

# Adaptation and Implementation of a Radically Reformed Introductory Physics Course for Biological Science Majors: Assessing Success and Prospects for Future Implementation

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**Abstract.** The physics department at California State University San Marcos has nearly completed work on an NSF CCLI-A&I funded project to adapt and implement UC Davis' reformed introductory physics course for students in the biological sciences. As part of the project, a group of physics instructors met to discuss criteria for measuring the implementation's success and the feasibility of implementing the course at other institutions. Criteria for measuring success fell into three areas—student outcomes, institutionalization of the course, and adherence to the original course's core philosophy. This paper describes the criteria in more detail, presents data for outcomes already measured, and discusses the challenges of measuring other outcomes. Finally, the paper briefly discusses the likelihood of instructors at other institutions meeting with the same or better success at implementing the course.

**Keywords:** curriculum adaptation, curriculum implementation, course evaluation

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## INTRODUCTION

For the last two years, after a two year pilot project, the first author has been formally adapting UC Davis' reformed introductory physics course<sup>1</sup> and implementing the course at California State University San Marcos (CSUSM). As part of an NSF CCLI-A&I funded project, the authors are assessing the success of this adaptation and implementation. While student achievement outcomes provide an obvious starting point for assessment, other factors like the sustainability of the course can be considered when assessing whether implementation of a reformed course was successful. This paper discusses some possible criteria for measuring success and some challenges specific to evaluating an adopted course, as well as presenting some initial results. Many of the ideas presented were generated at a workshop held to gain additional perspective on the success of this course implementation and to explore the feasibility of further implementations at other institutions. Participants included physics instructors from the University of California system, the California State University system, and the California Community Colleges system.

Table 1 lists criteria distilled from discussion among the instructors who met. In assessing a transferred course the most fundamental question is whether or not the course benefited students. In addition to various student achievement outcomes, the group wanted to see improved communication skills and better attitudes toward physics (both affective and epistemological).

This group recognized, however, that any student gains arising from a reformed course would be lost if the course “died” or reverted, so a number of criteria relating to the institutionalization of the course were identified. One of these criteria is stable enrollment, especially if students can choose alternative sections to avoid the reformed course. Other criteria related to course stability had to do with faculty resources—the original adopter's ability to continue teaching the reformed course and the existence of other faculty willing and prepared to teach the course. Acceptance of the course—within the department, at higher administrative levels, in other departments (biology, in particular), and at other institutions—would also help ensure course permanence. Finally, idealistically, the course would have some sort of impact on the institutional culture, possibly encouraging others to teach with a more student-active format.

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Fidelity to the original course was the one criterion specific to an adapted course, as opposed to a new reformed course. This could include adherence to the core philosophies of the course (based in constructivist learning theory, in this case). Structuring the course so that less time was spent for lecture and more time for discussion/lab was a primary concern for the course originator present at the meeting. Others at the meeting thought that facilitation style would be important, but that a broad range would be acceptable.

Many of the criteria described above lack commonly used and accepted measurement methodologies, let alone benchmarks for success. Predicting instructor burnout or determining how fully the administration has accepted the course require creative measures. Even some of the student outcomes, like degree of cooperation and sophistication of discourse, are studied rarely enough to make choosing a method of measurement and comparing to other courses difficult. Also, deciding on an appropriate benchmark for measuring success presents a challenge. Should results be compared to the original UC Davis course, the prior CSUSM course, other traditional and reformed courses, or an established benchmark for success? For this project, the answer to the question varies for each student measure and is based more on the availability of data than on consideration of which comparison would be most appropriate. With these issues in mind, the next sections present the work that has been completed and plans for future study.

**TABLE 1.** Suggested criteria for assessing an adaptation/implementation, with data already collected and to be collected (in parentheses) for this project.

| Criteria                              | Data Available                  |
|---------------------------------------|---------------------------------|
| <i>Student Outcomes</i>               |                                 |
| Achievement                           |                                 |
| Conceptual understanding              | FCI, CSEM, grades               |
| Problem solving                       | Observation                     |
| Reasoning skills                      | Observation, interviews         |
| Communication/Interaction             |                                 |
| Degree of cooperation                 | Observation                     |
| Sophistication of discourse           | Observation                     |
| Affect                                | Student evaluations, interviews |
| Attitudes/Beliefs                     | CLASS, observation, interviews  |
| <i>Institutionalization of Course</i> |                                 |
| Course permanence / stability         |                                 |
| Enrollment stability                  | Enrollment records              |
| Adopter's enthusiasm / endurance      | Personal opinion, interviews    |
| Involvement of other faculty          | (Interviews)                    |
| Acceptance of the course              | (Survey, interviews)            |
| Impact on local culture               | (Survey, interviews)            |
| <i>Fidelity to Original Course</i>    |                                 |
| Curricular materials                  | Course records                  |
| Structure (use of time)               | Course records                  |
| Facilitation                          | Observation                     |

## METHODS

The course being adapted is based on a non-traditional introductory calculus-based physics course for students in the biological sciences [1]. It follows a non-traditional content sequence, beginning with energy conservation rather than kinematics, and has a reduced emphasis on mechanics. Other topics include kinetic theory, waves, pressure and flow, and electricity and magnetism. The topic areas are organized around physical models (e.g., conservation of energy and flow with dissipation) with continued explicit emphasis on the nature of these models and on how to apply the models to solve problems. No standard textbook is used, but rather a set of notes developed by the course originator at UC Davis.

As implemented at CSUSM, there is one instructor who meets with the students twice weekly, with each class meeting lasting 3 hours. This differs from the UC Davis course, which has two 2.3-hour teaching assistant led discussion/labs and one separate 80-minute lecture per week. The students work in an active learning environment with a small amount of lecture woven in. In a typical class meeting, students participate in a number of activities that are about 1 hour in length. Students work together in groups to respond to a series of prompts and then report their responses to their peers in a whole class discussion. Total lecture time is about 1 hour and 15 minutes per week and is used mainly to organize the students' ideas about phenomena they encountered in their group activities.

At CSUSM there are typically 25 to 30 students enrolled in each section of the course, the majority of whom are juniors and seniors. Many are transfer students from community colleges. Most take physics later in their academic career than is suggested by their recommended course schedule. All have either taken calculus or are taking calculus concurrently. The class is ethnically diverse, and often students are the first generation in their family to attend college. Over the course of the implementation, 60% of the students were women.

Students take quizzes every two weeks (every week for the UC Davis course). Quiz questions always emphasize applying the model to make inferences, and students are expected to back up all claims with textual or mathematical arguments. The instructor develops a rubric for each question after reading through a number of responses.

Students have completed two common tests of conceptual understanding—the Force Concept Inventory (FCI) [2] and the Conceptual Survey in Electricity and Magnetism (CSEM) [3]—and the Colorado Learning Attitudes about Science Survey

(CLASS) [4]. The FCI was given as a pre- and post-test during Spring, 2005 and 2006. The CSEM was given as pre- and post-tests in Fall, 2005. Results from the CSEM data are in the process of being analyzed, while CLASS and FCI data are available as of this writing. The CLASS survey was given in Spring 2005 and Spring 2006; Spring 2005 data is presented in this paper.

Qualitative analysis of the implementation will be the subject of a future publication, but we briefly mention the procedure used here for the benefit of others planning to assess an adopted course. Data included field observation and videotaping of 6 classes, interviews with students (four times during the year), and regular interviews with the instructor during the two-year implementation period. These data were analyzed to look for emergent themes relating to both student outcomes and the role of the instructor.

## RESULTS AND DISCUSSION

### Student Outcomes

Attitudes toward science and sophistication of discourse improved noticeably, while conceptual gains were present but unremarkable. Matched pre-post CLASS data (N=20) indicated a positive shift in the number of favorable responses for 30 out of 36 questions. This shift was distributed across the 7 belief categories. The average percent of favorable responses increased from 52% to 65%. No CLASS data currently exists for the UC Davis course, but compared to other reported data, the initial favorable percentage is lower and the increase is greater [5]. Because physics courses have had a reputation for causing negative shifts on attitude surveys, any positive shift points to success in the course.

Qualitative analysis of video, observation, and interview data gave further support to the attitude shifts evident in CLASS survey results. Students were more likely to work as a group, keep thinking and trying when solutions weren't obvious, focus on the big picture, and apply models than they were before. They also became better at articulating their thinking. More detail on this qualitative analysis will be presented in a future paper.

Initial FCI scores from Spring 2006 (N=26) were quite low (28% correct). The normalized gain for the class (0.3) is comparable to that seen for students in the UC Davis course and is in the middle range relative to other classes (reported in Hake, 1998) with that initial score [6]. Relative to other reformed classes, the gains are not particularly high, but considering the small amount of time given to

mechanics (7 weeks) this result is not surprising. As more concept inventories are developed, validated, and used on large numbers of courses, fair assessment of this and other reformed courses that emphasize topics other than mechanics should become easier.

Future data collection efforts may include other concept inventories and analysis of quiz questions identical or very similar to ones used in the UC Davis course in the past. While differences in student populations would make comparisons difficult, this data could still be useful. A more ambitious, and possibly more revealing, instrument would be one aimed at assessing the sophistication of student discourse. Qualitative observation data from this study could serve as a springboard to development of such an instrument.

### Other Outcomes

In general, the opinion of those involved in this project is that the institutionalization and fidelity criteria have been met fairly well. For these criteria, however, no standard measures of success exist. Thus, we present what information we have and our plans for gathering further information.

Course enrollment data is available for the initial two-year pilot and the two years of formal adoption. During this period enrollment has grown from 17 to 46 students. It should be noted that while this is the only course designed for students in the biological sciences, students can take the standard introductory physics sequence which is offered in a more traditional lab and lecture format. Based on end of semester evaluations, students appreciate the course. Sixteen out of 35 "strongly agreed" that the "Overall quality of the course is high" in the first semester of the course during Spring 2005 (30 out of 35 at least "agree" with this statement). In the second semester during Fall 2005, 18 out of 41 "strongly agreed" that the "Overall quality of the course is high" (35 out of 41 at least "agreed" with this statement). Further investigation into student opinions about the course is in progress. Over the course of the pilot and formal implementation, the number of students needing to repeat the course due to low grades (C- or below at CSUSM) is 10%.

No complaints from the department, university administrators, other departments, or other universities have been received. The administration has shown support by offering course release time, which was essential for the project. Since the implementation, chemistry instructors started using wipeboards in an upper division physical chemistry course after seeing them in this course, and the physics department is currently reworking standard calculus-based physics

labs. As information on acceptance of the course and impacts on local culture currently consists of unsolicited anecdotal information, data in the form of brief surveys or interviews with faculty and administrators will be collected.

So far the first author is the only CSUSM faculty member who has taught the course. Having observed the difficulty many graduate student instructors have in adjusting to the changing role of the instructor in this course, we question whether an instructor “coming in cold” would be able to achieve the same success as the adopter. The adopter plans to gradually involve other tenure-track faculty in the course to ensure course longevity.

Regarding fidelity of the adaptation, the originators of the course foresee allowing some latitude for institutions adapting and implementing the course, and those at the meeting agreed that the CSUSM course fell within the acceptable range. What exactly constitutes fidelity to the course proved to be a more difficult question. A range of facilitation styles, re-ordering of topics, and use of time could be acceptable when applied within the basic philosophy of the course. At the extremes, straying from the basic philosophy would be easy to spot, but otherwise this criterion could prove difficult to measure. Other adapted courses might require more fidelity to the original course and thus this criterion might be more important and easier to measure than it is in this case.

## CONCLUSIONS

The CSUSM course has had positive student outcomes, is on its way to becoming a stable presence at the university, and has inspired change in other courses. Does this mean that others could adopt the course at their institutions with similar results? At this point, “it depends,” seems to be the most appropriate answer. While this adopter faced structural hurdles such as scheduling two labs weekly for each section while avoiding scheduling conflicts with other courses, he was also uniquely qualified to implement the course. Having taught the course at UC Davis for 6 years, he was familiar with the discussion/lab activities and the rubric method of grading quizzes. He also has worked to develop a facilitation style that is challenging yet fun for students.

We doubt that an instructor without experience teaching in an active-learning setting could take written material from the UC Davis course and adapt it with the same success as the first author. The ideal method for preparing future adopters would be an apprentice model like those that have worked at UC Davis (for faculty new to the course and graduate student instructors).

For others considering assessing an adaptation and implementation project, we would like to emphasize how useful it was to involve colleagues from the education department. A non-physicist may notice strengths and weaknesses that an experienced physicist would overlook. Also, we note that long term assessment projects would be useful to support, given that some student benefits may come to fruition well after students leave the course.

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