Foundations of Engineering: A Credit-Bearing Course for the Princeton University Freshmen Scholars Institute

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Abstract - **The current paper presents a work-in-progress: the development of a project-based, credit-bearing course for engineering students enrolled in the Princeton University Freshmen Scholars Institute (FSI) summer bridge program. FSI aims to engage a highly motivated community of incoming freshmen in rigorous coursework and meaningful social and professional development. A majority of students invited to participate in FSI are low-income, first-generation college students. The course, *Foundations of Engineering*, aims to provide a project-based introduction to engineering that mixes electronics, mechanical construction, and computational data analysis. Also, the course aims to provide a firm theoretical foundation for the project in both math and physics. The development of the course was informed by: (1) a research study conducted during the 2014 FSI summer program, and (2) an existing course, *Integrated Introduction to Engineering, Math, Physics*, that requires advanced standing in physics and mathematics. This paper will describe the FSI, present findings from the 2014 pilot and outline the curricular framework of the Foundations course, including the evaluation plan.**

Index Terms – Engineering Design, First-Generation, Project-based Learning, Summer Bridge

INTRODUCTION

The Princeton University Freshmen Scholars Institute (FSI) aims to engage a highly motivated community of incoming freshmen in rigorous coursework and meaningful social and professional development. As evidenced by the existing research literature, summer bridge programs, like the FSI, increase retention and graduation rates, as well as improve students' self-efficacy and social capital [1]-[3].

Some of the salient features of summer bridge and first-year engineering experiences that contribute to student success include: using evidenced-based teaching practices, providing opportunities for students to engage in authentic scientific and engineering endeavors early-and-often, and cultivating opportunities to enhance faculty-student interaction [4]-[6]. To address issues of student retention and satisfaction with STEM majors, the 2015 FSI summer bridge program will introduce two new courses: MOL 152 *Laboratory Research in the Life Sciences* and EGR/STC 150 *Foundations of Engineering* (heretofore EGR). The current paper discusses the EGR course.

The development of the engineering course was informed by: (1) a research study conducted during the 2014 FSI summer program, and (2) an existing course, *Integrated Introduction to Engineering, Math, Physics*, that requires advanced standing in physics and mathematics. The new course, *Foundations of Engineering*, provides a project-based introduction to engineering, physics and mathematics that will attend to students' cognition (physics, math, and engineering content knowledge) and affect (motivation, interest, and self-efficacy), which research [5]-[6] has shown to be effective in increasing retention and student satisfaction. The following section presents preliminary findings from the 2014 study that contributed to the development of the course.

FINDINGS FROM 2014 PILOT

During the 2014 FSI, the Princeton University Council on Science and Technology began a research study to understand the immediate and longitudinal impact of the program on the students' mathematics content knowledge and self-efficacy. The guiding research question was: *As described by the students, what is the lived experience and longitudinal impact of the FSI?* In particular, we were interested in describing the components of the FSI through the students' voices, with a focus on the quantitative reasoning (QR) course for students interested in STEM majors. We were also interested in gaining the students' perspective on the longitudinal impact of the FSI on their persistence in a STEM major and overall satisfaction with the undergraduate experience at Princeton University.

Academic preparation is a key factor to success in college and persistence in a STEM discipline [7]-[8]. Unfortunately, K-12 schools in economically depressed areas, typically, do not offer the most rigorous curriculum [9]-[10]. Summer bridge programs provide an opportunity for students to enhance mathematics content knowledge [11]-[14]. The students enrolled in the 2014 FSI described similar experiences.

Students identified the FSI as an opportunity to enhance their mathematical content knowledge. Many students described a desire to strengthen their mathematical "foundation." The students described their precollege math experiences as requiring "superficial" or rote understanding of mathematics that required little effort to master. In describing the QR course in the FSI, students discussed a focus on learning concepts and applying concepts to various problems and workshops. Students also described co-constructing a community of practice around the QR course.

Summer bridge programs have the potential to not only prepare students for the academic rigors, but also for the social rigors of college life [13]-[14]. Benefits of social preparedness include increase in students' perceived social fit and coping skills, as well as a decrease in anxiety. These benefits lead to higher persistence and graduation rates, as well as overall student satisfaction [1]. Two social factors, self-efficacy and social capital, emerged as students described the FSI. Broadly defined, self-efficacy is students' confidence in their ability to establish and execute a logical set of steps in order to succeed in or complete a task [15]. The study will focus on students' engineering self-efficacy. Social capital represents an individual's network that facilitates access and participation in a community [16]-[18].

Throughout the FSI experience, students discussed a desire to understand Princeton culture, address concerns of feeling "less than," and experience living away from home. Students also articulated an appreciation for the vast resources available at Princeton and gained the skills necessary to access and utilize those resources. Overwhelmingly, students described their connection with faculty, educators, and peers as contributing to their increased sense of belonging and positive outlook on succeeding at Princeton. Furthermore, students described the *Ways of Knowing* course as an opportunity to enhance their writing, critical thinking, and communication skills.

Recognizing that the FSI provided an opportunity to enhance their content knowledge, self-efficacy and social capital, the EGR course was designed to attend to these factors. The following section describes the engineering course curriculum.

COURSE CURRICULAR OUTLINE

The purpose of the course, *Foundations of Engineering*, is two-fold. First, we aim to provide a project-based introduction to engineering that mixes electronics, mechanical construction, and computational data analysis. Second, we aim to provide a firm theoretical foundation for the project in both math and physics.

During FSI, the course will meet four times weekly, for three hours each day, for six weeks. There are three integrated parts to the course: lab, math and physics. In lab, students will have the opportunity to build, test, and iterate the design of a rocket. Complementing the lab experience, the lectures and precepts will engage the students using evidenced-based teaching practices that enhance their physics and mathematics content knowledge.

With regards to mathematics, students will enhance their understanding of: functions, numerical integration and differentiation, creating and interpreting visual representations of data, and ordinary differential equations. In physics, students will enhance their understanding of: kinematics, work and energy, fluids, and momentum. The introduction of mathematics and physics content will be intertwined and in-service to advancing the design of the rocket. Throughout the course, students will be introduced to and required to use the "habits of mind" of engineers by utilizing the engineering design process to iterate their rockets.

Students will see a variety of assessments in the course. Short homework will be given after each lecture session. Short weekly quizzes will ensure students retain lecture content. Quality of participation in group work and precepts will be assessed by instructional staff. The lab project will result in a final write-up that will assess lab and data analysis skills. There will be a final exam covering all material from the course.

EVALUATION PLAN AND FUTURE WORK

The purpose of the evaluation plan is to understand the students' lived experiences in the new EGR course. Specifically, we are interested in evaluating the extent to which the course impacts students' cognition and affect, as well as their sense of identify and belonging to the engineering community. The overarching research question guiding the evaluation plan is: *As described by the students, what is the lived experience and longitudinal impact of the FSI?*

The evaluation plan aims to describe the components of the FSI through the students' voices, with a focus on the EGR course. We are also interested in gaining the students' perspective on the longitudinal impact of the FSI on their persistence in a STEM major and overall satisfaction with the undergraduate experience at Princeton University. As such, the following questions underpin the study's theoretical and analytical frameworks:

1. To what extent does EGR enhance students' science, math and engineering content knowledge?
2. How does FSI, in general, and the engineering course, in particular impact student affect?
3. What are the salient features of the engineering course that enhance faculty-student interaction?
4. How do students' identities as engineers evolve throughout the course of FSI and during their freshmen and sophomore years?

5. How do students describe the FSI and EGR community, climate and culture?

Using principles of Grounded Theory [19], we will conduct an in-depth, mixed-methods study to theorize a framework that explains the FSI experience. Six primary sets of data will be collected and analyzed: (1) longitudinal interviews with students and faculty, (2) classroom observations of the MOL and EGR courses, (3) course assessments, (4) the FSI pre- and post-questionnaires, (5) the Enrolled Student Surveys from the Office of Institutional Research, and (6) students course enrollment and grades for their freshmen and sophomore years.

The purpose of the longitudinal interviews is to provide an opportunity for the students and faculty to discuss their goals and reflect on their experiences. The semi-structured, qualitative interviews with students will occur at the start of the FSI, three-quarters through the summer experience, at the start of the students' freshmen year, and once each semester of enrollment through the end of the students' sophomore year. To understand the faculty perspective on FSI, the interviews with the faculty teaching the EGR course will be administered before the start, at the mid-way point, and at the end of the summer program. The purpose of the classroom observations is to document pedagogical approaches, student engagement and the evolution of students' content knowledge. The quantitative classroom observation data will provide basic descriptive statistics and the observer's ethnographic notes will be coded for analysis. Questions taken from the calculus and physics concept inventories will be included on early, mid and final course assessments to provide another data source on cognitive development. The FSI pre- and post-questionnaires and Enrolled Student Surveys will be analyzed to provide basic descriptive statistics and tests for statistical significance. In tracking retention in STEM majors, students' course enrollment and grades will be collected, as well as declaration of major.

Based on the evaluation and iteration of the course in summer 2016, we aim to offer the course during the academic year. The ultimate goal is to cultivate many pathways into engineering that enhance access and inclusion at Princeton University.

ACKNOWLEDGMENT

The authors of this paper would like to thank Dr. Norman Jarosik for his advice and guidance in adapting the EGR 192 course to fit the curricular framework of the course described in this paper. We would also like to acknowledge the University's commitment to the Freshmen Scholars Institute and other programming addressing issues of college access and inclusion.

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