Assessment of student preparation for calculus-based mechanics
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Summary
In the Fall 2013 semester, the Department of Physics and Astronomy at San Jose State University pioneered an optional introductory physics course ("Physics 49") to improve student outcomes in the first semester of calculus-based physics ("Physics 50"). We present the outcomes of our first cohort of eighteen "49ers" and compare their outcomes with the 400 other students in Physics 50 who opted not to take the intro course. We also find that the correlation of FCI scores with the grade in Physics 50 is 0.6. FCI gains of 0.35 were achieved after moving to a larger lecture and enhanced lab, both of which include interactive engagement methods. Our long-term goal is to identify at-risk students before they get poor grades in Physics 50, and consequently to improve STEM graduation rates, which correlate strongly with the grade in Physics 50. SJSU is a 30,000-student public university that serves the Silicon Valley area of California.

Physics 49 and 50
Physics 50 is the traditional calculus-based mechanics course taken by engineering and physical science majors at SJSU. This course covers dynamics and kinematic of particles and rigid-bodies, statics and simple harmonic motion. The text we use is University Physics by Young and Freedman. The only pre-requisite for the course is a C- or better in Calculus 1. Derivatives are used a little bit in Physics 50; integrals are used only at a conceptual level.

In Spring 2014, approximately 420 students were enrolled in this course. 18 of them had taken Physics 49 in Fall 2013. Physics 49 is a new course designed to ease the transition into the physics sequence by going very slowly over the first five chapters of the book, up through Newton’s Laws, instead of 12 chapters covered in 50.

While high school physics and college-level general education physics courses are somewhat helpful, Physics 49 was created based on anecdotal observation that the high failure rate (>30%) in Physics 50 occurred because students did not anticipate the fast pace, high expectations and demanding quantitative nature of the course, or perhaps even their major. Those in trouble often confessed "I thought it was just plug and chug," or "I got an easy A in high school physics, so I figured ‘how hard could this be?’"

The students who fared poorly were typically those who were not proficient with basic pre-requisite material from Day One, including simple trigonometry and interpreting graphs. They got behind immediately and never caught up.

Transcripts also contained the harbingers of trouble in Physics 50. Students who had previous D’s or F’s in science or math classes, and those who had ever required remediation in either English or math, were advised to take Physics 49.

Figure 1 (left). The grade in Physics 49 is a strong predictor of the grade in Physics 50. N = 18. The solid line is y = x. The correlation coefficient is 0.7. A = 4, B = 3, C = 2, D = 1, and F = 0. and – grades are 0.3 above and below the entire grade (e.g. C+ is 2.3, and C- is 1.7). C- is the minimum grade to meet major requirements and pre-reqs for future courses. All except 1 who got C- or better in 49 got C- or better in 50. 3 of the 4 students who got D in 49 got F in 50; one went from D to C+. 11 students got a lower grade in 50 than in 49; 7 improved. The median grade change from 49 to 50 was -0.35 (e.g. from a C+ to a C, or B- to C-).

Figure 2 (left). Normalized gain vs. pre-test score of SJSU’s students from prior assessments of SJSU’s traditional lecture sections of 45 students/section (<2010) and in the new IE large-lecture format with 200 students per section, where the normalized gain was 0.35 as shown in Figure 3. These data are shown along with data from other high schools, colleges and universities (Hake).

Figure 3 (right). Normalized gains for Physics 50 in Fall 2013. This was the first attempt at IE in a large-lecture format. Half of the 400-student enrollment was taught in traditional lecture and lab format, the other half was in a single large lecture of 200 students with an enhanced lab. Lab for these students was "traditional" except with weekly proficiency quizzes on core topics, which the students had to repeat until they mastered the topic (as opposed to simply "passing" it). Also, these students had three review sessions in lab, which were problem solving sessions facilitated by the lab instructor.

Figure 4 (above). FCI scores for Physics 50 in Spring 2014. All 400 students were taught in the large lecture format (200 students/lecture). All students took the enhanced lab as described in Figure 3. Average normalized gain was N = 284.

Figure 5 (above). Normalized gains for Physics 50 in Spring 2014. All 400 students were taught in the large lecture format (200 students/lecture). All students took the enhanced lab as described in Figure 3. N =284.

Conclusions
The introductory course, Physics 49, seems to be accomplishing its aims by predicting, and also improving, outcomes in Physics 50. The move to a large-lecture format with an enhanced lab, both using elements of IE, substantially improved FCI outcomes over those obtained with traditional small-lecture and lab. Exam (and also course) grade correlates with FCI post score. Future work will focus on improving the passing rate in Physics 50 and retention of students in STEM disciplines.

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