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Extracurricular Program for Girls to Improve Competencies and Self-Concept in Science and Technology

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Abstract: The gender gap in STEM areas is still a reality that constitutes a global concern. Many initiatives have sought to strengthen the scientific-technological aspirations of girls, among them extracurricular programs such as the one we present here. Its design is based on the available scientific evidence to promote female interest and self-concept in those areas. In this study, we analyze the impact of the extracurricular activities on the development of competencies and perceptive self-evaluation skills among eight girls aged between 8 and 11 years old regarding science and technology. The results showed the effectiveness of the extracurricular activities both for the development of skills and for the improvement of levels of self-concept, interest, and participation, which leads us to highlight the need to promote initiatives of this sort in order to overcome gender stereotypes and to achieve equality.

Keywords: STEM; gender gap; competencies; self-concept

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1. Introduction

The low presence of women in Sciences, Technology, Engineering, and Mathematics (STEM) constitutes a global concern [1,2]. In the European Union, different studies [3] have demonstrated that the problem of access and the permanence of women in these areas continues to be unresolved. Although the presence of women in some STEM areas has increased, their presence in Engineering and Technologies continues to be very low [4]. These data coincide with those of Spain: of the total of all university students, 55.3% are women, having a majority presence at all levels of training and branches of teaching, apart from qualifications related with Engineering and Architecture, in which their presence stands at around 25% [5].

There are various interlinked factors behind this gap [6,7], among them psychological factors, molded by family values and school [8,9], and social factors, such as social and cultural norms [2,3,7].

Various studies [7] show that girls start to lose interest in STEM careers as they grow older, to a greater extent than boys. If the experiences of students under 14 years old in science is the principal factor in motivating them to follow scientific careers [10], the stage between 4 to 10 years old, a stage when girls demonstrate a similar interest to boys with regard to the sciences, is the ideal time to change this situation. It is the period when greater interest is shown in STEM matters, and when the gender stereotypes are reinforced. In this framework, it appears fundamental to design actions that would help to reduce the gender gap in scientific-technological areas from early ages.

Considering the important role that extracurricular STEM involvement plays in girls' STEM development [11], an eight-month extracurricular program exclusively for girls was therefore planned and implemented, founded on the principle of equality [12] and on the scientific evidence for fostering girls' interest in science and technology. In this study, we present first its description and then its evaluation based on the changes observed in the STEM competences and self-concepts of the girls participating in one of the program groups.

2. Literature Review

In this section, we will summarize evidence related to topics that are relevant for the design of the extracurricular program presented here, as well as for its evaluation.

2.1. Factors behind the Gender Gap in STEM Careers and Some Educational Strategies to Reduce It

The literature addresses several factors behind the gender gap in STEM careers. Among the psychological factors, we can find self-concept (which will be addressed separately) and trust in one's own potential. The belief in one's own capacity influences one's choice of academic and occupational activities, because people might prefer or choose those areas in which they feel competent [8]. Thus, in fields where innate talent (a quality generally associated with men) is presumed to be a requirement for success, women tend to be under-represented, as is the case in engineering and physics [7].

These psychological factors are influenced and molded by broader social variables, such as family values and school [9]. Educational materials, beliefs, and the attitudes of the teaching staff, including their behavior and their expectations with regard to the students, can have profound effects on the academic interest and performance of children in STEM subjects [11,13]; girls' interest and confidence in STEM can be impacted through professional development opportunities for educators and parental awareness of STEM resources and careers [11].

Of particular interest is the perceived social relevance of the contents of the subjects and of STEM courses, since it predicts the intentions of girls to follow STEM careers both positively and significantly [14]. Thus, proposals that consider the interests of girls, for example, linking abstract concepts with real-life situations, can help to increase their interest. In addition, the evidence also appears to suggest that student-centered strategies and participative and investigation-based schemes can improve the interests of girls and reduce the gender gap for achievement in STEM, while at the same time benefitting all students [7,11].

Finally, at a social level, both social and cultural norms also have a strong impact on the roles that the girls will play in society. These stereotyped and gender-related attitudes, behaviors, and expectations normally make themselves felt in a subconscious way in academic and professional decisions and have a great potential to limit the STEM-related aspirations of girls [7,8]. The stereotyped representations of disciplines and professions, in which some specialists have female and others have male connotations conditioning their image and gender-specific identifications, may be added [15]. Connected with this factor, in view of the growing role of computer science and the strong masculine stereotypes that dominate in this area [16,17], specific strategies are needed to guarantee that girls have the same opportunities.

2.2. Girls' Scientific Self-Concept

Self-concept is a subjective evaluation of one's talents in a particular area that does not necessarily reflect one's genuine abilities [18]. It is a multifaceted construct that is influenced by various factors. In the educational sphere, several studies have shown that a high self-concept in a particular area predicts course choices and choices of field of study career field [19,20]. Boys estimate their scientific abilities more highly than girls, according to studies on gender disparities in science [18,20], and women pursuing science degrees have a more negative self-concept than men, while doing equally well [21]. Lower secondary female students can already observe this influence, as they doubt their ability to pursue a career in science [22]. Given that students begin to decide on their future professional objectives at the age of 12 [10], it is especially crucial to promote interest and, by extension, self-concept at early ages.

2.3. STEM Extracurricular Activities for Promoting Girls' Scientific Interest

Due to the positive relationships between activity participation and cognitive, psychological, and social outcomes, several studies suggest that extracurricular activities and programs, in any area, play a decisive role in increasing academic performance, raising the likelihood of attending college, and increasing employability chances [23,24]. Related to STEM extracurricular programs, such activities provide hands-on experiences that can sustain interest in STEM and help students develop skills relevant to STEM careers. In the case of STEM activities for girls, Heaverlo, Cooper & Santos Lannan [11] found that, besides family STEM influences and math/science teacher influence, extracurricular STEM involvement was a significant predictor of girls' STEM development. Also, Stringer et al. [25] showed that girls engaged in STEM extracurricular activities were more motivated by science and had more developed STEM career identities than non-participating girls. Both research groups suggest that it seems relevant to evaluate and add extracurricular STEM activities based on girls' interests to increase the number of girls pursuing careers in STEM fields.

3. Description of the Program

The extracurricular program called *Poderosas*, developed by a research group in science education from the University of Burgos and the FabLab León, was designed to promote self-confidence and support girls' aspirations to pursue scientific-technical careers. The program, exclusively for girls, is based on the principle of equity, which calls for equivalence to achieve equality. *Poderosas* addresses the Sustainable Development Goals of the United Nations' 2030 Agenda, especially those related to gender equality, quality education, and reducing inequalities. It also addresses the priority objectives of the European Union in the field of education.

Poderosas was the name given to Luz Rivas' initiative (an engineer from Los Angeles trained at MIT) to bring technology to girls and women of Latina descent. FabLab León has used the name since 2015 for the activities developed there for girls.

The general design of the program was based on the elements that the literature highlights as being the most conducive to encouraging girls' participation in STEM areas. Thus, the set of activities included in *Poderosas* had the following characteristics:

- Actions linked to real and socially relevant problems;
- Use of participative methodologies and methodologies of an experimental nature;
- Inclusion of current technological and artistic components;
- Reinforcement of self-concept in STEM areas, through specific dynamics;
- Modification of stereotyped representations of the disciplines and the professions through talks with young scientists and technicians.

The target public prioritized in the program were girls who, for family, social, cognitive, and economic reasons, were usually at some distance from scientific-technological disseminative actions and were therefore selected according to the following criteria: low annual family income, legally recognized large family status, concurrence of disability in either the girl or some of her parents or brothers or sisters, and foster care status or refugee status of the girl. As the program was developed thanks to the economic support of a national project funded by the Spanish Foundation for Science and Technology (FECYT), it was without cost for the participants.

The program was developed to run one day a week, from October 2020 to May 2021, for two hours in two cities, Burgos and León, with two groups of eight girls of different ages (6 to 8-year-olds and 9 to 11-year-olds) in each city. It is worth highlighting that, due to COVID-19 restrictions, no extracurricular activities took place in Burgos over three weeks and, over a period of two months, the duration of the workshops was cut to half an hour, because of the curfew. Also, the pandemic affected how the activities were developed, since the girls were not able to work in groups, as it was initially thought best for fostering cooperation. That is, they worked on the same activities and shared their results, but a physically closer cooperation was forbidden.

The *Poderosas* program starts with the contamination problem of our excessive consumption of clothes. It proposes to the girls a challenge: the "high-tech" customization of a textile piece (in the end, the girls decided to customize a backpack). To do so, they had to learn different concepts and techniques (among others, electricity, 3D design, image vectorization, vinyl printing, creation of QR codes, programming, etc.). Table 1 itemizes the objectives and activities that were utilized during the whole year to solve the challenge. In addition to these activities, two videos in which the girls explained some of the activities they participated in were produced: one directed at their close surroundings (family, teachers) and another for a Science Fair. The objective of the videos, from the program's point of view, was to consolidate the participants' self-concept and communicative skills. Likewise, through a remote link, they explained their activities in the *Poderosas* group to some girls from the local Gypsy association, who were shown how to make a self-supporting bridge. In this context, we ask ourselves about the effects on the development of self-concept and the competency dimensions in STEM areas for girls aged between 9 to 11 years old based on their participation in the *Poderosas* program. That is, we want to know if the activities designed were effective for increasing the participants' self-concept and competencies in STEM areas. It may be said that we understand these competencies as multidimensional constructs [26], including conceptual, procedural, attitudinal, contextual, and communication dimensions.

Table 1. List of activities with objectives and the scheduling of sessions.

Activity	Objectives
Presentation of *Poderosas*: presentation dynamics	Create a group atmosphere; present the girls to each other; share the approach of the program; personalize the material: design of face masks with fabric marker pens and decoration of pencil cases with stickers.
Self-supporting bridge and dome: construction, engineering concept, and problem resolution	Construct a self-supporting bridge in two sizes; construct a self-supporting bridge following a geometric design.
Poderosas challenge: high-tech customization of my clothes	Introduce the problem with the textile industry and the concept of customization. Propose the challenge of *Poderosas*
Engineering noticeboard: what do I want to do, what do I need to do it, and what do I know to do it.	Introduce the STEAM concept; create the engineering noticeboard for the challenge proposed. Introduce the dimensional design in two and three dimensions.
Image vectorization: introduction	Become familiar with the preferences, the aspirations, and the knowledge of participants in relation to the program.
Scratch: initiation to programming in blocks Online	Learn what image vectorization is, what purpose it serves, and how it takes place; know the characteristics with which the images must comply so that they can be vectorized.
Electricity: circuits with plasticine Online	Learn the basic principles of programming in Scratch.
Millennium Goals: what are they and what can we do?	Learn what a circuit is and how it functions; know the difference between insulative and conductive materials; design and construct circuits with conductive plasticine, cables, batteries, and LEDs; solve simple problems that prevent the circuit from functioning properly; develop creativity, imagination, and logical reasoning.
Electrical circuits on paper	Know the Millennium Goals and what their purpose is; design proposals for action to achieve some of the objectives within the daily life of the participants.
Christmas Session: Christmas cards with electrical circuits and decoration with 3D pens	Construct electrical circuits using conductive tape instead of cables; learn the concept of a switch and use it in the designs.
Image vectorization: introduction to the Inkscape program	Create Christmas cards that light up an LED when closed (contextualization of electrical circuits); learn how to use a 3D pen; development of spatial vision, imagination, and creativity.
Scratch: CodeHour	Learn the fundamentals of the Inkscape program; be able to break down figures into geometric bodies; development of spatial vision, logical reasoning, and creativity.
Recording the informative video for the families	Learn to perform simple programming operations using Scratch; carry out basic reasoning; identify and resolve errors in the functioning of a code.
Image vectorization: design, printing, and cutting out vinyl stickers	Express oneself naturally, making corrections where necessary; explain the knowledge and procedures that have been learnt.
Motivational talk: female student from a degree program in Computing	Design images related with the SDGs that comply with the requirements for vectorization. Vectorize the scanned images using the Inkscape program; handle the laser printer to print the sticker designs in vinyl; be capable of resolving the problems that arise.
Electrical plush toy: initiation into sewing	Let a current student introduce you to the world of computing; favor the development of self-concept and self-esteem in computing; provide a female reference figure.
Self-perceptions: how do our companions see us?	Know the image that we are projecting on others; develop self-esteem and self-concept within the girls when expressing their virtues. Favor affective-social links within the group
Electrical plush toy.	Learn the basic procedures of sewing

Table 1. *Cont.*

Activity	Objectives
Connection with the Gypsy Secretariat.	Become familiar with the reality of other girls and their scientific aspirations; explain the construction of a self-supporting bridge. Develop empathy, expressiveness, and reflection.
Which is our favorite place at the station?	Reflect on the workspace and the emotions that it provokes; develop self-concept and self-esteem in a scientific-technological environment.
Electrical plush toy: complete initiation to sewing.	Learn the basic procedures for sewing.
Motivational talk: Doctor in mathematics, researcher, and university professor.	Discover how mathematics is present in daily life; know which employment opportunities mathematics can offer beyond teaching; provide a female reference figure
Electrical plush toy: printing and sewing the eye to the body of the toy.	Learn to program a laser printer; put sewing knowledge into practice.
Electrical plush toy: making the battery carrier.	Put knowledge of electricity into practice to create an electrical circuit that lights up an LED when pressing the plush toy; put your knowledge of sewing into practice
Electrical plush toy: placing the filling and the battery carrier and the final sewing.	Put knowledge of electricity into practice to create an electrical circuit that lights up an LED when pressing the plush toy; put your knowledge of sewing into practice.
Backpack with tree motif: investigation into the selected tree and creation of a prototype.	Be capable of looking for information in a critical way; design a prototype to express the design ideas and organization of the decoration of the backpack.
Backpack with tree motif: creation of a document with the information copied out and the picture of the tree.	Summarize and write up the information in a coherent and grammatically correct way; draw the selected tree taking real images as a reference.
Backpack with tree motif: designs with Hama Beads.	Design figures with Hama Beads; develop creativity and imagination; work in a cooperative way to resolve problems as they arise.
Motivational talk: Architect, researcher, and university professor.	Discover different construction materials, their properties, and their use inside the home; know the importance of recycled materials; provide a female figure of reference
Backpack with tree motif: design in 3D.	Use the program Tinkercad to create 3D decorations for the backpack.
Recording of the video for the 7th Competition with Hands in Science.	Record an explanatory video of the backpack with tree motif project for a science competition
Backpack with tree motif: creation of a PDF with the information that once collected is transformed into a QR code and printed as a vinyl sticker.	Create a PDF with the previous document in which the information that has been collected is shown; create a QR code to access the PDF; use the vinyl printer to print the QR code.
Backpack with tree motif: placement of the QR and the decoration on the backpack at the end of the project.	Create a PDF with the previous document in which the information that has been collected is shown; create a QR code to access the PDF; use the vinyl printer to print the QR code.

4. Methodology

A case study [27] with a group of eight girls aged between 9 and 11 years old who formed one of the two groups participating in *Poderosas* at Burgos was conducted to give a response to the question of how participation might affect the development of self-concept and the competency dimensions. About their characteristics, it may be highlighted that two participants, VID and ELA, showed a higher-than-average intellectual capability; while IRD presented a borderline development disorder, perceptible in speech and fine motor skills.

4.1. Data-Collection Instruments

Instruments of a qualitative nature were selected, such as the self-portrait, a brief reflection, participative observation, and structured interviews; the informed consent of the families was requested for participation in this study at the start of the program and prior to the investigation.

4.1.1. Self-Portrait

As no instruments were found to evaluate self-concept in technological-scientific areas that suited the age of the participants, a new one based on drawings was designed. The girls were asked to imagine what they might be doing on a space mission to which they had been invited and to draw themselves in the spacecraft. This situation was chosen as it involves a highly sophisticated scientific-technological area, traditionally conceived of as masculine [28]. The instrument is an adaptation of the “Draw an Environment Test” [29] and the “Draw An Engineer Test (DAET)” [30]. Regardless of the topic, social experience interacts with the functions of perception, sensitivity, emotion, and motor skills in these drawing tests, which makes them adequate to evaluate individual perceptions such as self-concept. Their completion took place at beginning and at the end of the program, making it possible to observe any change in the participants' perceptions of the tasks that they could carry out. It is worth noting, as explained in the next section, that this instrument was passed to a larger sample of children, to compare the girls participating in *Poderosas* with that sample before and after the program.

4.1.2. Participative Observation

The first author of this study accompanied the girls in the majority of the sessions they attended. The information obtained during observation of the participants was recorded in a notebook, with special attention to behavioral, procedural, attitudinal, communicative, and participative aspects of the sessions.

4.1.3. Written Material

The girls were individually invited to describe the meaning of the name of their group (*Poderosas*), expressing it in writing, to gain insight into the views of the girls on their participation in the program and their own perceptions as participants.

4.1.4. Structured Interviews with the Families and with the Monitor

Finally, structured interviews with the monitor responsible for leading the sessions and with the families of the girls were held with the purpose of ascertaining the influence of the program from an external perspective. The families sent audio recordings commenting on their appreciation of the general changes and the elements that remained constant. The interview with the monitor was centered on specific topics related to the dimensions of competency, self-concept, and self-efficacy among the girls during the activities, as well as questions focused on improvements to the program. The audios were transcribed for their analysis.

Table 2 summarizes the objective of each instrument and its temporal domain.

Table 2. Objective and timing of each instrument.

Instrument	Objective	Timing
Self-portrait	Be aware of the views of the girls on their self-concept in scientific-technological areas.	At the beginning and at the end of the program.
Participative observation	Study the evolution of the girls with regard to their conceptual, procedural, and attitudinal development, as well as their communicative skills and self-concept in sciences and technology.	Implemented throughout the program.
Written material	Know the meaning of *Poderosas* for the girls to evaluate their self-concept.	Last session of *Poderosas*.
Structured interviews with the families	Discover the attitudinal development and the levels of self-efficacy among the girls within areas outside the program.	Last month of the program.
Structured interview with the monitor	Become familiar with the attitudinal, the procedural, the conceptual, and the communicative development of the girls, as well as the evolution of their levels of self-efficacy, and their self-concept in STEAM areas.	Last month of the program.

4.2. Analysis Techniques

The self-portraits were classified for their analysis in accordance with the mental models [29,31]. The primary idea begins with the assumption that the drawings represent the thoughts and the ideas that a person has and how that individual conceptualizes and understands specific events in the surrounding world [32].

In addition to the eight girls, the test was administered to a convenience sample of 160 girls and boys of the same age. With this total of drawings, the first author of this work characterized the different models from the observational analysis of all of them, looking for common elements and establishing levels of complexity according to the degree of self-concept. We consider that this self-concept is manifested in the functions that the subject draws herself performing on the ship (which can be active or passive); the drawing of technical elements (computers, etc.) and her relationship with them; and the location of the subject with regard to the the ship. Once grouped, the first author of the work described each mental model, and, with this description, two researchers (the second author of this work and an external researcher) classified a random selection of 20 drawings. An agreement of 85% was reached when comparing the results. The discrepancies allowed for the improvement of the descriptions of each mental model, and thus a unanimous classification was achieved.

Thus, the drawings were categorized as a function of five mental models, shown in Table 3, which describe five levels of self-concept, or, in other words, descendent categories of complexity with discriminatory characteristics prepared from the observation of the artistic productions. The response was classified as not valid in those cases in which the subject and/or the spacecraft made no appearance, as it could not be categorized in any of the existing levels.

The materials from the reflections, audio-transcriptions, and participant observation were analyzed based on their themes to establish categories in accordance with the individual and competency-related dimensions which were evaluated. The detailed categorization may be found in [33] and is summarized in Table 4. The data obtained from each instrument were analyzed independently from the others and were used complementarily to obtain a complete picture of each girl, regarding the dimensions (competencies and self-concept) studied. Therefore, in this study we triangulated the data and results.

Table 3. Exemplified mental models created for the categorization and analysis of the self-portraits.

Mental Models (MM)	Description	Example
MM1: A true astronaut.	The subject is inside the spacecraft, surrounded by technical elements, and carrying out some activity or other.	
MM2: Astronaut in training.	The subject is inside the spacecraft without carrying out any activity, but technical equipment (buttons, levers, dashboards . . .) and space suits can be seen.	
MM3: On the visit to the spacecraft.	Similar to MM2, but with neither technical equipment nor space suits.	

Table 3. *Cont.*

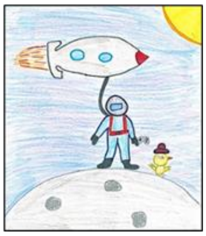
Mental Models (MM)	Description	Example
MM4: Space voyage.	The subject is outside the spacecraft, somehow linked to the spaceship and wearing a space suit.	
MM5: Lost in space	Loose elements appear: the subject, the spacecraft, space-related objects . . . The subject and the "spacecraft environment" seems to be unrelated.	
Drawings categorized as non-valid responses	The spacecraft is not represented so the drawing does not meet the requirements.	

Table 4. Categories and subcategories used for analyzing the participant observation, written material, and interviews.

Categories	Subcategories
Perceptual self-assessment with respect to science and technology	Maturity
	Self-concept
	Self-efficacy
Competence dimensions: conceptual and procedural	Conceptual learning
	Learning of specific tools
	Manual dexterity and manipulation
Competence dimensions: attitudinal and communicative competence	Interest and motivation
	Communication skills
	Interest in scientific and technological areas
Formal aspects of the program	Approach
	Activities and timing

5. Results

All the available material, once analyzed, was integrated into a single description for each girl, summarized in the individualized descriptive sheets shown below, including their identifier, the initial and final drawings of the self-portrait (specifying the mental model in which the drawings were classified), the initial opinion of the researcher, the final perceptions, the appraisal of the monitor, and the comments from each girl's family.

For example, Figure 1 summarizes the information about ELP. ELP started as a shy and quiet child who, as the program progressed, improved her self-confidence and self-concept, which is reflected in her dignification of Poderosa as "being unique and special". She has also opened up to the group, communicating more, expressing herself better, and participating significantly in the explanations and activities, which has influenced the development of her communicative competence. Her conceptual and procedural progress is outstanding. Her interest in learning technical concepts and elements has not been limited to the program; at home, she has also wanted to perform scientific activities. In this respect, it is worth noting that ELP has given her friends, for their birthdays, a cuddly electric toy like the one made in *Poderosas*. Her self-portrait moves from mental model 5 to mental model 3.

Taking another of the girls, VID, whose information is summarized in Figure 2, she was a very participative, extroverted, autonomous, hard-working child with an excellent capacity for communication. During the sessions, she learned many technological tools and procedures. In this respect, she has also shown her interest in the family environment, where her mother points out that she looks for videos related to 3D printing and is interested in sewing and design. At the same time, she has served as a role model for her classmates. In this way, seeing herself as a reference and role model has boosted her self-concept. As she says, "being Poderosa means having knowledge that I did not have before. Also, knowledge gives power, and if you have powers, you are Poderosa". These dimensions have been reflected in the improvement of the mental model of the self-portrait, going from being an invalid response because the spaceship specified in the statement did not appear, to a drawing framed at the highest level, mental model 1.

Figures 3–8 present the information obtained for the rest of the girls and can be read as the previous ones.

Focusing on the drawings, upon the completion of their participation in the program, the drawings produced by the participants were found to belong to higher mental model categories than those that they had occupied at the start. Table 5 shows the percentages of each mental model into which the self-portraits were categorized from the *Poderosas* group and the larger sample. The percentages of mental model 1 between the *Poderosas* pre-test and the post-test increased from 0% to 25%. Regarding the maximum values, the highest representativeness was no longer associated with the mental model 5 (37.5%), but rose to find itself at 50% in mental model 3; also, there was no response that was not valid. The effect size of the differences in the categories in which the drawings of the girls were classified before and after the program was estimated using the Hedges' g, obtaining a value of 0.91, which implies a big effect.

Table 5. Percentages of mental models in the *Poderosas* group and the larger sample.

Mental Model	***Poderosas* Group**		**Convenience Sample**		
	Pre-Test	**Post-Test**	**Boys (N = 82)**	**Girls (N = 72)**	**Total**
	Percentage	**Percentage**	**Percentage**	**Percentage**	**Percentage**
MM1	0%	25%	23.2%	16.7%	20%
MM2	25%	12.5%	14.6%	9%	11.9%
MM3	12.5%	50%	35.4%	48.7%	41.9%
MM4	12.5%	0%	14.6%	11.5%	13.1%
MM5	37.5%	12.5%	8.5%	11.5%	10%
Answers not valid	12.5%	0%	3.7%	2.6%	3.1%

If compared with the larger sample, it may be seen that the percentage of girls in the program who were initially found in higher mental model categories was much smaller than the percentage of girls and boys from the larger sample with those mental models, whereas, after their participation, that percentage was comparable to the children in the external sample. Besides, it may be highlighted that, in this sample, a difference was observed between the results for the girls and the boys: only 25.7% of the girls were found in the two first models, as compared with 37.8% of the boys.

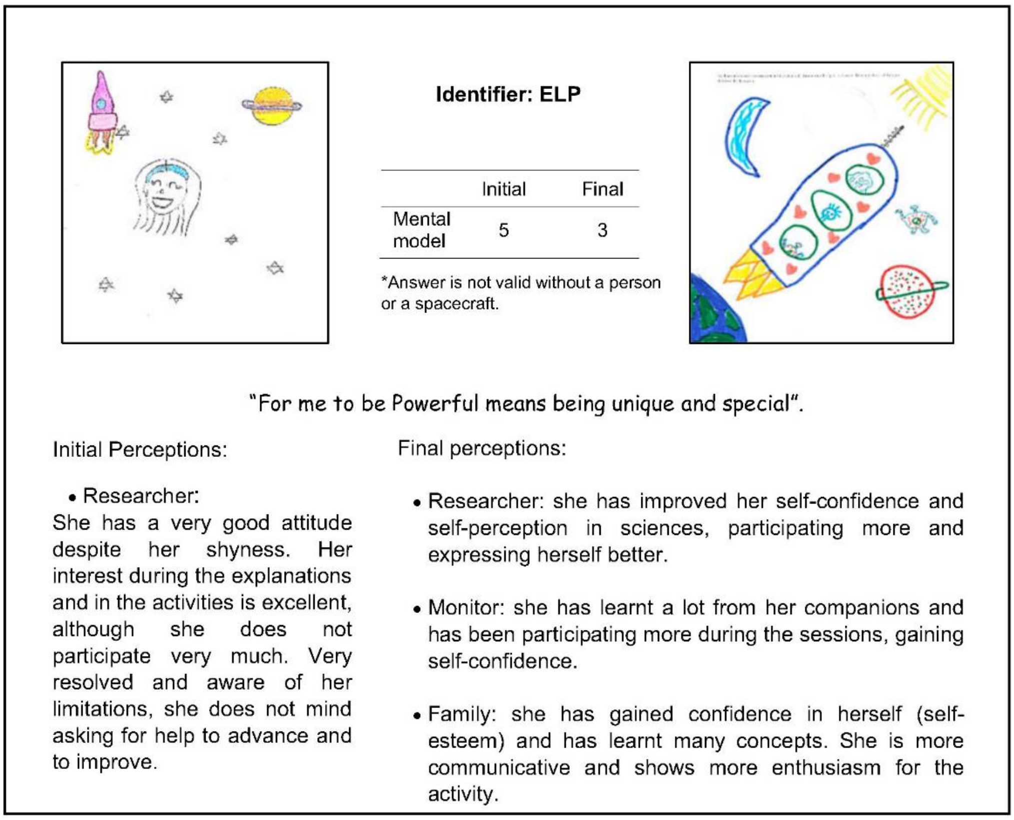


Figure 1. Descriptive sheet for ELP showing the information resulting from the instrumental analysis.

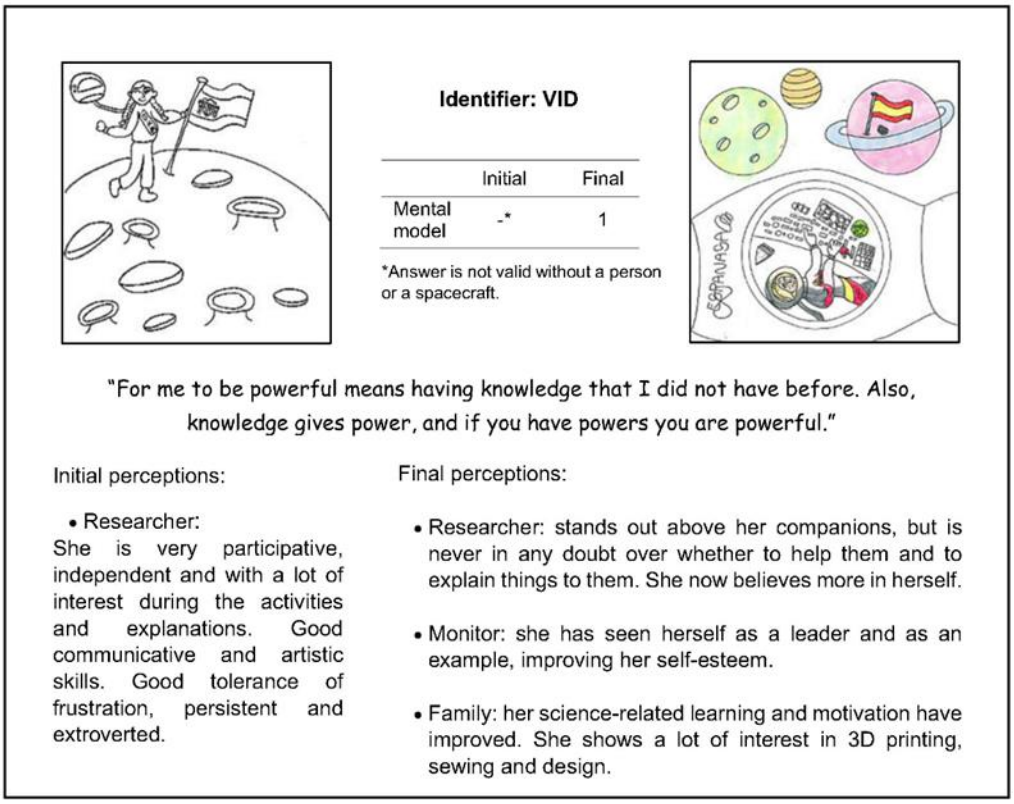
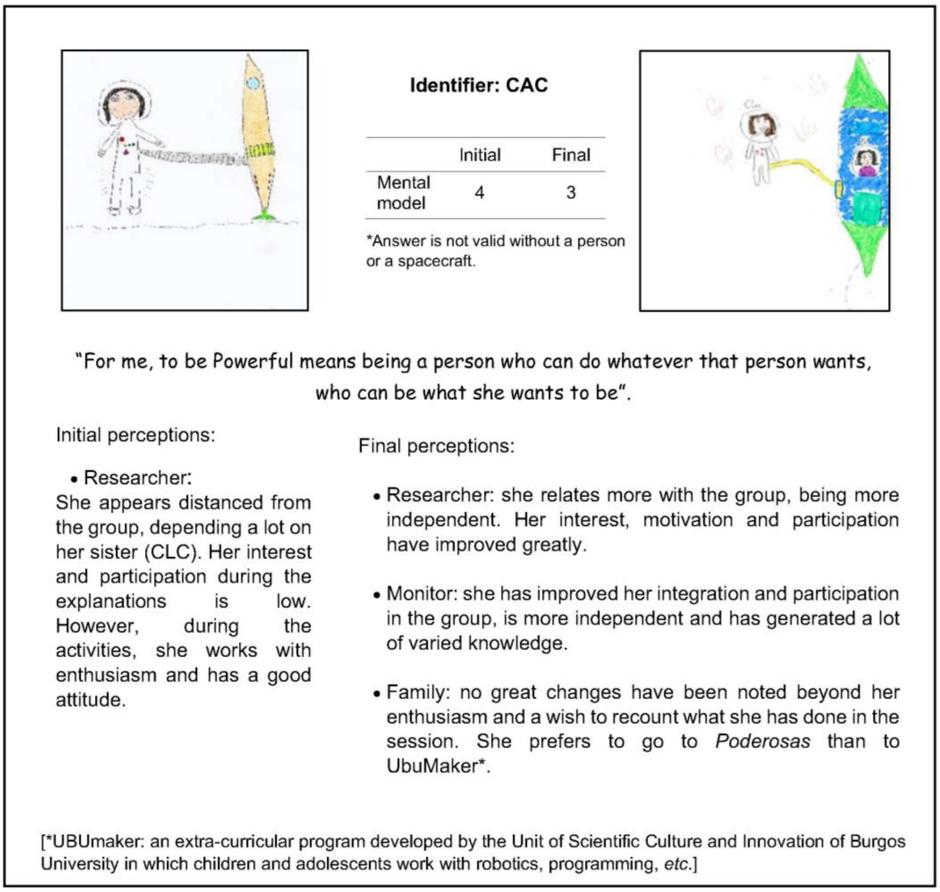


Figure 2. Descriptive sheet for VID showing the information resulting from the instrumental analysis.



Identifier: CAC

	Initial	Final
Mental model	4	3

*Answer is not valid without a person or a spacecraft.

"For me, to be Powerful means being a person who can do whatever that person wants, who can be what she wants to be".

Initial perceptions:

- Researcher:

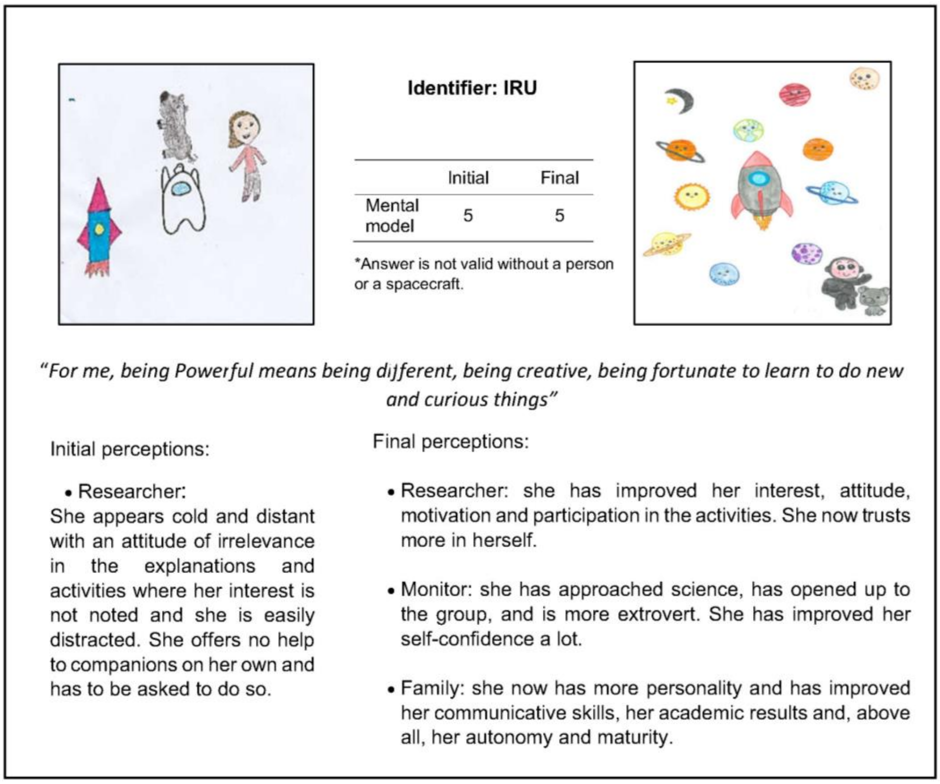
She appears distanced from the group, depending a lot on her sister (CLC). Her interest and participation during the explanations is low. However, during the activities, she works with enthusiasm and has a good attitude.

Final perceptions:

- Researcher: she relates more with the group, being more independent. Her interest, motivation and participation have improved greatly.
- Monitor: she has improved her integration and participation in the group, is more independent and has generated a lot of varied knowledge.
- Family: no great changes have been noted beyond her enthusiasm and a wish to recount what she has done in the session. She prefers to go to *Poderosas* than to UbuMaker*.

[*UBUmaker: an extra-curricular program developed by the Unit of Scientific Culture and Innovation of Burgos University in which children and adolescents work with robotics, programming, *etc.*]

Figure 3. Descriptive sheet for CAC showing the information resulting from the instrumental analysis.



Identifier: IRU

	Initial	Final
Mental model	5	5

*Answer is not valid without a person or a spacecraft.

"For me, being Powerful means being different, being creative, being fortunate to learn to do new and curious things"

Initial perceptions:

- Researcher:

She appears cold and distant with an attitude of irrelevance in the explanations and activities where her interest is not noted and she is easily distracted. She offers no help to companions on her own and has to be asked to do so.

Final perceptions:

- Researcher: she has improved her interest, attitude, motivation and participation in the activities. She now trusts more in herself.
- Monitor: she has approached science, has opened up to the group, and is more extrovert. She has improved her self-confidence a lot.
- Family: she now has more personality and has improved her communicative skills, her academic results and, above all, her autonomy and maturity.

Figure 4. Descriptive sheet for IRU showing the information resulting from the instrumental analysis.

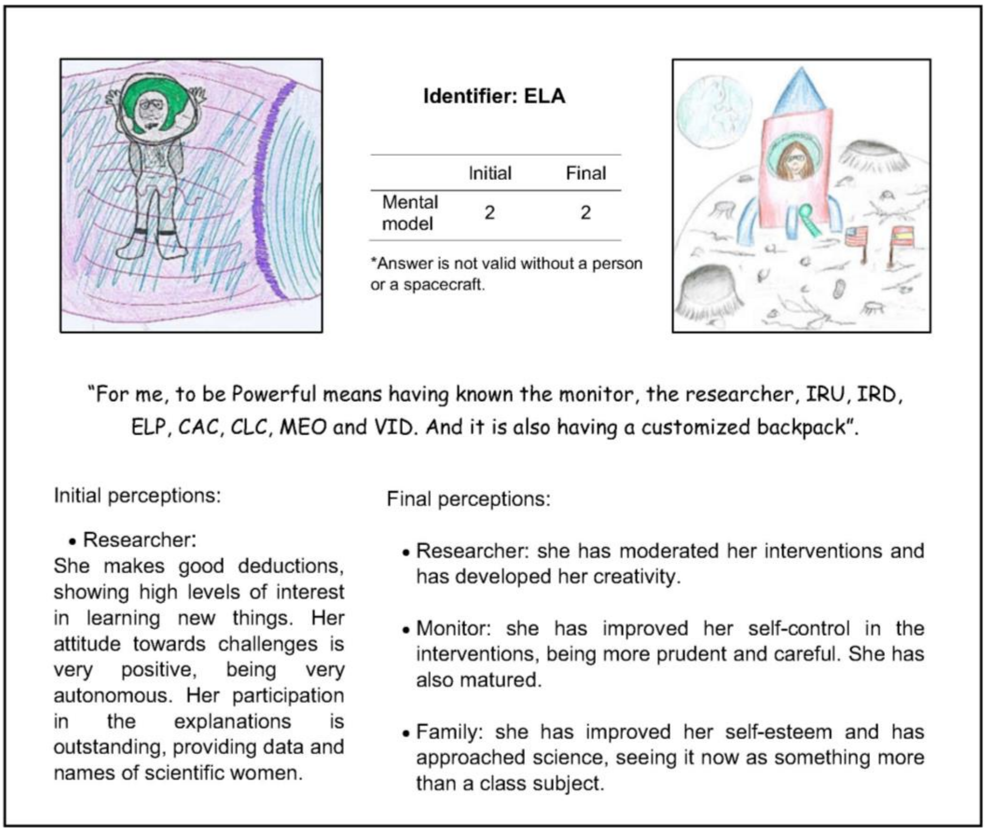


Figure 5. Descriptive sheet for ELA showing the information resulting from the instrumental analysis.

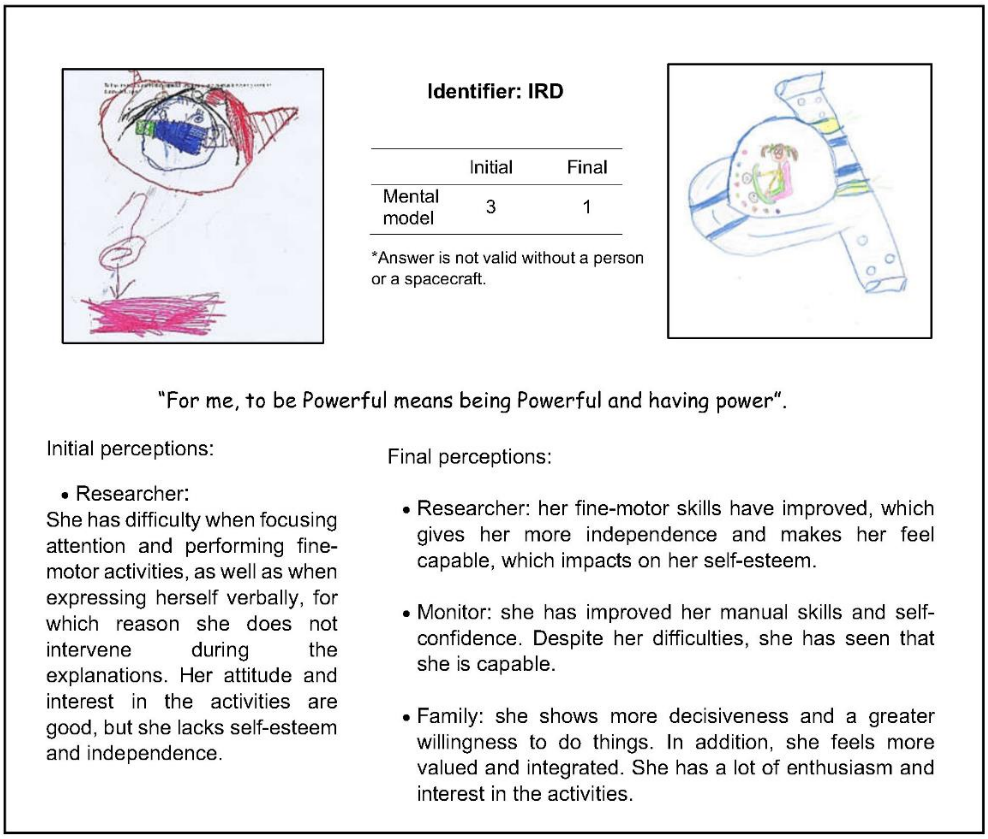


Figure 6. Descriptive sheet for IRD showing the information resulting from the instrumental analysis.

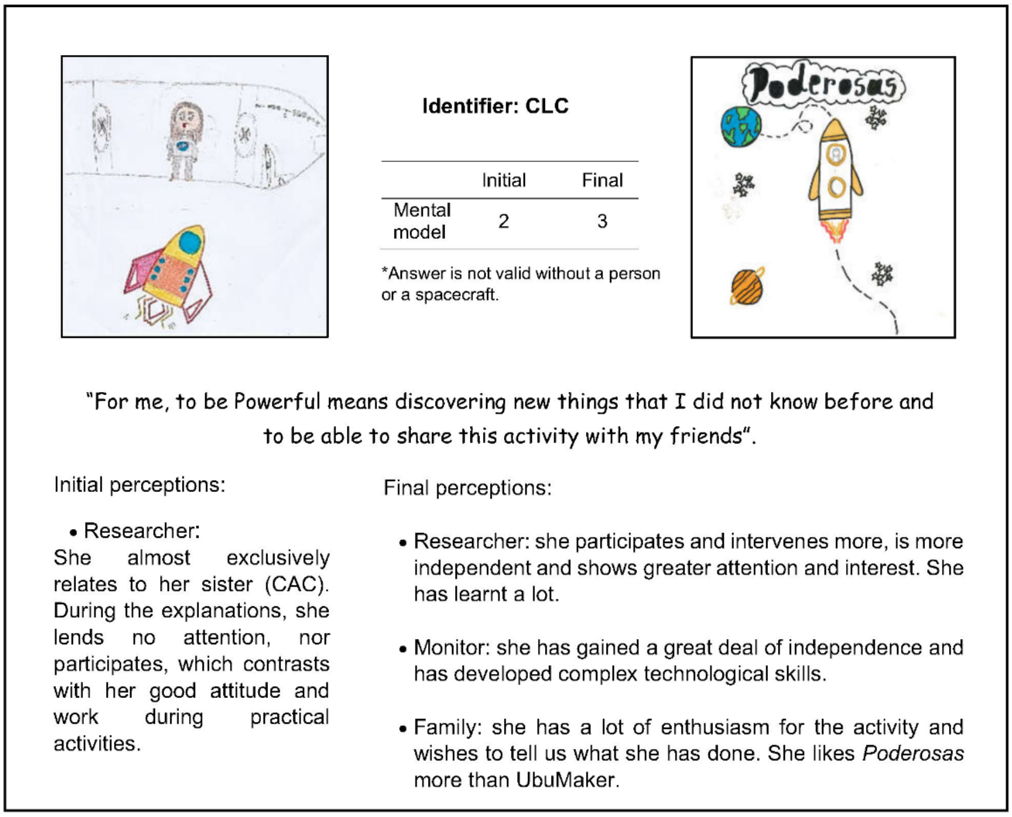


Figure 7. Descriptive sheet for CLC showing the information resulting from the instrumental analysis.

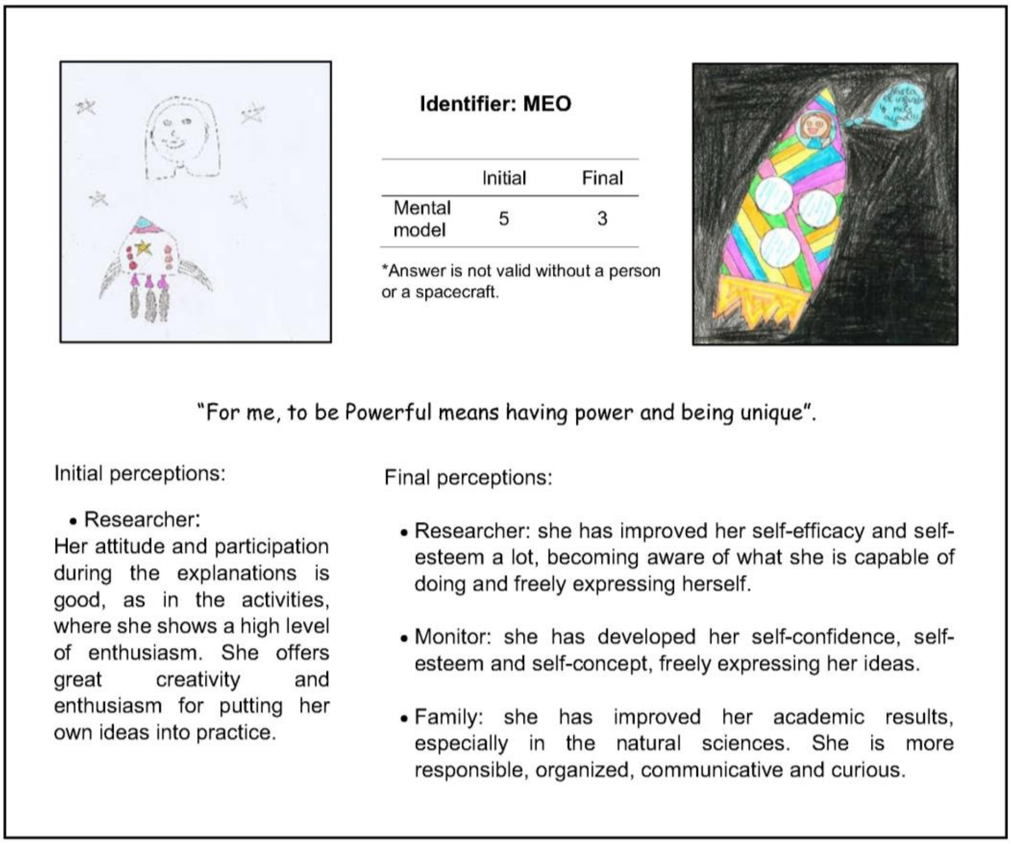


Figure 8. Descriptive sheet for MEO showing the information resulting from the instrumental analysis.

In relation to competence development, it is worth stressing that the majority of the participants, with the exception of ELP, held little or no technological knowledge at the beginning of the program. In addition, they all had little experience in this field and a degree of apprehensiveness towards working with computers, especially IRU. In this respect, the level of scientific scholarly knowledge of CAC, CLC, ELP, IRD, and IRU was low, which contrasts with the knowledge that MEO, ELA, and VID demonstrated. After their participation in the program, an improvement was detected in most of the girls, who proved themselves to be more autonomous and confident with the computers, with which they learned to use three software programs: Tinkercad, Inkscape, and Easy Cut, employed for 3D design, image vectorization, and vinyl printing, respectively. Likewise, they gained an inkling of programming, learning some basic notions from Scratch. In addition, they were all capable of applying in several contexts and explaining to others the concepts and scientific and technical procedures they had learnt, especially those related to electricity, a topic that was emphasized more than any other. They therefore demonstrated a good understanding for their age of the concepts of energy, electrical circuits, and conductive and insulative materials and were even capable of resolving simple problems that prevented the functioning of the electrical system.

None of the girls had participated earlier in an extracurricular program of a scientific-technological nature, and their mothers were the ones who encouraged them to participate in the *Poderosas* group. Their initial interest was therefore varied: IRU showed no great interest, nor did she participate; CAC and CLC were distracted during the explanations and never intervened in the group dynamics in the same way as MEO and IRD, who, despite showing a good attitude, never participated. In contrast, ELA, VID, and ELP presented an excellent attitude, and high interest and motivation, although ELP intervened less within the group context.

These viewpoints changed during the sessions, in such a way that, at the end of the program, the participation of IRU and CAC and their attitude and motivation had notably improved during those explanations and activities, showing them to be more interested and closer to the group. Regarding the other girls, ELA, VID, ELP, MEO, CLC, and IRD, they all showed similar levels of interest and participation, adopting a positive and proactive attitude.

In relation to self-concept and self-efficacy in sciences, and consistent with the mental models categories from the initial self-portrait, those aspects were at very low levels, especially in the cases MEO, ELP, IRD, and IRU. Also, IRD, IRU, MEO, ELP, CAC, and CLC initially did not intervene very much in the explanations, expressing themselves with little precision and with little reflection. Having concluded the program, a notable improvement could be observed in all the girls, and in particular in ELP, VID, IRD, IRU, and CAC: CAC and IRD had notably improved their expressive capability, and MEO, ELP, IRU, and CLC had strengthened their expressiveness, explaining their ideas with greater clarity, both in the *Poderosas* group and in the family setting. This improvement in the perception of their interventions as relevant and in the clarity of their interventions, together with the change in interest and the motivation, was particularly evident during the talks with the scientists who were invited, in which all the girls actively participated, asking numerous questions related to the topic that was covered, mentioning their interest in the topic or the knowledge that they held on it, and even referring to the specific profession of the guest and relating it to their future aspirations.

Figure 9 shows a summary of these results, in terms of the existence of either a positive or a negative change or no change at all within the girls (values of 1, −1, and 0, respectively) for the different dimensions under study. It is worth specifying that, rather than showing the levels that the girls reached, the change or absence thereof is shown, in such a way that the initial and final levels can differ in cases where a positive change happens.

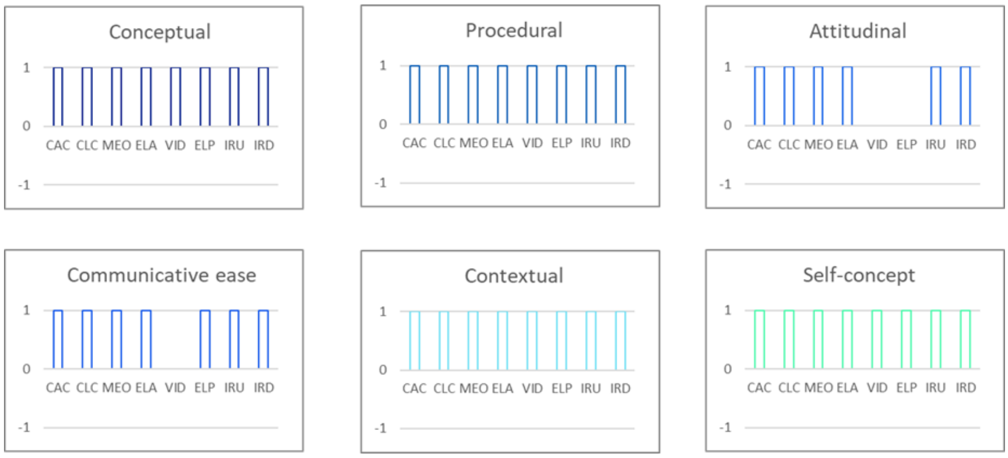


Figure 9. Representation of either positive or negative changes or no changes in the conceptual and individual dimensions under study.

6. Discussion

The results showed an improvement in the conceptual and procedural dimensions for all the girls. This improvement can be linked to the practical nature of the activities, which covered theoretical knowledge, but also manual procedures and skills [34]. This improvement seems to have been possible thanks to the proposal of a set of tasks with an adequate degree of complexity and that were focused on a final project, thereby linking learning with a goal grounded in reality, as highlighted in the literature [35,36]. In this respect, the families pointed out in the interviews that the approach adopted to the activities was fundamental to awakening the interest of the girls.

Likewise, the interrelations between the girls were favored, and a good group atmosphere was created. It is worth highlighting the case of VID, who was adopted as a role model by her companions, encouraging the development of a group identity [37]. This situation appears to have been favored [38] because all participants were of the same gender and felt they were equally valued and had the same opportunities, which stimulated their participation, motivation, interest, and attitude. Besides, the attitudinal improvement that was observed could have been strengthened by using technologies in an active methodology, through which interaction and cooperation were promoted [39].

With reference to self-concept in sciences and technology—where improvement was detected, among other indicators, in the categorization of the girls' last self-portrait in higher categories than the initial ones—they were favored on various fronts. As pointed out in various studies [40], self-concept in science and technological areas is intimately related to real-life experiences, especially during infancy and, more specifically, at the ages of 8 to 13 years old. In this respect, the inclusion of activities for the development of self-concept (such as self-portraits and specific dynamics for making explicit self-perfection) as well as of activities for the revalorization of the acquired knowledge (as the videos recorded or the sessions in which they showed others how to accomplish technological tasks) seems to contribute to improving the girls' self-concept [41]. In turn, the incorporation of female models of reference, both in the figure of the monitor and in the invited scientists, appears to have influenced the self-concept of the girls. As various authors have pointed out [42,43], one of the main reasons for female disinterest and the low representation of women in STEM areas is rooted in the absence of female models with which to identify, implying a masculine prototype.

Although we must be careful about the implications of this work, given its uniqueness, the results point to the relevance of improving girls' self-concept in STEM areas early, in environments where they can experiment without fear with new ideas and technologies. Extracurricular activities are very conducive to these actions. Improving self-concept is a long process, so the preferred extracurricular activities will be those extended over time.

In addition to the use of active methodologies, the activities seem to have to be focused on real problems, perceived as being of some social utility by the girls and allowing them to develop various technological skills (to which they usually do not have access) while at the same time deepening their understanding of scientific concepts. The results also indicate the need to favor the girls' oral and written expression, providing them with various opportunities to explain to others what they have learned.

Finally, as highlighted in the literature, dialogue with women in science and technology is essential. In our case, the selection of young women who worked in areas related to the activities that the girls were developing has allowed a strong identification and stimulation.

7. Conclusions

In this paper, we described an extracurricular scientific-technological program for girls especially designed considering the research evidence on the activities, methods, and actions that appear to foster better attitudes and skills among girls in STEM areas. For its evaluation, we studied whether participation in this extracurricular influenced their self-concept, as well as their development of competencies in scientific-technological areas.

Based on the results obtained, it seems that the participation of the girls in the *Poderosas* program has positively influenced their competences related to the scientific and technological aspects addressed throughout the program and their levels of self-concept in sciences and technology. These changes have occurred gradually over the course of their participation and were especially evident in the last term. It is worth saying that the girls who participated belonged to groups that are normally at a greater distance from the scientific-technological actions of dissemination and, as has been seen, their self-concept in scientific-technological areas, as measured in this study, was even lower than the self-concept of the girls from a larger sample. Moreover, considering the context in which the program was developed, the results were even more significant, as many of the initially planned activities were not carried out because of the COVID-19 pandemic, as in the case of the dynamics intended to strengthen cooperation. We therefore consider that the characteristics of *Poderosas*, which bring together the results of recent studies in a coherent educational, scientific-technological proposal, can serve as a frame of reference for future programs and initiatives that work towards the very necessary empowerment and scientific literacy of women in areas of STEM.

This study has been developed by systematically observing the evolution of this group of girls for eight months. In addition to the various data sources used, including their voices, we obtained information on the perception of their immediate environment. Although limitations regarding the data collection and analysis could be considered, the triangulation approach implemented allows us to consider the research findings described here to have been validated. However, the main limitation of this study lies in the transferability of the program and the results obtained to other groups of girls. This aspect needs more research. Also, it would be relevant to study the long-term repercussions of the program, for which a longitudinal study could be implemented, in which the progress of the self-concept, the interest, and the attitudes of the participants towards the sciences are analyzed within two, four, and six years, in comparison with other girls who have not participated in the program.

Despite the encouraging results obtained with this program, a lot remains to be accomplished to ensure the pipeline supply and to achieve an egalitarian future. Emphasis is therefore placed on the need to promote initiatives that take place over prolonged periods of time and that at the same time encourage the development of competence, self-concept, and self-esteem among girls, because it is fundamental to move beyond the eventuality of actions that, although important, are insufficient to tear down the barriers of gender stereotyping.

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References

1. Botella, C.; López-Iñesta; Rueda, S.; Forte, A.; de Ves, E.; Benavent, X.; Marzal, P. Iniciativas contra la brecha de género en STEM. Una guía de buenas prácticas. *Actas Genui* **2020**, *5*, 349–352.
2. UNESCO—Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura. *From Access to Equality: Empowering Girls and Women through Literacy and Secondary Education*; UNESCO: Paris, France, 2012.
3. European Commission. *Meta-Analysis of Gender and Science Research*; European Union: Luxemburg, 2012.
4. Rossi, C.A.; Barajas, F.M. Elección de estudios CTIM y desequilibrios de género. *Enseñanza Cienc.* **2015**, *3*, 59–76.
5. Ministerio de Universidades. *Datos y Cifras del Sistema Universitario Español*; Ministerio de Universidades: Madrid, Spain, 2021.
6. Jiménez, M.I.; Müller, J.; Ruiz-Mallén, I.; Kim, E.; Cripps, E.; Heras, M.; Vizzini, C. Gender and Innovation in STE(A)M Education. 2018. Available online: http://www.scientix.eu/documents/10137/752677/Scientix-SPNE12-Gender-Innovation-STEAM_Final.pdf/e907b19e-0863-4502-a396-9ad6a5184be0 (accessed on 1 July 2022).
7. UNESCO—Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura. *Cracking the Code: Girls' and Women's Education in Science, Technology, Engineering and Mathematics (STEM)*; UNESCO: Paris, France, 2017.
8. Bleeker, M.M.; Jacobs, J. Achievement in Math and Science: Do Mothers' Beliefs Matter 12 Years later? *J. Educ. Psychol.* **2004**, *1*, 97–109. [CrossRef]
9. Howard, L.W.; Tang, T.L.P.; Austin, M.J. Teaching critical thinking skills: Ability, motivation, intervention, and the Pygmalion effect. *J. Bus. Ethics* **2015**, *1*, 133–147. [CrossRef]
10. Lindahl, B. A longitudinal study of students' attitudes towards science and choice of career. In Proceedings of the NARST Annual Conference, New Orleans, OR, USA, 15–18 April 2007. Available online: http://urn.kb.se/resolve?urn=urn:nbn:se:hkr:diva-6093 (accessed on 1 July 2022).
11. Heaverlo, C.; Cooper, R.; Santos Lannan, F. STEM development: Predictors for 6th–12th grade girls' interest and confidence in science and math. *J. Women Minor. Sci. Eng.* **2013**, *19*, 121–142. [CrossRef]
12. Rawls, J. *La Justifica Como Equidad. Una Reformulación*; Paidós: Barcelona, Spain, 2012.
13. Odogwu, H.; Adeyemo, S.A.; Jimoh, J.A.; Yewonde, R.O. Science, mathematics and technology teachers' perception of school environment: Gender Differences. *Multicult. Educ. Technol. J.* **2011**, *4*, 274–287. [CrossRef]
14. Kyte, B.; Riegle-Crumb, C. Perceptions of the Social Relevance of Science: Exploring the Implications for Gendered Patterns in Expectations of Majoring in STEM Fields. *Soc. Sci.* **2017**, *6*, 19. [CrossRef]
15. Archer, L.; Moote, J.; Macleod, E.; Francis, B.; DeWitt, J. *ASPIRES 2: Young People's Science and Career Aspirations, Age 10–19*; UCL Institute of Education: London, UK, 2020.
16. Doubé, W.; Lang, C. Gender and stereotypes in motivation to study computer programming for careers in multimedia. *Comput. Sci. Educ.* **2012**, *1*, 63–78. [CrossRef]
17. Goude, J.; Estrella, R.; Margolis, J. Lost in Translation: Gender and High School Computer Science. In *Women and Information Technology: Research on Underrepresentation*; Cohoon, J., Aspray, W., Eds.; MIT Press: Cambridge, MA, USA, 2013.
18. Trautwein, U.; Möller, J. Self-Concept: Determinants and Consequences of Academic Self-Concept in School Contexts. In *Psychosocial Skills and School Systems in the 21st Century*; Lipnevich, A., Preckel, F., Roberts, R.D., Eds.; Springer International Publishing: Cham, Switzerland, 2016; pp. 187–214. [CrossRef]
19. Nagy, G.; Trautwein, U.; Baumert, J.; Köller, O.; Garrett, J. Gender and course selection in upper secondary education: Effects of academic self-concept and intrinsic value. *Educ. Res. Eval.* **2006**, *12*, 323–334. [CrossRef]
20. Simpkins, S.D.; Davis-Kean, P.E.; Eccles, J.S. Math and science motivation: A longitudinal examination of the links between choices and beliefs. *Dev. Psychol.* **2006**, *42*, 70–83. [CrossRef]
21. Ertl, B.; Luttenberger, S.; Paechter, M. The Impact of Gender Stereotypes on the Self-Concept of Female Students in STEM Subjects with an Under-Representation of Females. *Front. Psychol.* **2017**, *8*, 703. [CrossRef] [PubMed]
22. Todd, B.L.; Zvoch, K. The effect of an informal science intervention on middle school girls science affinities. *Int. J. Sci. Educ.* **2019**, *41*, 102–122. [CrossRef]

23. Chan, Y.-K. Investigating the relationship among extracurricular activities, learning approach and academic outcomes: A case study. *Act. Learn. High. Educ.* **2017**, *17*, 223–233. [CrossRef]
24. Garcia, M.B. Hackathons as extracurricular activities: Unraveling the motivational orientation behind Student participation. *Comput. Appl. Eng. Educ.* **2022**, *30*, 1903–1918. [CrossRef]
25. Stringer, K.; Mace, K.; Clark, T.; Donahue, T. STEM focused extracurricular programs: Who's in them and do they change STEM identity and motivation? *Res. Sci. Technol. Educ.* **2020**, *38*, 507–522. [CrossRef]
26. Ortiz-Revilla, J.; Greca, I.M.; Adúriz-Bravo, A. Conceptualización de las competencias: Revisión sistemática de su investigación en Educación Primaria. Profesorado. *Rev. Curríc. Form. Profr.* **2021**, *1*, 223–250. [CrossRef]
27. Yin, R.K. *Case study Research Design and Methods (Applied Social Research)*; Methods Series; SAGE Publications: Thousand Oaks, CA, USA, 1989; Volume 5.
28. Sage, D. Giant Leaps and Forgotten Steps: NASA and the Performance of Gender. *Sociol. Rev.* **2009**, *57*, 146–163. [CrossRef]
29. Spronge, L.E.; Martin, S.N. Exploring Indian Middle School Students' Conceptions of the Environment Using the Draw-an-Environment Test. *Asia-Pac. Sci. Educ.* **2020**, *1*, 152–178. [CrossRef]
30. Knight, M.; Cunningham, C. Draw an Engineer Test (DAET): Development of a Tool to Investigate Students' Ideas about Engineers and Engineering. In Proceedings of the American Society for Engineering Education Annual Conference & Exposition, Salt Lake City, UT, USA, 20–23 June 2004. Available online: https://ceeo.tufts.edu/documents/conferences/2004mkcc.pdf (accessed on 30 June 2022).
31. Shepardson, D.P.; Wee, B.; Priddy, M.; Harbor, J. Student's mental models os the environment. *J. Res. Sci. Teach.* **2007**, *2*, 327–348. [CrossRef]
32. Katz, P. *Drawing for Science Education: An international Perspective*; Sense Publishers: Rotterdam, The Netherlands, 2017.
33. Ruiz-Bartolomé, E. Efectos del Programa Poderosas en el Desarrollo Competencial en Niñas en Áreas Científico-Tecnológicas. Master's Thesis, Universidad de Burgos, Burgos, Spain, 2021.
34. Zompero, A.F. La adquisición de procedimientos de naturaleza científica de alumnos brasileños de enseñanza media. *Rev. Investig. Esc.* **2018**, *94*, 31–46.
35. Reinking, A.; Martin, B. La brecha de género en los campos STEAM: Teorías, movimientos e ideas para involucrar a las chicas en entornos STEM. *J. New Approaches Educ. Res.* **2018**, *2*, 120–188.
36. Berenguel, E.; Gil, F.; Montoro, A.B.; Moreno, M.F. Influencia de la autoconfianza y el perfil motivacional en el "flujo" en matemáticas. In Proceedings of the Investigación en Educación Matemática XIX, Alicante, Spain, 3–5 September 2015. Available online: https://rua.ua.es/dspace/bitstream/10045/51386/1/2015-Actas-XIX-SEIEM_15.pdf (accessed on 15 June 2022).
37. Jiménez, M.; De la Villa, M. Jóvenes, redes sociales de amistad e identidad psicosocial: La construcción de las identidades juveniles a través del grupo de iguales. *Rev. Galego-Port. Psicolaxia Educ.* **2004**, *9*, 183–206.
38. Huang, J.; Gates, A.J.; Sinatra, R.; Barabási, A.L. Historical comparison of gender inequality in scientific careers across countries and disciplines. *Proc. Natl. Acad. Sci. USA* **2020**, *9*, 4609–4616. [CrossRef]
39. Perea, M.R.; Muñoz, A.M. Los murales y carteles como recurso didáctico para enseñar ciencias en Educación Primaria. *Rev. Eureka Sobre Enseñanza Divulg. Cienc.* **2013**, *3*, 468–479. [CrossRef]
40. Vincent, R.P.; Schunn, C.D. The Increasingly Important Role of Science Competency Beliefs for Science Learning in Girls. *J. Res. Sci. Teach.* **2017**, *6*, 790–822. [CrossRef]
41. Rikabi, R.B.; Razzaq, U.S.; Abdul, Z.K. The impact of using caricature drawings in attitudes towards science among 5th grade females. *J. Basic Educ. Collage Educ. Hum. Sci.* **2016**, *25*, 340–354.
42. Olmedo-Torre, N.; Carracedo, F.S.; Ballesteros, M.N.; López, D.; Pérez-Poch, A.; López-Beltrán, M. Do female motives for enrolling vary according to STEM profile? *IEEE Trans. Educ.* **2018**, *4*, 289–297. [CrossRef]
43. Stentiford, L.J. 'You can tell which ones are the lady lads': Young women's accounts of the engineering classroom at a high-performing English university. *J. Gend. Stud.* **2019**, *2*, 218–230. [CrossRef]