

Perspectives from an Intervention Model to Improve Retention and Success Among Low-income Hispanic Engineering Students

Keywords: Institutional Interventions, Retention, Success Metrics

Abstract

Improving the level of success of students from low socioeconomic backgrounds in science, technology, engineering, and mathematics (STEM) disciplines has been a prevailing concern for higher education institutions for many years. To address this challenge, a pilot initiative has been implemented with engineering students at the University of Puerto Rico Mayaguez, a recognized Hispanic Serving Institution. Over the past four years, the Program for Engineering Access, Retention, and LIATS Success (PEARLS) has brought in an innovative intervention model that combines elements from socio-cognitive career theories and departure studies to impact students' success. PEARLS has established a comprehensive range of tools and services, including mentorship, professional readiness training, research opportunities, scholarships, and peer-mentor activities. These efforts have led to impressive outcomes, including a significant increase in retention and persistence rates, increased graduation rates having quad-fold those observed in the general student population, and an impressive record of engagements in industry, research, and leadership experiences. This paper discusses the program structure and outcomes from five perspectives that include background experiences, the structure of provided services, the results of their execution, the elements of knowledge derived from its application, and the challenges experienced throughout its implementation.

I. Introduction

Students coming from low socioeconomic status (SES) families commonly face more challenges in achieving success than peers coming from higher SES groups [1]. Studies at both local and national levels indicate that such challenges translate into detrimental factors affecting important success indicators such as retention, persistence, graduation rates, and limited post-graduation opportunities [2][3][4].

The Program for Engineering Access, Retention, and LIATS Success (PEARLS) assessed the effectiveness of an institutional intervention model seeking to increase the retention and success indicators of low-income, academically talented students (LIATS) in engineering programs.

For the last four years, PEARLS has been implementing interventions to boost retention, persistence, and academic performance indicators; and to reduce the time to graduation of low-income engineering students. The initiative, implemented in the College of Engineering (CoE) of the University of Puerto Rico Mayaguez (UPRM), unveiled new insights into the needs of students from low-SES backgrounds and the potential impact measures can have. The UPRM is a Hispanic Serving Institution with a long tradition of producing highly qualified engineering professionals nationally [5]. Over 70% of its student population comes from low-income families [6].

PEARLS interventions were organized according to a theoretical model that integrated elements from social cognitive career theory and departure studies. The strategy provided students with tools and services encompassing individualized mentoring, soft-skills training, research opportunities, internship/COOP experiences, scholarships, and peer-mentor activities. These

program elements were integrated into a learning community that joined the efforts of students, faculty, and university staff. After four years of program execution, salient results in the study group include retention rates above 97%, student persistence up to 98.8%, and graduation indexes four times higher than those observed in the general population. Moreover, quantifying the socioeconomic status performance gap within the group revealed reductions up to 50% with respect to that observed in the general population.

Throughout this work, results from the performance of a study group with 92 engineering students are described. The remainder of the document is organized as follows: Section II discusses the demographic characteristics of the study group. Section III describes the support services provided to students and the theoretical model driving the program interventions. Section IV summarizes the results obtained through the program execution. Section V outlines specific elements of knowledge derived from the implementation of the model. Section VI discusses challenges and lessons learned while implementing the model in an HSI. The last two sections address ongoing work and concluding remarks about this experience.

II. Study Group Demography

PEARLS targets undergraduate and master's level engineering students at the UPRM. A total of 92 students participated in the program, of which 61 have been directly impacted by scholarships and interventions (scholars) plus 31 participants who, although not receiving scholarships, have benefited from the interventions. Both groups received services in the form of faculty and peer mentoring, career planning, and curricular, co-curricular, and community-building activities. This initial group included 89 undergraduates from nine different academic programs and two grads from two different master's level programs. The average household family income among scholars was \$14,512/year; and \$44,216/year among participants. The gender balance included 43% females and 57% males. The group was composed of four cohorts that included undergraduate students from first-, second-, and third-year, as well as master's level graduate students, as listed in Table 1. The student distribution by study program somewhat resembled the student proportions in the engineering population at the start of the program. Table 2 lists in columns two and three the initial student count and percentages per program.

Table 1: Initial student distribution by cohorts.

Cohort	Count	Percentage
First-year	34	37.0%
Second-year	29	31.5%
Third-year	27	29.3%
Grads (M.S.)	2	2.2%
Total	92	100.0%

Over the years, the initial student distribution was reshaped by student mobility including study program transfers, graduations, and attrition. By year four, 76 students remained active in the project, distributed by study program as listed in Table 2. It can be observed that all students who initially entered through the Surveying and Topography (ST) program, by year four had transferred to other engineering programs. The demography in the resulting group remained similar to that in the original. The distribution by sex was 59% males and 41% females. Two-thirds of students (67%) were from public schools. Fifty-two students were scholars, of which, 75% came from public schools.

Table 2: Student distribution by study programs in the first and fourth years of the program.

Study Program	Year 1 Count	Year 1 Percentage	Year 4 Count	Year 4 Percentage
Chemical Engineering (ChE)	14	15.2%	12	15.8%
Computer Engineering (CE)	14	15.2%	8	10.5%
Mechanical Engineering (ME)	14	15.2%	13	17.1%
Electrical Engineering (EE)	13	14.1%	12	15.8%
Industrial Engineering (IE)	12	13.0%	9	11.8%
Software Engineering (SE)	9	9.8%	9	11.8%
Civil Engineering (CvE)	7	7.6%	6	7.9%
Surveying & Topography (ST)	5	5.4%	0	0.0%
Computer Science (CS)	2	2.2%	3	3.9%
Grads (M.S.)	2	2.2%	4	5.2%
Total	92	100.0%	76	100.0%

III. Student Support Services and Interventions

PEARLS introduced a series of support services and interventions organized around a theoretical structure named the LIAT College Access and Success model (L-CAS). The L-CAS model integrated elements from Lent's Social Cognitive Career Theory (SCCT) [7] and Tinto's Departure model [8] into a hybrid structure aimed at boosting success metrics among LIATS. Figure 1 reproduces the structure of interventions underpinned by the L-CAS model [9].

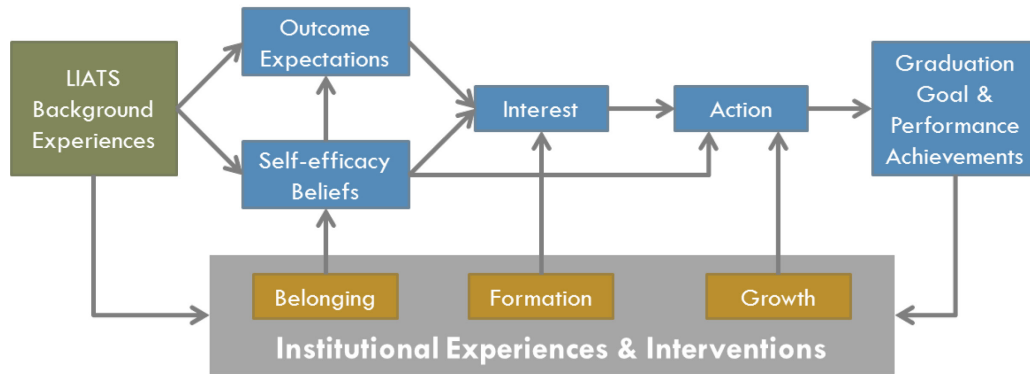


Figure 1: LIAT college access and success model [9].

L-CAS activities followed a longitudinal path consonant with student development, with objectives ranging from boosting their sense of belonging and self-efficacy beliefs to propelling them into actions and immersing them into real-life contexts [10]. Context scenarios targeted the development of collaborations and interactions in communities of practice that led students to develop practical skills for becoming future researchers, leaders, or practitioners in the STEM workplace.

Support services included creating and maintaining individual development plans; discipline-specific, individualized faculty mentoring; referral services; peer mentoring; experiential learning opportunities via undergraduate and graduate research, industry experiences, and leadership roles; and community-building activities.

Interventions included curricular and co-curricular activities. Four courses, namely Introduction to Engineering (INGE-3001), Introduction to Learning Communities (INGE-3002), Undergraduate Seminar (INGE-4995), and Information Literacy (INTD-3355) formed the PEARLS curriculum core.

INGE-3001 introduced students, mostly in their first year, to all engineering disciplines offered in the CoE. The course helped them to understand the structure and differences between programs to reassure their career choice. The course also included topics in ethics, the engineering method, and teamworking. Team activities and hands-on small projects induced them to know each other and develop community sense. INGE-3002 deepened students' knowledge about their chosen field of study and the importance of basic engineering courses for being successful later on in their study programs [13]. It connected freshmen, with seniors working on their capstone design projects, to learn how the latter carried an engineering design, followed up the solution development process, and attended presentations of completed designs. Freshmen were then tasked with identifying, with the aid of the course instructor, the usage by seniors of fundamental math science, and engineering concepts used to complete their designs.

The third course, INGE-3003, used the Affinity Research Group (ARG) Model to instill in students elements of cooperative learning. It was offered as a variable credit course (1-3cr), where students were driven to develop interdependence, individual accountability, promoting interaction, social skills practice, and group processing in a non-hierarchical model where they were deliberately taught research, social, and professional skills [11]. INTD-3355 introduced students to library services, provided them with introductory research skills, and taught them how to use citation managers and plagiarism prevention tools.

Co-curricular activities included talks and workshops organized each term to address a specific component of the L-CAS model. Forty-eight activities were offered during the reported four years of the program. Table 3 lists the co-curricular activities carried out during the first four years of PEARLS.

IV. Intervention Results

During these four years, PEARLS has impacted students in multiple aspects. Early results at the end of the first year revealed that student retention among first-year trainees was 97.1%, 5.7% higher than those in the general college of engineering (CoE) population [9]. During years two, three, and four, undergrad and graduate students persisted with indices 18.5% to 28.4% higher than those in the general CoE student body. All grad students continued in their respective programs, while undergrads maintained 96% or higher persistence rates.

Regarding academic performance, PEARLS students consistently maintained average grade-point averages (GPA) above those in the general CoE student population. Our results show that in the fourth year, 88.9% of active PEARLS students scored above the last reported CoE average GPA of 3.14/4.00. Specifically, 94.7% of PEARLS students had GPAs above 3.00, with 57.9% maintaining more than 3.50/4.00. Overall, PEARLS' average GPA was 3.52/4.00. PEARLS students also excelled in their progress toward graduation. During program years two and three, four students completed their degrees in five years or less, including one grad student and three undergrads from the third-year cohort. In the fourth year, twenty-one additional undergrads completed graduation requirements.

Table 3: List of talks and workshops offered as co-curricular activities.

Stage	Fall	Spring
First Year (2018-2019)	1. Pearls Info Session	1. Creating Your Career Path & IDP
	2. Scholarship Awards Ceremony	2. Introduction to Research
	3. First Meeting: Work Plan and Rules	3. Creating an ePortfolio
		4. Plagiarism and Academic Honesty
		5. Semester Closing & student recognitions (Social)
Second Year (2019-2020)	1. How to Manage a Budget	1. Anxiety Management in the Midst of Adversity
	2. National Fellowship Workshop	2. The Business Model Canvas
	3. Undergraduate Research Experiences: A Report	3. Undergraduate Research: A Necessity*
	4. From Business Idea to Business Plan	4. Social activity canceled due to the Covid-19 pandemic onset
	5. PEARLS Thanksgiving Dinner (Social)	
Third Year (2020-2021)	1. Resume writing, e-portfolio & LinkedIn Page Development for Engineering Students*	1. Academic Honesty in Times of Crisis - Panel*
	2. PEARLS Scholarships: Seeds for Transforming Lives*	2. Responsible and Appropriate Conduct of Research*
	3. Mentors and Mentees, Resume, e-portfolios, LinkedIn*	3. Ethics in the Engineering Profession*
	4. A New Perspective on Leadership*	4. How to Write Compelling Research & Personal Statements for Grad School Applications*
	5. Building Resilience for a Better Life*	5. Benefits & tools to carry out undergraduate research: Mentoring, research networks, & professional development plan*
	6. Tools for Handling Stressful and Difficult Situations*	6. Data Presentation: Dos and Don'ts of Figures, Plots, & Images*
	7. Semester Closing & Student Recognitions (Social)*	7. Semester Closing Activity & Recognitions (Social)*
Fourth Year (2021-2022)	1. Effective Time Management for Academic Success	1. Engineering Licensure: Laws, Processes, and Preparation for the Exam*
	2. Aspirational & Appropriate Research & Professional Practice*	2. Coping & Stress Management*
	3. Graduate Scholarships (3 sessions)*	3. Transitioning from the University to the Workplace and Graduate School*
	4. Graduate Studies: Challenges & Opportunities*	4. Considering Graduate Studies as Your Next Goal?*
	5. What About Graduate Studies at UPRM?*	5. Attitude, Passion, and Failure: Pillars of Entrepreneurship
	6. Teamwork Workshop*	6. Panel: Tips for the Workplace and Graduate School*
	7. Interview Skills: Unlocked!	7. Semester Closing Activity & Recognitions (Social)
	8. Term Closing Activity & Recognitions (Social)*	

* Carried synchronously online

The on-time graduation rate within this group reached 19.2%, a number equivalent to more than four times the ratio for the entire CoE population, which that year fell to 4.6%. During these past four years, the graduation rate of PEARLS students in six years or less (CoE programs are five years long) has reached 84.7%. If students continue progressing at this pace, the program is expected to reach its proposed goal of having 85% of students complete their degrees in 6.5 years or less.

Another important monitored metric in the study was the level of performance across undergraduate students from different socioeconomic status (SES) levels within the program.

This metric was evaluated between scholar and non-scholar groups, and its value was then compared to that of the last known gap quantified in the general CoE student population. In Section III, we reported that scholars and non-scholars had levels of family income that allowed for making SES inferences among them. The performance metric was based on the product of their average GPAs and the progress made toward graduation. During the four years of the study, this metric denoted an oscillating behavior placing high SES students slightly above the rest of the group by a proportion that changed between 4% and 8%. When compared to the 20% performance gap last reported in the general CoE population, PEARLS groups denote SES performance gap values 57.9% to 78.9% narrower.

Student engagements in research, industry experiences, and outreach activities were also significant. During the 4th year, 31.7% of the students participated in at least one work experience as interns or as part of the CoE cooperative education program. Also, 66.7% engaged in off- or in-campus research, and 52% assumed leadership roles in student or community groups. These outcomes unveiled a highly proactive group that strove to maintain good grades and progress toward graduation. The cadre has flourished in academic, professional, and leadership experiences to become highly competitive professionals upon graduation.

V. Knowledge Generated

Implementing the L-CAS model has unveiled innovative ways of successfully combining institutional interventions addressing socio-cognitive factors with high-impact practices to boost success indicators in LIATS, narrowing down the socioeconomic status gap of this group with respect to the general student population. Six specific areas of knowledge impacted so far by PEARLS include:

- i. A better understanding of the success expectations of Hispanic LIATS as they begin college life [12]. This knowledge helps devise effective intervention strategies to boost students' self-efficacy beliefs and outcome expectations as they begin to navigate their path to graduation.
- ii. A novel model of establishing learning communities among first- and senior-year engineering students to boost career interest, reinforce their sense of belonging to their chosen study program, and highlight the importance of early courses for success in the later stages of a study program [13]. Our findings indicate that such a model improves the retention and persistence of students in the critical period of adaptation to college life.
- iii. A strategy to use a cognitive apprentice framework to combine coaching, peer-led team learning, and reflection/self-assessment to boost leadership skills among Hispanic LIATS [14]. The combination of these methodologies enabled the development of leadership competencies among students impacting their emotional intelligence and demonstrated, in later stages of the study, to influence the roles assumed by them when given the opportunity of assuming leadership roles.
- iv. A systematic way to build career goals and boost self-efficacy beliefs of engineering LIATS by introducing customized individual development plans among first-year students [15]. This strategy was found to be highly effective for taking students to establish post-graduation objectives and what steps they would need to take early on to be able to reach that goal.

- v. A way of inserting a successful faculty mentoring strategy for Hispanic LIATS able to complement the guidance provided by traditional academic counseling offered in most study programs [16]. This strategy enabled a new dimension in the individualized treatment of LIATS, introducing community-building elements between students and faculty with mutually beneficial outcomes.
- vi. Strategies to improve the resiliency and adaptability of students upon unforeseen distressful events such as storms, earthquakes, pandemics, and the stressful situation ensued by them while maintaining focus on their study objectives [3]. The synergy developed with other concurrent initiatives revealed that, in the aftermath of multi-hazardous events, faculty and administrators must not expect that at-risk students will spontaneously seek the services they could need to thrive and succeed. Institutions have to proactively identify and reach out to those students to offer them and coordinate with them the academic, financial, and socioemotional services required to support their success.

VI. Achievements, Challenges, and Lessons Learned

Thus far, the project execution has faced many challenges. Some of them were successfully overcome, while others remain. Among the most important challenges successfully surpassed, there are:

- i. *Addressing the emotional effects of catastrophic events:* Year 2020 represented an important milestone for PEARLS students. A population still recuperating from the devastating effects of Hurricane Maria, was abruptly awakened in the early morning of January 7 by a magnitude 6.4 earthquake that shook the entire island of Puerto Rico. Thousands of buildings were severely damaged or reduced to rubble, creating a situation of distress for our students. As a consequence, PEARLS modified its calendar to incorporate activities to provide students with counseling and emotional support. Still affected by earthquake aftershocks, on March 13, the university closed again due to the onset of the Covid-19 pandemic. The collective scare of being indoors was now amplified by that of acquiring the virus. To cope with the emotional toll on our students, PEARLS offered training to the faculty on how to deal with students in crisis, incorporated in the student talks a series of topics that included stress and anxiety management, and recruited the help of experts from the psychology department to offer socio-emotional assistance to our students. At the same time, programmatic project events continued to be provided online while faculty, students, and staff transitioned to online activities.
- ii. *Continuity of program activities upon pandemic onset:* By design, all PEARLS activities, including talks, workshops, mentoring, courses, and community building, contemplated on-campus, in-person interactions. Executing this plan became a significant challenge after the onset of the Covid-19 pandemic. All on-campus activities were canceled, and all interactions were moved online. To cope with this situation, the PEARLS work team redesigned all activities to adopt an online format, including the meetings of the program executive board and work team. This strategy proved successful, as the calendar for all curricular and co-curricular activities was minimally affected. Tools such as Gathertown, SignRequest, and Poll Everywhere, along with applications such as Zoom, Google Meet, and Google Drive were adopted to facilitate the transition. This transition also required training students to professionally project themselves online, using e-portfolios, LinkedIn, and social media.

- iii. *Providing faculty mentors with the necessary time and resources for mentoring students:* Early in the program execution, some of the faculty mentors reported concern about the amount of time required to carry out an effective mentoring process. We decided to recruit one additional mentor and redistribute the students. Moreover, we negotiated with the Engineering Dean to assign time releases to all faculty mentors to provide better student attention, as regular office hours proved to be insufficient. As an additional measure, complementary Peer-lead Team Learning activities were set up to alleviate the load on faculty mentors.
- iv. *Providing PEARLS with a stable Project Manager.* During the first year of the program, personnel limitations caused going through three different project managers, with gaps of months between some of them. This caused discontinuities in some of the services provided to students and a significant overload on the program PI. Moreover, space limitations caused moving the program office with each different manager. Thanks to the support obtained from industrial partners and a compromise made with the university, starting the second year, PEARLS began to have an office assigned, furnished, and equipped, and a stable program manager who has continued to serve program students and faculty up to this date.
- v. *Achieving participative community building activities:* Program interventions aimed at building a community sense among students, faculty, and staff included social interactions, commonly performed at the end of each term. In the first round of social activities, the feedback received from the students via satisfaction questionnaires denoted the need to incorporate the students in the planning process, the format of the activities, and their content. Students expressed the need to have more activities focused on increasing interactions among scholars in an informal setting. As a result, a student-led initiative was adopted: peer mentors were included in the decision process, students from the program volunteered to work in groups and the recommendations generated by students were adopted and executed by them. This bottom-up approach was very well received by the students and their feedback was very positive.

Challenges still present include:

- i. *Increasing the participation of Master's level students:* A persistent challenge in PEARLS has been the ability to attract enough master's level students. Throughout the existence of PEARLS, the master's-level occupation has fluctuated between 50% and 75%, and for those who have participated, impact results have been as positive as those obtained with undergraduates. Multiple factors have contributed to the difficulty. First, the population of engineering grads has a large proportion of international students, who are not eligible for the type of scholarships provided in this work. A second factor is the effect of natural disasters in the period of execution, which has reduced the number of students entering graduate school. A third factor is that competing forms of economic aid available in the CoE for eligible students make PEARLS scholarships less attractive for students. Renewed efforts by the team hinged on the continuous promotion of the scholarship program among incoming Engineering students admitted into the master's programs to complete the graduate slots still available in the program.
- ii. *Establishing an agile institutional mechanism to process scholarship payments.* A challenge yet to be tackled is modifying the institutional process used for research scholarship. The mechanism in place is via stipend payments, which require a long list of approvals for each payment. An added factor is how students are qualified for academic eligibility, which requires a partly manual process in the registrar's office. The team has proposed several

strategies to the university administration. So far, none has been adopted. Meetings held last year with the registrar's office and the Engineering Dean raised some hope of the availability of a new tool, still under development, which promised to alleviate the student qualification process. Also, the recent designation of a new director in the finance office creates new hope in searching for a suitable solution to address this problem.

- iii. *Institutional Adoption of PEARLS Strategies*: PEARLS has unveiled multiple strategies to improve critical success indicators for low-income students. Salient approaches proven to be effective include offsetting the cost of attendance for this population segment, providing them with faculty mentors and career planning services, offering them courses that boost their sense of belonging and outcome expectations, and providing them with skills for professional practice. Adopting strategies from this list would have a profound impact on the efficiency of education administration for a university that has more than 70% of its student body coming from low-income families. Scaling-up PEARLS recommendations to impact LIATS at large represents a significant challenge as their implantation would require changes in university policies and resource allocation that go beyond the reach of our program. PEARLS' commitment is to disseminate its success at the upper-level administrative forums to motivate the adoption of successful strategies and interventions based on the performed research and experiences.

VII. Continuing Activities and Future Work

At the writing of this article, PEARLS is entering its fifth year. Continuing efforts include a calendar with student activities focused on supporting the success of those who are still on the path to graduation and their transition to post-graduation life. The quest to overcome prevailing challenges includes continuous promotion of the scholarship program among incoming master's engineering students, meeting with the newly appointed finance officials to bring the case for an agile mechanism to pay scholars, and follow-up on the development of the engineering student tracking tool. Hinging on the recommendations brought during the last engineering accreditation cycle, the PEARLS team plans to propose a strategy to use the program IDPs and its faculty mentoring model to create an engineering-level scaled implementation of the L-CAS and bring it to the upper university administration for its consideration.

VIII. Conclusions

Supporting the success of LIATS continues to be a top priority for many higher education institutions. The strategies implemented in PEARLS provide insight into practices that improve the success indicators of low-income Engineering students in a Hispanic Serving Institution. The discussion brought forth the implemented strategies from five different perspectives that included: the demography of impacted students, the support services and interventions, the results from their execution, the knowledge generated, and the challenges faced during its execution. The demographic perspective highlighted the background traits of the impacted students and their distribution among their corresponding study programs. The service perspective underscored the interventions deployed to impact students and the underlying theory. The results perspective emphasized the high impact on success metrics brought up by the execution of the proposed interventions. Success metrics included retention and persistence rates, academic performance and progress, time to graduation and graduation rates, socioeconomic status achievement gap, and professional preparation. In all evaluated aspects, results pointed to a high level of effectiveness in terms of student success. The knowledge generation perspective emphasized at least six areas of impact: understanding of success expectations of Hispanic

students, unveiling the impact of learning communities in boosting students' sense of belonging to their study programs, and insight into mechanisms that impact student role-playing. In addition, the approach provided a guide for the students to establish reachable career goals, highlighting the importance of faculty mentoring in low-income student development, and bringing about awareness of strategies to form resilient students. The last perspective looked into the challenges an HSI faces to implement interventions like PEARLS. In summary, the intersection of these five perspectives reveals a successful model able to make a difference in the lives of low-income students with portable strategies that can be implemented elsewhere.

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