To me BIOLOGY:
    1-means nothing to 7-means a lot
    1-is boring to 7-is interesting
  - To me CHEMISTRY:
    1-means nothing to 7-means a lot
    1-is boring to 7-is interesting
  - To me PHYSICS:
    1-means nothing to 7-means a lot
    1-is boring to 7-is interesting

Appendix B

This Appendix B contains the visual representation of girls' feedback on the evaluation of the summer camps recovered in the post questionnaires, as indicated in the Materials and Methods section. The questions included were related to what they noticed about the camp, why they joined it, how they felt during the camp, and whether they felt comfortable during the camp (Figure A1). In addition, the post test included a question on the possible impact of the camp on the girls' views of science and others focused on retrieving which camp aspects the girls appreciated more or less and suggestions for the improvement of future camp editions. In the latter respect, girls highlighted opportunities to meet new girls and the time invested with mentors ("*The practical sessions with the mentors, I found them very interesting*"; "*The scientific gymkhana, because I met more girls, apart from those in my group, and I had a good time*"; "*The project with mentors, it's the moment when you can apply what you have been studying, it's comforting*"), while aspects concerning the high temperature of the outdoor activities or other logistics issues ("*The visit to the botanic garden, it was quite hot and I couldn't appreciate the experience as much as I should have*"; "*Some group activities were uncomfortable because of the heat outside*"; "*Virtual visit to the museum, problems with the application made it difficult to appreciate it well*") were the less valued ones. Then, girls also suggested including more social activities and projects or extending the camp duration for the next edition ("*More game activities*"; "*More time, not just one week*"; "*More projects so that more people can participate*").

Figure A1. Pie charts showing data on feedback provided by girls after their participation in the summer camp (post questionnaire) evaluating the intervention.

Appendix C

Appendix C includes the questions asked in the educators' questionnaire analyzed in this study. These questions were translated into Spanish, with minor contextualization adaptations, after the administration of questionnaires.

- What was your role in the summer camp? (a. GEM mentor, b. Session leader, c. Teacher from participating schools).

- In your opinion, to what extent were these outcomes reached? Please mark your preference from 1 to 5 if applicable. *(Comment to support the preferences you marked above including any observations or other evidence)*.
    1. Girls will acquire scientific knowledge.
    2. Girls will have increased interest in STEM/digital disciplines.
    3. Girls will want to know more about STEM.
    4. Girls will want to be involved in STEM.
    5. Girls will have a better insight into ICT sectors.
    6. Girls will have a better understanding of topics such as stereotypes, including gender stereotypes.
    7. Girls will be encouraged to study or pursue careers in STEM/digital sectors.
    8. Girls will become aware of their own potential.
    9. Girls will have the confidence to consider leadership positions in STEM/digital sectors.
- What did you like about the summer camp and/or activity?
- What would you change from the summer camp and/or activity?
- Do you have any suggestions for improving the summer camp program?
- Do you have any ideas that can be used in another summer camp?

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