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Engaging secondary school minority students in pre-engineering education through project-based learning

For decades, several initiatives have been taken by the United States to increase minority students' interest and persistence toward engineering, to meet the fast growing needs of its STEM workforce. However, recent studies have shown a decrease in STEM graduates among minorities from higher education institutions, which is strongly related to the lack of minority youths' interest in math and science. To fill the gap, the Proyecto Access STEP program was implemented at Hostos Community College in 1997 to increase science and engineering career awareness among historically underrepresented and underserved K-12 students in the South Bronx, New York. The program offers an early exposure in science and engineering to secondary school students with the following objectives: 1) provide a solid background in mathematics through intensive summer enrichment courses and tutorial services; 2) provide hands-on engaging activities through science and engineering projects; 3) provide research experiences in STEM disciplines. The current education model suggests that early and continuing exposure of underserved students to various STEM contents, and engaging them in project-based learning fosters their interest in STEM during their academic journey, until their access to higher education. Furthermore, minority students' involvement in STEM research increases their persistence toward the completion of a degree in STEM.

1. Methodology

Despite the significant growth of the Hispanic population of about 51 million (Noe-Bustamante et al., 2020) from 1970 to 2019, African Americans and Hispanics' representation in the STEM workforce still remains low today (17%), according to the PEW research center (Parker, 2019). These challenges lead to an urgent need for the development of STEM programs for minorities in higher education institutions. Proyecto Access STEP is a year-round program that offers an intensive seven-week summer session followed by an after school programming during the academic year, both in which enrichment courses and tutorial services are provided in mathematics, physics, chemistry, science, technology, engineering, computer science, robotics and health related fields.

Students start the summer program at a young age in Prep I (grades 7th - 8th), where they learn basic engineering skills through a tower building project (figure 1), along with computer programming in ALICE, Python, and C++. The tower project teaches young learners basic mechanical engineering principles preparing them for future careers in design and construction. Recently, Proyecto Access partnered with the New York City Department of Design and Construction (DDC) implementing its Coastal Resiliency curriculum to teach students topics such as climate change, erosion, and hurricanes (figure 2). For example, students design hurricane models in which they learn the impact of wind velocity on the height of waves. In addition, students explore astronomy concepts through engaging hands-on projects replicated from the NASA Afterschool Universe curriculum (figure 2). They learn how to build simple telescope and spectroscope models and learn scientific concepts such as light travel time as well as the electromagnetic spectrum. As they learn how to model the Universe for example, middle school students reinforce their understanding of the size, structure, and evolution of the Universe.

In their second year, Prep II (9th-10th), students participate in a truss bridge construction project (figure 3), complemented by a training in AutoCAD, which is a commercial computer-aided design and drafting software. AutoCAD allows students to create a drawing model of their project, prior to the fabrication process. The bridge project offers students a platform to apply mechanical principles as they learn about force distribution, tension and compression, concepts critical to the engineering design process. The project is complemented by a computational simulation with the West Point Bridge Designer software. As students learn about the equilibrium of structures and important concepts such as stress and strain, the software allows them to experience the engineering design process including cost estimation and testing of their models according to a set of performance criteria.

Students that persist to the third year of the program, Prep III (10th-11th), engage in a robotics project using the VEX robotics kits (see figure 3). In this project, several groups of students design and assemble robots to accomplish specific tasks. For example, the robot is designed to pick up a bucket containing a 2lb load to be carried around a playing zone created with several obstacles. The robotics project teaches students mechanics principles such as center of gravity, torque, gear ratio, and force distribution. In addition, students explore basic electric and electronic components including sensors, electric motors, and microcontrollers. In addition, students receive training in Easy C, which is based on the C-programming language. The software allows them to program their robots to accomplish specific tasks, which prepares them for more challenges in the fourth level of the program.

In their last year, Prep IV (11th-12th), high school seniors are ready to be challenged in research activities (figure 4). As they take college-level courses in STEM disciplines, students may extend their computer modeling and drafting skills using the SolidWorks software. After the exploration of a variety of science and engineering projects, combined with different software skills, over three consecutive summer sessions, students feel confident enough to engage in research activities under the supervision of their faculty mentors. Students receive additional training in the scientific research methods, and participate in several workshops in topics such as literature review, abstract writing, research report writing, data collection and interpretations, poster design and presentations

2. Results and Discussion

Since 2014, the Proyecto Access STEP program has shown significant interest and confidence to increase its students' participation in local and statewide annual conferences.

The Annual Statewide STEP Student Conference takes place every year and involves over 40 higher education institutions. The conference offers a great opportunity for students to gauge their research skills, network with their peers, and attend research workshops, and guest speaker presentations by well-known STEM professionals. In recent years, Hostos students' research participation in STEM conferences increased by 50%. As a results, students have won prestigious awards at statewide conferences (figure 4), competing with their peers from higher education institutions from public, private, two-year, and four-year institutions across New York State. By presenting their projects at STEM conferences, students build confidence in STEM. This creates in them a sense of belonging to the science community, and increase their interest and persistence in STEM education. Since its inception at Hostos Community College, Proyecto Access has prepared over 5,000 minority students for future career perspectives in the STEM workforce.

3. Conclusion

The underrepresentation of minorities in the STEM workforce results from their low graduation rate in STEM majors from higher education institutions. This issue needs to be addressed at the secondary school level by early exposure of underrepresented and economically disadvantaged students in STEM disciplines. For better results, several afterschool programs including Proyecto Access at Hostos Community College, have proposed a model in which minority students are offered enrichment courses in a project-based learning to foster their interest at a younger age in STEM. The model suggests that a continuous and gradual exposure of minority students by engaging them in a variety of hands-on projects allow them to build confidence in their skills for future pursuit of STEM studies. In addition, students' engagement in STEM research seems to be the most effective way to increase their persistence toward a degree in engineering

4. Appendix

Fig.1: Middle school students working on their tower projects in groups

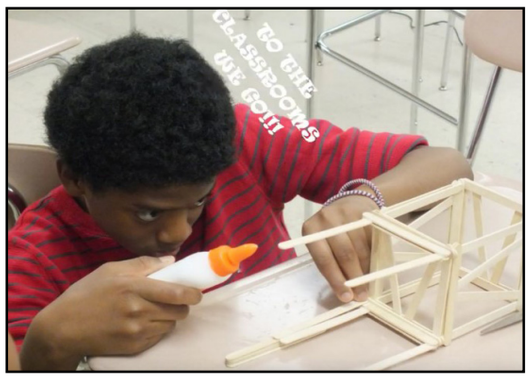


Fig.2: Modeling the Universe (Top) and Hurricanes (Bottom) with middle school students

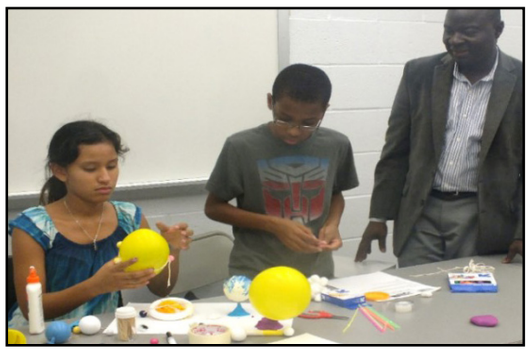
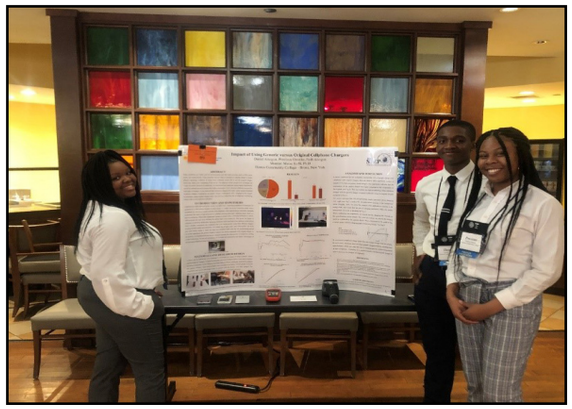
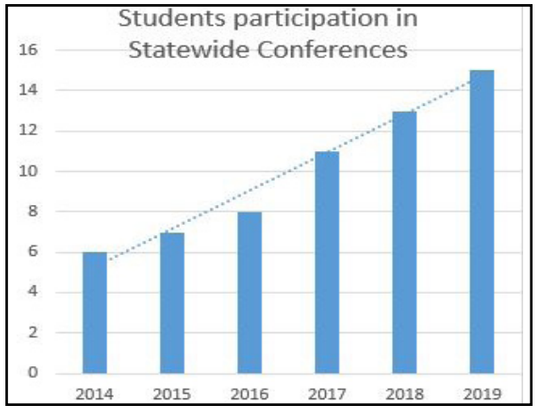


Fig.3: Truss bridge (Left) and robotics (Right) design by Hostos STEP students

Fig.4: Hostos STEP students' participation in local and statewide STEM Conferences





3. Bibliography

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