Work in Progress: Impacting Engineering First-year Students Retention through a Non-conventional Engineering Learning Community

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Work in Progress: Impacting Engineering First-year Student Retention through a Non-conventional Engineering Learning Community

Abstract

This work in progress explores the impact of activities developed to improve students' persistence in engineering undergraduate programs as part of a five-year NSF grant. The Program for Engineering Access, Retention, and LIATS Success (PEARLS), has been running for one year in the College of Engineering (CoE) in our institution attempting to increase persistence, retention and graduation rates, and professional success of low-income, academically talented students (LIATS). This paper describes the design of a novel engineering learning community (ELC) introduced as part of the PEARLS project interventions. The ELC is fostered through activities included in a course designed for PEARLS first-year students. During the course, first-year and senior students engaged in different ways: through senior design and capstone projects, peer demonstrations of team projects, and lab visits. We discuss the course structure, activities, and early findings of its implementation.

Introduction

Graduation and attrition rates are commonly used metrics when assessing the level of student's success in higher education institutions. Colleges with high graduation rates and low attrition are commonly considered successful. A large number of studies in education research have addressed the attrition phenomena and the factors affecting graduation rates. Representative examples include the works by Spady [1], Tinto [2], and Bean [3], that established a base knowledge on the reasons why students leave and became seminal works for dozens of subsequent publications on the subject. Studies have found that the level of success experienced by first-year students significantly impacts the rest of their academic life [4].

Engineering programs offered at the University of Puerto Rico at Mayaguez (UPRM) College of Engineering (CoE) are five-year long. Longitudinal data obtained for over one decade denotes a sustained high retention rate for first-year students (92.8%). Persistence for years two and three is also high, but indices beyond the 3rd year deteriorate. Institutional data shows an on-time graduation rate of less than 10% and a graduation rate of roughly 50%. At UPRM, graduation rates show a decline of more than fifteen perceptual points across the years as denoted in Figure 1. A snapshot of similar indicators in function of family income reveals that trends are markedly lower for students from low-income families, as seen in Figure 2 for data from 2016.

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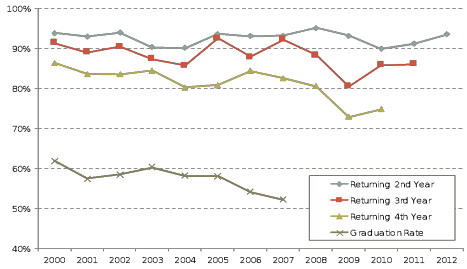


Figure 1. CoE retention, persistence, and graduation rates.

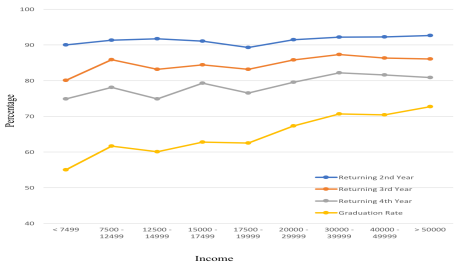


Figure 2. CoE retention, persistence, and graduation rates vs family income.

In an attempt to reverse this trend, and in particular, to close the gap for students from socioeconomically disadvantaged groups, the PEARLS Program was developed. "Poor teaching and advising; the difficulty of the engineering curriculum; and a lack of "belonging" within engineering" have been cited as possible explanations for transfers to other majors and drop out of engineering students [5]. Therefore, PEARLS was designed to provide institutional support, individual mentoring, workshops, and courses designed to nurture students' personal and academic development. As part of these activities, a sequence of three courses was designed to develop students' sense of belonging, explore and reinforce their professional identity, increase self-efficacy, and develop a learning community among students.

PEARLS Course Sequence

The first course in the sequence is Introduction to Engineering (INGE 3001). This one-credit elective course provides students from all engineering undergraduate programs offered by the CoE with critical information to discern the difference between engineering disciplines so that they can reassure their decision to study a specific engineering program.

The second elective in the sequence is Introduction to Engineering Learning Communities (ELC) (INGE 3002). This one-credit course is designed to deepen students' knowledge about their chosen field of study and highlight the importance of fundamental math, science, and basic engineering courses in the solution of real-life problems.

The third course, Undergraduate Seminar (INGE 3003) is a variable-credit elective (1- 3 credits), in which students are taught essential elements of engineering research and professional practice, leading them to identify sources of information for research, teamwork, creation of research plans, and how to communicate effectively. Trainings adopted the Affinity Research Group (ARG) model [6].

This paper focuses on the activities developed as part of the course INGE 3002 and provides insights into the assessment results obtained during the 2019 Spring and Fall terms.

INGE 3002: Introduction to Engineering Learning Communities (ELC)

The activities included in INGE 3002 are designed to foster a non-conventional learning community between first-year students and upper level students. Activities included presentations from students working in design teams for national competitions, visits to

laboratories, presentations from experts in areas related to engineering design, and matching first-year students with a senior level student working in the design of a special-project or with teams developing their capstone design project. Participation of first-year students in a capstone course or in a project was conditioned to the number of available projects during the semester and students' class schedules.

The course objectives consisted of 1) highlighting the importance of fundamental science, math, and engineering subjects in undergraduate education and professional development, 2) having students experience the process and end-product in capstone and design projects, and 3) providing students with enough theoretical and applied knowledge to understand what constitutes their engineering field.

We believe that if students receive information during the first year of study about their chosen career and how knowledge is put into practice, this will strengthen students' commitment to their program and help them evaluate, early on, if they want to pursue engineering as their career path.

Therefore, the research question guiding this study is to determine how these activities impact students' understanding of engineering and their commitment for completing their degree in engineering.

Course Activities

The activities included in the course INGE 3002, across the Spring and Fall semesters, consisted of at least two lectures, three workshops, six presentations from students working in a design team, and a minimum of two visits to laboratories or research centers.

The lecture topics included an introduction to engineering learning communities, how to write a proposal, and team-working. The first workshop included hands-on activities on systems design, the second one focused on mathematics of the human body, and the third one centered on how to design an experiment. After each activity, students were asked to write a reflective essay, of at least 500 words, explaining the relationship between science knowledge, either in chemistry, physics, biology, math, engineering graphics, or programming, among others, and the target topic.

Spring 2019 Semester Activities

Team Presentations

Cokí Car Team - The Department of Chemical Engineering sponsors the Cokí Racing Team (CRT) special project and students' participation in the Chem-E-Car annual competition hosted by the American Institute of Chemical Engineers (AIChE). Part of the competition consists of designing a small-scale car powered and stopped by a chemical reaction. INGE 3002 students had the opportunity to observe how this team designed a chemical reaction to control the running and stopping mechanisms of the car. Specifically, they used a H_2O_2 decomposition reaction and a sulfur precipitation reaction to design the propelling and breaking mechanisms.

RUMarino - The RUMarino project objective is to design and manufacture an autonomous underwater pirate-vehicle that executes and fulfills the tasks required to perform in the underwater sub competitions. During this visit, students were made aware of how differential equations were used for the design of this autonomous vehicle. In addition, team members emphasized the importance of creativity and self-learning to achieve more robust designs.

UPRM Steel Bridge Team - Students learned how this team organized and worked throughout the academic year to participate in a competition which requires the design and construction of a 1:10 scale bridge, based on the American Institute of Steel Construction (AISC) rules and specifications (e.g. lightweight, load resistant, rigid, construction speed, and economically profitable). During the presentation, the team assembled the bridge as if they were participating in a real competition.

UPRM Seismic Design Team – Team members presented their most recent design of a complex tall building model made from balsa wood and presented a video on how this structure is put to test on a shaking table with different seismic loads. The steel bridge and seismic teams emphasized the importance of physics in the design of bridges and buildings.

Visits to Laboratories

Applied Ocean Science and Engineering Laboratory - Students were exposed to a project whose objective is to apply mathematical models to predict the direction of sea currents in order to understand and predict where garbage would accumulate in the seas and oceans around the West Indies.

Process Instrumentation and Control Laboratory - First-year students had the opportunity to interact with advanced electrical engineering students working in the design and implementation of process instrumentation and control, as well as digital control design projects. Students were shown eight novel designs.

Fall 2019 Semester Activities

The following activities were offered in addition to the ones described for the 2018 Spring semester.

Team presentation

UPRM MoonBuggy Team – Students learned about this competition project that consists of designing and manufacturing a human-powered rover that can overcome several obstacles. This team is divided in seven groups or departments: Chassis, Powertrain, Suspension, Steering, Wheels, Telemetry, and Project Management. The working structure of this group was described as highly challenging because it requires coordination among sub-teams. This team highlighted the importance of physics concepts in the design of the chassis, powertrain, suspension, steering, and wheels.

Visits to Laboratories

Embedded System Laboratory - Students had the opportunity of learning concepts in hardware and software design to develop typical applications of embedded computers.

Real Time Process Control Laboratory - Provided students the opportunity to learn how to design, build, and control scaled models, mainly emulating real manufacturing operations. They learned how to use programmable logic controllers (PLC), industrial sensors and actuators, pneumatics, and computer-based human machine interfaces to design a scaled model.

Chemical Engineering Research Center – a researcher from the Center for Sustainable Water, Energy and Food Nexus, talked to the students. Through his presentation students learned how to use biomass deconstruction to improve soil quality, soil water storage, and crop yield. During the presentation, it was emphasized the importance of knowledge in biology and chemistry to carry out this type of research.

First-year and Senior students' capstone experience (2018 and 2019)

During the Spring Semester, 27% (6/22) of first-year students and 33% (4/12) during the Fall, were matched with seniors working in their capstone project. We were unable to match all students due to a limit of capstone courses and corresponding course schedules with available projects. First-year students observed how senior students put into practice problem-solving skills and knowledge obtained from their courses to reach a solution in an engineering design project.

Description of the Students Enrolled in INGE 3002

The course INGE 3002 was offered during the 2018 Spring and 2019 Fall Semesters. A total of 34 students were enrolled in the course (22 during the Spring term and 12 in Fall). The distribution of socio-demographic variables for the thirty-four students are reported in Table 1.

Table 1. Socio-demographic Information of Students Enrolled in INGE 3002.

Socio-demographic variable	Distribution
Gender	45.5% Female; 54.5% Male
Engineering Program Enrollment	
22.7% - Industrial Engineering 18.2% - Mechanical Engineering 13,6% - Chemical Engineering 13.6% - Electrical Engineering	9.1% - Computer Engineering 9.1% - Surveying and Topography 4.5% - Computer Science and Engineering 4.5% - Software Engineering 4.5% - Civil Engineering
High School of Origin	68.2% from public schools; 31.8% from private schools
PEARLS and Not-PEARLS	85.3% PEARLS; 14.7% Not-PEARLS

Assessment Results

A questionnaire was designed to assess the perceived impact of INGE 3002 on participating students. All students were asked to complete the form at the end of the semester. Results

include the data from both semesters.

General course evaluation

A high percentage of students evaluated the course experience as very positive. Figure 4 includes results for items included in this category. The scale used to answer each item consisted of "Very Much", "Much", "Somewhat", "Slightly", and "Not at All". Aggregated percentages for the options of "Much" and "Very much" for each statement were the following:

- Influential to my future career goals (85%, 29 of 34)
- It was interesting (97%, 33 of 34)
- I gained new knowledge (91%, 31 of 34)
- It was relevant to my major (82%, 28 of 34)

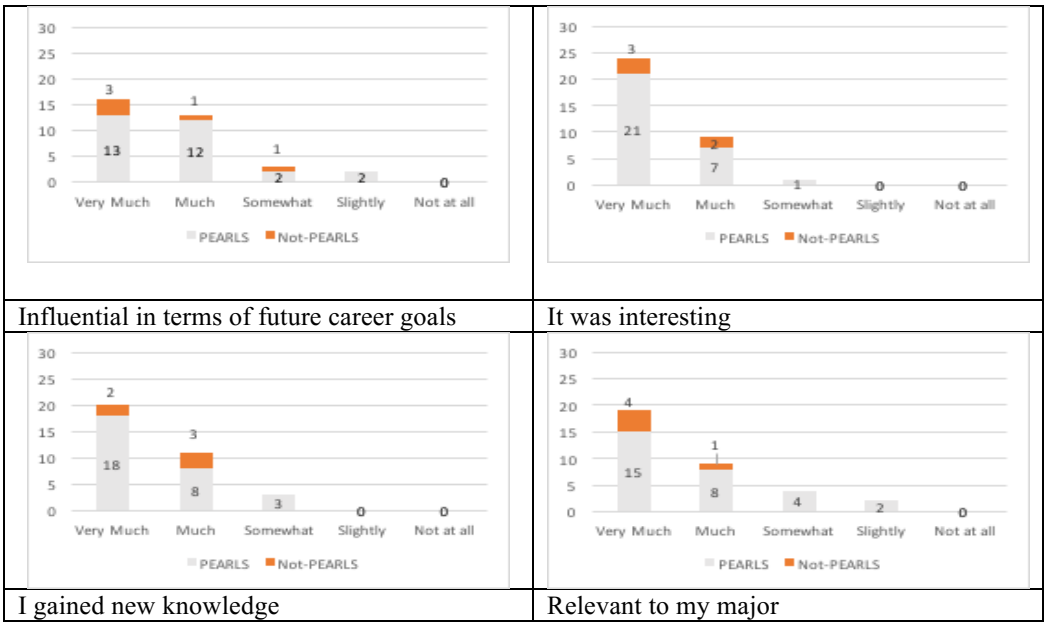
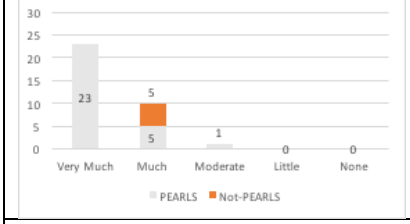


Figure 4. How would you rate the aforementioned experience?

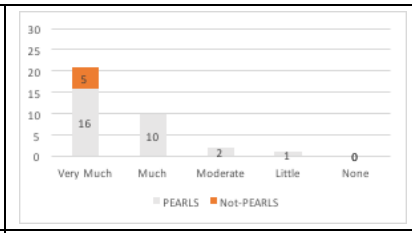
Students' knowledge

Figure 5 shows students' assessment of their perceived growth as a future engineer and perceived increase in their knowledge base from participating in the course. The scale used to answer each item consisted of "Very Much", "Much", "Moderate", "Little", and "None". Aggregated percentages for the options of "Much" and "Very much" for each statement were the following:

- Understanding the importance of mathematics and science (97%, 33 of 34)
- Applying the engineering method as an approach to reach a desired solution to a problem (91%, 31 of 34)
- Understanding the difference between engineering disciplines (88%, 30 of 34)



Understanding the importance of mathematics and science



Applying the engineering method as an approach to reach a desired solution to a problem

Understanding the difference between engineering disciplines

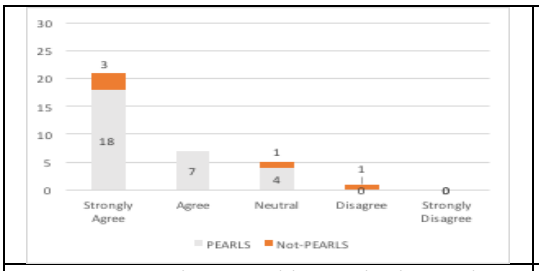
Figure 5. Assess your perceived growth as a future engineer as a consequence of taking this course.

A comparison of the graphs included in Figure 5, shows that the highest percentage corresponds to 'Understanding the difference between engineering disciplines'. INGE 3002 is the second course of a sequence of three courses, and all PEARLS students enrolled in INGE 3002 had already approved the first course (INGE 3001). The objective of INGE 3001 is to provide students with critical information to discern the differences among engineering fields and corresponding professional practice.

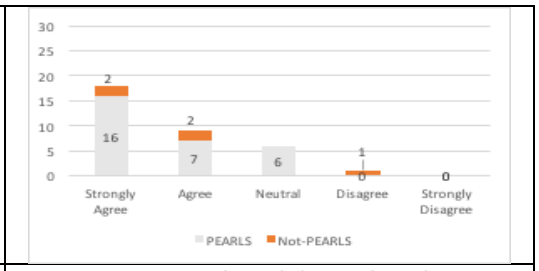
Students' Interest in Chosen Major

Finally, Figure 6 shows the answers to the question "How would you rate your interest in your chosen engineering major?" The scale used to answer each item consisted of "Strongly Agree", "Agree", "Neutral", "Disagree", and "Strongly Disagree". Most of the students answered that they "Agree" or "Strongly agree" to the following statements:

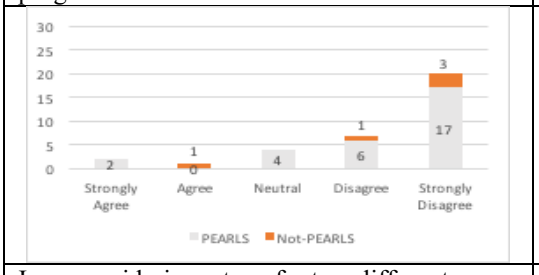
- Now I'm more interested in continuing and graduating from my chosen engineering program (82%, 28 of 34),
- Now I am sure I selected the engineering program that is right for me (79%, 27 of 34).



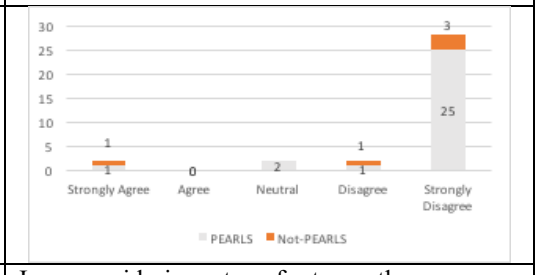
Now I'm more interested in continuing and graduating from my chosen engineering program



Now I am sure I selected the engineering program that is right for me



I am considering a transfer to a different engineering program



I am considering a transfer to another program outside engineering

Figure 6. Reported interest in chosen engineering major after completing INGE 3002.

To explore if students were considering a transfer, either to another engineering program or into another college, we included the following statements: "I am considering a transfer to a different engineering program" and "I am considering a transfer to another program outside engineering". Aggregated results for "Agree" or "Strongly agree" for each statement shows that three (9%) students were considering a possible transfer to a different engineering program and four students (12%) answered feeling neutral about this decision. In relation to considering transferring to another college, two students (6%) replied that they were strongly considering it, and two (6%) others were neutral with respect to this decision. Overall, 88% of the students expressed that they would continue studying engineering and most reported that they would remain in their current engineering specialization.

Conclusions

Often, fundamental engineering courses are theoretical, very technical, and many times devoid of examples of real applications to engineering design and problem solving. We understand that the lack of context jeopardizes students' interest in the discipline and eventually contributes to students' attrition. Therefore, the course Introduction to Engineering Learning Communities (INGE 3002) was designed to reinforce students' knowledge about their chosen field of study early on in their program and increase students' understanding of how significant math, science, and basic engineering courses are in the solution of real-life engineering problems. The course incorporates the development of a learning community composed of first-year and senior students; this arrangement provides first-year students with opportunities to visualize themselves as future engineers.

Assessment results demonstrate that the course objectives were achieved. Students reported having a better understanding of their field of study and of engineering practice. The majority of students reaffirmed their decision to continue studying in their particular engineering field and confirmed their intention of graduating with an engineering degree. Twelve percent of the students discovered that they wanted to pursue another field instead of engineering. Although this represents a potential loss for the program, it is in the best interest of the students to make an informed decision early on their baccalaureate. Students growth in terms of their knowledge base in engineering and how it is put into practice was evident.

Since this is a five-year program, we will continue to assess the outcomes for INGE 3002 and review the assessment methods. To explore the dynamics of retention and attrition, tracking and follow-up interviews will be performed to students considering transferring. It will take time to determine the effects of the proposed courses in students' retention, persistence, and graduation rates, but our expectations are to eventually demonstrate the contribution of INGE 3002 in students' success.

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