Best Practices Developed by the Model Institute for Excellence from Puerto Rico

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***Abstract*—In this paper we present two programs for underrepresented Spanish minorities: Model Institute for Excellence (MIE) and Broader Participation in Computing-Alliance (BPC-A). MIE was a National Science Foundation funded program ran in Puerto Rico, whereas BPC-A was a project designed to impact Hispanic American institutions in Puerto Rico and the African Americans in the US Virgin Islands. Both programs enabled pre-college students to participate in early research, during which they learned from mentors how to conduct research using university facilities – going through the whole research cycle starting from documentation, formulation of a research question up to giving oral presentations or making posters, which were then presented in a research symposium. The programs also affected undergraduates through an intensive ten-week summer research program at partner institutions in both the US and internationally. Mentoring by faculty and peer mentoring produced very positive outcomes in transferring these undergraduates to graduate schools: over 300 Bachelor of Science degrees in Science, Engineering, and Mathematics and 130 undergraduates went to graduate schools (70 Master of Science and 60 PhD).**

***Keywords*—project-based learning; underrepresented minorities; economically disadvantaged students**

I. Introduction

The largest proportion of Science, Engineering, and Mathematics (SEM) graduates in Puerto Rico has traditionally been produced by the resource-rich and highly selective state university. Since enrollments at state schools depend on state-allocations, budget constraints over the years have forced them to limit enrollments and consequently become even more selective. Therefore, the number of SEM Bachelor of Science (BS) graduates has stabilized. However, as private institutions do not depend on fixed allocations, they are able to substantially increase enrollments and are in the best position to fulfill the growing need for SEM BS degree graduates. Moreover, with offering the right financial schemes, they can serve a large pool of disadvantaged youth who would not otherwise have the access to the state colleges.

The goal of Model Institute for Excellence (MIE) program was to: a) increase the number of SEM majors; b) develop the capacity to institutionalize and sustain this growth and to continue to expand and improve well beyond National Science Foundation support; and c) develop a well-documented, replicable model for similar Hispanic institutions. This program focused on increasing recruitment, retention and advancement of students who have traditionally attended Universidad Metropolitana (UMET): low-income and disadvantaged students. Those students had the potential to succeed in SEM but, because of their background and lack of a quality education in our public schools, have not developed this potential, did not have the access to the free selective state university and would be otherwise excluded from SEM careers.

The implemented model was a **student-centered**, placing students in the center of a triad of faculty, counselors and academic and student services support personnel to create a nurturing, stimulating and supportive environment, where teaching and learning became central to all student/faculty activities. It also provided a **secure pathway** for students from before their freshman year through their undergraduate education to the Master of Science (MS) and PhD degrees, through a comprehensive set of academic programs, enrichment and support services at the undergraduate level. By focusing on **key transition points**: high school-to-undergraduate and undergraduate-to-graduate, MIE addressed **crucial obstacles** to sustain student progress by: focusing on cognitive and critical thinking skills, academic support, undergraduate research, and exposure to role models and other enrichment throughout the undergraduate years.

This program affected over 2,500 pre-college students and over 95% of the participants were transferred to colleges. At the beginning of the program, UMET had two BS programs and MIE initiative created four additional BS degree programs in Chemistry, Environmental Science, Cellular Molecular Biology and Biomathematics, and added ten new PhD faculty positions to the School of Science and Technology.

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MIE program found its successor in the Broader Participation in Computing-Alliance (BPC-A), which was designed to impact Hispanic American institutions in Puerto Rico and the African Americans in the US Virgin Islands, including women and persons with disabilities. It started by reaching out to the economically disadvantaged communities in Puerto Rico and the US Virgin Islands through consortia with municipalities, community-based organizations, and professional organizations in the field. A network of institutions, mentors, administrators in Puerto Rico, Virgin Islands, US mainland, and abroad became available for the implementation of Alliance activities. The BPC-A motivated and increased the recruitment of students who chose computing disciplines as their major in college. It influenced pre-college students, science and mathematics teachers, undergraduates, graduates, and economically disadvantaged community members.

In order to fulfill its goal, this Alliance established the Caribbean Computing Center for Excellence (CCCE) with a focus on four main objectives: a) increasing the recruitment of high school seniors in the computing and engineering through hands-on research experiences in university settings, b) providing professional training to in-service science, computer, and mathematics public and private high school teachers, c) providing research experiences in computing and engineering to undergraduates and graduates; and d) increasing the number of graduate students in the fields and transfering 40% of BS graduates impacted by this program to attend graduate schools.

In total, more than 600 pre-college students from public and private schools along Puerto Rico had the opportunity to conduct research and disseminate results of their projects at pre-college research symposiums. In addition to following good practices of MIE model in providing pre-college research opportunities, the second part of BPC-A project focused on in-service teacher training. A total of 114 math and science teachers have participated in professional development computer related workshops, which were held during the pre-college research symposium. Finally, the third part of this project focused on providing undergraduate research opportunities, namely more than 800 undergraduates participated in summer research activities in the US and abroad.

II. MIE MODEL

The MIE program was running at UMET for thirteen years (i.e. from 1995 until 2008). Its long-term goals for SEM at UMET consisted of specific activities in each of the following areas: 1) student recruitment; 2) pre-college-to-college bridge program; 3) student support; 4) student performance assessment and tracking; 5) undergraduate research; 6) student enrichment; 7) participation and collaboration with industry.

A. Student recruitment

More than any other institution on the island, UMET has succeeded in increasing the pool of talented pre-college students for SEM majors. Throughout it duration, each year the 300 top 9^{th} - 12^{th} grade students from the public-school system were selected among over 3,000 candidates for a rigorous SEM enrichment program on the campus; 24 sessions a year in Saturday academy, and eight weeks of summer pre-college research program. Students, while participating in research activities during Saturday academy, were guided by their research mentors who were mainly undergraduate and graduate students. Research mentors provided students with knowledge and skills that they needed to conduct their research [1]. The participants for summer pre-college research program were selected among the best performing students who attended research programs on Saturdays during the given school year.

B. Pre-college-to-college bridge program

UMET established a six week, four days per week, on-campus pre-freshman bridge program for 100 entering high school students. It included initial assessments; academic enrichment in mathematics; hands-on lab experiences in biology, chemistry, physics (2 weeks each) and computer science; academic, career and personal counseling; and intensive orientation on college life, the UMET and its services and resources in the surrounding area. The students also participated in workshops on test-taking, writing skills, study habits, library use and others. The participants were among those students who have showed a high potential in high school, but may not have the adequate support at home as being the first generation attending a university.

C. Student support

A Science Support Center (SSC) was established as the locus of the student support system. Activities coordinated by the Center included: a) intensive pre-freshman program; b) intensive two-week freshman orientation, including academic counseling (e.g. orientation on coursework, initial assessments, test-taking skills training), career and personal counseling by professional counselors and faculty, with assignment of a faculty mentor to each freshman; c) orientations each semester, including annual assessments and workshops on various personal and academic issues; d) financial aid information and assistance; e) on-going counseling by professional counselors following a case-management model; f) mentoring by a faculty member throughout the undergraduate years; g) a tutoring program in which all students had the access to SEM graduates for tutoring, to individualized tutoring through use of technology (computers/multi-media), and peer tutoring and cooperative learning; and h) recreation and sports activities, including cultural and recreational field trips and an intramural team sports program for science majors.

D. Student performance assessment and tracking

On-going, systematic assessment of student performance provided a feedback to faculty and students, such that an appropriate support (e.g. tutoring, individual work, academic counseling) could have been offered. Course and other assessments were a part of the Management Information System, where all data was securely stored and access to it was only given to need-to-know personnel, to ensure continuous access by faculty and students to information on students' academic progress. All freshmen were assessed through multiple assessments during the freshmen orientation and again each year. This served as baseline data for individual student academic profiles. A significant part of the faculty development program and the technical assistance by the SSC to faculty relied on testing and assessments.

E. Undergraduate research

All BS degree programs required one semester undergraduate research course, as related studies showed that students who become involved in research experiences are more persistent in pursuit of an undergraduate degree [2]. Taking on research that showed benefits of including undergraduate students in research [3], [4], we argue that underrepresented racial and ethnic students should be offered with more than just preventing them from dropping out of universities [5]. In addition to one semester research course requirement, 40 to 50 students per year were thus encouraged to engage in research that is more extensive and to present their results at conferences.

F. Student enrichment

To each entering freshman, a faculty mentor was assigned to lead the student throughout the undergraduate experience and to offer assistance in academic advising and referrals to university services. The faculty was expected to advocate for their students. In addition to faculty mentors, field experts were sought in industry and at other institutions to complement the faculty mentor's work. All SEM undergraduates were expected to participate in seminars and lectures. UMET significantly expanded its lecture and seminar series through its national laboratory contacts. At least three seminars/lectures were added to the initial lecture series in each discipline each semester. These served as supplements to other lectures/seminars with local researchers from universities and industry.

G. Participation and collaboration with industry

Industry was tapped through Industry University Research Center to provide research internships for students from UMET at industry labs, both in Puerto Rico and on the mainland. UMET was involved in each phase of implementation of this collaboration. First, feedback and recommendations from industry were obtained, followed by industry identifying opportunities in their own and other firms for student research internships and finally for industry staff to lecture, mentor students and become a visiting faculty. Third, these groups were a source of funding for specific initiatives and equipment.

III. Outcomes of MIE Best Practices

A comprehensive evaluation, which included performance criteria, measures, data requirements, evaluation procedures, data collection procedures and reporting design, has been developed to assess the success of our model. This design included continuous **formative** and **annual summative** evaluations using qualitative, as well as quantitative evaluations of program processes, progress towards goal attainment and actual outcomes. The **formative** evaluation focused on the process of program implementation and collected continuous feedback from participants in order to revise the program as needed. The **summative** evaluation focused on production of BS degrees, numbers of students entering graduate school, and students pursuing careers in SEM.

Students who have had early pre-college research experiences have reported an early awareness of the importance of working hard to pursue a more advanced degree [1]. On the other hand, students who have had late research experiences have reported regret for not being aware earlier of the importance of working harder to be able to later attend a graduate school. The design of an integrated program early in the pre-college years for underrepresented minorities addressed these issues in helping students understand the importance of selecting a career in SEM fields. As previously presented, after finishing our program, students reported substantial knowledge in relation to numerous scientific research-related variables and over 80% of students expressed their interest in majoring in SEM fields and enthusiasm for research [1]. Over the duration of the project, over 2,500 pre-college students who worked on almost 900 research projects were impacted (see Fig. 1).

In addition to utilizing research as an important part of pre-college-to-college bridge program, we provided research opportunities for undergraduate students to enable a smoother transfer from undergraduate to graduate programs (see Fig. 1). The participating institutions were from the US mainland, like MIT, National Laboratories, University of Texas, Arizona State University, but also from outside the US, such as the Spanish Research Council in Spain, New Zealand, Australia, Singapore and South Africa. The students would normally spend ten weeks working on their research project with a mentor from those institutions, followed by the final presentation of their results at the undergraduate research symposium held every September in San Juan, Puerto Rico.

We collected a short feedback from two of our MIE alumni - Terannie Vazqujez, who holds a PhD from Arizona State University and Jose Raul Matagira Sanchez, who earned his Master degree in Electrical Engineering from the University of Puerto Rico, Mayaguez. Terannie said: *The MIE scholarship helped me overcome multiple challenges by allowing me to utilize my scientific thinking. It not only helped me to become a scientific, but also influenced me personally and professionally by providing me with a good foundation of skill set and great positive thinking to overcome new challenges.* Jose added: *The program had a very positive impact on my academic and professional life. Having the opportunity to spend two summers as an intern in Spain and Serbia changed completely the way I looked at life, it expanded my horizons and exposed me to new cultures and people. It motivated me to pursue MS degree and added a valuable experience to my curriculum vitae, which was ultimately crucial for finding a full-time job.*

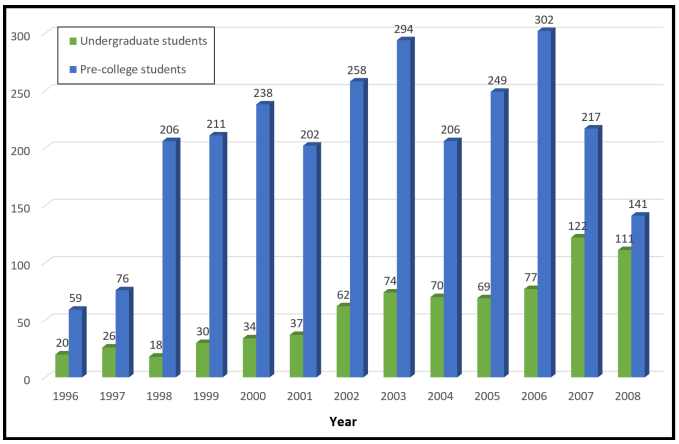

Fig. 1. Distribution of number of pre-college and undergraduate students affected by MIE program.

IV. BEYOND MIE

The development of BPC-A project, which was running from 2000 to 2013, followed the best practices of the MIE program that enabled UMET, a member of the Ana G. Mendez University System, to make a significant impact on the progress and success of Hispanic students in Puerto Rico. The MIE project at UMET created a pathway for science that went from pre-college to graduate school with programs that involve research at all levels. The thirteen years of MIE projects at six institutions produced a model for successfully helping minority students go through the science research pipeline including technology, engineering and mathematics. Three of the seven components of the MIE model have been selected for this project: 1) pre-college research program; 2) undergraduate research program; 3) bridge to graduate school. Additionally, we added two new components: 4) in-service teacher training and 5) community outreach (see Fig. 2).

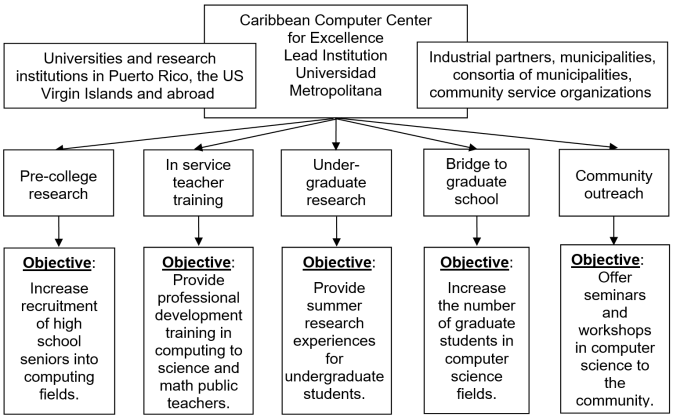

Fig. 2. Main components of BPC-A project.

The CCCE offered a pre-college research experience in computer science and engineering to total of 629 students during the thirteen years of project (see Fig. 3). A Saturday academy program supported the recruitment of talented high school students interested in science technology, engineering and mathematics. The second area of this project focused on in-service teacher training. A total of 114 public high school science and mathematics teachers, had the opportunity to participate in workshops on computer-based technology that were held during the pre-college research symposium. The third area this project enabled undergraduates to participate in research in computer science and engineering fields. In total, we had 559 undergraduates in computer science and 242 students in engineering participated in summer research activities in the US and abroad.

Outcomes of our programs are aligned with conclusions from an extensive body of related work on how universities can contribute to early research experiences [6]. For example, Steinmeyer showed how to increase the exposure of pre-college students to research experiences through the use of online environments [7] and Granchelli et al. showed how intensive classroom lectures and hands-on activities can be used in their experiential programs [8]. However, most of the studies are only concentrated on type of activity (e.g. Arduino [9], [10], Kinect [11], [12], robots [13], [14]) and are rarely focused on building pipelines as both of our program were [15].

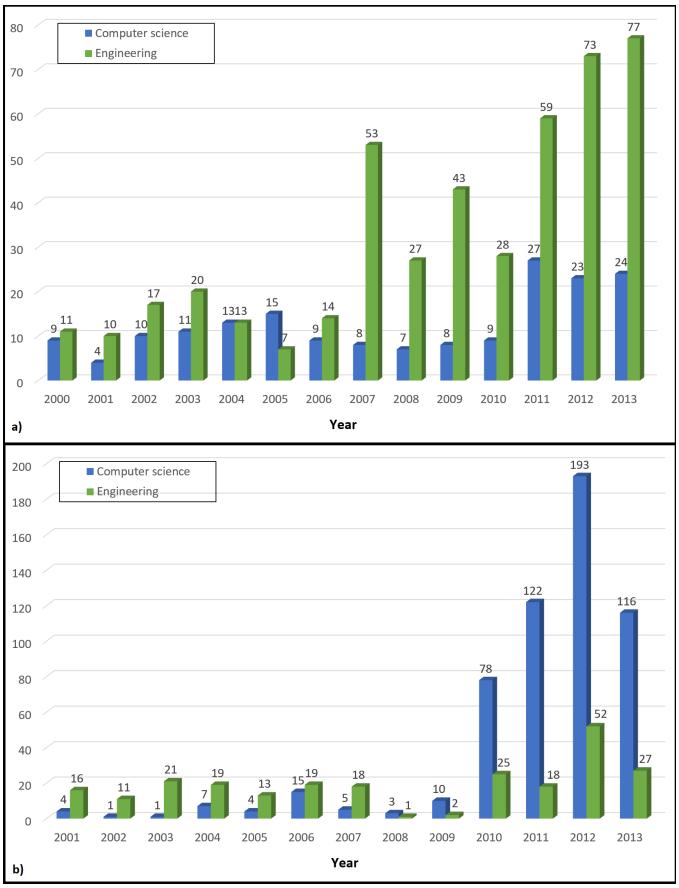

Fig. 3. Distribution of number of a) pre-college and b) undergraduate students, who were affected by BPC-A program, involved in research.

V. CONCLUSIONS

Our vision is to create an environment of high standards and expectations for all SEM students in which the entire university is involved in offering an array of rigorous, varied and exciting state-of-the-art academic programs, and learning is put in the center of all activities. Moreover, we are very keen on sharing our experiences and good practices with other institutions, as we did with our partners in Nicaragua [16].

Although the success of our efforts can be seen only through the numbers of pre-college and undergraduate students who participated in our program, we like to focus on each student individually as their success stories are the ones keep us going. Like the one from Josua Martinez who started working on a math-engineering-computer project while at grade 10, followed by finishing high school in Puerto Rico and being accepted at MIT for his undergraduate education. He graduated with honors, pursue a PhD at Johns Hopkins University and now is a post doc at Oxford University, UK.

Many other our pre-college alumni are now not only just successful scientists and academics, but they also created a positive loop, either through being mentors or just by setting positive examples for their younger fellow citizens. The main motivation for our projects was to build a pipeline from pre-college to PhD programs for economically disadvantage minorities and we are proud the results of both formative and summative evaluations show that we succeed in our efforts.

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