Sustaining Change: Instructor Effects in Transformed Large Lecture Courses

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Abstract. We investigate the transfer of classroom reforms from PER faculty to more traditional physics-research faculty. This study is part of an ongoing effort to assess necessary and sufficient requirements for success with research-based course transformations. We have previously demonstrated the ability of PER faculty to replicate the success that other researchers achieve when implementing research-based reforms in large, introductory calculus-based physics courses. Here, we present new data from four implementations of Physics II, including quantitative and qualitative measures of successful transfer of courses to new faculty: validated pre/post surveys covering content, assessments of student views about physics and learning physics, and informal affective surveys. We investigate questions of sustainability, reproducibility, and instructor effect through a contextual constructivist theoretical lens, and find that replication of research-based results is possible, but a variety of factors including instructor beliefs and institutional constraints play important roles.

Keywords: course transformation, replication, course assessment
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INTRODUCTION

Successful transformation of a physics course requires more than the initial implementation of research-based tools and practices. Questions of sustaining and replicating these course changes are central to the study of course transformation. At our institution, the University of Colorado at Boulder (CU), we have begun transforming our introductory calculus-based sequence with the explicit course goals of developing student conceptual understanding and supporting constructive beliefs about the nature of physics and learning physics. Once course changes are implemented, there are two main approaches to sustaining course transformations: 1) establish a dedicated set of faculty to continue the new practices, and 2) develop a mechanism for including the broader array of departmental faculty to engage in the new course structures. Our approach follows the latter strategy. There is considerable folk knowledge about the significance (or lack thereof) of instructor effects, and related issues of teacher-proof curricula, but questions about sustainability and transfer of educational reforms are not sufficiently well understood from a theoretical perspective [1,2,3]. We present new data from our ongoing implementation of Tutorials[4], Peer Instruction with personal response systems[5], and computer homework systems, in order to document the success of handoff, to demonstrate the importance of particular curricula, and to further investigate the importance of the role of the instructor.

In previous work [6,7] we investigated replication and essential features of the multiple reforms and the dynamics among them in Physics I, followed by an investigation[8] of transfer and replicability of Physics II to faculty who were also involved in PER research. Here, we present new data which follows Physics II as traditional research faculty teach in this environment. We demonstrate successful handoff of curricular reforms; students demonstrate significant conceptual gains, sustained productive beliefs about physics and favorable attitudes towards the course. However, these successful outcomes are not guaranteed or uniform. While a myriad of factors influence classroom practices and outcomes, these data suggest that there are at least four critical factors shaping the success of course transformation: institutional support, faculty beliefs and practices, curricular tools, and the students themselves.

BACKGROUND/ENVIRONMENTS

Phys 1120 is the calculus-based E&M course at CU. There are three 50-minute lectures per week. All terms studied here used ConcepTests[5] with peer discussion in class. All weekly recitations were replaced with Washington *Tutorials*[4], including weekly online Tutorial pretests and hand-written/hand graded homework, as well as traditional end-of-chapter problems using one of two computer systems [9,10]. For the Tutorials, graduate student TAs teamed with undergraduate Learning Assistants (LAs) [7,11], all of whom attended weekly preparation sessions following the University of Washington model.

To compare courses, we collected three principal types of data. A pre/ post conceptual exam, the BEMA[12], was administered in the first and last weeks of the term. A pre/ post research-based survey on student attitudes and beliefs about learning, the CLASS[13], was administered online. Finally, informal surveys were given online to collect students' opinions about the value of course elements at the end of semester. Courses at CU are dependent on individual instructor choices; a summary of some key features and differences among the four terms of implementation are presented in Table 1. In general, this course has a "lead" instructor (who lectures) and a "secondary" instructor in charge of recitations, many course administrative details and background work.

Term:	**Fa04**	**Sp05**	**Fa05**	**Sp06**
Lead Prof:	A	B	C	D
Secondary:	B	C	(none)	E
# Sections/ # Students:	2/479	1/333	2/455	1/365
Text:	HRW[14]	RK[15]	RK	RK
Homework system:	CAPA[9]	CAPA	CAPA	MP[10]
Faculty in PER?	A & B	B	(none)	(none)
Faculty in TA Prep?	A (start) & B	B (start) & C	C & lead TA	E & lead TA

TABLE 1. Summary of administrative, curricular and instructor backgrounds in the four consecutive implementations of this reformed course.

To summarize: Prof's A and B, both involved in PER, implemented Tutorials and ConcepTests Fa04. Prof. B attempted to closely replicate the course the following term (except for switching to the Knight text [15]), helping Prof. C (a traditional instructor assigned to the course) who quickly took over the Tutorial preparations. Prof. C took over the entire class the next term, his first experience ever teaching a large lecture course. He attempted to keep all materials (including lecture notes, homeworks, etc.) essentially unchanged from the previous term. He was assisted in running Tutorial preparation sessions by a new PER grad student, who had not yet run Tutorials on her own. The fourth term, two new (non-PER) faculty participated. Lecture notes were completely rewritten to utilize PowerPoint, and the online homework system was switched to Mastering Physics [8]. The same lead TA assisted the new professor in Tutorial preparations. A "book" of materials and suggestions was prepared by Prof. A to assist in those sessions. Roughly half the TA's from any given Fall term return to TA the following spring, and more than ¾ of the LA's are new each term.

DATA

Results of the conceptual assessment are shown in figure 1. The first two implementations replicated one another closely (59% posttest, statistically indistinguishable) [8]. In Fa05 the post-test average of 50% demonstrates successful achievement (high by national standards [12]), though is a statistically significant decline from the prior semesters' scores. The final distribution from Sp06 is visibly similar to the results from the initial implementations, although closer examination reveals fewer students on the high end of the distribution, and a density of students in the lower end, resulting in the 53% posttest average..

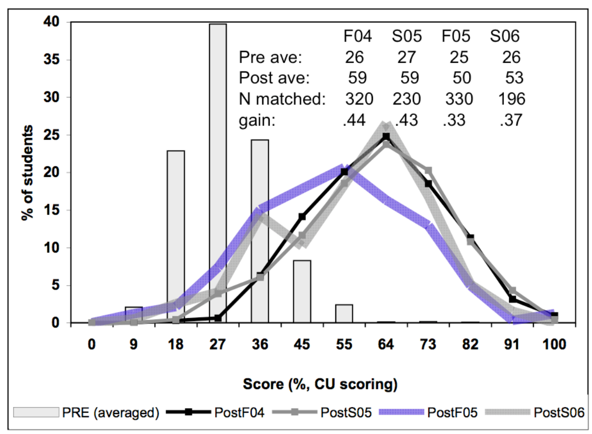

FIGURE 1. Histograms of BEMA[12] pre and post tests. (Pretests are very consistent, so averaged data are shown.) Data from the first two implementations (with PER faculty) are nearly identical, shown as solid lines; data from next two courses (with non-PER faculty) are shown with broad lines.

Student attitudes and beliefs about physics and the learning of physics were assessed with the CLASS survey[13]. A summary of the post-pre shifts in percent favorable response is shown in figure 2, for overall score and the "conceptual connections" sub-category. (Pretest scores are shown numerically to the side of the figure.) The courses mostly exhibit relatively small negative shifts (much smaller than the double-digit negative shifts generally observed in traditionally-taught courses [16]). The third semester (which scored lowest on the BEMA content survey) also shows the most negative CLASS trends.

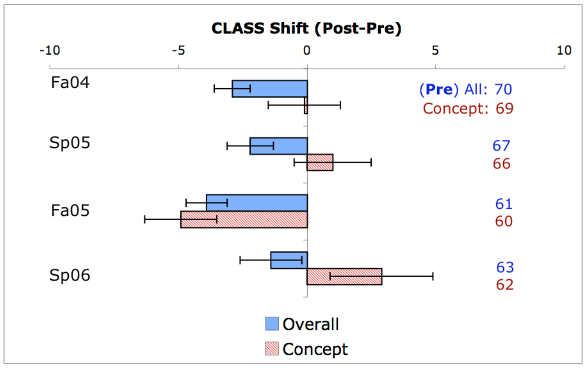

FIGURE 2. CLASS [13] shifts in pre to post favorable scores. Matched students, in overall score, and "conceptual connections" sub-category. Semesters are labeled on the left, numbers on the right indicate average pre-test scores

Fig. 3, summarizes some student opinions from the four course implementations, measured with an end-of-term online survey. Five questions surveyed students' ratings of: (1) how much they learned in lecture and (2) in tutorial, (3) how much they enjoyed lecture and (4) tutorial, and (5) overall rating of course. Responses were provided on a five-point scale. Fig. 3 shows student responses answering non-negatively, i.e. in the top 3/5 response categories. Students' affective responses are consistent across implementations, with small variations consistent with those seen in conceptual (BEMA) and CLASS scores.

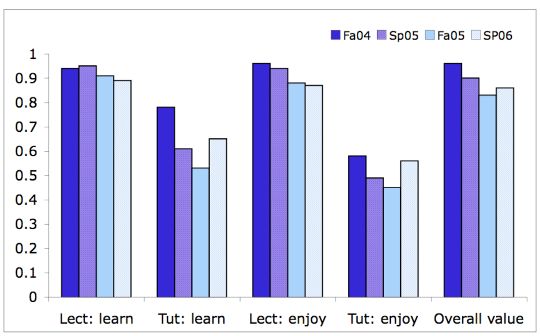

FIGURE 3. Online affective survey at the end of the terms, showing students' % neutral or positive rating of learning and enjoyment in lecture, Tutorial, and the course overall.

DISCUSSION AND ANALYSIS

To identify the factors that influence the success of these course transformations, it is helpful to compare the various conditions of implementation from a contextual constructivist perspective [7,17]. Contextual constructivism uses *frames of context* to help identify the particular factors that shape (and are shaped by) student learning. From this perspective we may identify four, roughly nested, frames of context that affect the success of the course transformation at CU: institutional level of support, faculty beliefs and background experience, curricular tools that are used in practice, and the students' background. These frames are nested in the sense that student background knowledge is evoked by tasks that are part of the curricular structure. The curricula are selected and framed by the instructors and their beliefs about the course. The instructor too is bound by institutional framing. Of course these frames are highly interacting, and neither strictly hierarchical nor mutually exclusive [17]. We compare the four implementations of the course transformation and use these frames to identify variation in application and success.

From the first implementation (Fa04) to the second (Sp05), we note that the institutional structure remains relatively constant– the number of faculty assigned to the course, the number of students per lecture section. The faculty have similar backgrounds: both have extensive experience in the introductory sequence, are involved in PER, and understand the underpinning philosophy and approaches to the curricular innovations. The course tools are very similar, with the mild exception that the textbook changed.[1] The other course elements, Tutorials, Peer Instruction, the homework system, and use of the web are very similar. Finally, the majority of the students in this course had arrived from a partnering mechanics course. In these two cases, the activities in the prior semester were similar in character, using PER-based materials. Notably however, the students in the Sp05 implementation had used the Knight workbooks [15] in recitation the prior semester, rather than Tutorials (which had been used for the Fa04 students' prior semester). Ultimately, we observe that these two courses are indistinguishable in terms of conceptual gains, shifts in students' beliefs about physics and learning physics. The one notable distinction is that students are less positive about the Tutorials. It is possible that this results from students' lack of prior experience with the Tutorials, or the new instructors slight de-emphasis of Tutorials in lecture and exams.

The second transfer of teaching responsibility occurs from Sp05 to Fa05. In many senses Fa05 is the highest fidelity form of replication from the prior semester. The tools from the prior implementation (Sp05) were used in as similar a fashion as broader constraints allowed. Lecture notes, ConcepTests, Homework sets, and Tutorials were nearly identical. Significantly, however, this implementation of the course is the only instance when a *single* faculty member is assigned to teach the entire course. This institutional constraint limits the amount of time the faculty member can spend on the course. While dedicated to the course, the work-load of this

[1] Because students generally do not read the text as assigned [19], it is unclear as to whether this would impact student achievement.

instructor is higher than any other instantiation. The institutional constraints are further exacerbated by the fact that this implementation is the first time this instructor is teaching in a large-scale environment. Nonetheless, this faculty member is committed to the endeavor, trained with the lead instructor the prior semester, and begins to adopt many of the beliefs favored by the PER community [18]. The students arrive from a course the prior semester that did not make as much use of PER materials as either of the prior implementations. Despite the limitations in institutional support, faculty background, and student prior experience, we do find measures of success that are considered significant by national standards [12]. Students post significant conceptual gains, show modest declines in their beliefs, and have generally favorable attitudes to the course and Tutorials. These successes may in part attributable to the materials and the faculty commitment.

The final transition occurs with a handoff of the course from Fa05 to Sp06. In many respects, the Sp06 incarnation is a mixed state of the initial implementations (Fa 04) and the more recent (Fa 05) implementation. The institutional support of the course transformation returns to standard level– two assigned faculty. The faculty themselves have no background in PER, nor have they trained in use of the PER tools. However, a variety of support structures (PER faculty discussing the reforms, the locally developed guide materials and a Lead TA) exist to facilitate their use of these tools. The actual curricular tools are largely the same, though lecture notes are re-written (and put into PowerPoint) and the homework system, Mastering Physics, is based on research. The students come into the course with similar backgrounds as the Fa05 cohort – less familiarity with PER tools, and specifically, no prior work with Tutorials. Overall success appears to be a mixed state of the prior implementations. Student conceptual achievement is high, falling between the first implementation and the last implementation. Interestingly, students post the most favorable beliefs in this course, which may be due to the instructors' commitments and framing [18], the new research based text and homework system, or likely, a combination of these factors. Student affect is generally favorable and again a mixture of the prior cases of implementation.

CONCLUSIONS

A comparative analysis of each of these implementations of course transformation suggests two conclusions: 1) new faculty can be brought in to transformed courses, potentially allowing for sustainable success of these reforms, and 2) there are many contributing factors affecting success, including: institutional commitment, faculty background, the tools and practices used, and the students themselves. While these findings may not be surprising, and are consistent with findings in prior research in PER, these results demonstrate some of the intricate relations of these components in real-world settings of large-scale classroom instruction in physics.

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