

## Executive Summary

This report documents the activities of the Physics Teacher Education Coalition (PhysTEC) project during its sixth year (August 1, 2006 to July 31, 2007). The purpose of PhysTEC is to produce more and better-prepared physics and physical science teachers around the country. The project's goals include a) establishing a network of institutions that are deeply engaged in science preparation of future teachers, b) providing compelling evidence of the importance and success of ideas and components central to preparing science teachers, c) encouraging physics and education faculty to collaborate 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. At its heart, this project is about engaging physics departments in this critical mission.

The project has two main institution groups: the PhysTEC institutions, and the national Physics Teacher Education Coalition (PTEC). PhysTEC institutions are a limited but diverse cadre of colleges and universities actively engaged in science preparation of future teachers with substantial project support. Each institution can demonstrate success in the local project elements. These institutions were selected for their commitment to advance teacher preparation within their physics and education departments, to evaluate the effectiveness of these elements, to build strong local programs, and to serve as national models. PTEC was formed to create a national network of institutions and individuals committed to developing and promoting excellence in physics and physical science teacher preparation.

The PhysTEC project completed its sixth year at the end of July 2007. We can report a number of significant accomplishments, including a doubling of the number of high school physics teachers graduating from our primary project institutions (PPIs); the development of the Teacher-in-Residence (TIR) program; systemic improvement of courses aimed primarily at elementary and middle school pre-service teachers at several institutions; and the institutionalization of a number of project components at various project sites. The project has collected data to assess the content knowledge of its teachers, and is in the process of acquiring data to document program impact on retention and understanding of pedagogy. The participating institutions have proven successful in working together to strengthen the project through joint meetings, cooperating visits between institutions to share experience and ideas, and an active on-going electronic discussion about various aspects of the project ranging from techniques for successfully administering assessment instruments to strategies for creatively using the skills of the local TIR. Current PPIs will spend the following year primarily disseminating results of their projects through presentations and journal publications.

In 2006 – 2007, PhysTEC management selected four new PPIs to join the project. Each of these institutions will receive funding for three years, and will incorporate into their teacher education programs many of the successful elements that project participants have developed, such as TIRs, pedagogy and content course reforms, and induction and mentoring programs. Project management is also preparing to submit a renewal proposal, which will work to multiply the successes of PhysTEC, and make a significant contribution to addressing the shortage of physics and physical science teachers around the country.

## 1. PhysTEC INSTITUTIONS

### 1.1 Primary Program Institutions (PPIs)

#### 1.1.1 Existing Primary Program Institutions

Table 1 shows the current and past PPIs and their project status. Campaign PPIs differ from the initial PPIs mainly in that their financial support continues for three years rather than five, and in that their initial funding came from the APS Campaign for the 21<sup>st</sup> Century.

**Table 1. PhysTEC Primary Program Institutions**

PPI	Location	Project Status
Ball State University	Muncie, IN	Initial PPI
California Polytechnic State University	San Luis Obispo, CA	Campaign PPI, began 2003-2004 Completed funding period 2006-2007
Oregon State University	Corvallis, OR	Initial PPI <sup>1</sup>
Seattle Pacific University	Seattle, WA	Began 2006-2007
Towson University	Baltimore, MD	Campaign PPI, began 2004-2005
University of Arizona	Tucson, AZ	Initial PPI
University of Arkansas	Fayetteville, AR	Initial PPI
University of Colorado at Boulder	Boulder, CO	Campaign PPI, began 2004-2005 NSF PPI 2005-2006
Western Michigan University	Kalamazoo, MI	Initial PPI
Xavier University of Louisiana	New Orleans, LA	Initial PPI <sup>2</sup>

Project management visited all active sites over the 2006-2007 funding year. Summaries of the findings of each visit are presented below.

- **Ball State University.** The focus of the Ball State’s PhysTEC program has been to concentrate on the recruitment of middle school science teachers, the reform of the introductory algebra-based physics courses taken by these students, and the development of an effective induction and mentoring program for newly certified physics teachers. The Physics Department at Ball State has produced over five secondary physics teachers per year during the PhysTEC project period – more than any other school in Indiana. In addition, Ball State graduates approximately

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<sup>1</sup> Due to changes in faculty at Oregon State there does not currently exist a commitment by the department to engage in the project at the depth required. Consequently, a joint understanding was reached prior to year four to suspend Oregon State as a PPI. Ted Hodapp visited the department in the fall of 2004 and held discussions with the department about the possibility of rejoining. Since departmental staffing was still in considerable flux, it did not seem appropriate to pursue rejoining as a PPI. Oregon State remains as a Coalition member.

<sup>2</sup> Owing to the tremendous hardships and difficulties associated with rebuilding the program in the wake of Hurricane Katrina, Xavier University asked for and was granted permission to suspend activity on the project for the 2005-2006 funding year. As of the drafting of this report, Xavier University has not sought to restart project activity. Xavier University remains as a Coalition member.

300 elementary education majors a year, each of whom takes the Physical Science Concepts for Teachers course. TIR Elaine Gwinn mentored, among others, her replacement Aaron Debbink (Ball State PhysTEC Class of 2006), which facilitated her principal's agreement to allow her a year's leave to accept the TIR position. Ball State University is considering a campaign to raise money for permanent, institutionally funded TIRs in multiple STEM departments.

- **California Polytechnic State University, San Luis Obispo.** Cal Poly completed its PhysTEC funding period in 2006-2007. The focus of Cal Poly's project was developing and assessing sustainable course reforms, increasing collaboration with the local school districts through a Teacher Advisory Group (TAG), and institutionalizing on-campus TIRs. Cal Poly now has one university-funded TIRs. Day-by-day plans have been developed for introductory calculus-based courses and the physical science for elementary education majors, to allow interactive course reforms to be institutionalized regardless of the particular instructor teaching a given course. Faculty and TIRs also worked with local teachers in the TAG to develop and evaluate observation instruments to use in the introductory pedagogy course
- **Seattle Pacific University.** Seattle Pacific, PhysTEC's newest site, is a fairly small (ca. 3000 student), four-year, liberal-arts institution. As a result, it has the potential to serve as a model for teacher preparation programs at liberal arts institutions around the country. It also differs from most project sites in that its TIR is funded by external sources (Boeing Corporation) rather than PhysTEC, and therefore has a somewhat different role from the traditional PhysTEC TIR. Seattle Pacific also benefits from its proximity to both the University of Washington and its renowned PER group, and to several progressive school districts, including Seattle and Bellevue, which have strongly endorsed authentic collaboration with the university to provide robust, content-rich professional development for teachers. Within the university itself there also exists a strong spirit of collaboration, as exemplified by the interdisciplinary Science Education Task Force formed between the Physics Department and the School of Education. Seattle Pacific also boasts a Learning Assistant program that includes a pedagogy course modeled after that of Valerie Otero of Colorado.
- **Towson University.** The PhysTEC program at Towson is unique within the project in that it supports only elementary science education. Towson graduates about 200 elementary education majors a year (more than any other school in Maryland), and each teacher candidate takes two courses in physical science and earth-space science content and methods, and an early field experience course in teaching science. Towson's PhysTEC efforts have focused on reforming the field experience course to foster inquiry teaching with the interns (student teachers), maximize contact time between interns and elementary students, and provide interns with mentoring and opportunities for self-reflection. In order to support the course reforms, the Towson project has also developed training and networking workshops and flexible curricular resources for both classroom mentor teachers and part-time course instructors. Using surveys and a classroom observational instrument based on the National Science Education Standards, the Towson project has been able to measure considerable progress in the course structural reform efforts, the interns' attitudes towards science and science teaching, and, most importantly, the interns practice of science inquiry teaching.

- **University of Arizona.** The PhysTEC program at Arizona is built around the College of Science Teacher Preparation Program (CoS TPP), and has graduated an average of two teachers per project year (up from one in three years pre-PhysTEC), with a far higher than average retention rate. The PI has conducted extensive outreach to the local teacher community in developing the TPP, including establishing an active TAG and involving teachers in pedagogy curriculum development. Course reform has met with some success, but also a certain amount of departmental resistance.
- **University of Arkansas.** The PhysTEC program at Arkansas develops student interest in physics with inquiry-based introductory courses, guides potential teachers through the licensure process, and mentors them during the early years of their professional lives. Arkansas also has a counterpart program to the Learning Assistants model at the University of Colorado that has played a significant role in recruitment and retention of new teachers. Course reforms in the calculus-based introductory sequence have proven quite successful in producing learning gains, independent of instructor. The PIs are currently pursuing further course reforms in the algebra-based sequence and the physical science for elementary teachers course, which is now required for all elementary education majors. The university has also funded a TIR position in the College of Education and Health Professions, which gives the physics department a strong ally in the College. Arkansas is a mature PhysTEC site with numerous successes to their credit – including the graduation of 6 teachers in 2006-2007 (up from about one per decade pre-PhysTEC) – and the PI will spend much of this coming year documenting and disseminating these successes to the broader physics education community.
- **University of Colorado at Boulder.** The hallmark of the Colorado PhysTEC project is the Learning Assistant (LA) program. Learning assistants assist with in-class Tutorials (developed by the University of Washington PER group) and help sessions for an impressive number of courses in the department. This program allows students to experience the positive aspects of teaching without many of the more burdensome duties such as grading and planning, and also serves as a recruitment tool into the teacher certification process. It is very popular, with over 50 students applying for approximately 18 spots each semester. Colorado has also gathered data to show that LAs post scores on commonly used content assessments that are as good or better than those posted by typical first-year graduate students. In Fall of 2006, PhysTEC PIs from Seattle Pacific University and Arkansas University participated in a reverse site visit to Colorado to gain first-hand exposure to the Learning Assistant program, and to observe how Colorado manages its NSF Noyce fellowship program (both SPU and Arkansas have been awarded Noyce fellowships as well).
- **Western Michigan University.** Western Michigan has focused its PhysTEC efforts on reforming its introductory course sequence, recruiting additional majors and minors, and preparing their teaching graduates to use interactive methods. As at many institutions, faculty adoption of course reforms has been uneven, and as a result, the PIs have been able to gather data to show convincingly that interactive courses yield higher gains on concept assessments than do traditionally taught courses. Western Michigan project leaders also reports that although they did not set out with this goal, they have “built a community of physics teachers composed of preservice teachers, novice teachers, and experienced local teachers of physics. This community served as a support system for our graduates and other novice teachers as well as

### 1.1.2 New Primary Program Institutions

In October of 2006, PhysTEC solicited applications for new PPI sites. The review process was modeled after that of the NSF, with a two-stage application procedure and a panel of reviewers. Forty-five institutions applied to the first round, which clearly demonstrates widespread interest in physics education reform, as well as respect for the efforts of PhysTEC thus far. At the end of the review process, the project selected four institutions to join PhysTEC:

- Cornell University
- Florida International University
- University of Minnesota
- University of North Carolina at Chapel Hill

Each of these universities has dedicated faculty and substantial demonstrated commitment to teacher preparation and involvement in the physics education community. The project spent much of the summer negotiating contracts with the new PPIs, and we look forward to working with them over the course of the next three years.

### 1.2 PTEC Institutions

In addition to the PhysTEC PPIs, which the project funds at a substantial level, the project is also building PTEC, a broader coalition of institutions committed to developing and promoting excellence in physics and physical science teacher preparation. These institutions do not receive direct funding, but are invited to participate at a reduced rate in an annual conference at which universities share best practices in teacher preparation through workshops and presentations. The Coalition currently boasts 86 member institutions – up from 52 in July 2006 – and the project runs an annual conference to allow PTEC members to share best practice information. The project is pleased to have attracted such widespread interest, and is undertaking a major effort to determine how best to use the combined resources of these institutions and future PTEC members to advance physics teacher preparation throughout the country.

A complete list of PTEC members (as of this writing), as well as a graph showing membership growth over time, can be found in [Appendix C](#) of this report.

## 2.0 ACTIVITIES AND FINDINGS

### 2.1 Impact (*All data current as of August, 2007*)

**2.1.1 Secondary Physics Teacher Recruitment.** A primary goal of the PhysTEC project is to help physics departments increase their production of qualified secondary physics teachers, and six of the eight institutions currently participating in the project have focused their efforts on increasing

these numbers (Ball State has focused on middle school teacher preparation, and Towson has focused on elementary teacher preparation). These six universities have increased their average production more than two-fold relative to baseline pre-PhysTEC rates, from an average of 1.56 teachers per institution per year to 3.31 teachers per institution per year.

**Table 2. Average Annual Graduation of Physics Teachers**

Institution	Baseline (3 years prior to PhysTEC)	PhysTEC Project*	Ratio of Project to Baseline Production
Arizona	0.33	2.00	6
Arkansas	0.33	3.50	10.5
Cal Poly	0.33	1.00	3
Colorado	1.00	2.00	2
Seattle Pacific	3.00	2.00	0.67
Western Michigan	4.33	6.83	1.58
<b>Average</b>	<b>1.56</b>	<b>3.31</b>	<b>2.13</b>

\*For Arizona, Arkansas, and Western Michigan, the PhysTEC project term is from 2002-2007. For Cal Poly it is 2003-2007; for Colorado it is 2004-2007; for Seattle Pacific it is 2006-2007.

In 2007, 29 secondary physics teachers graduated from all PhysTEC sites (including Ball State). Although these numbers are small, it should be kept in mind that these 29 teachers represent approximately 9% of the total national production of physics teachers, based on figures from the Title II Report<sup>3</sup>.

Recruitment strategies vary among sites. Institutions such as Arkansas that have successfully reformed their introductory “gateway” major courses use these as a recruitment tool, on the theory that an interactive class taught by an enthusiastic professor can demonstrate to students the joys and rewards of teaching. Those institutions that have Learning Assistant programs find these to be effective recruitment tools as well, as they expose students to many of the rewards of teaching and let them discover whether they would like to become a teacher while deferring some of the more tedious aspects such as classroom management. TIRs at some institutions such as Cal Poly and Western Michigan have played an active role in future teacher recruitment by visiting physics classes, Society of Physics Students meetings, and other student events in order to promote teaching as a career and offer their knowledge to those interested in pursuing teacher certification. Teacher recruitment is a topic of major interest in the teacher preparation community right now, and was the topic of the 2007 PTEC Conference, discussed in Section 3.2.

**2.1.2 Elementary Teacher Training.** Six of the eight active PhysTEC sites – Arkansas, Ball State, Cal Poly, Colorado, Seattle Pacific, and Towson – have implemented significant reforms in their science courses for elementary education students. In some cases, these courses are required for all elementary education majors. The goal of this effort is to better prepare elementary teachers to teach science lessons, to encourage them to teach as many as are allowed by local curricula guidelines, and to make these lessons inquiry-based and interactive. Led by Towson and Ball State, PhysTEC sites now graduate over 500 elementary teachers per year who have taken at least one reformed

<sup>3</sup> See [www.title2.org](http://www.title2.org)

science or methods course; in total, PhysTEC has improved the preparation of over 2400 elementary teachers.

**2.1.3 PhysTEC Students.** PhysTEC touches far more students than just those who complete a teacher preparation program. Nearly 17,000 students have taken reformed courses in algebra- and calculus-based physics at PhysTEC institutions, and nearly 3,000 students have been influenced by PhysTEC courses in elementary or secondary pedagogical methods. These numbers are especially important as many STEM students become teachers later in their careers, or help educate future teachers. Many of these students also become parents, and improving their attitudes toward science and science education will have a significant impact for many years.

## 2.2 Project-wide Assessment.

In order to determine to what extent efforts of the PhysTEC project have resulted in better-prepared physics and physical science teachers, the project has asked all sites to administer standardized assessment instruments to their students. These instruments are recognized in the physics education research community, and have been published in the peer-reviewed literature. We focus our assessment efforts on 1) *content assessment*, using standardized instruments such as the Force Concept Inventory (FCI), the Conceptual Survey of Electricity and Magnetism (CSEM), and other related tools, and 2) *pedagogical assessment*, using the Reformed Teacher Observation Protocol (RTOP). In some cases exceptions are made, when local instruments better match the local situation, the particular expertise of the faculty, or historical precedent. We also ask institutions to track the teachers who graduate from their programs, so that we can assess PhysTEC's impact on teacher retention, which is a much publicized challenge for the STEM teacher workforce.

**2.2.1 Content Assessment.** Conceptual surveys such as the FCI, CSEM, and others have done much to awaken the physics community to the understanding that while traditional didactic instruction may train students to produce correct solutions to seemingly complex problems, such instruction often does little to alter students' fundamental conceptual thinking. Modern instructional strategies acknowledge that students often approach physics with a set of contradictory preconceptions that must be replaced with more productive frameworks for understanding the world.

The well-known Force Concept Inventory assessment instrument of [Hestenes, et al.](#)<sup>4</sup> has been in use for over 15 years, and is now credited with stimulating significant reform within physics education. The FCI is specifically designed to assess students' understanding of basic concepts in Newtonian mechanics. Some institutions have chosen instead to use the Force and Motion Concept Evaluation, developed by Thornton and Sokoloff, which covers a smaller range of Newtonian concepts in greater depth.<sup>5</sup> [Results of the FMCE have been found to correlate strongly with the FCI.](#)<sup>6</sup> Similarly,

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<sup>4</sup> D. Hestenes, M. Wells, and G. Swackhamer, "Force Concept Inventory," *The Physics Teacher*, **30**, 141-158 (1992).

<sup>5</sup> R.K. Thornton and D.R. Sokoloff, "Assessing student learning of Newton's laws: The Force and Motion Conceptual Evaluation," *Am. J. Phys.* **66** (4), 338-352 (1998).

<sup>6</sup> J. Saul, *Beyond problem solving: Evaluating introductory physics courses through the hidden curriculum*. Doctoral dissertation, University of Maryland, 1998. Accessed Aug 16, 2007 at <http://www.physics.umd.edu/perg/dissertations/Saul/>.

the Conceptual Survey of Electricity and Magnetism (CSEM), developed by [Maloney et al.](#)<sup>7</sup>, assesses students' understanding of fundamental concepts in electricity and magnetism. The [Brief Electricity and Magnetism Assessment \(BEMA\)](#) of Chabay and Sherwood<sup>8</sup> is an alternative instrument that is geared towards the basic and central concepts of the calculus-based introductory E&M course.

Table 3 summarizes the results of content assessments that institutions have administered to their students during the course of the PhysTEC project. The scores in the table all came from calculus-based introductory physics courses – the “gateway” courses that nearly all majors (and therefore presumably all future teachers) at an institution take, and in which the majority of institutions focused their reform efforts. In some cases, sites were able to report results from sections of a particular course that were taught using reformed methods and from sections that were taught using traditional methods. The statistic provided in the table is the normalized gain, defined as follows:

$$g \equiv \frac{\text{gain}}{\text{possible gain}} = \frac{\langle \text{post \%} \rangle - \langle \text{pre \%} \rangle}{100 - \langle \text{pre \%} \rangle}$$

**Table 3. Summary of PhysTEC Content Assessment Results**

Conceptual Survey (# of sites)	2002-2003		2003-2004		2004-2005		2005-2006		2006-2007		Totals	
	N	g	N	g	N	g	N	g	N	g	N	g
<b>Reformed Courses</b>												
FCI (4)	357	0.46	424	0.43	600	0.52	435	0.43	424	0.54	2240	0.48
FMCE (2)			335	0.66	642	0.55	411	0.47	694	0.51	2082	0.54
CSEM (5)	225	0.41	357	0.40	483	0.43	349	0.47	400	0.47	1814	0.44
BEMA (1)					551	0.44	521	0.34	351	0.40	1423	0.39
<b>Unreformed Courses</b>												
FCI (4)	45	0.15					127	0.20	163	0.29	335	0.24
FMCE (1)					213	0.45	293	0.42			506	0.43
CSEM (3)	66	0.14	27	0.30	47	0.20	65	0.15	68	0.27	273	0.20
BEMA (0)												

*N* indicates the number of students taking the survey in a given project year, across all sites.

In his seminal paper comparing courses using “interactive engagement (IE) methods” and “traditional courses” that make “little or no use of IE methods,” [Richard Hake](#) found that on average, interactive courses yielded a normalized gain of 0.48 on the FCI (N = 4458 students), whereas traditional courses yielded a normalized gain of 0.23 (N = 2084 students).<sup>9</sup> As the above table shows, the aggregate average scores from PhysTEC sites over the course of the project are remarkably close to Hake’s scores. No surveys of data aggregated over many sites exist for the other assessment instruments; however, the FMCE and CSEM results from PhysTEC sites strongly

<sup>7</sup> D. Maloney et al., “Surveying students' conceptual knowledge of electricity and magnetism,” *Am J. Phys.* **69** (S1), S12-S23 (2001).

<sup>8</sup> L. Ding et al., “Evaluating an electricity and magnetism assessment tool: Brief electricity and magnetism assessment,” *Phys. Rev. ST Phys. Educ. Res.* **2**, 010105 (2006).

<sup>9</sup> R. R. Hake, “Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses,” *Am. J. Phys.* **66**, 64-74 (1998). Article available at <http://www.physics.indiana.edu/~sdi/ajpv3i.pdf>.

suggest that course reforms have been effective in raising gains on these instruments as well. Thus, the student gain data above provides evidence that course reform efforts have successfully incorporated inquiry-based methods into the curricula of PhysTEC institutions.

**2.2.2 Pedagogical Assessment.** In order to assess the extent to which the PhysTEC institutions are preparing effective teachers, the project has required that each institution have personnel trained in the [Reformed Teaching Observation Protocol \(RTOP\)](#).<sup>10</sup> RTOP is a validated research tool developed from the Arizona Collaborative for Excellence in the Preparation of Teachers that identifies the extent to which reformed-based practices have been incorporated into teaching.<sup>11</sup> The RTOP consists of 25 multiple-choice prompts that ask the observer to evaluate the lesson design, content, and classroom culture over the course of one classroom period, yielding a score between 0 for a completely traditional or “unreformed” lesson and 100 for a completely interactive or “reformed” lesson. It also encourages observers to consider the context in which the observed lesson takes place, and to take notes on what he or she observes in the classroom.

Because the RTOP is designed for use by trained observers, PhysTEC offered training in using the RTOP to all sites in fall of 2006. The project then asked each institution to conduct observations of its student teachers and graduated PhysTEC teachers, and to submit scores to the project. As 2006-2007 was the first year in which PPIs conducted live RTOPs, they were not able to provide research-quality data from the project institutions. Anecdotally, however, multiple sites reported that they found RTOP to be a useful tool for improving pedagogy, and the reported scores show that teachers prepared under the PhysTEC project often show a substantial mastery of interactive engagement teaching methods, as reflected by an average reported score of approximately 54 for PhysTEC pre-service and in-service teachers across all sites. The data also suggest that teachers were able to build on their experiences, as scores nearly always improved from one observation to the next for a given teacher.

**2.2.3 Assessment of Teacher Retention.** In 2006, to assist in PhysTEC assessment efforts, the project invited all PhysTEC teachers and soon-to-be teachers who were influenced by the PhysTEC project to respond to a brief survey regarding teaching choices and teacher retention. All those who participated received their choice of teaching resource materials, a one-year membership to AAPT (including *The Physics Teacher*) or a one-year junior membership to APS. Data collected from this survey was entered into a database that the project will use to assess its effect on retention. Because retention statistics usually refer to five-year intervals, the PhysTEC project is still too young to be able to report the long-term effect it will have on teacher retention. However, the recently released report [To Teach or Not to Teach? Teaching Experience and Preparation Among 1992–93 Bachelor’s Degree Recipients 10 Years After College](#) from the Department of Education's National Center for Education Statistics shows that ten years after graduation, about 54% of science, engineering, and mathematics majors who have ever taught have left the teaching profession,<sup>12</sup> which is a troubling statistic that demonstrates a clear need for action on the part of PhysTEC and other teacher preparation projects. A number of project institutions including Arkansas, Arizona,

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<sup>10</sup> [http://physicsed.buffalostate.edu/AZTEC/RTOP/RTOP\\_full/index.htm](http://physicsed.buffalostate.edu/AZTEC/RTOP/RTOP_full/index.htm).

<sup>11</sup> M. Piburn, D. Sawada et al., *Reformed Teaching Observation Protocol (RTOP)* ACCEPT IN-003 (2000)

<sup>12</sup> M.N. Alt and R.R. Henke, *To Teach or Not to Teach? Teaching Experience and Preparation Among 1992–93 Bachelor’s Degree Recipients 10 Years After College* (NCES 2007-163). U.S. Department of Education. Washington, DC: National Center for Education Statistics. <http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2007163>

Ball State, and Western Michigan have done an exemplary job tracking their PhysTEC teachers, and also have reported impressive teacher retention rates that are substantially higher than those nationally reported for STEM teachers.

The project also prepared a certificate (suitable for framing), signed by the presidents of each of the three societies in honor of their completion of a PhysTEC course of study. These were sent out to all 2006 PhysTEC graduates.

**2.2.4 Advisory Committee.** In addition to assessing progress at each of the sites, PhysTEC itself has received advice throughout the course of the project from an Advisory Committee composed of distinguished members of the physics teacher education community (see [Appendix A.3](#)). The Advisory Committee reviewed project goals, direction, and organization each year, and suggested numerous project improvements that the leadership team consequently adopted.

## 2.3 Teachers-in-Residence

Over the course of the project, 35 Teachers-in-Residence (TIRs) have served at PhysTEC institutions. TIRs are master teachers whom the PhysTEC project "borrows" to help form a bridge between the university and the local school districts, and to strengthen ties between theory and practice by sharing their expertise and classroom experiences with preservice teachers. The TIR can assume many roles, depending on his or her institution's needs. TIRs have recruited new teachers, mentored pre-service and beginning teachers, taught methods and content classes, redesigned existing course curricula, developed new courses, and given workshops and presentations at local, regional, and national meetings, including AAPT, NSTA, and PTEC conferences. Another of our TIRs has completed her doctorate this year in Science Education, and many TIRs from past years contributed to the induction session of the six new TIRs that were selected for 2007-2008. As a result of their involvement with PhysTEC, several PPIs have made the commitment to fund TIRs out of their own budget. The [2008 PTEC Conference](#)<sup>13</sup> will focus on master teachers, and will provide an opportunity for TIRs from all project years to disseminate their successes and catalyze the spread of teachers-in-residence to institutions outside the PhysTEC project.

Specific TIR work products this year include:

- A winning [Toyota Tapestry grant](#)<sup>14</sup> application submitted with local high school teachers, including the TIR's mentee.
- Work with undergraduates to develop a field trip for high school students coming to visit the Physics Department (in the TIR's own words - "What a blast!").
- Professional development workshops on Inquiry-based teaching. (multiple TIRs)
- A six-week evening course for future middle school teachers on Inquiry-based teaching.
- An adapted physical science curriculum for three six-hour workshops for elementary teachers.
- Invited Talks sessions at the AAPT winter and summer meetings.
- Publications in the *APS Forum on Education Newsletter*.

### 2.3.1 Mentoring

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<sup>13</sup> <http://www.ptec.org/features/newsDetail.cfm?id=129>

<sup>14</sup> <http://www.nsta.org/pd/tapestry/>

In the original conception of the PhysTEC project, “mentoring” was considered to be limited to the TIRs’ efforts in mentoring graduates of PhysTEC institutions. Over the course of the project, however, the concept of mentoring has expanded to include the entire teacher preparation continuum, and encompasses TIRs’ work with graduate students, faculty, pre-service teachers and novice teachers of physics (especially in cases when out-of-field teachers are “re-assigned” to teach physics). Mentoring is an important mechanism through which PhysTEC has been able to reach out to local K-12 communities. The TIR listserv has become a way to stay connected with other TIRs, share important elements of their work across the project sites, have conversations about teaching and learning, and reach out for advice to others with special expertise. The TIRs, through their presentations and listserv, have developed into a true learning community, and mentor each other in their individual specialized knowledge areas. There is specific evidence of the positive impact of this work in mentee questionnaires and teacher journals. One TIR’s mentee wrote:

*“You have always been a positive light in what has otherwise been a bleak time. Through all the stressful times and deadlines, you are a constant reminder of how a teacher should treat their students. I want to be just like you when I grow up. You rock!!!”*

Specific mentoring efforts this year include:

- Work with training and support of TAs and undergraduate learning assistants at various project sites.
- Maintenance of face-to-face and electronic contact with PhysTEC graduates through their first three years of teaching.
- Serving as both university supervisor and mentor for teachers during their internships.
- Use of the Reformed Teaching Observation Protocol (RTOP) as a tool for providing feedback and mentoring support.
- Multiple presentations by TIRs on mentoring in the PhysTEC project, at national and local meetings.
- A joint presentation on the critical elements of mentoring at the TIR gathering in Greensboro.

**2.4 Sustainability.** The purpose of the PhysTEC project is to catalyze systemic, long-term change at the departmental and institutional level, in order to increase the numbers and improve the preparation of graduating physics and physical science teachers. PhysTEC faculty have succeeded in institutionalizing many of the initiatives originally supported by PhysTEC.

**Ball State University.** At Ball State, department chairs of the Life Science, Earth/Space Science, Physical Science, and Mathematical/Computer Sciences departments have all endorsed a permanent line-item for a TIR, and there is hope for administrative support in the near future. Currently, startup funds for the department’s new 2007-2008 Physics Education Research faculty member were provided to fund a doctoral candidate who is an experienced physics teacher, and who will assume many of the roles the TIRs took on during the course of the project. The addition of a permanent PER faculty line was significantly influenced by the project activities at Ball State.

**California Polytechnic State University, San Luis Obispo.** The Dean of the College of Science and Mathematics at Cal Poly has agreed to fund one TIR per year, but has indicated the possibility

for as many as three, one for each STEM discipline. The Cal Poly TIRs serve a number of important roles in the Physics Department, including coordinating early field experiences for pre-service teachers, and induction and mentoring of newly graduated teachers. In addition, "day-by-day plans" developed for department courses allow interactive teaching methods to be transferred easily between faculty.

**Seattle Pacific University.** Because Seattle Pacific has only completed one year in PhysTEC, it is not yet clear which project successes will be sustainable for the long term. That said, the environment seems very promising for a significant degree of institutional adoption of initiatives in teacher preparation, as evidenced by the recently formed Science Education Task Force that brings together faculty members from the Physics and Education Departments. Although the TIR is currently being funded through private (non-PhysTEC) money, she will be teaching several classes during this coming academic year that were co-taught last year, thereby allowing the University to support a greater share of her salary than it did last year.

**Towson University (sustainability).** Towson has had considerable success in leveraging administrative support for the TIR position. The third year of funding was split into two years, funding two part-time TIRs and part of the mentor teacher and school support, with the remainder matched by the host department and colleges. The two Deans from the College of Education and the Fisher College of Science and Mathematics have also endorsed a proposal to create a permanent staff position to take on the TIR duties and other PhysTEC efforts that are currently made by the project PIs. This proposal is still pending but seems almost certain to be accepted given the universal recognition of the important gains of the project and the likelihood that they will ebb away without institutional support.

**University of Arizona.** Arizona's College of Science Teacher Preparation Program is now a well-established entity on campus, and its future is secure. The funding that supports two Adjunct Instructor positions is guaranteed through 2011, and may be renewed for an additional ten years after that. Outside funding is being sought to support TIRs in the future. The lead faculty of the PhysTEC project has recruited a sizable community of area mentor teachers to provide early field experiences to pre-service teachers, a major component of Arizona's teacher preparation program.

In addition, Arizona received one year of funding for a mentoring program for early-career science teachers in partnership with three area high-needs districts; it includes summer and monthly workshops for teacher participants, a teacher exchange program in which beginning science teachers visit the classrooms of experienced science teachers, and regular observations of beginning science teachers by the Project Coordinator, Julia Olsen, a former Arizona TIR.

**University of Arkansas.** Arkansas has enjoyed substantial success in leveraging administrative support to sustain PhysTEC initiatives. The University decided to dedicate its NSF Noyce proposal to the PhysTEC faculty, to allow them to fund tuition for preservice teachers. In addition, the graduate dean and the Physics Department have agreed to cost-share two positions for Master of Arts in Teaching students. Collaboration with the College of Education and Health Professions has also been quite fruitful – the College now supports a full-time TIR to work with preservice elementary teachers, and Physics for Elementary Teachers has been incorporated as a required class for all elementary education majors. Course reform in the gateway sequence for majors has been

very successful at both producing impressive assessment results and recruiting additional majors, and PhysTEC faculty have developed robust course systems that allow transfer of interactive teaching methods in this course to other faculty. The College of Engineering has supported these reform efforts, and even allows physics faculty to recruit future teachers from introductory engineering classes. Finally, the Physics Department's instructional lab curator has been trained in RTOP, which guarantees institutional ability to use the tool well into the future.

**University of Colorado at Boulder.** The Learning Assistant (LA) program forms a major component of the sustainability of the Colorado physics teacher preparation program. The LA program has received substantial funding from the university, and has spread to other STEM departments beyond Physics. It is a very popular program with students as well, with three students applying for every available position. The core LA course Teaching and Learning Physics has been successfully handed off to a new instructor, and is being prepared for submission as a regular course, as opposed to special topics. Although the University will not be supporting a full-time TIR, some TIR roles will be filled by a lead Physics TA and other hired students. Through exemplary data collection and dissemination, PhysTEC faculty have propagated the widespread use of clickers in both physics courses and other STEM departments.

**Western Michigan University.** Western Michigan reports that although administrative support exists for a university-funded TIR position, the university is currently suffering from significant budget pressure that precludes the possibility of such a position in the immediate future. Interactive engagement techniques have been adopted by faculty in some classes. To help support on-going efforts in teacher education, WMU made a decision during the project to hire a tenure-track faculty line in physics education research. Charles Henderson now holds this position.

### 3.0 Outreach

One of the goals of the PhysTEC project is to reach out to the greater physics and education communities to disseminate project successes widely. In order to reach as large and diverse an audience as possible, the project employs a variety of outreach and dissemination vehicles.

#### 3.1 PPI Publications

See [Appendix B](#).

**3.2 PTEC Conference.** The [2007 PTEC Conference](#)<sup>15</sup> was held in early March in Boulder, Colorado, and focused on teacher recruitment, a topic of great interest around the country. The interest was so great that registration had to be capped at 115 participants, the maximum that the space permitted. The plenary speakers were Carl Wieman, Nobel Laureate and advocate for physics department involvement in course reform and teacher preparation, and Cherry Murray, member of the Committee on Science, Engineering, and Public Policy (COSEPUP), which co-authored the [Rising Above the Gathering Storm](#)<sup>16</sup> report. As a result of the conference and the general increase in

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<sup>15</sup> <http://www.ptec.org/features/newsDetail.cfm?id=45>

<sup>16</sup> Committee on Science, Engineering, and Public Policy. *Rising Above the Gathering Storm*, Washington, DC: National Academies Press, 2007. <http://www.nap.edu/openbook.php?isbn=0309100399>

interest in teacher preparation, the ranks of PTEC have swelled to 86 member institutions as of this writing.

**3.3 PTEC National Task Force on Teacher Education.** PTEC has begun the steps to establish a National Task Force on Teacher Education, whose charge is to evaluate excellent programs of teacher education and produce a national white-paper with recommendations on how to create and maintain such a program. The task force is chaired by Stamatis Vokos of Seattle Pacific University, and solicitations have been made for task force members. It is anticipated that the report will provide guidelines for the improvement of a wide variety of teacher education programs both within physics departments and in other disciplines, and have an impact similar to that of the [National Task Force on Undergraduate Education's SPIN-UP report](#).<sup>17</sup>

**3.4 Websites.** Project leadership recognizes that a crucial component of any modern outreach effort is an attractive and engaging Internet presence. As a result, the project has devoted considerable effort over the past year to developing both the PhysTEC website and the broader PTEC-Digital Library (PTEC-DL) that will serve as a home for online teacher preparation resources.

**3.4.1 PhysTEC Website** The PhysTEC website ([www.phystec.org](http://www.phystec.org)) has been active since Fall 2001. The website includes, among other things, quarterly status reports, announcements, links to annual reports from all PPIs, and project statistics. A new and improved website is scheduled for roll-out in September of 2007, with a format that will allow the user to browse the project by key project components such as recruitment, mentoring/induction, retention, assessment, etc. The new web site will emphasize lessons learned from work at the various project sites in order to provide useful insights for the broader teacher preparation community.

**3.4.2 PTEC-DL<sup>18</sup> and ComPADRE<sup>19</sup>.** ComPADRE, an AAPT/AIP/APS/AAS partnership supported by the National Science Foundation, is a digital library in physics and astronomy education. ComPADRE is collaborating with PTEC to create a collection devoted to physics and physical science teacher preparation – the Physics Teacher Education Coalition Digital Library (PTEC-DL). This new library serves all Coalition members including PPIs, as well as the greater teacher preparation community.

PTEC-DL provides the following services:

- Document posting for Coalition and community members.
- Web pages for Coalition members.
- Links to research activities for teachers (such as NSF's Research Experiences for Teachers and QuarkNET sites for teachers).
- Browsing by topic of resources specifically targeted for teacher education.
- Hosting materials from each of the PTEC regional, national, and topical conferences.
- Current News and Events relevant to teacher education.

**3.5 Upcoming book – *Research and Practice in Physics Teacher Preparation*.** In order to provide a single source for scholarly work in the field of teacher preparation, the project has decided to

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<sup>17</sup> <http://www.aapt.org/Projects/ntfup.cfm>

<sup>18</sup> <http://www.compadre.org/PTEC/>

<sup>19</sup> <http://www.compadre.org/portal/index.cfm>

publish a compendium of articles on the preparation of physics and physical-science teachers. A distinguished editorial review committee has prepared [guidelines for submissions](#)<sup>20</sup>, and a call for papers has already gone out. The book will include new reports reflecting cutting-edge research and practice, as well as reprints of previously published seminal papers. It will have three primary objectives: 1) to provide a resource for physics departments and faculty members who wish to develop and/or expand efforts in teacher preparation; 2) to encourage scholarly documentation of ongoing research and practice in a form accessible to a broad audience of physicists; and 3) to encourage recognition of teacher preparation as a scholarly endeavor appropriate for faculty in physics departments. All papers published in the book will also be published either in the *American Journal of Physics* (AJP) or in *Physical Review Special Topics–Physics Education Research* (PRST-PER). It is planned that printed copies of the book will be distributed to chairs of all physics departments in the United States. The book will also be freely available online. The goal is that manuscripts be submitted by August of 2008, for a publication target date of early 2009.

**3.6 APS Forum on Education (FEd) Newsletter**<sup>21</sup>. John Stewart (University of Arkansas) served as 2006-2007 editor of the Section on Teacher Preparation of APS's *Forum on Education Newsletter*. This newsletter is distributed electronically to over 4000 APS members. The *Newsletter* published articles by PhysTEC participants from a number of project institutions, including Arizona, Arkansas, Colorado, Seattle Pacific, and Western Michigan. Former TIRs from Arizona and Western Michigan co-authored an article entitled "A Quiet Revolution in Preparing Future Teachers of Physics."

**3.7 PhysTEC Presentations.** Project PIs Ted Hodapp and Warren Hein deliver presentations on the project at a variety of events around the country. These presentations highlight the need for increased preparation of physics teachers, and the successes of the PhysTEC project. In 2006-2007, presentations were made at Florida International University, the North Carolina section of the AAPT, the AAPT Summer Meeting, the Association of Schools of Teacher Education's annual meeting, the AAPT Winter Meeting, the National Society of Black Physicists' annual meeting, the Renaissance Group at Kennesaw State University, and the PTEC annual conference in Boulder, CO. In addition, numerous other informal discussions and meetings featured discussions of how to push forward many of the initiatives that PhysTEC has been championing.

**3.8 PhysTEC Presence at the AAPT Summer Meeting.** Numerous PhysTEC participants gave workshops and presentations at the 2007 AAPT Summer Meeting in Greensboro, NC. Valerie Otero and her Colorado colleagues delivered a workshop on their LA program, and teamed up with Arkansas, Seattle Pacific, and Florida International for a poster session on LAs. In addition, a number of TIRs delivered presentations at a well-attended invited talks session.

## APPENDIX A: Project Personnel

### A.1 PhysTEC Management Team

#### A.1.1 Present Members

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<sup>20</sup> <http://www.compadre.org/PTEC/items/detail.cfm?ID=5691>

<sup>21</sup> <http://units.aps.org/units/fed/newsletters>

- **Theodore Hodapp**, *PI* (September 2004-2007), Director, Education and Diversity, American Physical Society. Hodapp is the primary contact for the NSF and is responsible for overall direction and fiscal management of the project. He coordinates the many components of the project and visits each PPI at least once a year. He maintains on-going communication and timely reporting to NSF. APS pays 100% of his salary, and he works 60-80% time on the PhysTEC project.
- **Toufic Hakim**, *co-PI* (2007), Executive Officer, American Association of Physics Teachers. Hakim joins the project to replace former co-PI Warren Hein, who has taken a position as a Program Director at the National Science Foundation. Hakim will be the official representative from AAPT and will work with Hein to help manage PhysTEC activities.
- **Jack Hehn**, *co-PI* (2001-2007), Director, Education Programs, American Institute of Physics. Hehn was a member of the original proposing team and now participates in leadership through the Project Management Team activities, communicates and consults with PPIs, and has participated in site visits to PPIs in each project year. He coordinated the activities of the External Evaluator (The Momentum Group, Inc.) in formative evaluation efforts. Hehn has been working with AAPT and APS to consider a Task Force effort centering on the science preparation of future teachers.
- **Warren Hein**, *co-PI* (2005-2007), Chief Academic Officer, American Association of Physics Teachers. Hein is responsible for coordinating PhysTEC activities that involve AAPT programs and staff. These activities include the Physics Teacher Resource Agent (PTRA) program, dissemination of PhysTEC activities through the *American Journal of Physics*, *The Physics Teacher*, *Interactions*, and *The Announcer*, as well as PhysTEC sessions at the AAPT Winter and Summer Meetings, and regional section meetings. AAPT provides 0.5 months of Hein's salary as match for the project.
- **Edward Lee**, *Project Associate* (2001-2007), American Physical Society. Lee's responsibilities include maintaining the PhysTEC and PTEC websites, drafting, editing, and proofreading documents, and participating in Project Management Team meetings.
- **Mary Fehrs**, *Associate Project Director for Coalition Development* (2005-2007). Fehrs is responsible for organizing and managing the PTEC annual conference, inviting speakers, writing and disseminating the publicity materials, and developing meeting structure. She recruits and communicates with potential Coalition members and is responsible for the ongoing development of the Coalition. Fehrs is supported by NSF funds.
- **Paul Hickman**, *TIR and Mentoring Consultant* (2005-2007)
- **Gabriel Popkin**, *Project Manager* (2007). Popkin manages many of the day-to-day operations of PhysTEC, including communicating with PPIs, aggregating project and budgetary data, and drafting major project documents.

### A.1.2 Past Members

- **John Layman**, *co-PI* (2001-2005) retired, Professor Emeritus at the University of Maryland. Layman participated in PPI visits. He led the effort and program to establish the TIR group, and helped in organizing the two previous annual meetings. Layman spearheaded the formal Induction/Mentoring program within PhysTEC and collaborated with AAPT's PTRA program to create the summer TIR/PTRA Induction and Mentoring workshop.
- **Fredrick Stein**, *PI* (2001- September 2004), former Director, Education and Outreach Programs, American Physical Society. Stein served as PI through September 2004 until his retirement from the APS. APS paid 100% of his salary, and he worked 50-60% time on the PhysTEC project. The Fund for the Improvement of Postsecondary Education (FIPSE) also contributed to Stein's salary for the first three years.
- **Victoria Kwasiborski**, *Project Manager* (2005-2007), American Physical Society.
- **John Gretz**, *Project Coordinator* (2004-2005), American Physical Society.
- **Kevin Aylesworth**, *Project Coordinator* (2002-2004), American Physical Society.

#### A.2 Management Team Consultants

- **Marcia Fetters**, *TIR Consultant* (2005)
- **Karen Johnston**, *Project Evaluator*, The Momentum Group (2001-2004)
- **Hal Richtol**, *Consultant for Site Visits* (2001-2004)
- **Gay Stewart**, *Outreach Consultant* (2005)

#### A.3 Advisory Committee

- **George H. Trilling**, Faculty Emeritus, Lawrence Berkeley National Laboratory, *Chair* (2001-2007)
- **Robert Beck Clark**, Professor, Department of Physics and Astronomy, Brigham Young University (2001-2007)
- **Sandra Harpole**, Director, Center for Science, Mathematics, and Technology, Mississippi State University (2001-2007)
- **Paul Hickman**, Director of CESAME, Northeastern University (2001- 2005)
- **E. Leonard Jossem**, Emeritus Professor, Department of Physics, The Ohio State University (2001-2007)
- **Lillian McDermott**, Professor, Department of Physics, University of Washington (2001-2007)
- **Jill Marshall**, Assistant Professor, Department of Education, University of Texas at Austin (2005-2007)

## APPENDIX B: PPI PUBLICATIONS

PPI	Year	Authors	Title	Citation
Arizona	2007	Talanquer, V., Tomanek, D., Novodvorsky, I.	Revealing student teachers' thinking through dilemma analysis	<i>Journal of Science Teacher Education</i> , <b>18</b> (3) 2007.
Arizona	2006	Novodvorsky, I.	Shifts in beliefs and thinking of a beginning physics teacher	<i>Journal of Physics Teacher Education Online</i> , <b>3</b> (3) 11-17, 2006.
Arizona	2005	Novodvorsky, I.	Secondary science teacher preparation at the University of Arizona	<i>APS Forum on Education Newsletter</i> , Fall 2005.
Arizona	2005	Novodvorsky, I.	Partners in the Preparation of Secondary Science Teachers	<i>APS Forum on Education Newsletter</i> , Spring 2005.
Arizona	2004	Novodvorsky, I.	US Coalition helps new teachers	<i>Physics Education</i> (News brief), <b>39</b> (16) 2004.
Arizona	2004	Novodvorsky, I.	The impact of educational research on physics teacher preparation, Quality Development in Teacher Education and Training	<i>Proceedings of 2nd International GIREP Seminar</i> , Udine, Italy, 2004.
Arizona	2004	Novodvorsky, I.	Teaching as they were taught: The importance of reformed university courses, Quality Development in Teacher Education and Training	<i>Proceedings of 2nd International GIREP Seminar</i> , Udine, Italy, 2004.
Arizona	2003	Tomanek, D., Talanquer, V., Novodvorsky, I., and Slater, T.F.	Responding to the call for change: The new college of science teacher preparation program at the University of Arizona	<i>Cell Biology Education</i> , <b>2</b> (1), 29-34, 2003.
Arizona	2003	Novodvorsky, I.	The Impact of Educational Research on Physics Teacher Preparation	<i>International Commission on Physics Education Newsletter</i> , <b>46</b> , 2003.
Arizona	2003	Talanquer, V., Novodvorsky, I., Slater, T., Tomanek, D.	A stronger role for science departments in the preparation of future chemistry teachers	<i>Journal of Chemical Education</i> , <b>80</b> (10), 1168-71, 2003.
Arizona	2003	Novodvorsky, I.	Beginning Your First Year	<i>The Physics Teacher</i> , <b>41</b> , 371-72, 2003.
Arizona	2002	Novodvorsky, I, Tomanek, D., Talanquer, V., Slater, T.,	A new model of physics teacher preparation	<i>Journal of Physics Teacher Education Online</i> , <b>1</b> (2), 2002
Arkansas	2007	Stewart, G., Stewart, J.	Pressures Lowering the Educational Value of Introductory Science Courses	<i>Cell Biology Education</i> , Summer edition (Accepted).
Arkansas	2007	Stewart, J., Griffin, H., Stewart, G.	Context sensitivity of the Force Concept Inventory	<i>Physical Review, Special Topics: PER</i> (Accepted).

Arkansas	2007	Stewart, J., McGee, J., Stewart, G.	Using Student Behavior Data to Better Understand Class Performance	<i>Physical Review, Special Topics: PER</i> (Submitted).
Arkansas	2006	Stewart, G.	Recruiting New Teachers At The University Of Arkansas	<i>APS Forum on Education Newsletter</i> , Fall 2006; <i>PTEC Newsletter</i> .
Arkansas	2006	Stewart, G.	Undergraduate Learning Assistants At The University Of Arkansas	<i>APS Forum on Education Newsletter</i> , Summer 2006; <i>PTEC Newsletter</i> .
Arkansas	2004	Stewart, G.	Practicing What We Preach.	<i>APS Forum on Education Newsletter</i> , Summer 2004.
Arkansas	2002	Bullock, D. W., et al.	Enhancing the Student-Instructor Interaction Frequency	<i>The Physics Teacher</i> , <b>40</b> , 535-541, 2002.
BSU	2004	Smith, W.	Starting the Semester at Odds: Science Educators' Versus College Students' Reasons for Studying Science	<i>Journal of College Science Teaching</i> , <b>34</b> (3), 44-49, 2004.
BSU	2004	Smith, W.	Data Mining the Internet: Immersing High School Students in Electronic Inquiry	<i>Science Activities</i> , <b>41</b> (1), 9-15, 2004.
BSU	2004	Smith, W.	Using Internet Technology to Address National Science and Teacher Education Standards	<i>The Teacher Educator</i> , <b>39</b> (2), 144-156, 2004.
Cal Poly	2005	Hoellwarth, C.	A direct comparison of conceptual learning and problem solving ability in traditional and studio style classrooms	<i>American Journal of Physics</i> , <b>73</b> (5), 459-463, 2005.
Colorado	2007	Price, E., Finkelstein, N.	Preparing Graduate Students to be Educators	<i>American Journal of Physics</i> (in press).
Colorado	2007	Kohl, P., Finkelstein, H. Rosengrant, D.	Strongly and Weakly Directed Approaches to Teaching Multiple Representation Use in Physics	<i>Physical Review</i> (in press).
Colorado	2007	Pollock, S., Finkelstein, N. Kost, L.	Reducing the gender gap in the physics classroom: How sufficient is interactive engagement?	<i>Physical Review, Special Topics: PER</i> , <b>3</b> (010107), 2007.
Colorado	2007	Pollock, S., Finkelstein, N.	Sustaining Change: Instructor Effects in Transformed Large Lecture Courses	<i>Proceedings of the 2006 Physics Education Research Conference (PERC)</i> , 2007.
Colorado	2006	Otero, V.	The Learning Assistant Model for Teacher Education in Science and Technology	<i>APS Forum on Education Newsletter</i> , Summer 2006.
Colorado	2006	Price, E.	Graduating Educated Graduate Students	<i>APS Forum on Education Newsletter</i> , Summer 2006.
Colorado	2006	Finkelstein, N.	The Role and Promise of Physics Education Research.	<i>APS News</i> , Back Page, Jan 2006.
Colorado	2006	Finkelstein, N, et al.	High-Tech Tools for Teaching Physics: the Physics Education Technology Project	<i>Journal of Online Learning and Teaching</i> , <b>2</b> (3) 109, 2006.

Colorado	2006	Otero, V.	Moving Beyond the 'Get It Or Don't' Conception of Formative Assessment	<i>Journal of Teacher Education</i> , <b>57</b> , 247 – 255, 2006.
Colorado	2006	Adams, W. K., et al.	A new instrument for measuring student beliefs about physics and learning physics: the Colorado Learning Attitudes about Science Survey	<i>Physical Review, Special Topics: PER</i> , <b>2</b> (010101), 2006.
Colorado	2006	Kohl, P.B., Finkelstein, N.	The effect of instructional environment on physics students' representational skills	<i>Physical Review, Special Topics: PER</i> , <b>2</b> (010102), 2006.
Colorado	2006	Kohl, P., Finkelstein, N.	The Effects of representation on students solving physics problems: a fine-grained characterization	<i>Physical Review, Special Topics: PER</i> , <b>2</b> (010106), 2006.
Colorado	2006	Podolefsky, N., Finkelstein, N.	Use of analogy in learning physics: The role of representations	<i>Physical Review, Special Topics: PER</i> , <b>2</b> (020101), 2006.
Colorado	2006	Pollock, S.	Transferring transformations: Learning gains, student attitudes, and the impact of multiple instructors in large lecture classes	<i>Proceedings of the 2005 Physics Education Research Conference (PERC)</i> , <b>818</b> (3), 2006.
Colorado	2006	Otero, V., et al.	Who is Responsible for Preparing Science Teachers?"	<i>Science</i> , <b>313</b> (5786), 445-446, 2006.
Colorado	2006	Podolefsky, N.	The Perceived Value of College Physics Textbooks: Students and Instructors May Not See Eye to Eye	<i>The Physics Teacher</i> , <b>44</b> (8), 2006.
Colorado	2005	Finkelstein, N., et al.	CU Physics Education, Recruiting and Preparing Future Physics Teachers and the Teacher Advisory Group	<i>APS Forum on Education Newsletter</i> , Spring 2005.
Colorado	2005	Finkelstein, N.	Replicating and Understanding Successful Innovations: Implementing Tutorials in Introductory Physics	<i>Physical Review, Special Topics: PER</i> , <b>1</b> (010101) 2005.
Colorado	2005	Kohl, P.B., Finkelstein, N.	Student representational competence self-assessment and problem solving in physics	<i>Physical Review, Special Topics: PER</i> , <b>1</b> (010104), 2005.
Colorado	2005	Finkelstein, N.D.	Replicating and Understanding Successful Innovations: Implementing Tutorials in Introductory Physics	<i>PhysRev Special Topics: PER</i> (in review).
Colorado	2005	Finkelstein, N., et al.	When learning about the real world is better done virtually: A study of substituting computer simulations for laboratory equipment	<i>PhysRev Special Topics: PER</i> , <b>1</b> (010103), 2005.
Colorado	2005	Finkelstein, N.	Can Computer Simulations Replace Real Equipment in Undergraduate Laboratories?	<i>Proceedings of the 2004 Physics Education Research Conference (PERC)</i> , <b>818</b> (3), 2005.

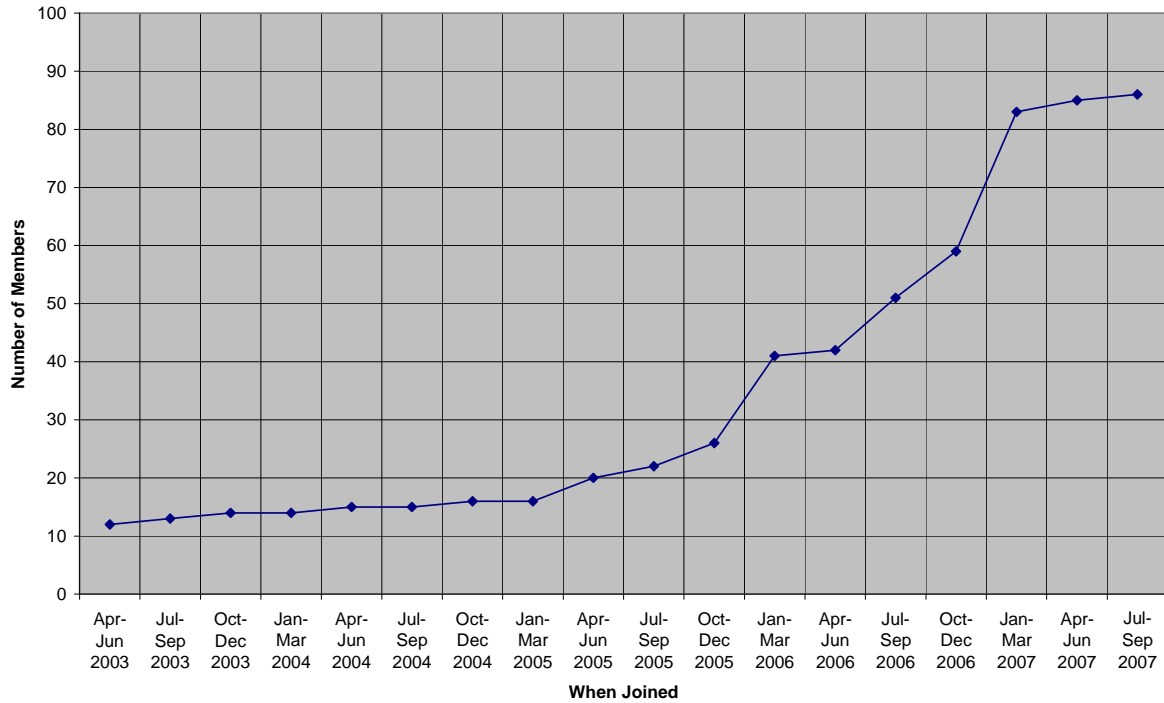
Colorado	2005	Finkelstein, N.	Seeding Change: The Challenges of Transfer and Transformation of Educational Practice and Research in Physics (Part I)	<i>Proceedings of the 2004 Physics Education Research Conference (PERC)</i> , <b>818</b> (3), 2005.
Colorado	2005	Kohl, P.B.	Representational Format Student Choice and Problem Solving in Physics	<i>Proceedings of the 2004 Physics Education Research Conference (PERC)</i> , <b>818</b> (3), 2005.
Colorado	2005	Finkelstein, N.	Evaluating a model of research-based practices for teacher preparation in a physics department: Colorado PhysTEC	<i>Proceedings of the 2005 Physics Education Research Conference (PERC)</i> , <b>818</b> (3), 2006.
Colorado	2005	Harlow, D.B.	Talking to Learn Physics and Learning to Talk Physics	<i>Proceedings of the 2005 Physics Education Research Conference (PERC)</i> , <b>818</b> (3), 2006.
Colorado	2005	Keller, C	Assessing The Effectiveness Of A Computer Simulation In Conjunction with Tutorials In Introductory Physics In Undergraduate Physics Recitations	<i>Proceedings of the 2005 Physics Education Research Conference (PERC)</i> , <b>818</b> (3), 2006.
Colorado	2005	Kohl, P.B.	Representational Competence and Introductory Physics	<i>Proceedings of the 2005 Physics Education Research Conference (PERC)</i> , <b>818</b> (3), 2006.
Colorado	2005	Pollock, S.	No single cause: Learning gains student attitudes and the impacts of multiple effective reforms.	<i>Proceedings of the 2005 Physics Education Research Conference (PERC)</i> , <b>818</b> (3), 2006.
Colorado	2005	Pollock, S.	Transferring transformations: Learning gains student attitudes and the impact of multiple instructors in large lecture classes.	<i>Proceedings of the 2005 Physics Education Research Conference (PERC)</i> , <b>818</b> (3), 2006.
Colorado	2005	Price, E.	Seeding Change: The Challenges of Transfer and Transformation of Educational Practice and Research in Physics (Part II)	<i>Proceedings of the 2005 Physics Education Research Conference (PERC)</i> , <b>818</b> (3), 2006.
SPU	2006	Seeley, L., Vokos, S.	Creating and Sustaining a Teaching and Learning Professional Community at Seattle Pacific University.	<i>APS Forum on Education Newsletter</i> , Summer 2006.
Towson	2007	Sandifer, C., Lising, L., Renwick, E.	Towson's PhysTEC course improvement project, Years 1 and 2: Results and lessons learned	<i>Proceedings of the Association for Science Teacher Education Conference</i> , 2007.
Towson	2007	Lising, L., Tirrochi, L.	A "teacher-in-residence" experience as professional development in elementary science inquiry	<i>Proceedings of the Association for Science Teacher Education Conference</i> , 2007.
Towson	2007	Lising, L., et al.	Instructor guide and resource materials for the Teaching Science in the Elementary School course at Towson University	Self-published.

Towson	2006	Sandifer, C., Lising, L., Tirrochi, L.	Our PhysTEC project: Collaborating with a classroom teacher to improve an elementary science practicum	<i>Proceedings of the Association for Science Teacher Education Conference, 2006.</i>
WMU	2007	Poel, B., Isola, D.	Recruiting a New Generation of Physics Teachers at Western Michigan University	<i>APS Forum on Education Newsletter, Spring 2007.</i>
WMU	2007	Isola, D., Olsen, J.	A Quiet Revolution in Preparing Future Teachers of Physics	<i>APS Forum on Education Newsletter, Spring 2007.</i>

Members of the project have given over 260 presentations to local, regional and national audiences. For a complete list of presentations by PhysTEC participants, please see the PhysTEC website: <http://www.phystec.org/presentations>.

## APPENDIX C: PTEC Institutions

PTEC Membership



- 1 Anderson University
- 2 Andrews University
- 3 Ball State University
- 4 Bemidji State University
- 5 Boise State University
- 6 Boston University
- 7 Bridgewater State College
- 8 Brigham Young University
- 9 Brigham Young University, Idaho
- 10 Buffalo State College
- 11 Cal Poly, San Luis Obispo
- 12 Cal Poly, Pomona
- 13 California State University, Chico
- 14 Casper College
- 15 Colgate University
- 16 College Misericordia
- 17 Cornell University
- 18 DePaul University
- 19 East Central University
- 20 Eastern Illinois University
- 21 Elon University
- 22 Emporia State University

- 23 Fairmont State University
- 24 Florida International University
- 25 Fort Hays State University
- 26 Francis Marion University
- 27 Hillsdale College
- 28 Hiram College
- 29 Hofstra University
- 30 Hope College
- 31 Illinois State University
- 32 Indiana University of Pennsylvania
- 33 James Madison University
- 34 Jacksonville State University
- 35 Kansas State University
- 36 Kennesaw State University
- 37 King College
- 38 Loyola College in Maryland
- 39 Millersville University
- 40 Morningside College
- 41 North Carolina State University
- 42 Oklahoma State University
- 43 Oregon State University
- 44 Pacific University
- 45 Radford University
- 46 Rensselaer Polytechnic Institute
- 47 Rutgers University
- 48 Seattle Pacific University
- 49 Southern Oregon University
- 50 Slippery Rock University
- 51 St. Joseph's University
- 52 St. Mary's College
- 53 Tennessee Technological University
- 54 Towson University
- 55 Tufts University
- 56 University of Alabama at Birmingham
- 57 University of Arizona
- 58 University of Arkansas
- 59 University of California, Davis
- 60 University of Colorado at Boulder
- 61 University of Connecticut
- 62 University of Kentucky
- 63 University of Maine
- 64 University of Maryland Baltimore County
- 65 University of Michigan-Dearborn
- 66 University of Minnesota
- 67 University of Missouri-Columbia
- 68 University of Nevada, Las Vegas

- 69 University of Nevada, Reno
- 70 University of North Carolina at Asheville
- 71 University of North Carolina at Chapel Hill
- 72 University of Northern Iowa
- 73 University of Notre Dame
- 74 University of Pittsburgh
- 75 University of San Diego
- 76 University of Texas at Austin
- 77 University of Texas at El Paso
- 78 University of Washington
- 79 University of Wisconsin-Madison
- 80 University of Wisconsin-Stevens Point
- 81 University of Wisconsin-Whitewater
- 82 Western Kentucky University
- 83 Western Michigan University
- 84 Winona State University
- 85 Wright State University
- 86 Xavier University of Louisiana