Promoting STEAM learning in the early years: "Pequeños Científicos" Program

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Education in the early years is an excellent space for promoting integrated learning. The STEAM education model combines Science, Technology, Engineering, Arts and Mathematics holistically and has gained force globally, mostly in developed countries. However, in developing countries of Latin America, STEAM education programs are incipient and still unfamiliar to many early childhood and primary school educators. "Pequeños Científicos" is a pioneer educational program in Chile aimed at providing extracurricular academic enrichment to students 3 to 10 years old, with a gender-empowering approach. With a cross-sectional design and integrating data from students, researchers and educators, this article documents program design and implementation issues based on a partial application of SWOT analysis grounded on strengths, weaknesses and opportunities. The strengths were identified the strongest elements that might be transferred to similar interventions, for instance, students were positively engaged in the learning processes and actively communicating their advances through diverse artistic formats. The weaknesses were mainly difficulties that can be prevented in future replication, such as teachers' management of children's behavior. Opportunities present alternatives to these types of programs to improve and grow; for example, through articulation of the courses and including children with additional needs. We call for tackling the weaknesses for more efficient application and discuss the promotion of STEAM learning in the early years in the contexts of high educational inequality for future replication in diverse contexts.

Keywords: STEAM, learning, early childhood education, gender

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1 Introduction

In the past decades, educators' and scientists' interest in early science learning has increased dramatically (Sharapan, 2012; DeJarnette, 2018). Pre-school children have a natural inclination toward science due to their sense of curiosity and ability to find solutions based on creativity and imagination (DeJarnette, 2018). Indeed, young learners can be engaged in scientific practices such as conducting investigations, observing diverse elements of nature and inferring patterns and regularities, or explaining the causes of natural phenomena (Legare & Gelman, 2014).

In this regard, STEM (Science, Technology, Engineering and Mathematics) education has spread globally, especially in developed countries in which critical relevance has been given to facilitate children's future success (Akturk & Demircan, 2017). However, in developing countries of Latin America, it is incipient and mainly focuses on secondary education, perhaps due to promoting interest in scientific careers or reducing gender inequalities (García-Holgado, Camacho, & García-Peñalvo, 2019). Consequently, evidence from STEAM programs comes mostly from developed countries. Further, it is relevant to incorporate STEAM programs oriented toward young children in diverse countries to advance educational opportunities, especially in areas with marked gender inequalities.

Our study focuses in the "*Pequeños Científicos*", a pioneer educational program in Chile aimed at providing extracurricular integrated courses to students 3 to 10 years old based on their interests by age, with a gender-empowering approach.

Given the centrality of research abilities for learning through life (UNESCO, 2015), it is crucial to infuse interest in and expose learners to scientific practice in their early years. STEAM integrates and uses the arts in the STEM curricula to construct knowledge and help children express concepts (Piro, 2010). Taking into consideration that arts are vital in early childhood education, combining STEM with arts, it is likely to engage teachers to develop and implement activities oriented to these areas (Sharapan, 2012). Following Sharapan's (2012) line of thinking, in the present study, we considered STEAM components as disciplinary areas with equal importance. For early childhood education, we understand each element as follows (Sharapan, 2012, p.37).

> Science. Science is about nurturing a sense of wonder and curiosity. It's about experimenting, encouraging investigation, and asking 'Why do you think...?' questions. In early childhood, science is about everyday experiences, like what makes shadows, how plants grow, why ice melts, and where different animals live and what they eat. When children tell you their idea of why something happens, that's a hypothesis!
>
> Technology. Technology is just a fancy word for tools. Adults tend to think of technology as digital equipment like cameras and computers or sophisticated machines in factories. But crayons and pencils are tools. So are rulers, magnifying glasses, scissors, zippers, and even dump trucks.
>
> Engineering. Engineering starts with identifying a problem, then moves ahead to thinking about solutions and trying them out. All of us have seen children go through these processes when they're trying to figure out how to make a strong foundation so they can build their blocks higher or when they're working on a toy boat that will float in the water table or making a stable base so their clay figures stand up.
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> Art. Adding the arts gives children the opportunity to illustrate STEM concepts in creative and imaginative ways, express ideas about the world through music and

> dance, communicate with descriptive language, illustrate ideas with crayons or markers, create graphs, and build models.
>
> Math. Mathematics is much more than counting. Mathematical thinking includes comparing, sorting, working with patterns, and identifying shapes. Language, too, plays a big part in math, for example, when we use comparison words like bigger, smaller, higher, lower, farther, and closer. Higher-level math thinking comes into play when we help children know that comparisons are relative.

Since an important objective of early education is that students gain a deeper understanding and practice using logic and evidence for reasoning about the natural world, STEAM educational contexts are suitable spaces to promote integrated learning. Further, teachers and educators are in an optimal position to connect early childhood learning experiences with the subsequent academic learning objectives and accomplish the goal of education beyond the specificities of separate disciplines (DeJarnette, 2018; Çiftçi, Topçu, & Foulk, 2020). Indeed, it has been documented that the reception of integrated STEAM lessons by pre-school children shows high levels of engagement and cooperation. Thus, it is crucial to increase the positive exposures and experiences related to these subject fields both for students and their teachers (Aronin & Floyd, 2013).

2 STEAM in the early years: Challenges faced by teachers

2.1 Engaging students in scientific practices

One of the challenges for educators designing STEAM experiences is engaging students in more authentic scientific practices. These include observing, experimenting, or carrying out scientific investigations and communicating ideas, discussing the evidence that supports these ideas with peers, and supporting metacognitive operations (Crawford and Capps, 2018). Research has shown that enhancing children's natural curiosity, and providing positive childhood experiences with enjoyable science, and encouraging family educational involvement plays an important role in learning outcomes (McClure, 2017; Monkevinciene, 2020). In fact, this is especially relevant knowing that parents can support or hinder their children's STEM education. Indeed, parents might hold negative attitudes about STEM or have limited STEM knowledge to support they children, thus, perhaps they limit the chances for children's learning in these disciplines (Milner-Bolotin & Marotto, 2018).

2.2 Building on children's interests

Another challenge is expanding children's natural learning interests by integrating them with areas of teaching. This purpose might be a problem if teachers are constrained by educational curricula based on excessive content rather than learning the processes (Cabello & Ferk Savec, 2018). Teachers can overcome this issue by integrating STEAM learning into everyday moments (Sharapan, 2012), student hobbies (Dabney, Chakraverty, & Tai, 2013) and student-posed questions (McClure, 2017; Sharapan, 2012), focusing on local phenomena (Lee, 2020), as well as using interactive technology such as labs (Proudfoot & Kebritchi, 2017). Nonetheless, critical positioning regarding technology and children's motivation is needed, not to assume that technological tools motivate students by default but considering the pedagogical intentions and ways of interaction technology might facilitate in the learning settings.

2.3 Dealing with STEM gender stereotypes

The gender gap is pronounced in STEM fields, but it is larger in computer science, engineering, and physics than in biology, chemistry, and mathematics (Cheryan et al., 2017). In some regions, such as Latin America where the present study takes place, it is particularly pervasive because of cultural norms that influence female behavior (García-Holgado, Camacho, & García-Peñalvo, 2019), and social stereotyping that discourage women from being interested in STEM learning, pursuing science or mathematics activities or professional careers (García-Peñalvo, 2019). Indeed, it is a challenge for teachers to consider elements of gender equity within the design of courses (MacDonald et al., 2020). As a result, partly explained by gender stereotypes operating early in pre-school (Beede et al., 2011; Bordón, Canals, & Mizala, 2020; Savinskaya, 2017), women are a minority in STEM areas at the university level. Nonetheless, teachers can influence the interest of young girls in learning these areas (Fadigan & Hammrich, 2004). Indeed, the gender of the teacher has a significant impact in modeling the role of women in STEM (García-Holgado, Camacho, & García-Peñalvo, 2019; Chen, Sonnert, and Sadler, 2020; Jeong et al., 2019). Though short time role model interventions in childhood sometimes change stereotypical beliefs about women but not necessarily shift the young girls perceive themselves regarding STEM disciplines (Olsson & Martiny, 2018).

3 Teachers' experiences with STEAM-STEM in the early years

STEM might be an unfamiliar term for many childhood educators (Sánchez Lozano & Casallas Ochoa, 2020) and confusing when applied to pre-school teaching (Moomaw & Davis, 2010). As it was previously mentioned, in the present study, we include the arts in the acronym because of its relevance for the early years' education. We define STEAM as an interdisciplinary approach integrating holistically the development of knowledge and skills in science, technology, engineering, arts and mathematics education (Monkeviciene et al., 2020).

Notwithstanding teachers' general positive beliefs and attitudes towards STEAM for young learners when they get to know integrated learning experiences, certain hesitation to implement activities in the classroom may be apparent due to lack of teachers' STEM content knowledge, feeling unprepared to teach, or uncomfortable to address concepts in these integrated science-related fields (Nesmith & Cooper, 2019; Sharapan, 2012). Some other barriers that educators often encounter are poor parental and school support, lack of technological resources, difficulties to use STEAM approach in a practical way with children (Ogegbo, & Aina, 2020), or insufficient experiences with the elements of the engineering process for young learners (Nesmith & Cooper, 2019).

Nonetheless, research has shown that with proper professional development, efficient and contextually relevant, early childhood educators and teachers are able to implement successful practices based on STEM or STEAM, or to do so more confidently (Brenneman et al., 2019; Çiftçi, Topçu & Foulk, 2020; Monkeviciene et al., 2020; Simoncini, & Lasen, 2018).

Teachers who have participated in STEM or STEAM professional learning experiences, gain confidence and perceive themselves to become more efficient in implementing these kinds of strategies in early childhood education (Nesmith & Cooper, 2019). Further, teachers' understanding of the advantages of incorporating these disciplines in early education is increased when they combine arts with STEM disciplines (Lawson et al., 2018). Indeed, STEM disciplines are being implemented in many contexts at the pre-school level with diverse emphases and results, taking arts as a standing point. Thus, in those positive conditions, STEM activities provide an effective platform for rich learning experiences (Brenneman et al., 2019). However, in early childhood education, creating opportunities for children to learn in a real, integral and meaningful context is needed (Sharapan, 2012). The role of arts in the creation of new knowledge, opening experiences to children exploration with materialities and allowing expression of students learning is essential in pre-school and primary education alternatives (Monkeviciene et al., 2020).

3.1 Study Context

Our study centers on *Pequeños Científicos*, an extracurricular educational enrichment program in Chile launched at a university-based Centre for the Development and Education of Talents, PENTA UC. It is aimed at students 3 to 10 years old and seeks to nurture their curiosity, inquiry, and positive attitudes towards learning while promoting XXI century skills such as creativity, problem-solving and systemic thinking. The latter is in line with the international trends that have positioned the integrated STEAM areas as a core part of future educational models. The program is offered twice per year (summer and winter intersessions) at the Pontificia Universidad Católica de Chile campus facilities. It is a week-long program where the students meet teachers for 4 hours every day of the week (20 hours total), complemented by a learning exhibition with families at the end of the week. During its five years of implementation, the program has reached hundreds of students with courses designed and taught by scholars, researchers, and educators. The innovation documented in this article embeds the arts within STEM, and explicitly promotes a gender-empowering approach. Instead of a disciplinary emphasis, courses have the integrated STEAM focus and enhance the critical role of women in the development of each discipline. This approach also includes elements of the nature of science afforded by the courses through hands-on inquiry and modeling-based learning.

The study documented here aims at answering the following research question:

What are the most significant strengths, weaknesses, and opportunities embedded in the design and playing a key role in the implementation of STEAM education for young children in the Pequeños Científicos program?

The purpose of the study is to document the design and implementation of a university-based program to promote STEAM learning in the early years and to discuss aspects for future replication. The presentation analyses issues that the program implementation raises regarding the application of the STEAM approach in early education in contexts of marked gender and educational inequality, based on a partial application of SWOT analysis grounded on strengths, weaknesses and opportunities. Results are expected to inform future replication of STEAM programs such as this one, in the contexts of inequalities and disadvantages, thus offering hope to the countries that do not count with advanced educational development. This is relevant for the educational community beyond the specific program and it illustrates that university teachers might interlock the learning needs of children in STEAM areas with their own interests to spread their knowledge to the younger learners, which is part of the novel contribution of this work.

4 Research Methods

4.1 Study design

The study had a cross-sectional design, anchored in the contextual features of the program implementation. The approach was observational in nature and oriented to capture the process at a single moment in time. We followed the guidelines of action-research, which commits not only to researching a phenomenon but proposing actions oriented to improving or transforming the experience of the study participants (Efron & Ravid, 2019). The scope was descriptive and integral, considering perceptions of the program's participants by combining student, researcher, teacher, and teaching assistants' views. In line with a participatory research paradigm (Bergold & Thomas, 2012), the epistemological belief that supports this decision is that every participant in a program has a unique and valuable perspective on the strengths and weaknesses of the program. The analytical strategy was mainly based on qualitative data of the information gathered, complemented by a sequential quantitative measurement. Thus, the study can be considered a multi-method approach with qualitative predominance with an evaluative purpose.

4.2 STEAM learning in the context of the Pequeños Científicos program

Pequeños Científicos puts the child at the center of the learning process, providing opportunities to choose the courses to enroll in. Likewise, keeping the classes small - between 10 and 17 participants, with one teacher and two teaching assistants is a crucial characteristic of the program, towards for favoring personalized interactions. The program consists of one-week courses delivered at the university; each student chooses two courses to enroll in. The description of the courses offered as part of the *Pequeños Científicos* program in 2020 is presented in Table 1.

The teachers of the courses are experts and researchers in their academic fields and were willing to teach their discipline in connection with the STEAM areas. The teachers usually work as academics in faculties of Sciences, Arts, Mathematics, and Education. Teaching assistants are undergraduate student teachers from the STEAM areas, coming from the Faculty of Education or PentaUC alumni. Teacher and teaching assistants have on-site training, which includes an initial organizational meeting and small groups' meetings for a thorough review of the course plan and articulations between courses within each age level; ages 3-4, 5-6, 7-8, and 9-10.

As characterized by their parents, children who attend the *Pequeños Científicos* program are fast learners in the disciplinary area they like the most; they usually get bored in their school lessons as oftentimes these do not provide optimal learning opportunities. Further, occasionally, these young learners have been labeled as behaviorally disruptive in their regular schools.

To monitor implementation, the program coordination team conducted several lesson observations during the week. At the end of the week, children, parents and teachers share their achievements and products in a learning exhibit.

Though course lesson teaching strategies reflect teacher's own style. All courses shared the following guidelines, which show the program ambitions:

- Authentic disciplinary learning methodologies including questions, problems, or solutions relevant to the disciplines.
- Children are exposed to exploratory activities and also expressive actions. This point means that they receive information and are encouraged to create products such as posters, expositions, explanations, artwork, etc.
- Teachers promote peer learning throughout the activities.
- By linking university experts with students from different educational contexts, both students and teachers learn from each other.

For the year 2020, the team decided to impart the program ~~courses~~ with a gender-empowering approach that materialized in the subsequent decisions. First, the process of teacher selection prioritized inspiring and charismatic women to favor the role-modeling of brilliant female researchers in their field. Second, each course highlighted the role of a woman in the history and development of each of the STEAM disciplines. Third, the difficulties faced, and the contributions of each iconic woman were explored through productive discussions and compared with the situation of women in the disciplinary fields nowadays. Finally, the program coordination team reviewed each course's plan -including the skills, content, materials, activities, and budget- to ensure coherence among the courses. The list of courses with the focus described above is presented in Table 1, while Table 2 presents examples of the teachers' questions that guided students' explorations.

Table 1. List of courses offered as part of the Pequeños Científicos program in 2020

Age group	Course	Description of the purpose	Contents	Methodology
3 - 4	Materials of my environment I	To explore fundamental properties of materials available in the environment, an inquiry-based approach aimed at developing scientific thinking skills; comparisons and classification	Stiffness and flexibility of diverse materials	Guided inquiry, communication through artwork.
3 - 4	Little science	To explore and experiment with diverse artistic materials and technologies to provoke curiosity and pose questions about daily life science.	Environment and biodiversity, plant life cycle, solar system, magnetic field	Experimentation, story analysis, group artwork
5 - 6	Paleo-artists	To develop the creativity and artistic skills to imagine the prehistoric world and, subsequently, enrich the ideas through scientific evidence.	History of science with themes of paleontology and geology; sediments and fossils, dinosaurs and mammals of the Cenozoic	Experimentation, drawing, and sculpture techniques
5 - 6	Materials of my environment II	To explore and communicate the mechanical properties of materials, relating them to their possible uses in everyday life. To design experimental situations to explain the materials' changes when applying force, heat, or water.	transparency / opacity, flexibility / stiffness, roughness / smoothness of diverse materials	Guided inquiry and experimentation, artistic communication through models, posters, and drawing
5 - 6	Microorganisms: heroes and villains	To design ways and prepare simple cell culture preparation to know microorganisms beneficial and harmful for humans, plants, and animals.	Definition and characteristics of microorganisms; types of microorganisms -bacteria, fungi, and viruses-; beneficial and harmful microorganisms for humans, plants	Guided inquiry and experimentation, artistic communication through painting
5 - 6	Astro-girls and Astro-boys	To explore introductory astronomy through technology and arts using astrophotography, simulations of other solar systems, and music created from orbit patterns and planet movements.	Formation of the Universe, the Solar system, other planetary systems, and exoplanets. Types of stars according to size and temperature, evolution and stellar death -supernovae, hypernova, and black holes-.	Observation of animated stories, augmented reality, artistic presentation in diverse formats

7 - 8	A trip from the Universe to the Earth Center	To develop scientific thinking skills such as hypothesizing about Earth's structure through learning mediated by technology.	Cosmo-vision, the Earth in the solar system, layers of the Earth, earthquakes, tsunamis, and volcanic eruptions	Guided inquiry, analysis of the history of science through story tales
7 - 8	Let's construct a science, art, and technology project!	To build innovative and creative projects to better relate to the people and living things around us, such as animals and plants. The projects are based on artistic work and the use of technology.	Steps to build a science, art, and technology project	Project-based learning with artistic communication - theater, comics, and photomontages-.
7 - 8	Researching with my senses	To put the senses to the test by exploring simple materials, collecting and analyzing data, and finally, representing them mathematically.	Where are the sensory systems located, and how do they work?	Guided inquiry, artistic presentation in diverse formats
7 - 8	Mysteries of water	To observe the characteristics of fluids and apply their different facets to elaborating artistic or technological projects.	Water properties; immiscibility, buoyancy, density, fluidity, capillarity, surface tension	Guided inquiry, experimentation with technologies
9 - 10	Illustrating science	To develop scientific illustration, a scientific - artistic discipline promotes learning through direct observation, drawing, and documentation.	Environmental awareness, ecosystem, needs of native plants their roots, stem and leaves, the life cycle of flowering plants	Project-based learning, drawing, and painting techniques
9 - 10	Physics-Chemistry of the living being	To apply science to solve daily life problems related to osmosis, photosynthesis, and digestion.	Differentiation between physical and chemical change, photosynthesis - reactants and products-, digestion and osmosis	Experimentation and communication: presentations and artistic posters
9 - 10	How does my bodywork?	To discover curiosities about body functions and make informed decisions regarding the care and integrity of their bodies.	Musculoskeletal, nervous, digestive, circulatory, and respiratory systems	Guided inquiry, experimentation, and models construction
9 - 10	Eclipse hunters	To understand solar eclipses' phenomenon through the artistic design of a dark box to model the phenomenon.	Rectilinear propagation of light, angular size, conditions for a solar eclipse, the arts in astronomy work	Modeling of phenomena through software

Table 2. Examples of teachers' questions that guided students' exploration

Course	Activity or contents	Examples of teachers' questions – mediations
Materials of my environment I	Characteristics of some insects' wings. Activity: Wings, Little wings, so light! The students answer teachers' questions to gather their prior knowledge. Then they observe a video with a simulation of butterfly wings movement in flight. Finally, they construct a model of the wings choosing the materials and their characteristics.	Do you know butterflies? Have you seen a butterfly flying? Where? Do you like them? Are you afraid of butterflies? How do you think there are butterfly wings? After the video: If we had to create wings similar to butterflies' wings, what materials would you use for the wings? And the butterfly body? Why? Which materials' characteristics would you have to look for? Why? Now we will build a model with the materials you have chosen.
Astro-girls and Astro-boys	Activity: To construct a scale model of the solar system and a black hole's hypothetical model. The students answered teachers' questions to gather their prior knowledge, and a productive group discussion was conducted after the construction of models.	How do you think the Universe was formed? What do you think is the size of the Universe? And its form? What questions do you have about the Universe? After constructing the models: Do you think we can observe the sun and black holes directly? Why? Do you think the stars and planets are immortal?
A trip from the Universe to the Earth Center	Activity: the students observed animated stories of famous scientists Alfred Wegner and Inge Lemann. They start a productive discussion guided by teachers' questions.	How was the scientific knowledge constructed in the time of Alfred Wegner and Inge Lemann? What the shreds of evidence to pose the ideas of Wegner and Lemann were? Why were both scientists not reasonably recognized in their trajectory? Similarities and differences?
	Activity: The students explore through augmented reality two simulations of phenomena: earthquakes and volcano eruptions. Then they answer in groups teachers' questions.	What did you observe in the simulation? What elements did you not know about these two phenomena? Why do you think these phenomena are caused? Which is the role of technology in scientific phenomena comprehension?

4.3 Ethical procedures

We followed the ethical guidelines to collect, process, and protect the data gathered in this research; anonymity, confidentiality, and the use of secure storage and controlled access to the data sets. In our data processes, none of the participants' names or identities were revealed. We assigned numbers to each participant and cover their names on the paper or artwork to ensure anonymity in the datasets. Moreover, in our study, the participants were voluntary. All parents signed an informed consent with detailed information about the program, students permitted to use their data for research purposes, and the teachers gave authorization to take notes during focus group meetings and use the information contained in the logs and summary sheets for evaluation and investigation purposes. If the students or another participant did not agree to participate in the study, the learning opportunities were offered, but their data were not considered in the analysis. In the same line, if a participant resigned the will of taking part in the study, information was separated from the dataset and not analyzed. To maintain confidentiality, only the research team had access to the data. The information was kept in a safe office and backed-up in a cloud with a password to assure controlled access and data protection.

4.4 Sample

Ninety-five students participated in the pilot version of the program in January 2020, which was under evaluation. Based on their age range and their interest in the courses, students were divided into six different groups. The academic body was composed of 10 teachers and 12 teaching assistants. The teachers, teaching assistants, parents, and students were aware of this version of the program's evaluative character. Thus, they knew beforehand that some lessons would be observed, some student products would be collected, and that teachers and teaching assistants would be invited to participate in group discussions at the end of the program implementation.

4.5 Assessment instruments for data collection

For children, we looked for validated scales to measure attitudes towards STEAM in Spanish language which was the first language of the students. However, in the literature reported so far and to the knowledge of the authors, the instruments with open access were oriented to each discipline separately. Thus, we decided to use a more general instrument regarding science than several instruments, to avoid overloading the students.

Hence, an adapted version of Gómez-Motilla & Ruiz-Gallardo's (2016) attitude survey to assess attitudes towards science in early childhood education for the Spanish speaking population was administered as a pilot test to one course of 7-8 years old's, representing 17 participants. The survey was applied at two points in time, before the first lesson started and again after the last lesson. Most original scale items were kept, but the 5-point Likert scale response format was simplified to three-points: totally agree/ neither agree or disagree / totally disagree. Moreover, we added emoticons with a happy face, neutral face, an angry face to represent the options (details can be seen in the Appendix). The teachers were instructed to read aloud each of the sentences and encourage students to paint, mark, use clay, or any other kind of material to express their response to the emoticons in front of each sentence. Survey items included ideas such as "Science is interesting," "I like to learn about science and technology," "Science and technology are good for life and useful," "All the students should learn these topics," and "I like talking about science with my family." This last question was particularly relevant as there is evidence that talking with friends and family about science during infancy is later predictive of a STEM identity (Dou et al., 2019) and that parents might serve as relevant sources to support STEM education (Milner-Bolotin & Marotto, 2018; Milner-Bolotin & Milner, 2017).

Researchers conducted also a non-participant observation in each course taught, using the regular class observation protocol of developed by the PentaUC program (in the Appendix). This instrument provides ratings of lesson structure, teaching methods, classroom interaction, and classroom climate, as well as learning assessment conducted by the teacher during the lesson. We decided to use this instrument because it was familiar for the coordination team, perhaps the implementation in this pilot version would be facilitated. No classroom recordings on video or audio were conducted, to fulfill children's data protection policy of the institution.

Teachers' and teaching assistants' views about this version of the program were collected through logs in the format of narratives, anecdotal records. This decision was taken considering the restricted time the teachers had to complete paperwork and the need to gather information for the research purposes and for the program monitoring at the same time. The log records of teachers and teaching assistants were collected both online and in paper-and-pencil through logs in the form of narratives and anecdotal records. Responses were included in the same pool of data to process all the data together. We obtained 44 logs from teaching assistants and 20 from teachers during the week of implementation.

To document the process of each course, teachers completed a written summary sheet with answers to the following questions:

1. Which were the main obstacles and advantages in the course implementation?
2. In your opinion, were the course objectives achieved? How could the course design be improved?

3. Did you need to make methodological adjustments to your course design? Why?
4. Do you have any other comments, suggestions, or relevant observations to mention?

At the end of the courses, focus groups with teachers and teaching assistants were organized into groups of 4-6 participants according to the age range of students. This means teacher and teacher assistants of children between 3-6 years old comprised a group, the ones of children between 7-8 years old in another group and so on. The guide questions were:

1. Which were the main obstacles and advantages in the course implementation for this age group?
2. How could articulation between courses improve course design?
3. Which methodologies were the most and less effective for this group?
4. Do you have any other comments, suggestions, or relevant observations to mention?

4.6 Data analysis

Qualitative analysis was chosen because of the nature of the information collected, mainly descriptions, observations and appreciations of the participants who conferred the meaning to the actions and interactions in the social phenomena (Cáceres, 2003). To avoid conflicts of interest, the qualitative coding was carried out by independent researchers who did not participate as teachers. The steps we followed for creating the codes were: i) pre-analysis, which implied the recognition and identification of concepts in the analysis units of each topic; ii) determination and definition of initial codes for each of the topics; and, finally iii) integration and establishment of the final categories to refine the analysis.

The analysis of the data followed a multiple-methods approach.

Responses to the group discussions were analyzed as vignettes and organized first into emergent themes with illustrative excerpts from the participants. Next, themes were connected within a frame of strengths, weaknesses and opportunities to pursue an integral evaluation of the program.

Similarly, teacher's log narratives were categorized into strengths, difficulties and opportunities, following the guidelines of content analysis (Krippendorff, 2004). Content analysis is "the research technique for making replicable and valid inferences from text (or other meaningful matter) to the context of their use" (Krippendorff, 2004, p.18). The steps followed were: a) To determine the object (the educators' narratives written in their daily logs) b) To define the coding rules organizing them from the most to the least frequent ideas in the material considering also those that were repeated between the different courses, c) To determine the categories (strengths, difficulties and opportunities for promoting STEAM in the early years through this program) d) To verify the system of coding and categorization, including the validation of the program director and checking the transparency of the codes through inter-rater agreement calculation, e) To generate the inferences.

The process of analysis was aided by the online software Dedoose (https://www.dedoose.com), a commonly used program for qualitative data that is suitable to integrating and reflecting on the information obtained from diverse sources transformed into texts (Talanquer, 2014). To validate the integration of the final codes and categories, a review was carried out by two expert judges on the subject of talent education and co-authors of this article. Estimated inter-rater levels of agreement were high, specifically at 80% for the categories and codes.

There was also a quantitative analysis of the data obtained in the student survey. The mean of each affirmation of the survey obtained was introduced into a spreadsheet. We used the SPSS statistical package (IBM Corp., 2010) for conducting a Student *t*-test, which is the most common statistical method for comparing means (Wilcox, 1992) within the traditional parametric tests for comparing normally distributed population (Siegel, 1956). This analysis was done to explore possible differences in the students' attitudes at the beginning and the end of the program.

5 Results

The student survey analysis illustrated that the group of participants had marked interests regarding science and technology, which was expected as they joined the program voluntarily, as was expressed by the agreement on sentences related to positive attitudes toward science in general and learning about science and technology. All the students marked a happy face in those sentences, which was an indicator of "I agree" (see the instrument in Appendix). However, less agreement was found in the question about the extent to which students like to talk with their families about these topics. No statistical differences were found in the pre and post-surveys.

The next section presents the main results, categorized as a) strengths, b) weaknesses, and c) opportunities for the program to develop by integrating information from the logs, summary sheets, discussions, and observations. These are organized from the most to least frequently mentioned by the participants.

5.1 Strengths

One of the most valued aspects of this pilot program on STEAM learning mentioned by participants was allowing young learners to view scientific work as an exciting endeavor. Researchers, teachers and teaching assistants noted that the students showed particular commitment to the construction of models in the lessons, during which they put hands-on learning into practice. The teachers observed enthusiasm in children and positive engagement working with diverse materials and settings.

> "The children begin the lesson designing a house, a model, using different materials. They were enthusiastic, these models will be shared on the last day in a learning exhibition with their parents".
> "The children worked in the Faculty yard, very engaged on making pastry and adding yeast to observe the reaction. They were committed later on to keep the pastry properties by holding it on a special paper to maintain a specific temperature".
> "The children presented a different disposition today since we have to carry out practical activities that are more of their interest."

A second strength of the program implementation was the integration of science with other disciplines. Students were immersed in enriched experiences, mostly provided by technology as part of STEAM education. We, as researchers, think this experience was novel and challenged some students' previous expectations of what constitutes science practice.

> "A facilitator was using technologies, as immersive audio and projector. In the beginning, we watched a star size comparison video, and the children liked it a lot. We had to play it three times! In the end, we asked them what they have learned, and several students answered the concept of 'exoplanet,' although they did not remember its name".
> "Students show great interest in working with tablets."
> "The use of audiovisual resources such as science videos were aspects that motivated the boys and girls a lot."
> "The topic worked arouses the interest of the children and the (integrated) way in which the session was carried out allowed them to participate actively, asking questions and sharing their knowledge."

In sum, the integration of STEAM disciplines was crucial for promoting young learners' interests and enhancing engagement and motivation for learning in an amalgamated way, going beyond each discipline's particularities.

A third perceived strength was the high enthusiasm displayed by teachers and teaching assistants. Together, they constructed nurturing relationships with students and created a climate of respect among them. This was a crucial aspect recognized by researchers, teachers and teaching assistants.

> "All the activities planned were carried out, the students worked in an enthusiastic and respectful way with each other. The educators were enthusiastic, respected the children and they answered being kind with the educators and between them".
> "The boys and girls interact with each other without involving conflicts; they are willing to learn new games and make companions; the activities consisted of an approach to science without taking them so far away from their daily experiences."

Finally, another strength of the program implementation according to researchers and educators was that the teaching assistants were available for the students through the whole session each day. Their presence provided a sense continuity and facilitated group management, i.e., providing structure through daily routines, particular songs for the group, etc.

> "Having a teaching assistant during all the morning with the same group was a facilitator because the children knew the routines they have conducted on the first module. It fostered a sense of continuity and better articulation between the courses and modules".

5.2 Difficulties

The difficulties identified in this pilot version of the program refer to two different issues: infrastructure and materials, and teacher management of student emotions. Difficulties are seen in this work as restrictions or deficiencies that limited the implementation of the program generated from internal decisions, facts or issues. In this sense, difficulties might connect with opportunities of improvement, which are described from the participants' point of view in section 5.3

Regarding the weaknesses reported by teachers and teacher assistants, the most frequent comments represented the infrastructure and were related to the inappropriate design of the university furniture and classroom spaces to accommodate the needs of children. There was agreement on the traditional university classroom arrangement, usually with fixed seats, did not meet the needs for comfort, versatility for activities, and movement required in children's education. Similarly, on some occasions, the program's materials were not the most appropriate for the tasks, especially for artwork. Particular attention should be put on the textures and characteristics of the resources requested by the teachers to fulfill the objectives, because guided exploration and expression required some specific materialities which were nor replaceable.

> "We think it is really important to get the requirements that each course has in terms of materials and resources to teach the (STEAM) disciplines, especially regarding equipment of the classroom, i.e. tables that can be moved to reorganize the spaces, access to water for arts and science".
> "(Something to improve is) the classroom infrastructure; lack of tables and chairs adequate for children' age."

The second area of concern was related to teachers' management of student frustration. A few students, especially in the groups of 7-8 and 9-10-year-olds had difficulties working in teams; other students with high learning expectations occasionally were very self-critical and perfectionistic, which led to strong, usually disruptive reactions when they thought their products were not what they expected. Bearing in mind that most of the teachers did not have pedagogical formation, as researchers we believe some of the difficulties of students' behavior management could have been explained because of the lack of early childhood education preparation in teachers. However, the teachers attributed these difficulties to external factors, i.e.:

> "There were some problems to solve, both in terms of discipline and emotional regulation, but we need to take into consideration factors such as the hour of the course, the hot weather, and the tiredness of children."

As researchers we believe that keeping class time within the average attention span and closely monitoring of children's fatigue may help prevent episodes of disruptive behavior. It is important to note that part of the innovative structure that was piloted in this version was the inclusion of younger children, 3-4-year-olds. For some of them adjustment to staying in the classroom without their parents took a long time and some emotional dysregulation appeared during the first days. Considering that this was a one-week program, this situation might have affected their disposition to learn and make the best of this short-time program.

Finally, from the coordinating team's view, the program design needed more articulation between the courses and STEAM areas. They observed a difficulty regarding the integration of mathematics contents or skills into the activities. The connection between topics and skills between the courses might avoid redundancies and help with curricula alignment. This last element is discussed in the next section as an opportunity for the program improvement.

5.3 Opportunities

The opportunities for program improvement that were most frequently mentioned related to articulation between courses. During the final learning exhibition, teachers and researchers had a chance to learn in more detail what the other courses had done and accomplished, and many connections for future collaboration were identified. Although the teaching team for each age group met before the program started, sharing detailed lesson plans, and having other occasions to strengthen articulation between courses during implementation was suggested, they realized there were opportunities to improve the program with more time dedicated to aligning the activities. This element is relevant in the light of the integrated STEAM orientation of the program and introduces a priority for the future implementation rounds.

> "As teachers, we think that with better articulation and being more organized by discipline, we can potentiate our courses. If we look for more articulation, we need to be aware that it requires time, more work, and more prior team meetings".
> "It would have been an ideal scenario to get a prior articulation between both courses (of an age range)."

Moreover, some researchers and teachers proposed as an opportunity for the program to grow, testing how integrated science and arts can enrich children's educational experiences with atypical development (e.g., Asperger syndrome) or special learning needs, considering that there are academics in the university who work in special education and curricular adaptation for responsive education.

6 Discussion

The purpose of this study was to document the design and implementation of a university-based enrichment program in science education for young children. Two novel features of the program course design were the integrated STEAM approach and the infusion of a gendered approach to encourage visibility of participation of women in science. We included the "A" in STEM because of the natural link with early childhood and pre-school education. Our study found this element allowed implementing activities that engaged students grounded on children's natural interest in how the world works, which has also been stated by Monkeviciene et al. (2020). The teachers, all female, provided several opportunities to learn and express their advances with diverse materials and formats.

Arts played a crucial role not only as a way of communicating or expressing results of the learning processes, but also helping children to connect with the multiple forms and materialities for learning. We have described the list of courses, their objectives and the approach they had related to STEAM disciplines. In the program context the pilot version under evaluation included environments, settings and activities that encouraged children to explore natural objects and phenomena such as water, soil, heat, motion, plants, animals, the human body and systems such as the Ecosystem, the Earth, the Solar system. It also aimed at children exploring and creating models of these processes, phenomena and systems aided with technology and arts. Within the technology connections, the students were encouraged to use measuring tools, magnifying glasses and instruments such as microscopes, scales, seismograph, using augmented reality, among others.

By design, the intervention selected passionate young female scientists and artists to teach the integrated STEAM courses, all of which were framed historically to highlight the contribution of notable women in the areas. Therefore, the role of women in their respective disciplinary fields was experientially integrated into teachers' lesson plans, and through role-modeling teachers engaged students from different ages in authentic scientific practices. We consider this fact in our program to face the known discomfort feeling of early childhood educators when teaching science (Monkevincene et al., 2020) by including history of women in science and highlighting the role of arts in the construction of scientific practices. This perhaps helped the teachers to familiarize with the STEAM approach and overcome the unwillingness found by other authors (Nesmith & Cooper, 2019; Sharapan, 2012). Moreover, most of the teachers in this study embodied positive role models of women in STEAM areas, which was one of the program objectives. However, more research is needed to determine if the participants considered this a benefit or began to question or challenge the stereotype of male-dominated STEM areas. To this point, a limitation of this study was not measuring gender stereotypes at the beginning of the program, which would have been a valuable element for research and practice. Regarding the gender focus of the course presented in this version of the program, we cannot confirm if this may have had a role in the student learning experience. This element was not mentioned by researchers, educators or teaching assistants. Thus, the question of if short-time experiences such as *Pequeños Científicos* might trigger shifts in the way young girls perceive themselves (Olsson & Martiny, 2018) is still an open question.

Similarly, teachers' sense of competence in their topics was not an issue in this program as they were successful in integrating the STEAM areas and going beyond each discipline in order to create enriched learning opportunities for children. This finding reinforces the role of integrative pedagogy by placing the children at the center of the process of learning, rather than focusing the experience on the axis of the content. We agree with Sharapan (2012) that holistic experiences, connected with children's interests and natural environments have the possibility of being a transformative learning experience. We observed the holistic approach in the design of the courses, and all the participants reception of the activities and the subsequent evaluation of *Pequeños Científicos* program was good which implies it was a satisfactory experience for them.

Acknowledging that this might be an ideal scenario to engage children in science, it is important to recognize that self-selection might have contributed to current findings. Nonetheless, as researchers we do not consider this as a weakness. This type of project has value because it offers an educational opportunity to students that need it for their advance in knowledge and passion construction. Despite, we see this issue in the light of conducting to a question for future interventions, for instance, with pre-school teachers' challenges in scenarios where conditions for implementation might be very different. Some of the challenges or concerns reported by other studies in regular education (Çiftçi, Topçu & Foulk, 2020; Simoncini, & Lasen, 2018) were not found with participant teachers, perhaps because their characteristics. Thus, replication or transfer of this experience may be more likely within university contexts with similar highly qualified and committed academic teachers willing to adopt an integrated STEAM approach, with children who like to learn more about these areas.

A possibility for future research is to conduct longitudinal studies with comparison groups of students that participate in several versions of the program and other cohorts that have participated sporadically and not participated, in order to test diverse variables as outcomes of the program. This is particularly relevant in contexts of high educational inequality such as Latin America, however, it transcends the relevance to other contexts on which male-gender stereotypes are still dominant. In this work, we have shown the characteristics and the implementation evaluation of a program mainly delivered by women, with a gendered approach based on role-models and history of relevant women in the disciplines, which is an original emphasis that might illuminate the possibilities for the STEAM educational community beyond the specific program described here. We consider that history of woman in STEAM areas is a potent alternative to work in gender-empowering objectives, even in contexts with economic deficit, places with a lack of resources or where materials are not available.

Overall, the program engaged participant students positively in their STEAM learning processes, and they demonstrated enthusiasm during the process and the learning products exhibited at the end of it. The high levels of children's engagement and cooperation found by this study are a strength of the program and concur with the findings of Aronin & Floyd (2013), who also observed that STEAM experiences promoted student interest in learning. The aspects that McClure (2017) found crucial to increasing student engagement - children's natural curiosity, family educational encouragement and enjoyable science, also played an important role in the implementation of the *Pequeños Científicos* program. However, it is important to note that besides parents' encouragement of their children to join the program and participate in the learning exhibition at the end of the program, given the brief duration of the program, there were no other instances of direct collaboration with parents. This might be an aspect to reinforce in order to sustain program effects over time. In spite of being a self-selected group, many of the children in the sample were not exposed to these experiences at home, as reflected by their response to the survey (e.g., disagreement with "I like talking about science with my family"). We consider that family attitudes and experiences with science are important issues when designing interventions for general school populations.

Regarding the impact measurements of the program, we believe that the student selected instrument was not sensitive enough to capture changes, or, the intervention was too brief to produce changes. Still, we as researchers cannot estimate how educationally relevant this difference, if it existed, would be. The students who participated in the program had already expressed their high interest in the STEAM areas; therefore, measuring possible improvements in their STEAM attitudes or interests is difficult. A recommendation for future developments is to design instruments oriented to integrated STEAM in early childhood education, which might explore the attitudinal dimensions or the diverse sources of children's learning support such as parents, friends, and teachers.

The measurement interval might be another issue, also considering that students' self-selection variables might have influence their attitudes already positive towards sciences. Although the length of the program was not identified by the participants as a problem, we wonder if a week to tight to accomplish all the program goals. In fact, it is still a challenge to identify sensitive measures that might capture small changes or emergence within the short time span of the program. These elements are essential to improving the design and implementation of educational innovation to promote STEAM learning beyond the regular classroom.

Given differences in the age range of participant children, course design needs to consider different time allocation and formats for younger students in order to accommodate their attention span, working memory, and time to warm-up with the requirements of the learning situations. Most of the teachers in this program did not have prior pedagogical training, and the difficulties of behavior management in the classroom could potentially have been alleviated with support from teaching assistants experienced with young children. Nonetheless, it is interesting to note that teachers did not link their lack of capacitation in early childhood education with this difficulty, which might mean a blind spot. We believe that stronger preparation of the support staff would be useful to encourage more confident action and closer connection with the students, helping to overcome emotionally difficult situations.

In terms of transferability, we encourage the potential of generalising the alliance between the university context and early childhood education in STEAM areas to the diverse educational contexts on institutions as a model. Considering that education in the early years is an excellent space for promoting integrated learning (DeJarnette, 2018; Çiftçi, Topçu & Foulk, 2020), approaching the interest of university academics to work with children is a possibility that other institutions -i.e. scientific academies, colleges, research centers- might take into consideration as a link with society and communities particularly affected by inequalities. However, it is important to count with the appropriate infrastructure and identify safe spaces that best suit the needs of children. We strongly believe that learning outdoors or in spaces capable of accommodating for instance, mats rather than traditional furniture, might help to overcome this problem. Another suggestion from the experience gained in *Pequeños Científicos* is to consider student concentration time and divide the university schedule into shorter periods, combining it with breaks for free play in order to be responsive to the needs of young learners.

Finally, we want to problematize and demystify stereotypes about the capabilities of young children in STEAM learning, highlighting the notion that enriched opportunities for learning are not only valuable for children's education but trigger their development in several dimensions. Interestingly, participants were surprised to learn forms of connections between science, mathematics and arts, which might enhance identity development, especially in the academic self-concept (Dou et al., 2019). We consider that strengthening the links between sciences, interactive technology such as new advances in labs (Proudfoot & Kebritchi, 2017) with the arts and mathematics is crucial to construct knowledge with children from the early years. It might lead to understanding sciences, technology and mathematics as creative endeavors and, consequently, making it easier and more significant to include the STEAM approach in this age range (Sharapan, 2012). In the *Pequeños Científicos* program integrating artwork provided crucial opportunities for students with diverse interests to explore and communicate how they carried out their learning processes as well as the difficulties they identified using different materials. Thus, the creation process was not only expressed but afforded by the artwork, which makes STEAM approach including arts a valuable advance from STEM models that in our view, perhaps helps young learners and teachers with no prior training to make the best of the integrated disciplines without reluctance.

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Appendix

Students' survey (in Spanish)

SURVEY	do I accept this information is used for research purposes? YES-NO	
Name:	Age:	Date:

Please mark, Paint or circle the face that represent your option in front of each sentence. Remember that there are not correct or wrong answers, please answer honestly.

Sentence	Agree	Neither agree nor disagree	Disagree
1. I think that science is interesting			
2. I like to learn about science and technology			
3. I like listening to my teacher when she speaks about science			
4. Science and technology are good for life			
5. Science and technology are useful and can help us			
6. I like talking about science with my family			
7. Understanding science is important			
8. All the students should learn these topics			

Thanks!

PENTA UC Observation protocol

LESSON OBSERVATION GRID

1. **Protocol objective:** To monitor the teachers' work during a course, take field notes of activities that promote integrated learning, to give feedback to teachers based on the evidence collected.

2. **Lesson identification**

Teachers' name		**Observers' name**	
Course		**Number of students**	
Course objectives			
Lesson objectives			
Date		**Time of observation**	

3. **REGISTER**

During the lesson, observe and register elements related to each dimension and teachers' actions as "evidence."

DIMENSION	INDICATORS	YES	NO	EVIDENCE
Lesson structure	1. The lesson objective is presented			
	2. Prior knowledge is activated			
	3. There are activities or procedures oriented to reach the lesson objective			
	4. The activities are formalized or synthesized during the lesson, checking the fulfillment of the lesson objective			
Methodologies	1. The methodology is oriented towards students' meaningful learning			
	2. The methodology is oriented towards reaching the lessons' objectives			
	3. The methodology is adequate to the course discipline(s)			
	4. The methodology promotes the development of critical disciplinary skills or transversal skills			
	5. The methodology promotes the discipline(s) attitudes			
	6. The teacher uses precise vocabulary according to the knowledge area(s)			

	7. The teacher integrates into the lesson the students' interests, problems, and themes they want to solve or develop			
	8. The methodology develops students' higher-order skills			
Classroom interaction	1. The teacher promotes students' participation in the lesson			
	2. The teacher promotes student-student interaction			
	3. The teacher validates individual and group students' interventions			
	4. The teacher promotes the participation of students' less interactive			
	5. The teacher promotes students' regulation and self-regulation			
Classroom climate	1. The teacher favors the respect of diversity and dignity			
	2. The teacher integrates errors as part of the learning process			
	3. The teacher promotes formatively conflict resolution in the classroom			
	4. The teacher promotes the agreement and respect of norms and the consequences of transgressions			
	5. The teacher promotes respecting the turns to speak			
	6. The teacher promotes an environment of confidence to express opinions and questions			

4. OTHER FIELD NOTES

Please complete with the observation elements not included on the grid or those that combine the prior dimensions.

Dimension(s)	Qualitative register	Assessment	Suggestions