"Playful STEM-promotion": a Initiative to Encourage STEM Programs in Primary Schools

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Abstract. Nowadays, studying in detail the gender situation in careers in science, technology, engineering and mathematics (STEM) has been fully encouraged. Despite the relevance of STEM disciplines around the world, women continue to be underrepresented in STEM programs as well as the lack of academic engagement for STEM education in primary and secondary schools and universities. Whereby, there is a growing interest in analyzing the gender gap and motivating both boys and girls in primary education to participate equally in STEM careers. The aim of this article is to collaborate and encourage strengthening the teaching of STEM programs at earlier levels and to reduce the aforementioned gap. To accomplish our goal, we present the design of an initiative called *Playful STEM-promotion* to define a series of STEM-oriented activities in primary schools focused on the gender variable. Preliminary results show that we have proposed a methodology that will serve as a guide to develop our initiative. A set of valuable learned lessons had been identified as part of the experience of conducting a STEM-oriented inter-university research.

Keywords: STEM · Gender · Primary school · Volunteering · Playful

1 Introduction

Disciplines of science, technology, engineering and mathematics (also known by the acronym STEM) had become very trending among organizations and also in scientific and technological fields. Women continue to be underrepresented in programs related to STEM areas [10, 15], due to factors such as: cognitive ability, work preferences, stereotypes, biases [30], lack of mentors and female role models, unequal growth opportunities or gender pay gap [6].

It has been recognized that there is a lack of academic engagement in introductory STEM courses across high schools and universities [11]. In that matter, the main focus of STEM education in primary and secondary schools has been addressed towards more theoretical aspects instead of implementing practical and experimental learning, where STEM disciplines might be encouraged in a more adequate way [26]. This could be seen as a problem-based condition that consider aspects such as: reduce the gap of having qualified professors to teach STEM-based courses, and lead strategies that encourage a cohesive and gender equity learning of STEM study topics. Additionally, being supported by role models that are able to share their personal experience in their fields of science, technology, engineering, and mathematics may positively inspire and attract more children to study STEM programs. The existence of a gap regarding the competences that children require and what is being taught is striking and raises the need to optimize the preparation given to students so that they can better perform their future professional position. Despite the importance of STEM areas at a global level, there is a tendency for efforts to develop activities focused on promoting STEM programs to be carried out in high schools and universities, or even in doctoral studies [13]. For instance, authors in [16] presented a study that analyzed the role of the high school context for plans to major in STEM areas. They highlighted two relevant aspects: (a) attend a school that provides girls' STEM orientations might reduce the gender gap; (b) gender segregation of extracurricular activities have influence in establishing a plan to study a STEM program.

Therefore, the objective of this work is to present the design of an initiative to encourage boys and girls in primary education to participate equally in STEM-related subjects. To achieve our goal, we proposed to design of a set of activities in primary schools to promote STEM programs and we considered the design of *Case Study* research to create our initiative called *Playful STEM-promotion* focused on the gender variable. This paper describes the design of our initiative; and as future work the initiative will be carried out in primary schools the next year.

The rest of this paper is organized as follows. The related work is presented in Section 2. The motivation behind this work is presented in Section 3. Section 4 describes the proposed initiative, including the planning process and *Case Study* description. In Section 5, we describe and discuss our early lessons learned in designing our initiative. Finally, Section 6 presents the conclusions and shows future research topic.

2 Related work

This section initially focuses on difficulties that female students face when they are in primary school. Later, some initiatives carried out in primary schools are shown, which can minimize those difficulties and promote STEM programs.

2.1 Gender issues in primary schools

It has been shown that female students have been classified as deficient in subjects of technology, science and mathematics. Therefore, studies have been car-

ried out to find out if there are gender differences in primary schools. A gender issue is the relationship between teachers-students, e.g. a study analyzed the effect of teacher gender on primary school student outcomes (1,664 students from 17 schools), and found that female teacher has a negative impact on scores of female students on the math test [1]. Following the same issue, quantity and quality of teacher-student interactions were studied to know if there are differences between male and female students; this study had a sample of 590 hours of videotaped classes from fourth grade students from 137 schools [3]. Results show an imbalance in attention and interaction of teachers favoring male students, and gender attention gap is correlated with lower scores in mathematics for female students [3].

However, not only teacher-student relationship is a difficulty faced by female students, also visual resources used in science education classes show gender bias. It was determined that men are more represented than women in a scientific profession, and teaching profession is represented mainly as women, indicating a stereotypical representation in science education resources [14].

Likewise, another problem that has been investigated is the confidence of the students in an exam, for example: a study with fourth grade students (439 students) in primary school, found that female students report higher levels of test anxiety than male students [2]. This result reflects the difficulties women face in an evaluative environment where they doubt their ability to answer an exam, then, teachers must be aware of this situation [2]. Therefore, teachers must open new spaces in primary science classrooms, so girls grow up understanding that science is an area in which they can participate [8]. Likewise, the school curriculum in Costa Rica is still promoting and justifying the differential treatment of people according to gender, producing serious implications in terms of personal development [12].

2.2 Gender initiatives in primary schools

The belief that providing girls with access to primary and secondary education automatically results in gender equality and the empowerment of women is not uncommon [28], whereby researches have recommended strategies to address gender equity in primary schools. One of the initiatives is to provide training adapted to gender-sensitive teaching to avoid imposing stereotypes [9] e.g. Germany launched a program to eradicate gender-based stereotypes in textbooks. Likewise, Department of Education of Alberta, Canada has produced guidelines to define reviewing educational resources to ensure that they promote gender diversity, and Belgium provides tools and training programs to help teachers eliminate gender stereotypes in their teaching practices [18].

A second initiative is to promote quality education, which allows boys and girls to learn and participate in safety, develop identities, promote health, and thus to have same economic, political and cultural opportunities [19]. The messages included in classroom activities should not be gender-based, for example: in *Bell School* in UK a teacher teaches the topic of *speed* using a car that rolls down a ramp (a male artifact), which created a semiotic assembly reinforcing

that this topic is recognized as a male activity. Otherwise, at *Campbell School* in UK during a science class that has artifacts, such as batteries and light bulbs, that can be considered male valency, the teacher orchestrated an environment of autonomy. Children worked with friends, walked freely around the room, and accessed texts when the whim took them. This freedom of movement positioned children as legitimate participants in scientific activities [8].

Finally, the empowerment of girls must be accompanied by a change in the community [29]. *Prerna School* is a school for girls in India, where teachers actively advocate for girls' rights within their communities through meetings, parent dialogues, awareness rallies, among others [29].

However, in Latin America girls and young women, when they finish school, have the idea that they are second-class citizens [20]. Education does not necessarily lead to empowerment or gender equity; in consequence, the focus on process, content and curricula must be critically addressed to eliminate inequitable social norms [23]. Therefore, this paper is aimed at explaining in detail the design an initiative call *"Playful STEM-promotion"*. In this first paper we focus on explaining the design of the initiative, since the implementation of the initiative will take place next year.

3 What motivated to start the project?

The motivation for this project comes when authors from some universities in Costa Rica talked about the small number of women in STEM programs. The conversation focuses on what elements cause the low participation of women. It is mentioned that the main problem is socio-cultural, since in Latin American countries there is a preconceived idea about the role of women in society; which is stigmatized through stereotypes, behaviors, language, lifestyles, among others.

Therefore, the idea of reaching out to primary school children is born, to minimize preconceived socio-cultural thinking about women and STEM programs. Authors determined to create an initiative to promote STEM programs through playful activities. Likewise, participation should be for both girls and boys, so the message is the same for everyone.

4 Methodology

To design our initiative *"Playful STEM-promotion"* we used the research methodology *Case Study*, which is defined as the exploration of a real phenomenon within its context through a variety of data sources [4]. This methodology helps to explain the process and results by including quantitative and qualitative data, which are used to collect and generate data with the triangulation of methods and data [21]. In addition, it allows closeness between researchers and participants [4].

We selected this research methodology because it is a flexible process [5], since it allows researchers to focus on the behaviors, attributes, actions and interactions of the contemporary phenomenon within some real-life context [21, 31]. In our case, the research focuses on examining and describing the phenomenon to design activities to promote STEM programs in the classrooms of primary schools; mainly studying the gender variable.

We use guidelines provided in [22] to conduct a *Case Study*. We modify the scheme to fit our project in six phases (see Figure 1).

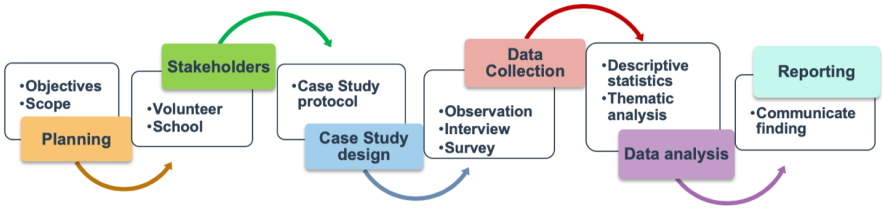

Fig. 1. Phases to conduct our case study

4.1 Phase 1: Planning

In this phase, objectives and scope are defined. Likewise, researchers must determine the target social group and geographic area. To carry out this first phase, weekly meetings were held virtually with research team.

Objectives regarding our research the following general objective was identified: *Promote STEM programs to primary school children through playful activities, so they can consider STEM area in future decisions.*

Secondary objectives emerged from the main objective. We defined the following ones:

a) Present basic STEM concepts, so that the context of STEM area is known.
b) Promote the development of STEM skills and capacities, where volunteers can give back to the communities the knowledge that they have acquired.
c) Encourage boys and girls in STEM area through playful activities so they can consider STEM area in future decisions.

Scope the initiative involves the design of a *Case Study* to encourage STEM programs, for which activities to promote STEM area will be implemented in a fun way through organized events. Activities will carried out in public schools, specifically with students of fourth, fifth or sixth grade.

4.2 Phase 2: Stakeholders

In our research, volunteers are fundamental, they are who will carry out activities in public schools, as a meaningful way to contribute to their communities. Volunteers are students of a STEM program in an university. An important aim of this research is that volunteers can contribute to their primary schools (school where they attended when they were children). Therefore, primary schools are another stakeholder in our research.

To select volunteers and schools that will participate in this initiative we use *criteria sampling* since in this type of sampling the selection of participants must meet certain conditions or criteria, which are previously defined [17]. This initiative has two important stakeholders: *volunteers* and *primary schools*, which must meet a set of requirements to be candidates in this research. The following inclusion criteria are proposed for choosing volunteers and schools.

Volunteer inclusion criteria: Volunteers will work with children and teachers, whereby, it is important that they interact with them appropriately. A volunteer must have knowledge of the STEM area, providing guidance and support during each activity, consequently, children should feel safe, integrated and even with confidence to express their feelings. Additionally, a volunteer must have the following skills: gender sensitivity, public speaking, communication skills, teamwork, being responsible and willing to contribute to the community (Figure 2).

Fig. 2. (a) Primary School inclusion criteria. (b) Volunteer inclusion criteria.

To evaluate these criteria, we propose a volunteer recruiting process, which involves the following steps: (1) students enroll through an online form; (2) students are called for an interview with at least one researcher; and (3) students are accepted to participate as volunteers, if they meet inclusion criteria.

School inclusion criteria We establish a protocol that involves inclusion criteria and different steps for the selection of primary schools where our *Playfull Stem-promotion* initiative can be put into. If a volunteer wants that her/his primary school to be considered as a candidate, she/he must submit the school's information through an online form. In addition, the volunteer must attach a letter of authorization from the school, which stipulates permission to carry out the initiative in that educational center. After obtaining the list of candidate schools, researchers will choose schools distributed throughout the country, to carry out the initiative to different regions.

The inclusion criteria to select primary schools is presented (Figure 2):

1. The school must be public to include heterogeneous student groups.
2. The initiative includes activities that take place inside and outside the classroom, so the school must provide a suitable place for that purpose.

3. Students (boys and girls) participating in the initiative must have the consent of their parents.
4. The school must meet the following conditions:
   a) A teacher in charge must be at the place where the activities are carried out.
   b) The group of students must be mixed (girls and boys).
   c) The school must provide conditions so that students who require it can carry out activities (e.g. support physical disabilities).

4.3 Phase 2: Case Study design

The *Case Study* is the main part of our initiative, since it is where we will work with boys and girls of primary schools. The *Case Study* protocol includes phases to design and develop STEM promotion activities in primary schools; researchers defined four phases: training, activities, execution and reflection.

Training before conducting the training, researchers will create groups of volunteers so each group meets the set of skills required to carry out events. The number of volunteers per group is three. Each group of volunteers will be in charge of activities in the previously selected schools. Training will be provided to volunteers by the researchers. The training will last 6 hours in one day. The topics that will be developed are: objectives, goals and scope of the research, volunteer tasks, volunteer responsibilities, case study process, and soft skills to use during the initiative. In addition, researchers will inform the school assigned to each group of volunteers. Also, volunteer questions will be addressed and it will be an activity for volunteers to meet and share.

Activities to prepare the design activities, researchers met virtually and determine that it includes two events. Each event will take place on different days. The first event will work with girls and boys, and the second event will carry out activities with girls only (girls from the first event). Furthermore, researchers defined the objective and a list of requirements for each activity, this document is called *Volunteer Activity Guide*.

In this phase, groups of volunteers will be in charge of creating and designing activities of the events. Each group of volunteers will establish the set of playful activities to be carried out based on the guide provided by the researchers, so that the activities in all schools will have the same objective. This phase will last for two weeks. The *Volunteer Activity Guide* establish for each event:

1. The first event will aim to introduce general STEM concepts to boys and girls. Requirements given by the researchers are:
   a First, volunteers show STEM concepts to children using tangible materials such as paper, cloth, drawings, among others; for example, creating a storybook to communicate the concepts in a fun way.
   b Second, in another activity children are the main actors. They must express what they learned from the previous activity. The use of drawings is recommended.

   c Third, renowned people in STEM area and their contribution are presented by volunteers. The idea is to show experiments that women and men in the STEM area have performed. Children will carry out one of these experiments, which must be attractive to children.
2. The second event is only to girls who participated in the first event. It will be focused on encouraging girls to know STEM area and provides a more confident environment, encouraging girls to explore STEM concepts while they can strengthen their skills in a fun way. The requirements guide says:
   a Girls play a game outside their classroom, where they must use skills related to STEM area. Some games' examples are: treasure hunting or passing levels of obstacles.
   b Girls give their appreciations about the abilities that they used during the game, e.g. create a wall of thoughts with girls' words.

After that, volunteers will explain the designed activities to the researchers, so that researchers will approve them.

Execution volunteers will visit the school, introduce themselves, carry out the events with children. During events, a volunteer is taking note of what he/she observes, while other two volunteers are in charge of carrying out the activities. In addition, in the first event, a survey is applied to find out what children in STEM area know, and after each event, interviews are conducted with children.

Reflection volunteers will meet with researchers after each event and analyze and discuss the information collected. It is a time of reflection that each researcher makes about the work done, being evidenced the results.

4.4 Phase 3: Data collection

In the case of study, both qualitative data (e.g. interviews, observation) and quantitative data (e.g. surveys) are collected. Likewise, different sources of information are used to avoid the effects of a single interpretation. The data is collected through:

1. **Interviews**: interviews are semi-structured and will be carried out after executing each event. Interviews will be applied to children to know their perception about the activities and their opinion about what they have learned. Interviews will be recorded and the number of participants required is a minimum of 30 participants, since it is the recommended number in descriptive qualitative research [24].
2. **Observation**: volunteers will take notes during activities. It focuses on children's behavior, verbal and physical expressions. In addition, they are pending to describe how each activity was carried out, and to report particular situations.
3. **Survey**: a simple questionnaire of 10 to 15 questions will be applied to obtain information about the characteristics of children, as well as ideas and thoughts about STEM area. This instrument will have multiple answers and will be done before starting the first event.

4.5 Phase 4: Data analysis

To analyze the data from the interviews and observation, the *Thematic Analysis* method [7] will be used. The *Thematic Analysis'* process consist of: (1) Transcribing the interviews and organize the observation notes. (2) Creating the initial themes that emerge from data. (3) The list of topics is taken and classified. In this process, a description of the themes is used to select similar themes and place them in a new sub-list. Data is re-read several times, and themes are identified by means of a process of repetitive interpretation, synthesizing, and theorizing. To ensure the methodological accuracy of the results, we use a triangulation strategy [25], which involve the participation of two or more researchers to have different points of view when analyzing the data (inter-subjective). (4) Finally, the themes are revisited and adjusted, and a consensus is reached on the generated categories. Additionally, the quantitative data will be analyzed with descriptive statistics.

4.6 Phase 5: Reporting

The last phase will consist of creating a document that contains the main findings and conclusions of the research with notes or quotes from participants. This document will be distributed in school centers, institutions and people interested in the outcomes of our research.

5 Lessons Learned

In this section we present the lessons learned (LS) from the design of our *Playful STEM-promotion* initiative. An online spreadsheet was created to collect the LS provided by the researchers; included three columns: a) What was the identified situation; b) What is the lesson learned; and c) How this knowledge can be used in future research. We describe the lessons learned into three main categories, and we provided some tips about how we can use the obtained knowledge to improve future research (*takeaways*).

5.1 How to conduct a research project

We discovered that there is a lack of experience to conduct research projects in some of our researchers.

Researcher's background covers different research skills and areas, which helped to take advantage of the skills in which each one was stronger to create this initiative (e.g. design and conduct a research, formulation of activities). Additionally, we identified that interdisciplinary research requires a high level of organization, collaboration and commitment.

Takeaways:

- Encourage researchers to participate in events e.g. academic webinars, research courses or research groups.
- Take advantage of each researcher profile
- Read related literature about how to conduct research

5.2 Research team interaction

Our second lesson learned is related with the interaction among the professors who have participated in this initiative. First, the collaboration between the team members provides a much stronger generation of ideas that comes from the different fields of study. Also, there is a better support for conceptualizing and conducting research when people with research background participate. Second, is very important consider differences in work schedules of each team member, and the support they have to develop research projects, and in particular, related to STEM programs.

Takeaways:

- Further encourage interdisciplinary work
- Obtain support from university authorities to promote STEM research.
- Self and group motivation for continuous learning
- Encourage activities to strengthen interaction between the team (e.g. [27]).

5.3 Research context

As expected, we found relevant aspects regarding the participating institutions and the field in which the project is developed.

In the one hand, we identified different processes across the universities that are part of this initiative. For instance, the processes involved to assist students (Office of Student Affairs), or the different academic calendars or schedules (six-month or four-month period). Also, something we realized when starting this initiative, is that we need to have a broader knowledge about primary education systems and their regulations (e.g. process to obtain approval to conduct research in primary schools and cognitive development process of children).

Similarly, it is important to define the ethical protocol corresponding to the consent of the principals, teachers, children and parents to participate in our initiative. In addition, the authorization to collect and analyze data when photos or videos are included (if apply).

Takeaways:

- Strengthen support for STEM programs through different educational institutions
- Promote STEM programs through volunteering opportunities
- Encourage industry and government collaboration, to adapt curricula to include emerging technologies and STEM topics.
- Supporting in legal and ethical regarding the execution of research projects when there are children involved.

6 Conclusions and future work

In this document we explained in detail the design of our initiative called *Playful STEM-promotion* to promote STEM area in primary school and focused on the gender variable, so that other institutions can use this initiative to promote STEM in a fun way, especially encouraging girls to study STEM programs without any prejudice.

An initiative that includes researchers with diverse backgrounds and from different universities needs robust logistics and complex coordination. Therefore, the commitment of the members of the work team is and will be essential to successfully complete the objectives.

Last, the identified lessons learned have allowed us to establish key improvement aspects to conduct research, propose research projects that involve STEM disciplines, and that these projects involve initiatives for early learning levels such as primary education

The next step will be to carry out our initiative in Costa Rica the next year, and thus execute the design proposed in this paper.

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