

Supporting Equitable Access to High Quality STEAM Education: Experiences from The Arecibo Observatory's STAR Academy

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Introduction: STAR Academy was founded in 2019 with the goal of contributing to the scientific development of Puerto Rico through quality educational experiences for high school students. The curricular activities of the program focus on developing conceptual knowledge of astronomy, research skills, and programming. However, the core of the program has been to provide the opportunity for students from diverse backgrounds to have access to top quality scientific education, as well as opportunities to engage in meaningful interactions with scientists from different backgrounds, popular science communicators, among other STEAM professionals.

Developing the student's scientific identity through means of representation and sense of belonging among the scientific community is an aspect that is considered, and up utmost importance, when designing the agenda for each semester. The term identity can be defined as the collection of stories about a person and how the narratives of their experiences materialize and shape their own reality [1]. Culture is an aspect that is usually not attended in the science classroom, but it has been shown in the literature that it can relate to one's self-concept and the subjective values that students assign to specific tasks or goals (such as studying for or being a scientist) through the development of gender roles and personal or cultural identity [2]. These social beliefs of gender roles and cultural identity can become limiting to some students. In STAR Academy each student is mentored throughout the development of their research project, as this has been shown to help students identify themselves as future scientists [3]. Similarly, the activities that take place in the academy serve as pathways to promote interactions amongst a diverse community of students, to create spaces where students feel represented, supported, and where equity takes place.

In Puerto Rico, even though many advances have been made in terms of access to education, a difference in terms of access to quality education by geographic regions is still observable. This is also reported in the literature in other countries [4]. Due to the Covid-19 pandemic, the academy has had the opportunity to explore with the idea of offering the program in a virtual modality, which allowed us to expand the offering to students from different areas of the island.

Currently, and considering the increase in reach and impact that was observed, STAR Academy is offering a hybrid modality that allows students to participate in most meeting virtually, with periodical visits to the on-site facilities.

Achievements: The academy has been offering opportunities for high school students for five consecutive semesters, starting in the fall 2019 semester and more recently starting its sixth semester in January 2022.

Pre-Test – Post Test	t	df	p
Fall 2019	-32.227	29	< .001
Spring 2020	-37.365	20	< .001
Fall 2020	-17.385	28	< .001
Spring 2021	-9.781	27	< .001
Fall 2021	-11.949	26	< .001

Note: For all tests, the alternative hypothesis specifies that Measure 1 is less than Measure 2.

Table 1: Pre and Post-Test Paired Samples T-Test

In Table 1, we show the results of paired t-tests for each of the semesters for which STAR Academy been active. A statistically significant difference between the results of the pre and post tests scores exists, demonstrating the efficacy of the instructional program. These observations sustain the claim that the students that have participated in STAR Academy have significantly improved their knowledge about the basic concepts in the field of astronomy. The offering of the pre-assessment takes place during the first day of meetings, while the post-assessment is given as a final assessment for which the students can prepare for. However, the students are never informed that the final assessment includes the same items as the pre-assessment, with the purpose of maintaining the validity and integrity of the data being collected.

In Table 2 we observe the number of students that took the pre and post test for each semester (N), mean score and standard deviation. From the data we can see that each semester has had slight variations in N from pre to post test, except for the spring 2020 semester, which included some students that had to leave the academy by personal choice among the pretest scores,

while the post test includes some students that joined further on during the program.

	N	Mean	SD
Pre - Fall 2019	33	21	4.514
Post - Fall 2019	30	30	2.901
Pre - Spring 2020	21	19.857	3.864
Post - Spring 2020	21	27.714	3.566
Pre - Fall 2020	32	17.781	6.394
Post - Fall 2020	29	30.931	2.034
Pre - Spring 2021	30	17.567	4.125
Post - Spring 2021	28	27.643	3.592
Pre - Fall 2021	32	16.656	3.738
Post - Fall 2021	27	28.778	3.055

Table 2: Pre and Post-Test Descriptive Statistics

The skills and scientific knowledge assessed in the pre-post test include astronomy specific content, but also basic ideas like the scientific method. It was observed in most of the semesters that the students struggle to define the scientific method, as well as other simple concepts. Even though traditional curriculums cover these concepts, it is a fact that students do not entirely synthesize it, which could be due to multiple factors such as poor learning experiences, lack of relevancy for the student, perceive cost of learning by the students, among others. However, our results show that the students can learn simple and complex scientific ideas in a short period of time (semester), given the right motivation, mentoring, and combination of meaningful learning experiences.

Conclusion: A distinctive component of STAR Academy is the student's research projects. This experience includes having the students explore a topic of their own choosing and interest, which can be related to astronomy, engineering, technology, general science, or mathematics. The students are mentored during one full semester with the goal of helping them complete their research, write a paper, and present the results in a mock-scientific symposium. From the past five semesters, six projects have been selected to be presented in a professional scientific conference, having four of these already presented and two pending. This component is what we've observed to have the most impact in the student's development, even when they're not selected to present in a professional conference. Students participating in the academy have increased their affinity towards science and developed a positive scientific identity through the

process of doing science, being this a case of active learning. Being exposed to an environment where everyone can do and is encouraged to do sciences serves in favor of the student's development. This is achieved through continued exposure to scientists and other STEAM professionals, as well as through the general dynamic that takes place at the academy. Through the combination of representation and active learning, we understand that it is possible to deconstruct social and cultural expectations and beliefs of what it is to be a scientist, as well as increase the chances that the students are motivated to continue to pursue their passion for science.

In a survey conducted after each of the semesters ended (with sample size N=70), 90.5% of the students that participated and were currently in high school indicated that they plan to pursue a career in a field related to STEM. Out of those that were already at the university level, 85.17% indicated that they are enrolled in a field related to STEM. When evaluating the influence that STAR Academy had on their decision or plan, using a Likert scale of 5 points, 64.3% indicated that the academy was highly influential on their decision, 32.9% indicated that it was influential, 2.9% that the influence was neutral, while 0% reported not influential or highly not influential. These results are encouraging and expose the importance of programs like STAR Academy, even more when we consider that it's the only extracurricular program of similar design and purpose. It is recommended that schools and outreach institutions adopt similar curriculum design, focused on providing meaningful learning experiences through the development of the student's scientific identity and active learning.

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