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First-Year Experience (FYrE@ECST): Pre-Physics Course (WIP)

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First-Year Experience (FYrE@ECST): Intro to Physics Course (WIP)

The College of Engineering, Computer Science, and Technology (ECST) at California State University, Los Angles, an Hispanic Serving Institution (HSI) with over 60% Hispanic students, is committed to improving graduation rates through the Grad initiative 2025 (the California State University's initiative to increase graduation rates for all CSU students while eliminating achievement gaps). The majority of our students are under-represented minorities, low-income, Pell-eligible and first generation. Currently, one quarter of the students leaving the major before the second year. Many that "survive" the first two years of math and science do not develop the knowledge and the skills that are needed to succeed in upper division engineering courses, leading to more students unable to finish their engineering majors.

Three years ago, we launched a pilot program for the First-Year Experience at ECST (FYrE@ECST) for incoming freshmen. The program focuses on providing academic support for math and physics courses while introducing students to the college community, and comprises a summer bridge program, a hands-on introductory course, cohorted math and science sections, and staff and faculty mentoring. Academic support is provided through peer-led supplemental instruction (SI) workshops. The workshops have led to a significant improvement in student performance in Math, but have had no significant impact in the student performance in physics. Our hypothesis is that students, in addition to having limited understanding of calculus, struggle to understand the fundamental principles of physics and thus cannot apply their knowledge of math to theories in physics to solve problems. This work-in-progress paper describes an inquiry-based hands-on pre-physics course for first-year students as part of the FYrE@ECST program. The course is intended to prepare students for the calculus-based mechanics course in physics and covers about half of the competencies of a classical mechanics course, with focuses on the fundamental concepts of mechanics (i.e. Newton's Laws, Types of forces, vectors, free-body diagrams, position, velocity and acceleration). Equations are only introduced in the second half of the semester, while the first half is directed to help students develop a deep understanding of these fundamental concepts. During classes, students run simple experiments, watch segments of movies and cartoons and are asked questions (written and orally) which can guide them to think intuitively and critically. A think-pair-share mode of instruction is implemented to promote inquiry and discussion. Students work in groups of five to discuss and solve problems, carry out experiments to better understand processes and systems, and share what they learned with the whole class. The paper presents preliminary results on student achievement.

Background

The California State University is the largest four-year public university system in the U.S. and graduates about half of the bachelor's degrees in California. The Los Angeles Campus (Cal State LA) service area extends to a large part of LA county, including some areas of South LA, Pasadena, much of the San Gabriel Valley and the neighborhoods around East Los Angeles. The service area has the census tracts with (i) the largest percentage of population under 18 living under poverty, ranging from 40-100% (Figure 1); (ii) the lowest level of education attainment for population 18 years and older (<9% with college degrees, compared to 18% and 20% in California and the US respectively) (Figure 2); and (iii) the highest concentration of Hispanics (>80%) (Figure 3) in the Los Angeles County[1]. Also, according to the California

Figure 1. High-child poverty census tracts with respect to Cal State LA service area.

Figure 2. Low-education attainment census tracts with respect to Cal State LA service area.

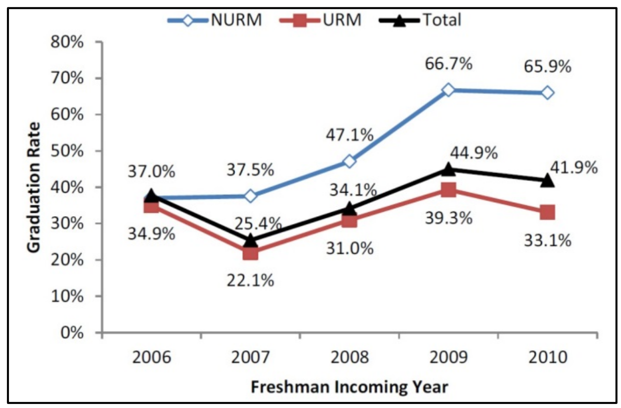

Figure 3. High-Hispanic concentration census tracts with respect to Cal State LA service area.

Figure 4. Six-year frosh graduation rate in engineering and computer science at ECST

Department of Education, the percentage of economically-disadvantaged students that meet English and Math standards are 32% and 21%, respectively, compared to 62% and 50% for not economically-disadvantage students[2]. The socio-economic characteristics of the regions match closely the student population at Cal State LA, which is mostly comprised by first-generation, low-income and academically underprepared and underrepresented minorities (URMs). About 69% of incoming freshman do not demonstrate English and Math proficiency at entry. Against all odds, many students do succeed in college, professionally and move upward economically, as indicated by the fact that Cal State LA was recently ranked number one in the nation for upward mobility[3]. Nevertheless, about 60% of URM incoming freshman are not completing their engineering program. In 2008, the College of Engineering, Computer Science and Technology (ECST) established the Summer Transition to ECST Programs (STEP) program, which focuses on helping students place into Calculus during their first semester. Currently, approximately 40% of engineering and computer science frosh start their first year "calculus-ready" compared to virtually no "calculus-ready" students prior to STEP. The improvement observed in math readiness, and potential reduction in time-to-graduation, did not however translate into increase in retention and graduation rates for URMs, as shown in Figure 4.

In the Fall 2015 semester, ECST piloted the First-Year Experience at ECST (FYrE@ECST) program[4], with focus on addressing the challenges that are commonly associated with low academic peformance of underrepresented minorities (URMs) in STEM. For the first two years, FYrE fellows, who are randomly selected from a list of interested students (during summer STEP program), were block-scheduled into (i) Calculus and physics sections; (ii) Supplemental Instruction (SI) workshops which provide additional academic support in Math and Physics by assisting students to develop proactive study habits[5], adopt a growth mindset[6], and improve their academic capacity; (iii) a redesigned project-based introduction to Engineering Course that focuses on student development learning outcomes, including introduction to careers in their respective disciplines and academic success strategies[7]; and (iv) access to a new holistic, developmental advisement approach using a web-based tool named Golden Eagle Flight Plan (GEFP)[8]. Although there was a noticeable improvement in the math performance of FYrE cohort, and better progress to degree (based on number of major courses completed) when compared to control groups, FYrE treatment group continued to struggle in the physics (mechanics) course. As depicted in Figure 5, FYrE students' GPA were lower and percentage of students who failed the course was higher. It is important to note, however, that control group students are not cohorted, so the data is an average of many course sections, which may explain the high failure rate of the first cohort (i.e.: strict grading). Nevertheless, the second cohort showed no improvement in comparison to the control group. Our hypothesis is that students, in addition to having a weak math foundation, struggle to understand the fundamental principles of physics and thus cannot connect their knowledge of math to theories in physics to solve problems, which is consistent with the literature. In fact, research shows that the ability to apply knowledge learned to different scenarios is in most cases

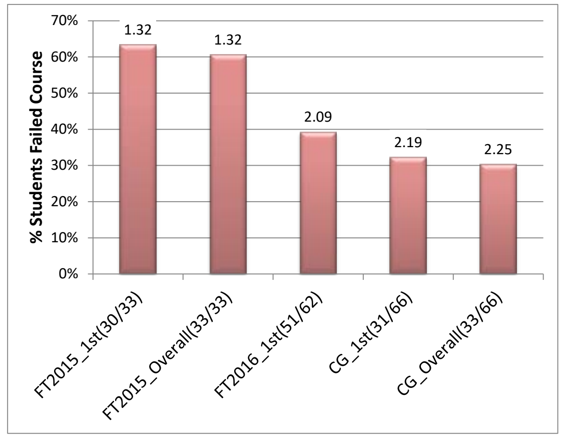

Figure 5. Failure rate in first physics course (mechanics) for FYrE Treatment (FT) groups and control groups 1st attempt and overall (GPA of each cohort is shown on top of the columns)

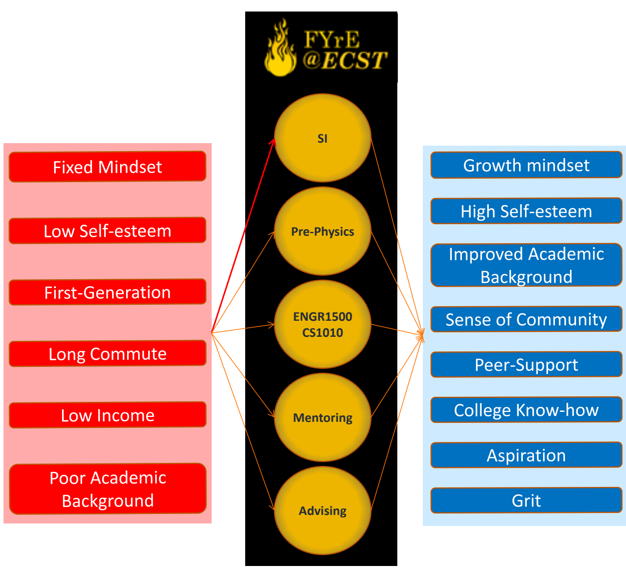

Figure 6. FYre Program interventions and addressed challenges

only achieved by physics majors later in the program.[9]

In the Fall 17 semester, an intro to physics course was added as a new intervention to the FYrE program (Figure 6) with focus on helping students develop a better understanding of fundamental physics processes and laws and then make connections between them. The new course, which is based on modules of the *Mathemagics* workshop series[10] introduced in the first year of FYrE, is further described next.

Introduction to Physics for Engineers

Because physics laws and concepts are part of our daily lives, it is often assumed that most people should not have a problem understanding these physical principles. However, even when one can visualize and accept the physical behavior of objects as being true (e.g.: ball falling, car accelerating), it is difficult to understand the science behind these behaviors. In fact, research has shown that many times even physics instructors do not have an in-depth understanding of the underlying principles and laws of physics[9,11].

Students who have stronger math knowledge and skills are able to overcome these struggles in physics because they are able to replicate the methodologies used to solve the numerical problems. It gives them confidence and a feeling that they do understand the concepts and principles. However, students who are not as well-prepared in math struggle in understanding both the principles and assimilating the mathematical formulation involved in solving problems. Thus, the "Introduction to physics" class is designed to help students, before they enter a formal physics class, develop a strong conceptual understanding of basic physical principles that will be learned in the next semester's classical mechanics course.

When FYrE students are enrolled in the physics course, different ways of learning will be provided to help them succeed in the class, including a lab and an activity course that uses the inquiry model developed by the University of Washington's Physics education group[12]. Also, as part of FYrE, students will be enrolled in Supplemental Instruction workshop for physics.

Course Structure

The course was designed with the assumption that most of the students in the course have not taken any mechanics related classes in their high schools, which is often the case. Also, as indicated earlier, the course goal was to help students develop an in-depth understanding of the concepts and principles. Thus, only about half of the topics of a normal college level mechanics course were covered, including Newton's Laws, types of forces, vectors, free-body diagrams, and position, velocity and acceleration. The course was divided into two half-semester parts. The first half focused on helping students develop basic conceptual understanding by connecting theory with real-world applications. The goal was that by the end of the first half semester students would be able to explain real world events using the concepts learned. In the second half semester, the course introduced the mathematical framework to help students build the ability to connect mathematics to mechanics, and apply a proper theory to solve practical problems.

The structure of each class was composed of three major parts: inquiry-based lecturing, in-class activities, and reflection, as is shown in Figure 7.

The inquiry-based lecturing time was mainly spent on learning theory. The whole learning process was guided by a series of logically connected questions to strengthen students' critical thinking and learning abilities. To raise student's interest and keep students engaged throughout the class, videos and demonstrations of real-world applications were used.

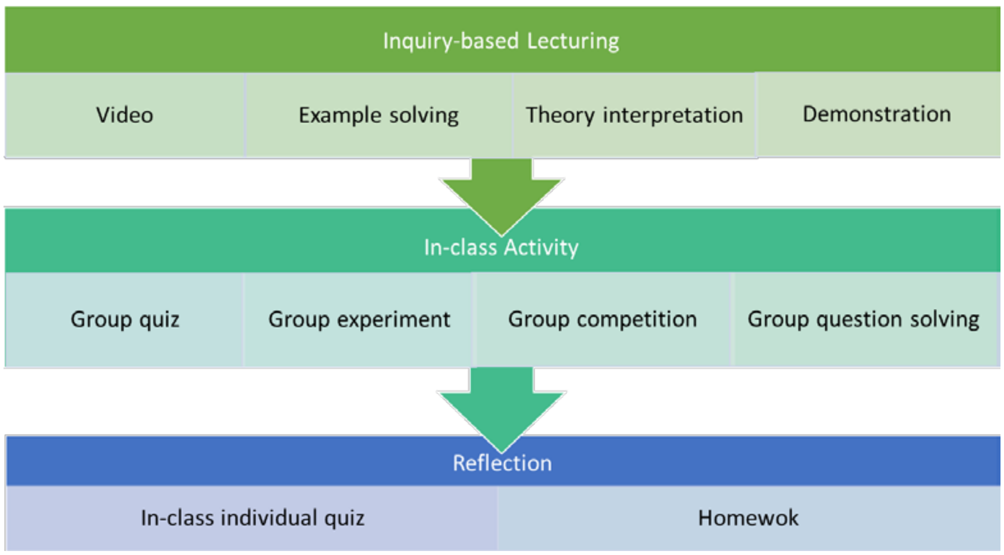

Figure 7. Basic structure of class

The classes usually started with an animated cartoon, a movie or a problem, and then questions related to the scene or problem are posed to students, leading them into thinking about the concepts involved (Figure 8). Students had group discussions and then shared their answers with classmates.

Figure 8. Sample videos and cartoons used in introduction to physics course.

A variety of active learning activities related to the discussions were used in this class. Some examples of these activities are as follows.

1) Group experiments: In the first phase, students were asked to answer a series of pre-experiment questions individually, in which they needed to apply the knowledge they had learnt to forecast the phenomenon they should expect in the experiments. Then, they shared their thoughts with groupmates and reached a consensus on their answers. This helps students deeply understand a theory, since they need to defend their thoughts through reasoning with their team. At the same time, it also provides students a chance to learn from their peers. In the second phase, students carried out the experiment,

and verified their answers from the first phase. In the third phase, students were required to solve post-experiment problems in group. Here, students compared their preliminary and experimental results, and explained the reasons if they were different. It further strengthens students' understanding of theories and fosters their ability to think critically. Moreover, students have a chance to apply their knowledge to other similar applications, which helps them learn how to transfer the knowledge to solve new problems.

2) Quiz and question solving: In these activities, the students worked on the assigned problems in groups or individually to solve 3-5 problems. The students discussed and shared their thoughts to their groupmates or the whole class. These activities help students think critically, communicate effectively, and solve questions logically.

3) Group competition: Kahoot, which is a game-based learning platform, was also used in the class. The questions shown in Kahoot game was designed by the lecturers to be solved within 2 minutes. The students worked in groups and competed with other groups. They needed to input their answers through cell phone accurately and quickly. The advantage of this platform is that it provides instantaneous feedback to the instructor who can adjust his/her teaching strategy accordingly. In addition, competitions are students' favorite activity and can increase their interest to learn.

In both the lecturing and in-class activities, the strategy "think-pair-share" was used to promote students' enthusiasm and learning. At the end of each class, an individual quiz was normally carried out to test students' learning outcome. The instructor revealed answers right after the quiz to give students real-time feedback. On top of all these, homework was assigned on a weekly basis with 3-5 questions.

Preliminary Findings

The Fall 2017 FYrE cohort included 55 students students from Civil, Mechanical and Electrical Engineering and Computer Science, who were divided into two sections. All the materials used were the same for both of the sections. Aligned with what has been reported in the literature, students struggle with understanding and explaining concepts and principles, as indicated by the grades of the midterm exam which averaged at 45% and 50% for the two sections. For the final, the average increased by 5 percent points for both sections, which indicates that students have better performance in the numerical problems. On a survey completed by students after the final, 90% of the students completely agree or agree that they have a good understanding of Newton's Laws of Motion, while 63% and 53% agree or completely agree that they have a good understanding of linear motion problems and projectile motion problems, respectively. Although student responses indicatate that they are more comfortable with their knowledge of concepts and principles, exam results disagree with that. Also, even though they feel less confident solving the numerical problems, their performance is better for such problems.

To measure student learnin goutcomes directly, in the first week of Spring semster, a Force Concept Inventory[13] (FCI) was administered to all students in Physics 2100 (Mechanics). This included the 35 FYrE students who had completed the pre-physics class and got C or better in Calculus I in the Fall, as well as all other students (235) taking this physics class. The goals of the FCI are two-fold: (i) assess if students in the FYrE program are better positioned to succeed in the physics course when compared to the non-FYre students; and (ii) evaluate the learning performance of FYrE students compared to the other students in physics by comparing the results of pre- and post- FCI. Results of FCI pretest for FYrE and non-FYrE students enrolled in PHYS2100 - General Physics I: Mechanics are depicted in Figures 9 and 10.

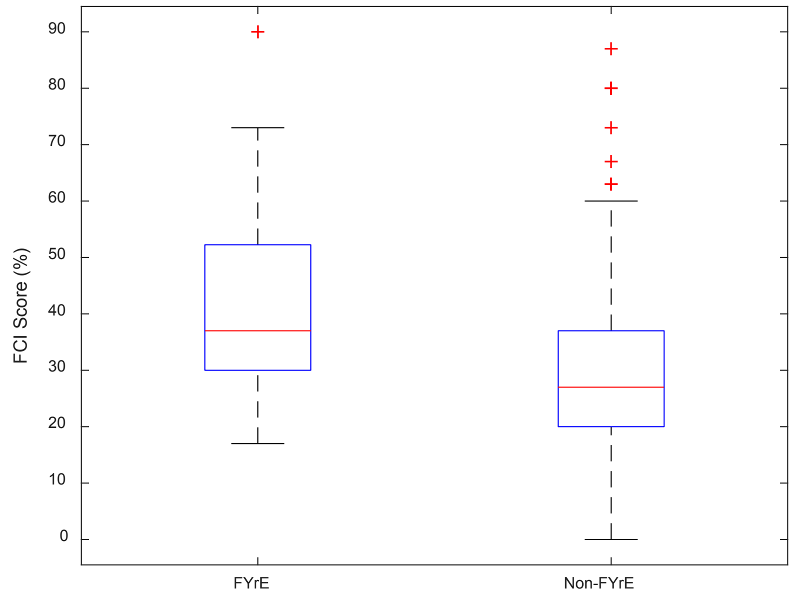

Figure 9. Results of FCI Pretest for FYrE (n=35) students compared to other non-FYrE (n=235) students enrolled in PHYS2100: General Physics I (Mechanics)

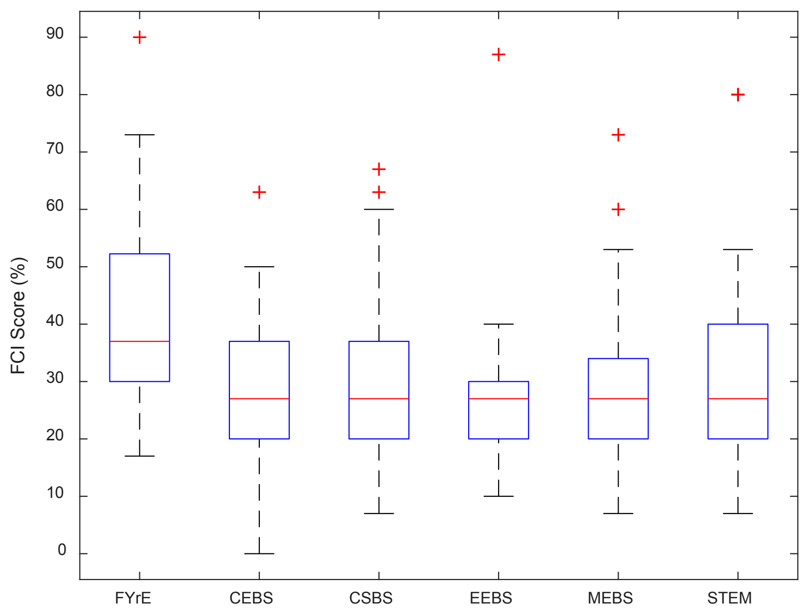

Figure 10. Results of FCI pretest for FYrE (n=35) compared to other non-FYrE students by major: CE(n=34), CS(n=68), EE(n=22), ME(n=49), other STEM majors (n=62).

The median FCI pretest score of FYrE students, who participated in the intro to physics course, was 37%, which is 10 percentage points higher than the median of non-FYrE students (median = 27%). The FCI pretest 2nd and 3rd quartiles mean was 45.6% higher for FYrE students ($\mu_{0.25\text{-}0.75}$=41.5%) when compared to non-FYrE students ($\mu_{0.25\text{-}0.75}$=28.5%). Figure 10 shows that the results were not significantly different across majors, with non-FYrE median being the same (27%) for all majors, compare to 37% for FYrE students. Overall, FCI pretest performance of FYrE students was better than that of non-FYrE students, indicating that FYrE students should be better prepared for the General Physics I: Mechanics Course. Results of the FCI post-test will provide additional insight on the benefits of the Intro to Physics course, with focus on concepts and principles.

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