Empowering futures: motivational strategy applied to high-school students for STEM degree choice

Eliana Acurio, PhD.[1]
[1]Escuela Politécnica Nacional, Physics Department, Ecuador, eliana.acurio@epn.edu.ec

***Abstract*– This work describes the results of a project that aimed to motivate high-school students to study degrees associated with STEM areas (Science, Technology, Engineering, and Mathematics) through a series of interactive, informative, and practical activities carried out during the 2021-2022 school year in zone 2 of the Ministry of Education of Ecuador. This project also pursued undergraduate students from the Faculty of Sciences of Escuela Politécnica Nacional to develop their skills in scientific dissemination, public speaking, and effectively transmitting their knowledge. Since it was identified that the main cause of disinterest in STEM areas is misinformation, an easy-to-use platform was designed by using the first-hand experience of undergraduate students in conjunction with the planning and development of different motivational activities. The obtained results demonstrated that it was possible to increase the interest of high-school students in degrees related to STEM areas.**

***Keywords*— STEM, motivation, dissemination, science, high-school.**

I. Introduction

Education in STEM fields is fundamental to the development of key skills for the future of society and the global economy. In recent years, there has been a growing interest in understanding the factors that motivate high school students to engage in STEM disciplines, as well as identifying the barriers that may hinder their interest and participation in these areas.

Motivation plays a crucial role in students' academic engagement and performance, and its influence in the STEM domain is particularly relevant. Previous research has shown that students who exhibit a high degree of intrinsic motivation toward STEM subjects tend to perform better and have greater persistence in these areas [1][2]. Therefore, understanding and applying the mechanisms that drive student motivation in STEM is essential to foster interest and engagement in these disciplines.

However, despite the growing importance of STEM areas in the educational and employment landscape, significant challenges persist in terms of student motivation. The gender gap in STEM, for example, remains a major problem, with lower participation rates among females compared to males [2]. In addition, socioeconomic disparities may also influence motivation and access to educational opportunities in STEM [3].

About 22,000 people in 2019 were working in the Ecuadorian technology industry, however, concerning the needs, it is estimated that the number will triple by 2024 [4]. STEM degrees have a high demand, and it has been increasing over the years, however, there is a low percentage of students applying to these careers in Ecuador, and those who do so drop out and do not complete their studies [5].

The economic factor also affects many students and prevents them from continuing their studies. However, it is not the only reason why they are not motivated to study university careers in general, and particularly in science and engineering. The psychological factor also interferes at the moment of choosing their occupation/profession, for example, fear of certain subjects discourages students from choosing careers related to those subjects. A particular case is the math anxiety (lack of confidence in the student's ability to learn mathematics) that high-school students experience, causing a decrease in the demand for STEM careers. In addition, other factors that are present in the lives of students should be considered, which intervene in their decision, such as school or personal motivation, misinformation, gender discrimination, and the great influence of parents, teachers and friends [6].

Considering all these factors, this work aims to encourage students in the second year of high school to pursue degrees in these areas of science. Employing a different educational dynamic in which undergraduate STEM students from Escuela Politécnica Nacional motivate high-school students to study the same degrees, this work seeks to give a new perspective to the disinterest and rejection that students have for degrees related to STEM fields. This dynamic implies a more participatory, interactive, and practical learning method, in such a way that the activities demonstrate that the knowledge and teachings imparted in class are applicable in daily life. In addition, this project seeks to reach rural and remote areas of Ecuador, so we worked with high schools located in Zone 2 of the Ministry of Education of Ecuador, corresponding to the provinces of Napo, Orellana, and rural Pichincha.

The remainder of this paper is organized as follows: in Section II, we provide details of the methodology; in Section III, we show and discuss the project results; and finally, in Section IV the main achievements of this paper are summarized.

II. Methodology

A. Human Resources

1560 second-year high school students, 139 high-school teachers, 30 students, and 2 professors from the Faculty of Sciences of the Escuela Politécnica Nacional participated in this work.

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B. *Project stages*

In the first stage, the topics to be developed were chosen based on the high school books of the Ministry of Education and the curriculum. The topics were developed with the university students of Mathematics, Physics, and Economy to complement the three STEM areas of interest studied in high school (Mathematics, Physics, and Entrepreneurship). This made it possible to link interesting topics in these areas with the knowledge that students receive in class. Table I shows the selected topics for this work.

TABLE I
SELECTED TOPICS FOR MOTIVATIONAL ACTIVITIES

Physics	Mathematics	Entrepreneurship
Introductory talk to the Physics degree	Introductory talk to the Mathematics degree	Introductory talk to the Economics degree
Energy transfer	Propositional logic	Economical photo mural
Electromagnetic fields	Sets	Economics agents
Nature of waves	Cardinality	Ultimatum game
Light behavior	Natural numbers	Generational accounting
Wave-particle duality	Induction principle	Generational accounting (case study)
States of matter	Vectors	Basic finances
Entropy	Matrices	Dollarization

In the second stage, interactive activities were planned with the aim of motivating and arousing curiosity in STEM areas (talks, interviews, conversations, videos, experiments, games, simulations, etc.). Most of these activities were located on a website and the talks were given by university students as real spokespersons for their careers.

In the third stage, the motivational activities were executed starting with teachers training on the methodology to be used during the implementation of this project. This allowed teachers to be predisposed in advance to collaborate with their different responsibilities. The execution methodology is summarized in Fig.1.

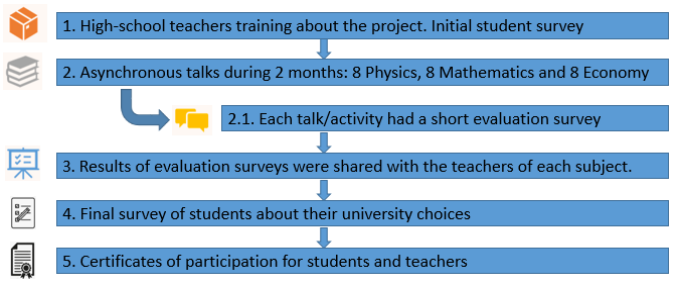

Fig. 1 Chronological project execution activities

The last stage focused on processing the information and analyzing the impact that this work had on high school students. Initial and final surveys were carried out on second-year high school students. The initial survey sought to identify the main college degree options considered by students, as well as the reasons why they do not consider a degree in STEM areas. The final survey sought to determine if there is a change in student perception of STEM degrees and if there is an increase in the percentage of students interested in pursuing these degrees.

C. *STEM platform*

The platform to develop motivation activities in STEM areas was developed as a free access website designed in WordPress. The main page describes the general objective of the project and has 4 sub-tabs. The first of them directs a news portal developed by third parties so that high-school students can explore the latest technological advances. The remaining three tabs direct to an individual portal for each area of interest (Mathematics, Physics and Economics).

Each selected topic has the following structure: a section of instructions, a section of main material where the video of the topic developed by the university students is found, a section of complementary material with videos, games or activities, and finally a short multiple-choice test to evaluate the compression of the main video. The complete platform can be found at https://proyectostemepn.wordpress.com/

D. *On-site talks*

The talk entitled "Importance of STEM areas" highlighted how technological advances have improved our quality of life and have allowed us to obtain impressive achievements. For example, vaccines in record time, capturing images of black holes, the development of an artificial uterus, detection of gravitational waves, interplanetary travel, etc. The professional profiles and fields of application of degrees in Mathematics, Physics, and Economics were also discussed. In this part of the talk, the participating EPN undergraduate students were the spokespersons of these careers and shared first-hand their experiences, expectations, and difficulties. This helped to demystify some of the high school students' beliefs and to get a closer look at the academic offerings provided by the EPN Faculty of Science. Fig.2 shows a couple of pictures of this event at “Unidad Ecucativa 11 de Noviembre”.

Fig. 2 Photographs of the talk titled “importance of STEM areas” at Unidad Educativa 11 de Noviembre.

III. Results and Discussion

The first parameter that was evaluated is the percentage of student participation in each area of interest (mathematics, physics, and entrepreneurship). It is important to mention that the interaction with the platform was carried out as homework within each subject and with the support of the respective teacher. The second parameter was the average of the evaluations of the topics in each area. Table II shows the results obtained with the 11 high schools. It can be seen that, although the participation percentages are below 70%, the average grade obtained in the educational units that did participate in the platform activities exceeds the satisfactory grade, with the exception of the mathematics area. As mentioned previously, the support of the teacher of each subject was essential to ensure that all students participated in the activities. Unfortunately, some teachers did not contribute enough to get all of their students involved in the activities. Furthermore, since it was a homework assignment without a grade within the subject, the students did not take it as seriously as expected.

The low average in mathematics is mainly due to the grades in topics 6 and 7, which are vectors and matrices respectively. Although the vectors are treated in the academic curriculum of this subject for the second year of high school, the matrices are reviewed in the following course. The topic of matrices was selected due to the large number of applications in everyday life, but the results show that students are not yet prepared for this topic. In subsequent editions of the project, these topics will be replaced with the purpose of improving understanding.

TABLE II
GLOBAL RESULTS OF PARTICIPATION AND GRADE AVERAGE

	Physics	**Mathematics**	**Economy**
% Participation	58.73	59.04	47.20
Grade average /10	8.00	6.18	7.20

The results of the survey prior to the execution of the motivation activities are summarized in Table III. It was found that students are unaware of the existence of degrees associated with STEM areas, so they do not consider them as options for their professional future. Even if students have heard of these degrees, they consider them very difficult or the information received is very limited.

TABLE III
SURVEY RESULTS PRIOR TO MOTIVATIONAL ACTIVITIES

Question: Have you ever heard about degrees in STEM areas?		
Choices	**Number of students**	**Percentage**
Nothing	301	19.29%
A little	1052	67.44%
A lot	207	13.27%
Question: What do you think about STEM careers?		
They are difficult.	352	22.56%
This is only for nerds.	23	1.47%
Anyone can study them.	106	6.79%
They are fun.	138	8.85%
They are boring.	37	2.37%
They have few job opportunities.	73	4.68%
They have many job opportunities.	397	25.45%
I haven't heard anything about these degrees.	434	27.82%
Question: Have you ever considered pursuing a degree in STEM areas in the university?		
Yes	514	32.95
No	452	28.97
No, because I haven't heard anything about them.	594	38.08

In order to measure the impact of this project, a second survey was carried out after its execution and the results are inidcated in Table IV.

TABLE IV
SURVEY RESULTS AFTER MOTIVATIONAL ACTIVITIES

Question: Do you think that knowledge in Physics is useful in your life?		
Choices	**Number of students**	**Percentage**
Almost nothing	39	4.20%
A little	423	45.58%
A lot	466	50.22%
Question: Do you think that knowledge in Mathematics is useful in your life?		
Almost nothing	26	2.80%
A little	201	21.66%
A lot	701	75.54%
Question: Do you think that knowledge in Economics is useful in your life?		
Almost nothing	50	5.39%
A little	353	38.04%
A lot	525	56.57%
Question: Did the activities of this project influence your consideration of pursuing STEM-related degrees?		
No	104	11.21%
A little	578	62.28%
A lot	246	26.51%

As can be seen, the students found the knowledge in the areas of interest useful. This implies that the design of the

activities that sought to connect knowledge and daily life made the participants notice their importance.

Finally, 88.79% (62.28%+26.51%) of the students indicate that the motivation activities had an influence, even a slight one, on their university degree decision. This is because, as mentioned above, there was a high percentage of students who had not heard anything about STEM areas and the degrees associated with them. In addition, 85% of teachers found that the approach of the lectures/activities was novel and that they could even use some of these methodologies (memes, animations, simulations, games, etc.) in class.

This project has shown that high-school students recognize that degrees associated with STEM areas are relevant not only for the development of new technologies that will revolutionize the world, but also in their daily lives. It became evident that it is important to keep working on these motivational activities since there is a great lack of knowledge about the professional opportunities of these degrees. The support of school teachers is essential to encourage students to become interested in STEM-related subjects, allowing them to make decisions based on what they really like.

IV. Conclusions

This paper summarizes the planning, methodology, and execution of a project that aimed to motivate high school students to study STEM degrees. Considering the 11 participating high schools from Zone 2 of the Ministry of Education of Ecuador in the project, less than 70% of the students participated in the motivational activities. This could be due to several factors such as the lack of persuasion of the teachers for the students to use the platform, dedication of the students to other qualified tasks, and lack of technological resources necessary to participate in the lectures, which were developed remotely. Another relevant result is that in Physics and Economics, the average grade of the students is above 7 points out of 10, which is considered a satisfactory grade. Only in the area of mathematics was the average obtained below 7, which could be due to the complexity of the taught topics. Finally, 88.79% (62.28%+26.51%) of students agree that this process altered, even slightly, their decision about what degree to pursue at the university. Therefore, this work showed that it is important to maintain initiatives and/or projects like this one since the lack of knowledge about STEM-related degrees prevents high-school students from choosing them for their university studies.

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