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Boosting Study Program Awareness via a Structured Introductory Experience to Engineering

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Abstract
This paper discusses the implementation of an introductory course to engineering established to provide students with knowledge about the roles of engineers, the engineering method, ethics, teamwork, and detailed information about each of the engineering majors offered in the College of Engineering (CoE) of the host institution. The course is offered as part of a larger initiative seeking to improve success indicators among low-income students. This paper provides details about the course structure, implementation context, metrics, and results measured via descriptive statistics among participant students. The results of a longitudinal implementation, suggest that early provision of career information and awareness can impact the engineering retention and persistence of students and their interest in their chosen majors, particularly in educational settings where students declare their major on the entrance to their first year.

I. Introduction

The experiences accumulated by students during their first year in college have a lasting impact on the rest of their academic lives [1]. The sense of career and institutional belonging, as well as the self-efficacy beliefs of students, have been identified as crucial factors for their persistence and success [2] [3]. We argue that both these factors are affected by the awareness first-year students have about their chosen field of study. This is particularly true for institutions admitting students into a specific major since their first college year.

An assessment of the reasons reported by first- and second-year students in the host institution for choosing an engineering major denoted a wide range of responses. The influence of parents or relatives, expected salaries, and curiosity were among the most reported reasons.

Surprisingly, less than three percent of responses pointed to career or vocational assessment tests, professional orientation, or academic-related interventions as determinant factors. Moreover, when asked about the kind of jobs they understood were performed by engineers in their chosen fields of study, a substantial proportion of respondents denoted incongruity and a narrow view of the role of engineers. This mismatch is considered a reason for the observed number of early program transfer applications, low academic performance, and late attrition among students.

In an effort to address the perceived low level of awareness about engineering, the Program for Engineering Access, Retention, and LIATS Success (PEARLS) introduced a pilot one-credit Introduction to Engineering course for first- and second-year students. Although first-year introductory courses are commonplace in many engineering schools [4][5], the UPRM does not offer such a course in a consistent manner to all first-year engineering students.

PEARLS is a college-wide initiative that seeks to increase success statistics among low-income, academically talented students (LIATS) in the College of Engineering (CoE) [6]. It incorporates multiple strategies, including talks and workshops, faculty and peer mentoring, and career planning. PEARLS' initiative of an Introduction to Engineering course tries to answer the question of how the early provision of career information and awareness will impact the engineering retention and persistence of students and their interest in their chosen majors. In this paper, we discuss the course implementation and its results.

The rest of this manuscript is organized as follows. Section II provides a brief description of the context where the course was established, allowing for seeing how it fits in with the overall college-wide structure. Section III discusses why and how the course was introduced. Section IV describes the course organization, activities, and methods. Section V presents the results obtained from offering the course during the peak enrollment of program students, highlighting students' impressions and their changes in study program perspectives. The last section provides concluding remarks about this work.

II. A Macro View of Engineering PEARLS

The academic setting where this study was carried is the University of Puerto Rico Mayaguez, a Hispanic Serving Institution part of a state-supported university system. With 10,949 students in fall 2022 (23.3% of the system's student body), the host is the largest unit in the eleven-campus University of Puerto Rico system [7]. The College of Engineering (CoE) in the host campus serves 4,936 students, 94% of them distributed in nine academic programs at the BS level, and the remaining 6% in master's, and Ph.D. levels. The host has for many years maintained a prominent position as one of the largest providers of Hispanic engineers in the US, graduating more than 500 new engineers each year, from which approximately one quarter are females [8]. The CoE offers five-year-long academic programs in disciplines that include Civil, Electrical, Computer, Computer Information Science, Industrial, Mechanical, Chemical and Software Engineering. The ninth program is a four-year-long BS degree in Surveying and Topography.

For many years, CoE-level statistics have shown a persistent gap in the level of achievement attained by students coming from disparate socioeconomic groups. Students coming from households with low-income levels graduate at rates up to 20% lower than those from middle- or above-income levels. Similar disparities could also be observed in retention and persistence rates, and time to graduation [7].

The Program for Engineering Access, Retention, and LIATS Success (PEARLS) was developed as a college-wide initiative to impact observed trends, establishing a set of institutional interventions aimed at increasing success statistics of low-income, academically talented students (LIATS) [6]. PEARLS design consists of a hybrid intervention model combining elements from Lent et al. Social Cognitive Career Theory [9] and Tinto's Departure Model [10], coupled with a scholarship program that seeks to mitigate LIATS' economic hardships. Interventions are longitudinally organized around five major areas that include background experiences, student sense of belonging, formation, growth, and graduation.

Background interventions were aimed at outlining socio-demographic and family variables identified to affect students' self-efficacy beliefs and outcome expectations [11]. The next intervention area, the belonging phase, developed in students a professional identity and sense of belonging to their selected study program [12]. This stage also induced students to establish post-graduation goals and a plan for their reach through the elaboration of individual development plans [12]. The formative stage intervened with students to help them develop professional skills via structured talks and workshops utilizing well-known high-impact educational practices [13] and Affinity Research Group strategies [14]. Growth interventions encouraged LIATS to take actions directed at participating in undergraduate research, industry experiences, and leadership roles [15]. The last intervention stage, graduation, guided students on how to leverage their college experiences for competitively entering either graduate school or the engineering workforce. Ninety-two students enrolled in PEARLS in year one, distributed in four cohorts that included 34 first-year, 28 second-year, 28 third-year, and two graduate students. From these, 57% were males, 70% came from public schools, and 88% came from families with less than $30,000 of yearly income.

III. The Introduction to Engineering Course: Why and How

The Introduction to Engineering course falls within the set of interventions fomenting students' sense of belonging. PEARLS used two mechanisms for such a goal. The first was by creating awareness in students about what engineering is in a broad sense. This was the purpose of the Introduction to Engineering course (INGE3001). The second mechanism was establishing learning communities through project-oriented engineering teams. In this latter approach, advanced students helped first- and second-year students deepen their engagement with their specific engineering fields by exposing them to the design process used in the completion of capstone and special projects problems. This second interaction was enabled through a second course named Introduction to Learning Communities (INGE3002) [16].

The decision of creating an Introduction to Engineering course was based on observations made on the way students are admitted to academic programs in the host institution. The admission process is centrally managed for the entire university system. In the application form, students select three study program alternatives, ranked in order of preference, allowing students to mix different academic programs and campuses.

The campus and program selected as the first choice assesses the student application. The second or third alternatives are considered only if the student was not admitted to his or her highest priority choice. As a result, students are admitted into programs with vacant spaces that match their highest selected priority and for which they satisfy a minimum admission index (MAI).

Each program has a MAI that is established by its demand: the higher the demand the higher the MAI. MAIs are satisfied through an individual General Admission Index (GAI), computed from the student's high-school grade-point average (GPA) and College Entrance Examination Board score (CEEB). Vacant spaces in study programs are filled with applicants with the highest GAIs. Students not admitted into any of their three choices can appeal the decision and might ask to be re-considered for other programs or campuses. This implies that not every student is admitted into a program that represents his or her highest preference. Engineering programs have the highest MAIs in the university system, only matched by the school of medicine programs. Admitted students enter the first year directly into a degree program.

Another factor affecting how a student ends up in a specific study program is the way students decide their three program choices in the application form. An ad-hoc survey of 216 engineering first-year students asking the reasons for their career choices in the university application forms denoted a wide range of responses. Parents' or relatives' influence, expected salaries, curiosity, and the perceived likelihood of being admitted were among the most reported reasons.

Surprisingly, less than three percent of responses pointed to career or vocational assessment tests, professional orientation, or academic-related interventions as determinant factors. Moreover, when asked about the kind of jobs they understood were performed by engineers in their chosen fields of study, a considerable proportion of respondents denoted incongruity and a narrow view of the role of engineers in their responses. This mismatch was considered a reason for the observed number of early program transfer applications, low academic performance, and late attrition among students.

To address the low perceived level of awareness about engineering, PEARLS proposed a one-credit course, INGE-3001: Introduction to Engineering for first- and second-year students. The introduction of INGE-3001 to these students tried to answer the question of how the early provision of career information and awareness would impact the engineering retention and persistence of students and their interest in their chosen majors.

Introduction to Engineering was structured to provide students with knowledge about the roles of engineers, the engineering method, ethics, teamwork, and detailed information about each of the engineering majors offered in the host institution's CoE. It also incorporated a hands-on, cross-disciplinary team project that allowed students to use science and math to design a solution for a simple problem and to develop a prototype to test the accuracy of their designs. Through this experience, they not only put into practice the engineering method but also began to cultivate professional skills, to develop a sense of community with their peers, while learning about the roles of engineers in their own and other majors.

IV. Methods

Introduction to Engineering was offered as a one-credit free elective to students from high schools enrolled in a dual enrollment program offered by the CoE and to first- and second-year students from all engineering undergraduate programs and other disciplines. The course provided them with critical information to discern the difference between the undergraduate engineering study programs offered in the CoE. The course explained what an engineering career is, with dedicated talks by professors from each engineering discipline. These talks were structured to present the engineering discipline, the type of courses that distinguished it, and the problems tackled by professionals in the area. It also discussed the opportunities encountered by engineering students and professionals, typical salary ranges, and the kind of organizations hiring these kinds of professionals. The course offered lectures on the roles of engineers, on the ethical principles that guide the profession, and how to develop collaborative work as part of a team. Each of these themes was covered in an active way, requiring students to search for information, discuss among them, and bring their inferences as to how they impact the formation and practice of engineers.

The course contents were arranged in such a way that prospective high-school students could make informed decisions when selecting which career to pursue. At the same time, this strategy provided first- and second-year students with essential information to reassure their decision to study a specific engineering program. Also, students had the opportunity to clarify doubts about different engineering programs offered at the CoE, learn about typical tasks performed by different engineering branches, learn about research laboratories, manufacturing, and service facilities; and use math and science concepts in the solution of engineering problems.

A. Course Delivery

The course was offered as one weekly meeting of fifty minutes for fifteen weeks per semester (1 credit hour). The topics covered in the course included: Introduction to Engineering; Team Building in Engineering; The Engineering Design Process; Ethics in Engineering Design; and seven lectures, one on each of the academic departments in the CoE. Departments offering more than one undergraduate academic program presented them all in one lecture. In addition, the course incorporated a hands-on team project that allowed students to design an engineering solution to a faculty-provided problem by applying the knowledge of the engineering design process, teamwork, and engineering ethics learned in the course. Throughout this project, the students also develop both oral and written communication skills. They were required to provide three progress reports on the solution to their project, one comprehensive written report about the project solution, a demonstration of a prototype developed to solve the problem, an oral presentation of the analysis and methods, and an assessment of the fitness of their solution to the problem. The lectures on the academic programs included Introduction to Civil Engineering, Surveying, and Topography; Introduction to Electrical Engineering and Computer Engineering; Introduction to Software Engineering and Computer Science; Introduction to Chemical Engineering; Introduction to Industrial Engineering; and Introduction to Mechanical Engineering.

B. Course Evaluation

The course evaluation did not include exams. Instead, each discussion was preceded and ended by a pre- and post-questionnaire where students provided their opinions about the discussed topics. Participation in these questionnaires accounted for 40% of the course's final grade. The lecture on ethics accounted for 20% of the grades. It had as an assignment selecting a documented case of engineering ethical conflict and analyzing the decisions made by the players in the light of the code of ethics, discussing it within their team (3 to 4 members), and presenting their collective analysis in class. The course project accounted for the remaining 40% of the grades. Students were divided into teams of three or four members and assigned a problem to solve. The problem required using high-school math and physics for its solution. Students were tasked with planning a solution and predicting its performance based on calculations. Then they had to figure out a way of completing a prototype based on their calculations and corroborate how their estimates compared to their implementations.

The problem assignment was accompanied by an explanation of the principles behind the problem so that they had an idea of which concepts were required to reach a solution. One example of such a project was in the design of a newspaper bridge able to withstand the weight of two 16 oz water bottles. They received a lecture on bridge structures, static analysis, and force diagrams, and were taught how to characterize truss elements in tension and compression. Next, they were tasked to make a design using this information. The analysis was used to estimate the maximum load their designs were able to withstand. Next, they had to build their prototypes and demonstrate how they were able to hold the target load. As a last step, they were asked to perform a destructive test to find the breaking load of their prototypes, perform an error analysis with respect to their initial calculations, and produce an explanation of their findings. Teams were given two months to complete the distinct stages of their designs, and at the end, offer a presentation of their design, calculation, and findings along with a short video of their tests. On the last day of classes, they completed an exit questionnaire about the course, their experience, and their perceptions of what engineering is.

V. Results and Analysis

Introduction to Engineering has been offered eight times during the last four years. A total of 159 students took the course in that period (90 in year 1, 14 in year 2, 47 in year 3, and 8 in year 4). During the first-year offer, 28 out of 34 (85.3%) first-year PEARLS students took the course. The rest corresponded to non-PEARLS students. As most eligible program students completed the course during year one, offerings in subsequent years impacted mostly non-program high schoolers in their senior year and engineering first-year students or from other disciplines seeking to have a more detailed knowledge of what is engineering.

To quantify the course impact on students' sense of belonging, the answers to selected questions in the input and exit questionnaires of a group of 33 students (20.8% of those who took the course) were analyzed. We focused on the questions that defined students' identification with engineering and their selected study program, and their understanding of what an engineer is. Results are based on a sample of 32 students who completed both questionnaires.

A. Input Questionnaire

In the input questionnaire, 93.4% of the students (30 of 32) indicated they were enrolled in a study program they had identified as their first option in their admission application. However, 48.9% (15 of 32) indicated they were not enrolled in a study program that represented their top choice. In this group, 11 (34.4%) answered that their top choice was a study program outside engineering. When asked if someone had influenced their decision for choosing engineering in their admission application, 28.1% (9 of 32) responded affirmatively.

When asked to describe an engineer in their own words (open question), 15.6% (5 of 32) provided answers associating an engineer with someone who applies math and science to solve problems; while 78.1% (25 of 32) associated an engineer with someone who solves problems with no mention of the use of math and sciences. Two students did not associate engineers either with problem solvers or with the usage of math and science. When asked about what jobs were performed by engineers (open question), 34.4% (11 of 32) pointed to jobs whose performance required engineering training, like building a bridge or a spaceship, 56.3% (18 of 32) specified jobs that could be done by engineers or professionals in other areas, and 9.4% (3 of 32) responded they did not know or did not answer.

B. Exit Questionnaire

In the exit questionnaire, when students were asked if they were interested in continuing in their current study program and graduating from it, 90.7% (29 of 32) responded they agreed or strongly agreed. Two students (6.3%) responded that they strongly disagreed and expressed their intention to transfer to another program. When asked to describe an engineer, all respondents associated them with problem-solving and using science and math. When asked about the roles of engineers from different specialties, 66.0% correctly selected the corresponding roles of each career. In engineering areas other than computing, the percentage of students associating roles with disciplines reached 81.3%. The computing disciplines (computer engineering, computer science, and software engineering) were perceived with similarities and caused answers with mixed roles resulting in an average of 33.4% correct. Despite the confusion with roles specific to each computing area, all respondents correctly associated engineering areas with engineering roles.

Other exit questions assessed their satisfaction with the Introduction to Engineering course. All respondents indicated they would definitely or most probably recommend the course to other students. The top three most liked course activities were receiving explanations of the engineering areas (37.5%), the project (31.3%), and teamwork (15.5%). The three least liked course aspects were having to use physics and algebra in the project (9.4%), not having more group interaction activities (9.4%), and the platform used to share course documents (9.4%). Those who did not like having to use math and physics in the project reported in another question that they did not receive instruction in those subjects in their high schools.

C. Analysis

The responses received in the entry questionnaire denoted many students who chose an engineering study program unsure of their career choice. After taking the Introduction to Engineering course, most students were reassured of their choices regardless of how they came to the decision to select engineering. For a small proportion of students, the experience provided the insight to understand that engineering was not their call, and decided, early in their study program to transfer to another discipline. Such an early decision reduces the impact of accumulating credits in the wrong study program, saves years of study, and minimizes the emotional and academic performance toll associated with this situation.

An important aspect highlighted by the input questionnaire was the low level of knowledge about the engineering profession brought in by the students. Addressing this aspect early in the study pathway to become engineers gave students a core purpose to their efforts to earn an engineering degree.

In addition, we observed that a course like this brings enthusiasm to students about their chosen study program and the possibilities that lie ahead as future professionals. Moreover, an early understanding of engineering, in particular of the design process, was observed to help students understand why math and science are core competencies in their formation. Exposition to this kind of information, early in their study years, provided them with the knowledge to make correct course decisions on how to prepare for succeeding later in advanced courses.

After four years of study (CoE programs are five-year long), success metrics in the PEARLS group are apparent. Among salient statistics, retention levels reached 97.1%, persistence levels were measured at 96%, and graduation rates and time to graduation were four times higher than those observed in the CoE general population. Moreover, the level of involvement of students in professional preparation activities was significantly higher than those observed in the general population. While these results cannot be exclusively attributed to the impact of the Introduction to Engineering course, we can infer that the experience provided by this course to these students indeed contributed to the level of success they have experienced on their path to graduation.

VI. Conclusion

The experience of offering the course Introduction to Engineering remarked our initial perception that not every student entering engineering has a clear definition of the preparation he or she will be acquiring and how they would use it. Three important aspects were found to be reinforced by this course: student knowledge about what it takes to be forged into an engineer, knowledge of the roles played by professionals in this area, and reassurance that students are being prepared for a career that they identify with. These experiences, when combined with the rest of the strategies embedded in the PEARLS program, offer renovated alternatives to positively impact the level of success achieved by students in their paths to complete degrees in science, technology, engineering, and mathematics (STEM) disciplines.

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