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Enhancing Engineering First-Year Experience (FYrE) through Supplemental Instruction

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Abstract

The College of Engineering, Computer Science and Technology (ECST) at Cal State LA recently introduced the First-Year Experience (FYrE@ECST) program that focuses on building a more academically focused engineering mindset in freshmen engineering majors during their first year of college. While FYrE@ECST consisted of a number of proven practices integrated into the freshmen experience, the goal of this paper is to present the benefits of implementing a supplemental instruction (SI) model, adapted from the UMKC model to enhance student learning in Calculus and Physics, which are pre-requisite courses for most core upper division engineering courses, but have very high attrition level. In 2014 leading up to the development of FYrE@ECST, we examined 6-year graduation rates of the most recent 5 years, and thus we had data from the Office of Institutional Research for the Fall 2007 through Fall 2011 first-time freshmen cohorts. Out of those total 1052 students, only 567 even took Calculus I, and out of those who took Calculus I, 203 failed the course on the first try, yielding 35.8% of students needing to repeat the course. Historically, very few (~6%) of our freshmen completed their Physics I requirement within their first 2 terms. Therefore, FYrE@ECST interventions focused on effective learning pedagogy and practices in these traditionally challenging but foundational courses.

In particular, we wanted to demonstrate the benefit of SI workshops in a majority first-generation, underrepresented minority, predominantly academically unprepared student population. The peer-led workshops are mandatory for FYrE@ECST students and designed to promote inquiry-based and collaborative learning environment and increase students' mathematics self-efficacy. Supplemental Instruction was assessed using self-efficacy surveys, physics and math grades, pre- and post-tests, and focus groups. FYrE@ECST students were compared to concurrent (CG-2) and historical (CG-3) control groups. The math average GPA for FYrE@ECST students at the end of the first year was 2.9, compared to 2.2 and 2.45 for CG-2 and CG-3, respectively, and completion rate of Physics I within the first 2 terms for FYrE@ECST students was 81%, compared to 9.4% for CG-2 and 6.3% for CG-3. Results from focus groups and surveys indicated that students had a very positive experience in the SI workshops.

Background

California State University, Los Angeles (Cal State LA) is the Cal State campus serving the Los Angeles Region. Cal State LA is a minority-serving institution (MSI), with 82% of undergraduate students identifying themselves as minorities, and a Hispanic-serving institution (HSI), with 64% of students being Hispanic. The median household income of incoming students is $36,600, with 33% of family income in the bottom income quintile. The demographics of the College of Engineering, Computers Science and Technology (ECST) matches closely that of the university. In terms of academic preparation, 40% of incoming engineering first year students join Cal State LA testing into remedial math, while the percentage of calculus-ready freshmen has traditionally been very low. Cal State LA serves as a gateway to higher education for the youth in this population, and our College of Engineering, Computer Science, and Technology (ECST) serves as a gateway to STEM careers. Recently, Cal State LA was ranked 1st in the country in social mobility for propelling a higher percentage of students from the bottom fifth of income into the top fifth of U.S. earners (Turner & Treasury, 2017). About 80% of incoming engineering freshmen participate in ECST's summer bridge program for engineering (STEP). After STEP was implemented, the number of students starting in Calculus I, increased from virtually zero to between 30 and 40%. Nevertheless, students continue to struggle in Math and Physics. On average, students fail Calculus I and Calculus II at a rate of 35% and 40%, respectively. In the case of physics, the rate of DWFs are 30% and 40% for Physics I and II, respectively. Consistent with engineering education literature, the poor performance in foundation courses has led to low retention and graduation rates.

In the Fall/2015 semester, ECST implemented a new First-Year Experience (FYrE@ECST) program (Menezes, Won, Tufenkjian,M.,Allen,E., & Schiorring, 2017) funded through a grant from the Helmsley Foundation with a number of interventions that focused on these success variables. FYrE@ECST interventions included (i) a redesigned introduction to engineering course with focus on design and hands-on learning (Tufenkjian et al., 2017); (ii) *Mathemagics (Sharif, Menezes, Schlemer, & Won, 2016)*, a series of workshops integrating physical processes and phenomena to math; (iii) a new comprehensive advisement tool called Golden-Eagle Flight Plan (GEFP) (Sun, Won, Allen, & Gadhia, 2016); and (iv) Supplement Instruction (SI) workshops for physics and calculus for a freshman cohort. This paper reports on the implementation and assessment results of the Supplemental Instruction workshops as part of the FYrE@ECST program in a student population academically underprepared particularly in STEM.

Study Design and Objectives

In the Fall/2015 semester, faculty from ECST piloted the FYrE@ECST program with a cohort of 32 students. The students were selected by institutional research personnel to match the engineering college demographics. The 32 FYrE@ECST students (treatment group) were compared to a concurrent, matched Control Group (CG-2) of 33 students from the same entering class who participated in the summer bridge program but none of the other FYrE@ECST interventions; and a historical Control Group (CG-3) with 33 students from the previous year who participated in the previous version of the summer bridge program. Students from all 3 groups started in Calculus I during their first Fall term, after participating in STEP.

Supplemental Instruction was implemented as a mandatory intervention for all FYrE@ECST participants (Figure 1), to help them succeed in Calculus and Physics courses, which are high attrition courses. SI was selected because the model had been widely investigated in engineering education and a great deal of researchers has reported on the positive results of SI workshops (Martin & Arendale, 1994), since it was initially proposed in 1973 by Dr. Deanna Martin at the University of Missouri–Kansas City (UMKC). But most importantly, SI UMKC model goals were aligned with our goals to improve student performance in these high-attrition courses and to increase retention and graduation rates of engineering students. The model was hypothesized to be effective with our student population who mostly graduated from very low-income public school districts.

Figure 1. Supplemental Instruction Workshops

Calculus SI Workshops

It has been reported that the four ways to increase mathematics self-efficacy are mastery experiences, vicarious learning, social persuasion, and emotional and physiological states (Lent, Lopez, & Bieschke, 1991). The leaders of the workshops are undergraduate engineering students. They have successfully mastered calculus and are academically integrated and socially integrated into the university. The workshops are scheduled two days a week, 75 minutes each session. The SI workshops were run independently from physics and math departments, since were not able to agree on running SI as part of the respective courses.

In the beginning of each session, student leaders instruct for approximately 10-15 minutes on key concepts that students find more difficult to grasp. Then, students work on problems and activities designed to go from easy to difficult, allowing the development of self-efficacy through prior mastery experiences. Throughout the session, peer-leaders assist their peers through the process of problem solving without giving away the solutions. In addition, leaders continuously encourage the students to do well and give them the tools to succeed through social persuasion. Facilitation of the workshop by near peers creates a lower-risk atmosphere for the students, and frees them to ask questions and to work through problems themselves with less worry about professors seeing their mistakes.

Our focus here is on the main characteristics of SI that appear to be especially apt for our student population who has shown to perceive more barriers and less support to pursue engineering than other universities across the country on average (Ojeda, Flores, & Navarro, 2011). The SI participants are taught to self-regulate by reviewing and solving problems they did incorrectly on quizzes and exams. Despite the importance of adopting a mastery goal orientation, our students tend to find it challenging to do so. Thus, student mentors discuss with the freshmen students the importance of setting short and long term goals. Participants are taught to use self-regulation strategies so that it becomes a habit. They are asked to set goals for the amount of time they expect to study calculus each evening. They are asked to grade their own worksheets, putting them in control of their own learning goals. The worksheets are designed to break down complex tasks into smaller pieces. The mastery goal orientation enables them to master learning tasks according to self-set standards, develop new skills, and improve their understanding or insight.

Another important aspect of the SI model particularly apt for our student body is the shift in paradigm from the tutoring sessions in which tutors are seen as mini-professors to one where student mentors are there to guide workshop participants through the learning process. The ability to relate to the workshop leaders helps our students, who according to Navarro & Flores have significantly lower engineering self-efficacy than the national average, to ask more questions and participate more in their learning. Redirecting questions and wait time are thus essential components of the SI workshop. Redirecting questions assists the students to think about what they are asking. The student leaders ask the students questions. E.g., *What is the question asking for? Why are you thinking of it that way? Can you be more specific? Let's look that up in your text book. Let's write down everything you know about this topic/problem/theory.* Wait time is the time that elapses between an SI leader's initiated questions and the student response. Increase in wait time allows the brain more opportunity to consolidate info which allows for deeper processing of information. After waiting 15-20 seconds the leader will repeat the question, rephrase the question, simplify the question into its components, make the question more specific and ask students what it is about question they do not understand.

The SI format encourages social integration by giving our students an opportunity to engage with each other academically in a more intimate setting than typical lecture classes or even than the traditional tutorial format. In our commuter university, students typically spend only a modest amount of time on campus and the student body lacks the network of coherent and influential student culture. The leaders and their supervisor facilitate collaborative peer learning and host study-a-thons before final exams. The SI format encourages our students to devote more physical and mental energy to be more involved on campus and experience increased frequency of non-classroom interaction with peers as a result.

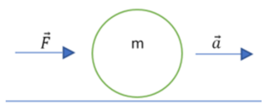
Physics SI Workshops

Most aspects of the Physics SI workshops were similar to those discussed earlier for the Math workshop. However, the applied nature of physics problem provided hands-on learning opportunities that more effectively engage student interest in math and physics and at the same time improve students' performance in their classes as they better understand the physical processes and how they are addressed mathematically. To enhance student thinking in this area, the workshop was designed to promote dimensions of mathematical, scientific and engineering literacy by: (i) asking questions (for science) and defining problems (for engineering), (ii) developing and using models, (iii) planning and carrying out investigations, (iv) analyzing and interpreting data, (v) using mathematics and computational thinking, (vi) constructing explanations (for science) and designing solutions (for engineering), (vii) engaging in argument from evidence, and (viii) obtaining, evaluating, and communicating information. The workshop focuses on concepts that have common applications across engineering, including pattern recognition; cause and effect relationships; mechanism and explanation; scale, proportion, and quantity; understanding of energy and matter: flows, cycles and conservation.

At the beginning of each workshop, students were provided an overview and objectives of the hands-on engineering challenge they needed to complete. The hands-on engineering challenges were aligned with the weekly topics presented in the physics lecture. For example, while students were learning about the concept of force in lecture, they were tasked with completing a challenge to deepen their intuition of physics concepts and principles. This approach required students to employ critical thinking and problem-solving skills. Moreover, it gave students an opportunity to solve a real problem using physics theory while showing how physics can be used in engineering design. Figure 2 illustrates they type of activities used to accomplish the goals listed above. In this activity, student mentors briefly discussed Newton's second law of motion and asked students to identify the forces acting on the car. Then, students were asked to develop a free-body diagram and add the forces. Students used the resultant force to compute the time to travel a certain distance and compared the calculations to experimental data.

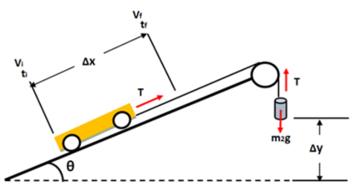
Force and Motion Activity – Dr. Zanj K. Avery El

Overview: The concept of **force** (something that influences a change in motion or causes the shape of an object to change) is one of the most fundamental ideas in physics because of the effect that it has on an object's motion. The below diagram describes how a force acting on a mass will cause it to accelerate. For this challenge, you will measure, collect data, draw a free body diagrams (FBD), and use the FBD in conjunction with kinematics equations to predict the motion of an object.



$$\sum \vec{F} = m * \vec{a}$$

Materials: Car-ramp system, Angle finder, Meter stick, Digital Scale, Timer, Engineering Journal



Objective: Using materials provided, find the time it takes for a vehicle to move up a ramp using force analysis methods and kinematics equations.

Figure 2 – Sample Physics SI Workshop activity

Results

One of the most obvious achievements of the SI workshops was its potential to strengthen the social integration and academic integration by forming a study community which persists throughout their whole academic career. Thus, the participants felt comfortable seeking help from their instructors and became familiar with other faculty members, who took an active role in the SI workshops. This social integration served as encouragement to our first time college students. As one student said during the focus group interview, "Working in teams helps me understand the material better. Working in groups gets you more". It is important to note that student cohort were enrolled in the same math, physics and SI workshops, and that SI workshops were mandatory to all students in FYrE@ECST program, an approach that differs from the original model proposed by the UMKC model.

Supplemental Instruction was directly assessed using physics and math grades and focus groups. Performance in Math and Physics was significantly better for students participating in the SI workshops and other FYrE@ECST program interventions. The math average GPA for FYrE@ECST students at the end of the first year was 2.9, compared to 2.4 ($p = 0.027$) and 2.2 ($p = 0.002$) for CG-2 and CG-3, respectively Thus, at 5% level of significance, the data provide sufficient evidence that on average, students participating in the Calculus SI workshop performed better than control group. Completion rate of Physics I within the first 2 terms for FYrE@ECST students was 81%, compared to 9.4% for CG-2 and 6.3% for CG-3. Since completion rate was low for control groups, GPA comparison with treatment group was not possible. Also, although physics completion rate was higher for FYrE students, overall GPA was below 2.0. Results from focus groups and surveys indicated that students had a very positive experience in the SI workshops. Student indicated that: "engineering workshops helped a lot because it allowed us to solve problems, ask questions, and work in groups in order to be on top of our subjects", and "SI workshops really helped the process of my first year be successful".

Conclusion

Supplemental instruction workshops for Math and Physics were developed and implemented for a cohort of students in engineering participating in the First-Year Experience (FYrE@ECST) program. The goal of SI workshops was to improve student performance in the Math and Physics, which are high-attrition courses for engineering students. The peer-led workshops focused on supporting students academically (problem solving, activities, study habits), enhance social integration and increase self-efficacy. Results of the pilot were very positive, with students in the treatment group outperforming the control group students in math and physics courses. In addition, workshops were successful in promoting social integration and academic integration by forming a study community. Although the performance in physics was better for treatment group, the average was below passing grade. Thus, we are currently developing an engineering preparation course that will introduce basic concepts used in engineering, i.e.: forms of energy, energy transformation, conservation of energy, forces, equilibrium, pressure, velocity and acceleration. The course will help students with abstract physics and math concepts and lead better student performance in math, physics and engineering courses. Overall, seems to be effective with our student population who mostly graduated from very low-income public school districts.

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