Programs to Enhance Retention and Success of Students Enrolled in Two-year College Engineering Programs

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I graduated from The University of North Carolina with a PhD in Physics and an interest in STEM education. I am passionate about finding ways to help students learn and retain difficult concepts and help give them the confidence to pursue and tackle challenging problems.

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In addition to her work at Cañada College, Chris actively supports local education having acted as a board member for the Healthy Cities Tutoring Program, San Carlos Education Foundation, Sequoia High School Education Foundation, and the Sequoia High School AVID Advisory Committee.

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Abstract:

A majority of California community college students enter college with low levels of preparation for college level work, especially in STEM (Science, Technology, Engineering and Math). As a result, community college students wishing to pursue careers in Engineering are often under prepared for the foundation courses required as pre-requisites to beginning engineering classes. Due to their low preparation many students withdraw from courses or even change majors before completing transfer-level STEM courses. This paper describes the development and implementation of two programs designed to improve retention and success in these critical pre-requisite courses. Programs include supplemental instruction to target pre-requisite physics and math classes and Physics Jam, a pre-semester physics preparation program.

Supplemental instruction (SI) is an academic assistance program that creates a safe environment for students to get their questions answered and receive feedback from peers who have been successful in their course. SI leaders act as “prototype” students who model successful classroom behavior and study skills. Because SI is not designed to be a remedial approach it targets high risk courses not high risk students. Therefore, for the first implementation of SI at Cañada College (a two-year school in the San Francisco Bay area) targeted Trigonometry, Pre-calculus, Calculus I, and General Physics I to facilitate retention and success in pre-engineering major STEM courses. All students in the course are encouraged to attend Supplemental Instruction sessions each week.

In addition to SI, students entering General Physics I were given the opportunity to participate in “Physics Jam,” a four-week physics preparation program that is offered during the summer prior to the fall semester. Physics Jam is modeled after Math Jam (a week-long intensive math preparation program on our campus), which showed improvement in student success and creating a sense of community among program participants. The focus of Physics Jam is to unify the student’s math skills with introductory physics problems prior to the semester, thereby improving their success in their upcoming course. Physics Jam students were given a pre-assessment and then allowed to proceed self-paced through prearranged video content and practice problems with constant access to tutor support and an instructor.

This paper will discuss the successes and obstacles that were met implementing these programs in a two-year college setting. We will highlight the unique set of challenges in implementing even well-established programs such as Supplemental Instruction in a two-year college setting as well as those encountered when transitioning a successful Math boot camp model to Physics.

1. Introduction

The interdependence between student academic preparation and performance in high school mathematics to performance in college physics courses has been well studied. [1] This correlation can be extended to other STEM courses. Students are frequently underprepared to take these traditionally difficult STEM courses after graduating from high school. [2] These trends are even more pervasive when looking at specific demographics. In the Silicon Valley region of California only 24% of Latino and 27% of African American students reached the academic requirements set by The University of California (UC) and California State University (CSU) systems. This is in stark contrast to the 70% of Asian and 57% of Caucasian students that meet the requirements. [3] Cañada College is a federally designated Hispanic-serving institution (HSI) in the Bay area and serves a diverse population of students that are frequently under-prepared for college-level work, in particular physics and transfer-level STEM courses.

Students beginning their preparation for a degree in engineering at Cañada College must complete a series of transfer-level math classes that include Trigonometry, Pre-Calculus, Calculus 1-3, Linear Algebra and Differential Equations. In addition to the math requirements students must complete at least one semester of chemistry, and the calculus-based physics series. It becomes quickly obvious that an under-prepared student will face many challenges completing an engineering program at XXX college for the purpose of transferring to a 4-year institution. This is evident in the retention and success rates for these courses as illustrated by the calculus based physics series averaged over the past 10 years at Cañada College as can be seen in

.

Table 1: Average retention and success rates for calculus-based physics courses at Cañada College from 2001 through 2010

Course	Retention Rate	Success Rate
Physics 250	77.6%	67.6%
Physics 260	91.1%	83.1%
Physics 270	87.3%	79.5%

There are currently no preparation courses in place at Cañada College to address student's math or study skill deficiencies before beginning the physics series. The College of San Mateo (CSM), a comparable institution offers a semester long math and physics preparatory course before students begin taking their physics series. A description of the physics preparatory course offered at CSM from the course catalog is as follows:

> "**PHYS 150 PREPARATION FOR PHYSICS** Focuses on review of algebra and trigonometry required for physics; problem solving; study skills; and description of motion. Designed for students planning to take PHYS 210 or 250"

It is for these reasons that the STEM center at Cañada College began implementing a series of programs to help students progress efficiently and successfully through the engineering program requirements. These programs are Math Jam, Physics Jam and Supplemental Instruction. Math Jam has been discussed extensively in other publications [4] and thus this paper will focus on Physics Jam and Supplemental Instruction and the challenges faced implementing academic support programs at a two year institution.

2. Physics Jam

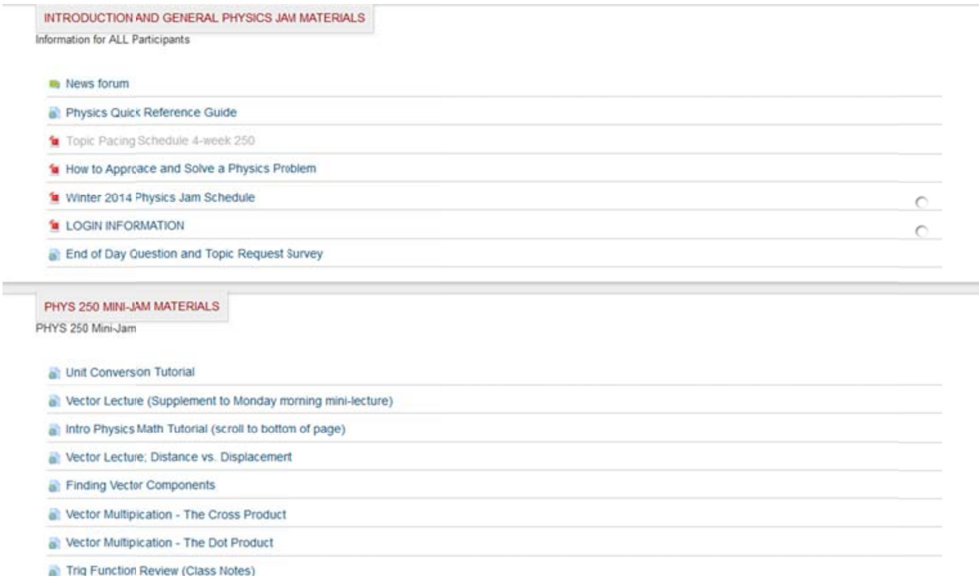
To help improve the retention and success rates in the calculus-based physics series an academic preparation program boot camp has been developed called Physics Jam. The focus of Physics Jam is to give the students the necessary mathematical based tools in the context of physics, and introductory physics concepts that they will need to be successful from the start of their physics course. From discussion with faculty at Cañada College the two major barriers that they perceived their students have are a poor understanding of trigonometry, which translated to a lack of understanding of physics concepts presented in the course, and general trepidation when approaching the subject. To address these concerns and set up a path of success for the students Physics Jam was developed.

Physics Jam involves the use of online resources to create a self-paced program with bench marks for the students to complete. The beginning of the physics jam is dedicated to math course work and this is accomplished by using MyMathTest (a Pearson online product.) Mini courses are created to target the specific math concepts that the students will be using in their upcoming course. A pre-test is administered involving the desired concepts to get an initial gauge for the student's level and what areas they will need to work on. Based on their performance MyMathTest recommends a study plan that has lessons and practice problems to help students master the concepts. An example of the topics included in MyMathTest for a first semester calculus-based physics class include review of basic trigonometry (trig) functions and applications of the trig functions as they are relevant to physics, a review of derivation techniques of basic and trig functions, and application word problems involving derivatives. For a second semester physics course integration and multivariable/double integration is also included. The aim is to choose problems and content that encourages students to think about the meaning of the mathematics so that they will be more comfortable applying it in their physics courses. Upon completion of the study plan, which will take a varied length of time depending on the student's current math level and learning abilities, students take a post-test to demonstrate their level of mastery on those concepts. After completion of the mathematics-based portion of the content students will begin applying their math knowledge to physics work.

The physics content of the program is contained in an online web environment. Before the first semester students begin their physics content they are given a concept pre-test to get a baseline for any previous physics knowledge that they may have. The standard Force Concept Inventory (FCI) developed at Arizona State University is used to assess the students. Special precautions are taken to administer the test based on the ASU specified parameters to allow for a consistent evaluation of student knowledge and progress. Once a statically significant number of students have taken the test this will allow for direct comparison of Physics Jam to other physics programs and courses. On the last day of the program students are again given the FCI to measure improvement. For the 2013 Summer Physics Jam students improved anywhere from 0-20% with an average improvement of 12%. Due to the small number of students that completed the program additional analysis of future students is needed to determine the actual effectiveness of the program. Additionally, to assess the incoming and outgoing physics concept level of the student tutors they were also required to take the FCI pre and post tests. For tutors that began with lower than a 95% average improvement was 18%. An unintended positive product of physics jam was the development of a core group of experienced, competent, and confident group of physics tutors for the upcoming academic year. Recruiting students to tutor physics is a challenge particularly at a two-year institution for a number of reasons including low student confidence in their ability to tutor and highly qualified students transferring to four year institutions shortly after they complete their physics curriculum. For non-transferring student tutors summer physics jam gives them the practice and confidence to be an effective tutor throughout the upcoming school year. Student tutors are essential to helping students with new physics concept knowledge.

Cañada College uses Moodle for its online learning communities and course contents. A specific Moodle course was created for Physics Jam and serves as the main content for the course. Sections are dedicated to the specific Physics course that the student plans on enrolling in the next semester. Modules have been created for each of the 3 introductory calculus-based physics courses, and the first semester introductory algebra-based physics course. A screenshot of a portion of the modules included on the Moodle site can be seen in Figure 1.

Figure 1: Screenshot of moodle site showing links to course content.



The modules include online videos, tutorials, and practice problems from various web sources such as Khan Academy, YouTube, HippoCampus, and Wolfram MathWorld. Students are allowed to proceed through these videos at a pace they are comfortable with and encouraged to reach certain benchmarks throughout the program to keep them on track. After students complete a set of video lectures over a specific physics concept such as kinematics or Newton's laws they will test and develop their knowledge on a set of online homework problems. Webassign assignments are used to give students instant feedback on their performance and get them used to submitting online homework for a physics course. This is usually where students begin to struggle because applying physics concept knowledge to homework problems is different than most homework from other courses in their academic history. It is crucial that the students have access to one-on-one or small group tutoring and instructor support to coach them about how to properly approach their physics problems. As has become evident a crucial part of Physics Jam are the student tutors who aid the main instructor to answer student questions and help the students understand how to approach learning physics and physics problems.

Physics Jam is offered multiple times during the year, and the timing and duration of the program has been evolving since its inception in Summer 2012. Physics Jam has previously been offered as an intensive continuous four week program over the summer. While effective in preparing students with a large amount of physics content for their upcoming semester the persistence of the students to complete the entire four-week voluntary summer program was low. Of the 17 students enrolled in the beginning of physics jam for summer 2013 18% completed the program in the entirety and 33% completed at least half of the program. There were a few reasons that can be attributed to the drop in attendance. First being that at least 40% of the students had not planned on taking physics the following semester or were not currently at an appropriate math level for an introductory physics course. This was fixed in the next iteration by having a mandatory question on the application requiring the students to report the physics course they are enrolled in next semester. The scheduling of the program in the middle of the summer also resulted in some scheduling problems for students that were taking summer classes, working, or going out of town. This has been corrected for summer 2014 by having two separate two-week long sessions at the beginning and end of summer to not conflict with summer courses and address student fatigue. Students will be given the option to take either two-week session as a mini-jam or both two-week sessions to allow for more content to be covered.

An additional mini Physics Jam was offered for five days prior to the start of the Spring 2014 semester to prepare students for their upcoming first and second semester calculus based physics courses. Targeted recruiting of students enrolled in physics courses for the Spring 2014 semester resulted in 26 participants in the physics jam program which constitutes the largest program to date. Due to the shortened time constraints the main focus for three out of the five days was an intensive math preparation with a small introduction to physics concepts for the last two days. The math concepts that first semester students focused on were basic trigonometry, vectors, and differentiation whereas the second semester students focused on a review of vectors and the cross and dot products as well as integration and setting up single and multiple variable integrals. Students were given pre and post math tests to evaluate the effectiveness of the program. The median improvement on post test scores was 25% for the 18 students that completed the program. Because of the abridged nature of the mini physics jam students did not cover enough material to have a useful evaluation by the FCI.

Development and implementation of Physics Jam at Cañada College is still in the beginning stages; however, we have already determined qualitative results from student exit surveys that students are more confident about their upcoming physics course compared to their initial feelings reported on the pre-program survey. Questions included in the surveys detail any previous physics experience, student reasoning for enrolling in program, student thoughts and feelings about upcoming physics course, and what they are hoping to get out of the program. All students that participated in and completed the Summer 2013 program received a B or better in their physics course, however at this point in time there is a need for more iterations of the program and student participation to have conclusive statistically significant results. Recruitment for the winter 2014 week long mini-jam has already improved over the summer session. All thirty participating students are enrolled in a first or second semester calculus based physics course for spring 2014. Special care was taken to directly recruit students that were signed up to take a course in the spring, or were currently enrolled in a qualifying course (Physics 1 or Calculus 1.) To increase enrollments campus-wide advertising was done via signage and in-person classroom visits to directly recruit qualified students.

3. Supplemental Instruction

The Cañada College STEM center began implementing Supplemental Instruction (SI) based on the University of Missouri-Kansas City model for transfer level math and physics courses during the Fall 2013 semester. Supplemental instruction has been widely used in 4-year institutions to improve course retention in traditionally difficult courses. The aim is to target "at-risk" courses instead of "at-risk" students to provide an in-class presence and out-of-class academic support. [5] [6] [7] Previously successful students serve as model students and attend class, and run three weekly study group sessions outside of class. The goal of the study sessions is to help teach students how to be successful in the course, and provide a low-stress and less intimidating environment for them to ask questions about course material. This program has been implemented with much success at four-year institutions across the country, however implementation of this program in the two-year setting includes a different set of complications that need to be addressed.

The typical two-year university student has less campus involvement, persistence, grit, and success when compared to their four-year university counterparts. [8] To effectively implement the SI program at a two-year institution these facts need to be addressed. Though still in its infancy, we have already come across and addressed a number of issues that are not necessarily encountered at a four-year institution. First is finding students that are qualified to serve as SI leaders. At four year institutions SI leaders are typically junior or senior level students with more course and student interaction experience. As such, the students that made the most effective (based on student participation and feedback) SI leaders at Cañada College were faculty recommended students who received an A in the course that they were an SI leader for, had an overall GPA of 3.5 or better, outgoing personalities, and the ability to convince students to attend their sessions. An overwhelming majority of students that attended an SI session for their course attended multiple sessions throughout the semester. Another obstacle to implementing a successful SI program is faculty participation. Students are most likely to attend the out-of-class study group sessions if they were encouraged by their instructor. Highest attendance occurred in classes where the instructors gave SI leaders assignments or worksheets to go over in their sessions. This becomes more difficult with adjunct faculty who are frequently commuting between multiple campuses to get a full teaching load and do not have extra time at the college to work with their SI leaders or create extra assignments. At Cañada College a third to 70% of instructors are adjunct or part time instructors as shown in Table 2.

Table 2: Comparison of number of Part-Time vs. Full Time faculty members at Cañada College for Fall 2013 Semester

Faculty	Full Time	Part Time (Adjunct)	Total	Percentage of Total Instructors that are Adjuncts
Chemistry	2	3	5	60
Math	7	16	23	70
Physics	2	1	3	33

It is also useful to consider the percentage of courses that are taught by part time adjunct instructors as compared to full time faculty. On average about half of all math (trigonometry and up), physics and introductory chemistry courses are taught by adjunct instructors as seen in Table 3.

Table 3: Comparison of the number of part-time vs. full time faculty members at Cañada College for Fall 2013 semester

Courses	Full Time	Part Time (Adjunct)	Total	Percentage of Total Course Sections Taught by Adjuncts
Chemistry	6	5	11	45
Math	24	28	52	54
Physics	8	1	9	11
Total	38	34	72	47

When determining which courses to target with SI the most effective in terms of attendance are courses that are taught by a full time faculty member or adjunct faculty member willing to dedicate a small amount (usually less than an hour) of time outside of course time each week to work with the SI leader. For the first iteration of SI at Cañada College, courses were chosen based on retention data for the course, and serving as a course that is part of the engineering curriculum. To determine reasons that students attended or did not attend SI sessions a broad survey was sent to all students enrolled in a course that had an SI leader. Questions on the exit survey were geared to both students that attended and did not attend SI sessions. The reason most commonly cited by students for attending SI sessions was to improve their grade or get help in the course. Students that did not attend SI sessions cited that they felt they were already doing well enough in the class or that the sessions were at a time that did not work in their schedule. This second issue will be addressed next semester with online scheduling of SI sessions to ensure that students that want to attend sessions from the beginning of the semester will have the most input on when the sessions will be. In the initial SI semester scheduling was based off the availability of all the students in the class and not weighted by likelihood to attend a session. Based on attendance records of the students and faculty reported in-class incentives students in SI courses students were most likely to participate in the SI sessions if they were strongly encouraged by the faculty, and given a specific task to complete in the SI session. Courses taught by faculty with higher average course scores had lower SI session turn out because the students did not have a desire to improve their grade beyond how well they were already doing in the course. On average, it is important to target courses/faculty with lower student course scores and higher drop rates.

The location and scheduling of SI sessions is also an important factor in determining student participation. At Cañada College SI sessions were held in study rooms in the STEM center to encourage students to make use of the other resources that the STEM center offers and develop comradely and study groups with their fellow students. This was advantageous because in the event that no one attended an SI session SI leaders could be out on the floor and serve as drop-in tutors for all students studying in the STEM center. This allowed for paid tutor hours to not go unused in courses with lower attendance. All SI leaders were also given the opportunity to serve as Drop-In tutors in the STEM center at times other than their study sessions. The SI leader tutors were frequently sought out by their class students to answer questions outside of study group sessions as well. Further analysis is underway to conclusively determine but it qualitatively appears as though students in courses with an SI leader sought out more tutor help from STEM tutors than in previous semesters without the SI leaders.

4. Conclusions

Students attending two-year institutions need extra incentive and encouragement to get involved on campus and promote their academic success. They are frequently under-prepared for STEM courses and this consequently leads to lower retention and persistence levels. There are many factors that need to be considered when implementing academic support programs. Student needs must be specifically targeted, such as trigonometry deficiencies for introductory physics, to effectively develop programs that promote student success. Additionally, special attention needs to be given to teaching students not just course concepts but how to study and be successful. As seen with the SI program special care also needs to be taken to involve faculty while being respectful of their time constraints. Exit survey data from students that have participated in Physics Jam and SI have demonstrated a positive attitude of the students to the programs and their impact on course performance however, further comprehensive analysis is needed and underway to develop a clear picture of student success as a result of participation in Physics Jam and Supplemental Instruction at Cañada College.

Bibliography

[1] R. &. S. P. M. Tai, "Success in Introductory College Physics: The Role of High School Preparation," *Science Education,* vol. 85, no. 2, pp. 111-136, 2000.

[2] R. V. A. Chait, "Improving Academic Preparation for College," *American Progress,* 2009.

[3] Joint Venture Board of Directors, "The 2013 Index of Silicon Valley," *Joint Venture Silicon Valley,* p. 36, 2013.

[4] D. H. C. W. B. P. D. R. L. a. Amelito Enriquez, "Creating Accelerated Educational Pathways for Underprepared STEM Students through an Intensive Math Placement Test Review Program," in *Proceedings of the 2013 American Society for Engineering Education Pacific Southwest Conference,* 2013.

[5] R. A. D. L. &. M. D. C. Blanc, "Breaking the attrition cycle: The effects of Supplemental Instruction on undergraduate performance and attrition," *Journal of Higher Education,* vol. 54, no. 1, pp. 80-89, 1983.

[6] R. A. &. M. D. C. Blanc, "Supplemental Instruction: Increasing student performance and persistence in difficult academic courses," *Academic Medicine: Journal of the Association of American Medical Colleges,* vol. 69, no. 6, pp. 452-454, 1994.

[7] T. J. &. J. J. Bowles, "The effect of Supplemental Instruction on retention: A bivariate probit model," *Journal of College Student Retention: Research, Theory, and Practice,* vol. 5, no. 4, pp. 431-437, 2004.

[8] T. R. B. a. M. Alfonso, "Paths to Persistence: An Analysis of Research on Program Effectiveness at Community Colleges," Community College Research Center, Teachers College, Columbia University, New York, 2005.