Evaluating a model of research-based practices for teacher preparation in a physics department: Colorado PhysTEC

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Abstract. We describe and evaluate the first year efforts of the Colorado Physics Teacher Education Coalition (Colorado PhysTEC), which is designed to increase the number and quality of preparation of future pre-college physics teachers. The Colorado PhysTEC program partners the Department of Physics, the School of Education, and other University of Colorado programs (particularly STEM-Colorado), with local schools and K-12 physics teachers. We report on efforts to engage students in transformed teaching practices, programs to create educational partnerships among all of the participants, and research that documents local educational practices and larger features of sustainable and scalable educational transformations.

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INTRODUCTION

Over the past several years, the University of Colorado at Boulder (CU-Boulder) has dramatically expanded its efforts to recruit and nurture the highest caliber future high school physics teachers. With the formation of the Physics Education Research Group at Colorado (PER@C)[1], the STEM-Colorado Teacher Preparation program[2], and the newly initiated Physics Teacher Education Coalition (PhysTEC)[3], CU-Boulder has brought together faculty and students from the Department of Physics and the School of Education to partner with local pre-college teachers, informal science educators, and K-12 students.* This collaboration has provided a rich venue for research, support for local communities and classrooms, and a coordinated recruitment, preparation and induction program for future K-12 teachers. One of the hallmarks of the CU-Boulder program is that the preparation of future physics teachers begins in the physics department. Not only do undergraduate students have the opportunity to engage in teaching experiences early in their studies, but also our approach emphasizes the modeling of best teaching practices in the undergraduate physics courses. Thus, we purposefully blend the mastery of physics content, pedagogy, and authentic practice.

The local efforts couple with the national PhysTEC initiative[4], which is designed to create a network of institutions and programs seeking to achieve these same objectives: to help produce more and better prepared physics and physical science teachers. The national PhysTEC program is a joint effort of AAPT, AIP and APS formed to address this nationally recognized need for teachers. According to the PhysTEC program[4] the project's goals include, "a) establishing a network of institutions that are deeply engaged in the science preparation of future teachers, b) providing compelling evidence of the importance and success of ideas and components central to preparing science teachers, c) engaging physics and education faculty in collaborating in the preparation of these teachers, and d) using the joint resources of the AAPT, AIP and APS to promote and disseminate these ideas and programs."

The Colorado PhysTEC project seeks to:

- increase the number and improve the preparation of students who go into physics teaching;
- transform the introductory physics sequence (to model new pedagogical practices, increase student ability and interest in physics);

* These efforts build on longstanding commitments to education at CU, including the Wizards Program, the Saturday Physics Series, CU Science Discovery, and the pioneering work of many scholars including Frank Oppenheimer, Al Bartlett, John Taylor, and many others.

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- build faculty awareness and application of productive educational practices, and to increase faculty support of teaching as a career;
- develop these efforts and links with synergistic programs in a sustainable (and scalable) manner;
- conduct research on each of the above issues – both the specific, e.g., how do students interact with computer simulations? and the broader: e.g., what is the nature of these structures? What does it mean to replicate successful programs?

COLORADO PHYSTEC PROGRAM

The Colorado PhysTEC program is a model of coordinated courses and practices of induction, community partnership, and research. The effort links several existing programs, including an NSF CCLI, the STEM-Colorado Teacher Preparation program, and the newly developed physics education research group at Colorado. By coordinating these efforts we aim to provide students a suite of structured activities to support their induction into teacher preparation, create strong partnerships with local community programs, and conduct research on the nature and success of such efforts.

Student Engagement

Our program is designed to provide students multiple pathways of participation. We present students with a series of educational experiences that model productive practices in physics education, as well as provide opportunities for researching and studying these practices.

As part of PhysTEC and an NSF-sponsored course reform effort[5], we have introduced *Tutorials in Introductory Physics*[6] into the physics-majors' sequence, and observed increased student mastery of content and improved attitudes and beliefs about the subject and educational process.[7,8,9] The success of the reforms has required additional staffing of the Tutorials which has been supplied in the form of undergraduate Learning Assistants (LAs). LAs are usually students who have just completed the introductory sequence. The LAs support the Tutorials by playing a role of "learning coach"– asking guiding questions in a Socratic manner without explicitly explaining the answers. Each week, the LAs participate in the standard Tutorial preparation session (where they focus on specifics of conducting the Tutorial for the coming week), and in either a course in the School of Education (ARSC 4040) or a course on teaching and learning physics. The STEM-Colorado program, which developed and supports the LA-model, requires that all first-time LAs participate in ARSC 4040 to introduce them to educational issues, learning theory, instructional techniques, and experiences working in K-12 schools; the LAs receive course credit in the School of Education. Meanwhile, physics majors and graduate students interested in teaching and educational practice can enroll in a new course: Teaching and Learning Physics[10]. This course, often recruiting from the pool of LAs, engages students in study of physics content (paralleling the introductory sequence), study of theories and practices of teaching and learning in physics, and fieldwork opportunities where students teach and conduct classroom research projects. The course has been shown to increase students' grasp of physics, improve understanding of education, and increase the likelihood of going into teaching.[11] While these programs are sequenced, where the LA program follows the introductory courses, and Teaching and Learning Physics follows the STEM LA program, students are encouraged to engage in these activities at any and all stages they choose. By having students cycle through the activities (e.g., LAs direct the Tutorials they had participated in as students, and often repeat as LAs) they support the programs themselves, build communities of education and teaching, and develop interest and facility in teaching.

Educational Partnerships

A core element of the Colorado PhysTEC program (and all PhysTEC endeavors) is an emphasis on strong partnerships among existing educational efforts: the STEM-Colorado program, several programs within the Department of Physics, and local high school teachers and schools.

The Colorado PhysTEC Program has been able to build on STEM-Colorado's program which coordinates four STEM departments and the School of Education at the University of Colorado with a focus on teacher preparation in science. The goals of STEM-Colorado include reforming introductory undergraduate courses to emphasize student- and learning-centered approaches, enhancing the use of technology within the courses, and utilizing trained undergraduates (the LAs) to assist the instructors in facilitating student learning As part of the STEM-Colorado and PhysTEC grants, a high school science teacher is supported as a Teacher in Residence (TiR) to work with the faculty in a variety of areas including collaboratively conducting courses, ARSC 4040 and Teaching and Learning Physics.

The programs have grown to include summer workshop experiences for local high school teachers. During our first summer workshop about 20 teachers participated in sessions that allowed the university

faculty to showcase their reformed courses and share web-based resources. The Colorado PhysTEC Program has capitalized on these experiences by inviting some of the summer workshop teachers, and other local science teachers, to form a PhysTEC Teacher Advisory Group (TAG). The TAG provides regular communication with a cadre of high school faculty in several surrounding school districts, enlightens the CU Physics faculty about life in high schools, and expands the network of concerned physics educators. A critical component of the TAG program is that it serves as a starting point for placing students in productive and engaging K-12 environments. Students get a positive and safe exposure to real pre-college classrooms, while teachers benefit from the added human resources and content expertise of the college students. These TAG teachers have formed the nucleus of school-based contacts for students' semester projects that are part of the Teaching and Learning Physics class. In the first semester of the university-high school partnerships with the TAG, we have established placements for students in half a dozen schools, informal science environments (from science outreach workshops to the planetarium), and teacher in-service professional development opportunities. Finally, it is through the TAG that we recruit future TiRs and increase teacher participation at CU-Boulder. The TiR and TAG continue to support campus-based efforts and liaisons with local schools, work with the PER group, and promote university–community collaboration.

Research

By conducting research studies in these educational environments, we may document the success (and failures) of our efforts, and contribute to the broader PER literature on sustainable programs for teacher recruitment preparation and retention. Studies have included:

- documenting the transformation of the introductory sequence through the use of pre- and post-tests, surveys, and observations of student content mastery, attitudes and beliefs, and affective response[7,8,9]
- documenting the course on teaching and learning physics, using similar measures and approaches[11]
- studies of student use of simulations in the introductory sequence[12,13]
- studies of what it means to successfully replicate proven reforms. While the Tutorials have been proven successful by their original authors and we have demonstrated their productiveness locally, we have studied what it means to replicate this success at different institutions[9]
- Currently we continue the above studies by examining the conditions of sustainability, or what happens when existing productive reforms (Tutorials) are conducted by different faculty.[8]

EVALUATION OF PROGRAM

While only in its first year, we may assess the progress of the Colorado PhysTEC at achieving each of the stated goals: increasing student engagement in teaching, transforming introductory courses, engaging faculty in education, and conducting research. The methods for evaluation and assessment draw from both quantitative measures (from numbers of students, to performance on pre- and post-surveys), and qualitative measures (from forms of student engagement, to types of synergistic funding and programming). We provide a brief summary with more thorough documentation available online[3].

We have clear evidence of increased engagement of students in education and future teaching. Each semester, the number of LAs and the number of students applying to become LAs has increased. From Spring 2004 to Fall 2005 the LA program has expanded from 7 to 10 students. In this same time, the number of applicants has increased from 15 to 31. In its first year of offering at Colorado, the course on Teaching and Learning Physics enrolled 9 undergraduates (physics and astronomy majors) and 12 graduate students (11 physics; 1 education). At the end of this year (June 2005), three physics students enrolled or were planning on enrolling in education programs for the coming Fall; whereas historically less than one student annually enrolls from physics. Additionally two affiliated students are engaging in teaching opportunities (through temporary or emergency credentialing programs).

The most dramatic shifts in course practices were implemented in the introductory physics sequence for engineers and majors (Physics 1110 and 1120). The sequence serves up to 600 students each semester and each class is offered each semester. It is now standard practice to use personal response systems with concept tests, online homework systems, and pre- and post- evaluation of content mastery (using either the FMCE or BEMA) and of student beliefs (using CLASS). Tutorials have been successfully coupled into both the mechanics and E/M courses, though currently, we only run Tutorials in one of these courses at a time (due to financial and structural constraints). In these environments (using Tutorials) we have posted repeated and large conceptual gains (63% on the FMCE and 44% on the BEMA). Simultaneously the courses reported no regress in students' expert-like beliefs about the domain, as opposed to the typical negative shift seen in other

courses.[14] More on these efforts can be found in [7,8,9]. In related efforts, departmental colleagues have restructured the physics for non-scientists sequence and are currently working on the modern physics course for non-majors.

A number of programs support faculty interest in educational practice and transformation. The faculty have committed to supporting a new research-line, graduate program, and faculty hires in physics education research. The department faculty also have broadly engaged in and supported education transformations. Bi-weekly Brown Bag Discussions in Education are a faculty forum for regular, informal examination of departmental practices and concerns in education. These seminars typically include 1/4 to 1/2 of the active faculty (10 –25 of the 40+ faculty) and have resulted in reorganizing of the major's sequence, revision of laboratories, and regular use of research-based practices in a variety of courses. The use of concept tests and personal response systems has grown from one course in 2002 to 10 courses in 2005. Furthermore, the use of these tools that began in physics has spread (through concerted effort) across campus departments so that currently 14 departments are using these materials in over 40 courses. Finally, the department supports the Preparing Future Physics Faculty Program (PFPF), which augments traditional CU physics graduate and postdoctoral student preparation by including bi-weekly seminar discussions of education, future employment prospects, and the broader framing of what / where / how PhD's go. The program has been attended by 50 grads, 6 faculty and 9 postdocs, with regular attendance of approximately 35 people. More info can be found in [15,16].

In the Colorado PhysTEC model, the PhysTEC program does not sit in isolation, but couples with other organizations at CU to strengthen a community of concerned educators and to increase each program's effectiveness. We anticipate that these coupled efforts insure not only more effective programming, but also an increased likelihood of being sustained. The current efforts are jointly supported and reinforced by partnerships with the Physics Department, STEM Colorado, the Physics Education Technology (PhET) project, the Faculty Teaching Excellence Program (FTEP), the Leadership Education for Advancement and Promotion (LEAP) program, and the Service Learning Program. At the same time, we foster strong partnerships with local school districts and teachers. Our TAG program includes roughly a dozen local teachers and educational practitioners; through these partnerships we have placed students in day-long to semester-long teaching experiences at six local schools.

While the details of recent research studies are described in the references, PhysTEC has contributed to and supported a variety of studies which have resulted in: 3 journal articles, 9 conference papers, posters, workshops, and 5 informal pieces and seminars. In the present (2005) summer meeting of AAPT / PERC, PhysTEC is supporting 8 talks and posters and 4 paper submissions to these proceedings.

CONCLUSION

We are at the beginning stages of the Colorado PhysTEC effort and anticipate the program to continue to grow, to increase the number of physics majors enrolling in education programs, to couple more strongly with other efforts, and to continue its tradition of research. Of course these efforts are subject to the vagaries of funding; however, our goal is to build programs that ultimately become sustainable.

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