STAR Academy: Space and Planetary Sciences for High School Students at the Arecibo Observatory. B. Rivera-Muñiz[1], S. Santiago[1], and A. Virkki[2], [1]Arecibo Observatory (SUAGM) (brivera@naic.edu), [2] Arecibo Observatory (UCF).

Introduction: STAR Academy is an out of school program for highly qualified high school students living in Puerto Rico, that aims to close the gap between demand and production of STEM graduates in Puerto Rico. The academy focuses on four main pillars: Space and Planetary Sciences, Research, Coding, and Leadership Skills. The first pillar, space and planetary sciences, refers mainly to the core-content of each unit. The second pillar responds to one of the program's main goals; providing the opportunity, instruction, mentoring, and space for high school students to develop their scientific research skills before pursuing undergraduate studies. The third pillar responds to one of the most necessary skills for 21st century scientists, coding [1]. And the fourth and last pillar is the promotion and development of leadership skills, necessary to guarantee success in STEM fields. These four pillars are developed in each student via an engaging curriculum developed at the Arecibo Observatory as part of their Research Experience for Teachers program. The students that participate in STAR Academy meet at the Arecibo Observatory on a weekly basis, every Saturday, to participate in learning and research activities, as well as in conferences offered by local and international scientists. STAR Academy requires 16 on-site meetings, consisting on 1 day of interviews and selection of candidates, 14 weeks of intense study of space and planetary science concepts/units and research, and 1 day of scientific research presentations. During the days that the students are not required to meet at the Arecibo Observatory, they continue their individual research and are assigned work via an online platform, to provide continuity on what is being done during the meetings and provide the opportunity for greater retention by continuous exposition to content-related activities.

Curriculum: The curriculum that was specifically developed for STAR Academy includes 13 units, covered in a period of 14 weeks. Each of the units is aligned to middle school and upper school Next Generation Science Standards [2]. Each class meeting targets task-specific objectives that are measurable and observable, to provide a meaningful assessment on the scientific development of each student. All meetings were carefully designed with a combination of traditional and contemporary instructional methods and strategies, as to provide greater variety and more instructional efficacy to students from diverse learning styles and backgrounds [3]. The integration of coding, specifically in Python, using Jupyter Notebook, is present in all the units. All of this is established with the purpose of having all students present the results of an individual or collaborative research project in a topic of their interest that is related to space or planetary sciences.

Unit Content: STAR Academy's main content focus is planetary sciences, however, there is relevance in developing the student's knowledge in all fields related to astronomy and STEM. The curriculum is divided into 13 units that cover topics such as the scientific method, early astronomy, the electromagnetic spectrum, chemistry, atmospheric science, the solar system, asteroids and comets, space weather, space exploration, stars, galaxies, and cosmology.

Pedagogical Background: One the main theories of focus in the curriculum is Bloom's Taxonomy [4]. Benjamin Bloom's Taxonomy addresses mastery learning by a series of steps in the process of knowledge acquisition that need to be developed in order to reach the next level of thinking. STAR approaches Bloom's taxonomy in three groups: lower (remember, understand), mid (apply, analyze), and higher-order thinking (evaluate, create). The lessons are designed to provide stepped exposition to each of the mastery levels so that each student has the opportunity to develop higher-order thinking skills and create their own original research project. The class structure takes into consideration Bloom's Taxonomy, and a simple 3 parts approach, similar to introduction, development, and conclusion. Introductions aim to invite students to be part of the class, motivate them, and spark conversations. The lecture provides the pre-college experience that characterizes the curriculum, but with contemporary approaches like problem-based learning [5], with the purpose of developing main concepts and ideas, and having the students answer the questions they posed to themselves during the introduction [6]. Lastly, the student applies the new concepts to solve a related problem, either evaluating or creating, in a higher-order thinking activity that fosters scientific aptitudes.

Instructional Materials: Most of the content that is used during the lessons has been develop specifically for STAR Academy, such as content presentations, online quizzes, and essay prompts. However, some of the instructional materials that are used were developed by other organizations such as the National Informal STEM Education (NISE) Network and the Har-

vard-Smithsonian Center for Astrophysics. The NISE Network has developed various kits for hands-on activities that correlate with some of the topics present in STAR's curriculum [7], and serve as great introductory activities that help students visualize and/or explore complex concepts in fun and engaging ways. Another of the instructional materials used at STAR is the Laboratory for the Study of Exoplanets [8] developed by the Harvard-Smithsonian Center for Astrophysics, which introduces students to the search for exoplanets using a series of online labs where students get to use the Micro Observatory telescopes located at the Whipple Observatory in Arizona.

Selection of Students: Students interested in participating in the program complete an online application that follows with an in-person interview, after preselection of candidates. During the first semester of STAR Academy (Fall 2019), 104 applications where received, and 70 students were interviewed, of whom only 34 where selected. Each student was evaluated based on attitude towards the program, genuine interest in space and planetary sciences, career goals, and academic achievement. The students that were not selected are encouraged to re-apply the following semester, as this process will be repeated for Spring and Fall semesters of sub-sequent years.

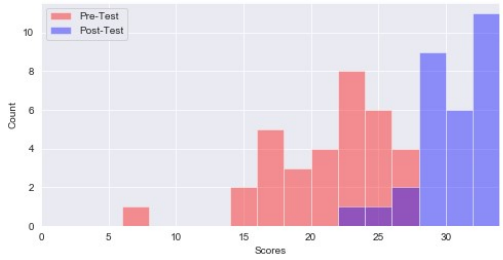

Figure 1: Distribution of Fall 2019 Test Scores

Outcomes: At the start of the Fall 2019 semester, each student took a pre-test that evaluated their knowledge in basic scientific concepts and astronomy, with a maximum score of 34 points. The results of this test showed an average score of 21, a median of 22, and a range of 6-27. After completing all 13 units, the students took a post-test that was identical to the pre-test. The results of this test showed greatly improved scores, with an average score of 30, a median of 30, and a range of 22-34 points. 30 students successfully completed the program and presented 20 individual and group research projects in a variety of topics related to astronomy. Each presentation showcased the quality of the program by engaging the audience and students, and fostering the development of a future generation of scientists. One student was selected to participate in the 51st Lunar and Planetary Science conference, and potentially present her work, with all expenses covered.

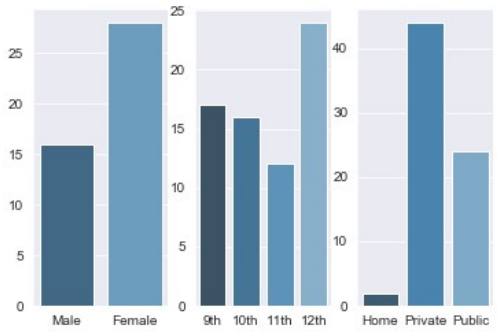

Figure 2: Fall 2019 Students Overview

Conclusions: The opportunities for local students in Puerto Rico to participate in programs where they learn astronomy and develop research concepts are extremely limited. STAR Academy is the only currently running program in space and planetary sciences for high school students in Puerto Rico. Its curriculum is developed with a solid foundation of pedagogical theory, and in its first semester implementation, has shown excellent results in student development. STAR Academy provides a platform for the development of our next generation of scientists.

Acknowledgments: Funding for this program is provided by NASA's Near Earth Observation Program grant for the Arecibo Observatory Planetary Radar Program, awarded to the University of Central Florida. The program is administered by the Ana G. Méndez University.

References: [1] S. Leon. (2015) *"An education for the 21st century means teaching coding in schools"*. The Conversation. [2] L. Okhee, E.C. Miller, and R. Januszyk. (2014) *"Next generation science standards: All standards, all students"*. Journal of Science Teacher Education. 25.2, 223-233. [3] H. Gardner, (1992) *"Multiple intelligences"*. 5. Minnesota Center for Arts Education. [4] L.W. Anderson, (1994) *"A Revision of Bloom's Taxonomy"*. Univ. Chicago Press. [5] G. Gorghiu, et al. (2015) *"Problem-based learning-an efficient learning strategy in the science lessons context. Procedia-social and behavioral sciences"*, 191, 1865-1870. [6] Č. Serafín, Dostál, et al (2015) *"Inquiry-based instruction in the context of constructivism"*. Procedia-Social and Behavioral Sciences, 186, pp.592-599. [7] B. Herring, et al. *"The National Informal STEM Education Network."* https://www.nisenet.org/. [8] A. Ibrahim, *"Laboratory for the Study of Exoplanets: Teachers"*, https://www.cfa.harvard.edu/