Sustaining Programs in Physics Teacher Education: A Study of PhysTEC Supported Sites

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Sustaining Programs in Physics Teacher Education: A Study of PhysTEC Supported Sites

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Cover design by Krystal Ferguson


An electronic version of this report is available at www.phystec.org/sustainability

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Preface

The Physics Teacher Education Coalition (PhysTEC) project was launched in 2001 by professional societies\(^1\) concerned about the severe shortage of qualified high school physics teachers. Since that time, the project has directly supported over 30 institutions to build model programs, and has established a coalition of more than 300 institutions committed to improving the education of future physics teachers. PhysTEC supported sites have collectively more than doubled the number of graduates per year from their physics teacher education programs. To put this in perspective, if all 760 institutions that grant a physics degree collectively doubled the number of well-prepared physics teachers per year, this would substantially address the national need for new physics teachers.

The PhysTEC project funds sites for a limited number of years,\(^2\) after which the host institution is expected to sustain the program. The success of PhysTEC sites rests not only on increasing the number of graduates per year prepared to teach physics; equally important is sustaining these increases over time, as well as the high quality programs in which physics teachers are educated. In 2012, we embarked on a formal study to investigate the sustainability of PhysTEC programs and engaged a consultant, Rachel E. Scherr at Seattle Pacific University. Scherr provided critical expertise in physics education research, including qualitative methods that were key to getting the story behind the numbers. Just as importantly, she provided an independent perspective, and was able to calibrate and interpret the narratives among the different sites in the study.

To carry out the study, we assembled a team that included Scherr and selected members of the project management team. Our goal was not to create a completely independent report divorced from any input from the project management. Rather, we wanted a report that would be deeply informed by the project, highly relevant to existing and future sites, and fine-tuned in guiding the project management in its next steps. Therefore, we established a partnership with Scherr in the lead role and project management in close communication with her, providing support throughout the effort. With this arrangement, we felt it would be possible to generate high quality research findings while creating a report that would also be highly valuable to the project. Scherr took the lead role in the study, conducting all site visits and phone interviews, gathering most of the quantitative data, and writing the report. As the project director, I provided insight into the historical development of the project as well as knowledge specific to the eight individual sites that were the focus of the study. I helped identify key individuals for interviews, participated in discussions with Scherr about the nature of the findings and conclusions, and reviewed draft versions of the report. Co-PI Renee Michelle Goertzen analyzed the quantitative data and created graphs, participated in discussions about the findings and conclusions, and reviewed the draft report. Project coordinator Renée Royal assisted with gathering existing project data and communicating with sites.

In a study that encompasses the entire span of the PhysTEC project, we need to acknowledge the evolution of the project over time. There have been a number of changes in response to learning what works (and what does not) in physics teacher education. Perhaps most importantly, PhysTEC developed an increased emphasis on sustainability over time. Recent requests for proposals for new sites explicitly ask for sustainability plans, and it is noted that all recent awardees committed up front to sustain their programs for three or more years beyond the PhysTEC award period. Expectations for sustainability were much less clear at the beginning of the project, and several of the initial sites are included in this study. With this in mind, it is all the more remarkable that these sites have sustained their programs. In addition, there have been other significant changes over time, including a decrease in the award period from 5 to 3 years; a decrease in support for reforming introductory physics courses; and the addition of key components such as recruitment, Learning Assistants, and institutional commitment. Given these changes and the varied institutional contexts of the eight PhysTEC sites in the study, the site reports should be treated as case studies, and the synthesis chapter Research Findings should be treated as a preliminary understanding of sustainability.\(^3\)

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\(^1\) Initial PhysTEC project partners included the American Physical Society (APS), the American Association of Physics Teachers (AAPT), and the American Institute of Physics (AIP). In 2009, PhysTEC became a project of APS and AAPT.

\(^2\) The first PhysTEC sites launched in 2001 were funded for 5 years; after this, the project switched to a funding period of 3 years.

\(^3\) In about 5 years, approximately 20 more PhysTEC sites will have completed funding and will be several years into their post-award periods. We anticipate updating the results of this report at that time.
Preface

We believe this report offers a rich array of findings that are immediately applicable to institutions seeking to establish sustainable programs in physics teacher education. It extends the work of the Task Force on Teacher Education in Physics (T-TEP) by more precisely defining the role of the champion and including a detailed description of typical activities. The report also documents the necessity of institutional motivation and support in sustaining programs, and lists activities that typically contribute to such support. A compilation of funding sources from the eight sites studied can serve as a guide for institutions seeking funding. Further, some institutions showed remarkable growth in funding for physics teacher education as a result of leveraging PhysTEC and other sources of support. Individual site reports from a variety of institutions provide a detailed look into the operations of successfully sustained programs, and offer specific examples of institutional motivation for supporting physics teacher education.

We wish to express our deep appreciation to all the site leaders and other key individuals at the eight studied PhysTEC sites who generously gave their time to participate in interviews and supply requested data and other information. These individuals are listed at the end of each site report in this document. In addition, Ed Lee, formerly a member of the PhysTEC project management team, did a meticulous job of copyediting the report and provided a number of valuable suggestions for improving its coherence and format. Krystal Ferguson in special publications at APS lent her considerable talents to the design of the cover and the layout of the report. Also, we wish to acknowledge everyone who has contributed to the PhysTEC project, including current and past members of the project management team, project consultants and editors, and site leaders and other personnel. These individuals are listed at phystec.org, and the project owes its success to each and every one.

Finally, the PhysTEC project would not have been possible without support from the National Science Foundation (grant numbers 0808790, 0108787, and 0833210) as well as private donors who contributed to APS fundraising efforts. In addition, we acknowledge the significant organizational support that APS and AAPT have contributed over many years to the operation of the project.

Sincerely,

Monica Plisch
PhysTEC Project Director
June 2014

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4 The full T-TEP report is available at www.phystec.org/taskforce.
Executive Summary

The following is a brief summary of the results of this study. Detailed results are presented in the chapter titled Research Findings.

1 | Are PhysTEC legacy sites\(^1\) sustaining an increase in production of physics teachers?

Yes. During the post-award period, three of the eight PhysTEC legacy sites studied have sustained an increase in production of physics teachers. Moreover, during this period four of the eight sites studied have further increased production of physics teachers. One site has stopped producing physics teachers. These results suggest that the activities taking place at PhysTEC legacy sites are effective for increasing teacher production in the long term.

2 | Did the PhysTEC award precipitate long-term support for physics teacher education at the legacy sites?

Yes. During the post-award period, three of the eight PhysTEC legacy sites studied have sustained increases in funding for physics teacher education. These are the same sites that have sustained increases in production of physics teachers. Moreover, during this period four of the eight PhysTEC legacy sites studied have further increased funding for physics teacher education. Three of these four also have further increased their production of physics teachers. At one site, personnel continue to contribute to physics teacher education but funding has not increased; this site stopped producing physics teachers.

All studied sites that invested in physics teacher education sustained an increase in their production of physics teachers. Sites with a greater investment saw greater increases in their long-term production of physics teachers.

Seven of the eight PhysTEC legacy sites studied are identified as having “sustained” physics teacher education programs, in that they have sustained increases in teacher production and funding for physics teacher education. Four of the eight studied sites are identified as having “thriving” physics teacher education programs, in that they have sustained large increases in both teacher production and funding for physics teacher education. One site has not sustained its physics teacher education program.

3 | What features should be prioritized for building sustainable physics teacher education programs?

Two features are common to all studied sites that sustained increases in production of physics teachers: a champion of physics teacher education and institutional motivation and commitment. Only one studied site lacks this pair of features, and that site stopped producing physics teachers. These results suggest that in order to sustain increased production of physics teachers, sites need both a champion and institutional motivation and commitment.

All studied sites have at least one champion, defined as one who secures funding and personnel benefiting physics teacher education and negotiates with the institution for changes beneficial to physics teacher education. In other words, every studied site has at least one person who creates, funds, staffs, and institutionalizes physics teacher education at his or her institution. This suggests that the champion is essential.

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\(^1\) PhysTEC “legacy sites” are PhysTEC sites whose award period has ended.
All studied sites that have sustained increases in production of physics teachers have substantial institutional motivation for and commitment to physics teacher education. The one site at which institutional commitment was greatly reduced stopped producing physics teachers. Institutional motivation to support physics teacher education, as observed in this study, may include fulfilling the institutional mission; serving regional needs; improving the reputation of the institution in the community; supporting strong members of the faculty; and being visible on a national stage. Institutional commitment to physics teacher education is evidenced by funding for physics teacher education programs and personnel, alignment of the institutional mission with physics teacher education, establishment of infrastructure supporting physics teacher education, and support for champions such as promotion, leadership opportunities, and a mandate to dedicate substantial effort to physics teacher education.

Many activities contribute to sustaining physics teacher education at legacy sites, such as recruitment, advising, and early teaching experiences. One goal of this study was to determine whether certain activities correspond strongly with sustaining an increase in physics teacher production. Every site that has sustained an increase in production of physics teachers has sustained its program of recruitment, providing evidence that recruitment is necessary for sustaining increases in teacher production. However, overall, the data does not offer strong evidence that any one specific activity holds the key to teacher production. Instead, this study suggests that physics teacher education activities at each site reflect local priorities and opportunities, including the expertise of local personnel. This study offers a catalogue of such activities as a metric by which to compare specific activities conducted at different sites and as a guide for sites seeking to increase their personnel and award activities in support of physics teacher education.
Methodology

1 | Site selection

The sites selected for this study meet two criteria:

- They received awards from PhysTEC to support secondary physics teacher education.
- Their award period had ended when the study began in 2011 (they were “legacy sites”).

Nine sites met these criteria. One site was unavailable to participate in the study due to extended medical leave of the site leader. Thus, this study includes the following eight sites:

- UArk: University of Arkansas
- CU-B: University of Colorado, Boulder
- FIU: Florida International University
- SPU: Seattle Pacific University
- UAz: University of Arizona
- WMU: Western Michigan University
- UNC: University of North Carolina–Chapel Hill
- Cornell: Cornell University

The study period for each site extends from three years before that site’s PhysTEC award to the Spring of 2012. Data about PhysTEC graduates extends one additional year, to Spring of 2013, because it was readily available and added important information on sustainability.

2 | Quantitative data collection

Quantitative data was collected to document specific activities at each site over the study period, including the number of PhysTEC Secondary Graduates each year, the extent to which PhysTEC Key Components were sustained, the quantity of time that faculty and staff dedicated to physics teacher education, and the quantity of funding for physics teacher education.

PhysTEC Secondary Graduates (referred to in this report as secondary physics teachers, or physics teachers) are students who have graduated from a PhysTEC Institution, have a major or minor (or equivalent coursework) in physics, and either have certification to teach high school physics or have completed a teacher education program. PhysTEC regularly collects data on PhysTEC Secondary Graduates from all funded sites. Graphs showing the PhysTEC Secondary Graduates over time are presented in each site report, including the average production during the pre-award period, the award period, and the post-award period. The national yearly average physics teacher production by institutions with a stated interest in physics teacher education is included in the graph for comparison.

Each site completed a survey summarizing briefly whether each of the PhysTEC Key Components had been maintained, had grown, had productively evolved, had been reduced, or had been eliminated since the period of PhysTEC funding. These characterizations are subjective and difficult to standardize across sites. The study authors reviewed these characterizations and validated them where possible.

Information about the quantity of personnel time and award funding dedicated to physics teacher education was initially requested during in-person interviews with site leaders and other personnel during site visits. (Site visits are
described in more detail below.) In order to be as inclusive as possible and learn about all the activities that sites considered important, the study did not initially specify which activities should count as contributing to physics teacher education. These interviews generated an extensive catalogue of kinds of activities that sites consider relevant to physics teacher education. The study authors then selected the items in this catalogue that are consistent with PhysTEC’s vision of physics teacher education. For example, PhysTEC no longer supports introductory course transformation with its awards, so introductory course transformation was removed from the catalogue of personnel and award activities supporting physics teacher education, whereas courses primarily serving preservice physics teachers are still consistent with PhysTEC priorities and were retained in the catalogue.

The resulting catalogues of personnel and funded activities provided metrics with which to quantitatively compare activity across sites. (These catalogues are presented in Appendix A1, and within the Research Findings chapter as Figure 1 and Figure 3.) Site leaders and other personnel were interviewed remotely to document (1) which personnel at each site engaged in the each of activities in the catalogue, and what fraction of their time they spent on those specific activities; and (2) which awards to that site funded each of the activities in the catalogue, and what fraction of the award funded those specific activities. The resulting information is presented in tabular form in Appendix A1.

Graphs showing the personnel and funded activity as a function of time were generated for each site and are presented in each site report. In the funding graphs, three types of funding are distinguished: PhysTEC funding, funding from external agencies other than PhysTEC, and funding from the local institution. This choice corresponds to a priority for the study to observe the means by which each site sustained funding for physics teacher education. In the personnel graphs, five types of personnel are distinguished: champions, other faculty, Teachers in Residence funded by PhysTEC, Teachers in Residence not funded by PhysTEC, and other personnel such as graduate researchers and staff. This choice corresponds to a priority for the study to observe the extent to which each site sustained personnel in key roles.

Personnel who contributed a total of less than an average of 0.1 FTE to activities supporting physics teacher education were not included in the quantitative documentation of personnel time. For this reason, most administrators and many other contributing personnel do not appear in the data.

### Qualitative data collection

In addition to quantitative data, this study attempted to document the history, development, pressures, opportunities, motivations, and constraints on physics teacher education at each site.

Based on the amount of activity known to be occurring at a given site, five of the eight participating sites (UArk, CU-B, FIU, SPU, and UNC) were selected for a comprehensive in-person site visit lasting two or three days. The other three sites (UAz, WMU, and Cornell) were selected for a “remote site visit” consisting of a few interviews conducted by telephone. Both kinds of site visits were conducted by the Sustainability Consultant. The determination as to whether to conduct a comprehensive in-person site visit or a remote site visit was made in consultation with the PhysTEC project management team (PMT), based on the amount of activity and number of personnel contributing to physics teacher education at a site.

Comprehensive visits consisted primarily of interviews with as many different kinds of personnel with a stake in physics teacher education as possible, along with observations of courses and facilities relevant to physics teacher education. For example, the site visit to Florida International University included interviews with the champions (faculty members in physics and education), the Chair and the former Chair of the Physics Department, other faculty in physics, the Dean of the College of Arts & Sciences, the Dean of the College of Education, the Associate Director of the School of Integrated Science and Humanities, the Vice Provost, a Teacher in Residence, the coordinator of the secondary science education program, a graduate student researching physics teacher education, and a number of physics learning assistants. The questions asked at each interview were specific to the interviewee’s role in
Methodology

contributing to physics teacher education at that site. The goal of these interviews was to document and synthesize the activity contributing to physics teacher education at that site (present, past, and anticipated); the different contributions of personnel in different roles supporting physics teacher education; the institutional motivation and support for physics teacher education; the activities of the champions; and the pressures, opportunities, constraints, and so on experienced by site personnel that promote or inhibit the production of physics teachers by that site.

Remote site visits consisted of one to three interviews with site personnel (including the champion). These interviews had the same purposes as those described above.

4 | Definitions of terms

In this report, the terms “site” and “institution” refer to one of the universities participating in this study.

The term “physics teachers” is used in this report to denote PhysTEC Secondary Graduates. PhysTEC Secondary Graduates are students who have graduated from a PhysTEC Institution, have a major or minor (or equivalent coursework) in physics, and either have certification to teach high school physics or have completed a teacher education program.

In order to determine if a site has sustained an increase in physics teacher production or funding for physics teacher education, the value of that quantity is compared for the periods before and after the PhysTEC award. For example, to determine whether there is a sustained increase in teacher production at a site, the average production of physics teachers in the years since that site’s PhysTEC award is compared to the average production of physics teachers in the years before the award. Since the PhysTEC award period is typically three or more years long, this calculation provides a sense of long-term change in the quantity.

5 | Validation

Information reported in this study was primarily provided by personnel at the studied sites. Numbers of PhysTEC Secondary Graduates were extensively verified through PhysTEC’s data collection processes. Awards supporting physics teacher education were verified to the extent that they are a matter of public record (e.g., awards from the National Science Foundation). Much of what is reported concerns the history, development, constraints, pressures, and opportunities that sites perceive as being important to physics teacher education in their local context. The PhysTEC PMT checked reports for accuracy. Further validation is through member-checking: Each site checked that the report on its site accurately described its site’s events and conditions.

Quantitative results are presented with the caveat that any study of physics teacher education is necessarily based on a small number of people and events, and conclusions are therefore tentative.
Research Findings

1 Are PhysTEC legacy sites\footnote{PhysTEC “legacy sites” are PhysTEC sites whose award period has ended.} sustaining an increase in production of physics teachers?

Yes. Seven of the eight PhysTEC legacy sites studied have sustained an increase in production of physics teachers. Four of the eight sites studied have sustained a large increase in production of physics teachers. One site has stopped producing physics teachers. These results suggest that the activities taking place at PhysTEC legacy sites are effective for increasing teacher production in the long term.

A site is defined as having a “sustained increase” in production of physics teachers if the average number of physics teachers produced per year in the post-award period (ending in the spring of 2012) is greater than that in the pre-award period by at least 1.0. To sustain an increase in physics teacher production is an achievement: A site with a sustained increase in teacher production has typically maintained the increase it achieved during the PhysTEC-funded period of the program. An increase of one physics teacher per year is considered substantial in that it is approximately equal to the national average number of physics teachers produced by institutions with a stated interest in physics teacher education (the over 300 members of the PhysTEC Coalition). In other words, if every institution produced one more physics teacher per year than it does currently, the total number of physics teachers being produced would approximately double.

A site is defined as having “further increased” production of physics teachers if the average number of physics teachers produced per year in the post-award period (ending in the spring of 2012) is greater than that in the pre-award period by at least 2.0. To further increase physics teacher production is a high achievement: A site with a further increase in teacher production has typically exceeded the increase it achieved during the PhysTEC-funded period of the program. One studied site is defined as having further increased teacher production even though its increase is not quite two per year, because it shows an increasing average over the pre-award, award, and post-award periods.

The current yearly average production of physics teachers at the legacy sites ranges from 1 to 6 teachers per year, which compares favorably to the national average yearly production of physics teachers for institutions with a stated interest in physics teacher education (about 1/year). Production in the post-award period ranges from three to six years, with an average of 4.4 years.

Table I details the results for each studied site. The “pre-award average” and “post-award average” are the average number of physics teachers produced per year before and after the PhysTEC award, respectively. The difference between the post-award average and the pre-award average is indicated in the “Increase” column. Since the PhysTEC award period is typically three to five years long and it takes one to three years to produce new PhysTEC Graduates, this calculation provides a sense of long-term change in the quantity. The average yearly production of all PhysTEC Coalition members taken together is provided for comparison.
Table I. PhysTEC legacy sites’ production of physics teachers over the long term. “Pre-award average,” “award average,” and “post-award average” are the average number of physics teachers produced per year before, during, and after the PhysTEC award, respectively. “Increase” denotes the amount by which the post-award average exceeds the pre-award average. Production status is “sustained” for sites whose increase is at least 1.0, and “further increased” for sites whose increase is at least 2.0. “Coalition” refers to all PhysTEC Coalition member institutions, which have a stated interest in physics teacher education, averaged together.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Pre-award average</th>
<th>Award average</th>
<th>Post-award average</th>
<th>Increase</th>
<th>Teacher production status</th>
</tr>
</thead>
<tbody>
<tr>
<td>UArk</td>
<td>0.3</td>
<td>4.3</td>
<td>6.0</td>
<td>5.7</td>
<td>Further increased</td>
</tr>
<tr>
<td>CU-B</td>
<td>1.0</td>
<td>2.0</td>
<td>3.2</td>
<td>2.2</td>
<td>Further increased</td>
</tr>
<tr>
<td>FIU</td>
<td>0.0</td>
<td>1.0</td>
<td>2.0</td>
<td>2.0</td>
<td>Further increased</td>
</tr>
<tr>
<td>SPU</td>
<td>2.3</td>
<td>3.0</td>
<td>4.0</td>
<td>1.7</td>
<td>Further increased*</td>
</tr>
<tr>
<td>UAz</td>
<td>0.3</td>
<td>2.0</td>
<td>1.6</td>
<td>1.3</td>
<td>Sustained increase</td>
</tr>
<tr>
<td>WMU</td>
<td>3.7</td>
<td>6.4</td>
<td>4.8</td>
<td>1.1</td>
<td>Sustained increase</td>
</tr>
<tr>
<td>UNC</td>
<td>0.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>Sustained increase</td>
</tr>
<tr>
<td>Cornell</td>
<td>2.0</td>
<td>0.5</td>
<td>1.0</td>
<td>-1.0</td>
<td>Not increased</td>
</tr>
<tr>
<td>Coalition**</td>
<td>1.26</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* SPU has sustained an increase in teacher production that is close to the threshold for a large increase and follows the trend of other institutions that further increased teacher production in showing an increasing average over the pre-award, award, and post-award periods.

2 Did the PhysTEC award precipitate long-term support for physics teacher education at the legacy sites?

Yes. Seven of the eight PhysTEC legacy sites studied have sustained increases in funding for physics teacher education. These are the same sites that have sustained increases in production of physics teachers. Four of the eight PhysTEC legacy sites studied have sustained large increases in funding for physics teacher education. At one site, personnel continue to contribute to physics teacher education but funding has not increased; this site stopped producing physics teachers.

All studied sites that invested in physics teacher education sustained an increase in their production of physics teachers. Sites with a greater investment saw greater increases in their long-term production of physics teachers.

Seven of the eight PhysTEC legacy sites studied are identified as having sustained physics teacher education programs, in that they have sustained increases in teacher production and funding for physics teacher education. Four of the eight studied sites are identified as having thriving physics teacher education programs, in that they have sustained large increases in both teacher production and funding for physics teacher education. One site has not sustained its physics teacher education program.

1 Status of funding at studied sites

PhysTEC awards are intended to catalyze increased production of physics teachers at a specific site. Sites are funded
for a few years to establish a PhysTEC program, after which the institution is expected to sustain the program. Funded activities supporting physics teacher education are defined in Figure 1. Such funding may derive from the institution, from grants by agencies such as the National Science Foundation, or from other sources.

Figure 1. Funded activities supporting physics teacher education. When only a fraction of an award is dedicated to these activities, only that fraction of the award is counted as supporting physics teacher education.

Table II details the results for each studied site. Yearly average funds supporting physics teacher education are reported in thousands of dollars for the pre-award period, award period (including PhysTEC funds), and post-award period. “Funding increase” is the difference between the average yearly funding in the post-award period and the average yearly funding in the pre-award period, in thousands of dollars. A site is defined to have “sustained” an increase in funding for physics teacher education if the yearly average funding contributing to physics teacher education in the post-award period is greater than that in the pre-award period by at least $100,000, the yearly amount of a typical PhysTEC award. Three of the studied sites have a funding increase of $100,000-$200,000. Four sites have a funding increase of $500,000 or more; these sites are defined to have “further increased” their funding for physics teacher education.

Table II. PhysTEC legacy sites’ funding for physics teacher education over the long term. “Funding increase” denotes the difference between the average yearly funding in the post-award and the pre-award periods.
Research Findings

Funding is reported in thousands of dollars. Institutions whose funding increase is at least $100K are identified as having “sustained” an increase in funding for physics teacher education; institutions whose funding increase is at least $500K are identified as having “further” increased their funding for physics teacher education.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Pre-award funding ($K)</th>
<th>Award-period funding ($K)</th>
<th>Post-award funding ($K)</th>
<th>Funding increase ($K)</th>
<th>Funding status</th>
</tr>
</thead>
<tbody>
<tr>
<td>UArk</td>
<td>20</td>
<td>290</td>
<td>600</td>
<td>580</td>
<td>Further increased</td>
</tr>
<tr>
<td>CU-B</td>
<td>70</td>
<td>320</td>
<td>570</td>
<td>500</td>
<td>Further increased</td>
</tr>
<tr>
<td>FIU</td>
<td>120</td>
<td>500</td>
<td>770</td>
<td>650</td>
<td>Further increased</td>
</tr>
<tr>
<td>SPU</td>
<td>30</td>
<td>580</td>
<td>1030</td>
<td>1000</td>
<td>Further increased</td>
</tr>
<tr>
<td>UAz</td>
<td>40</td>
<td>300</td>
<td>200</td>
<td>160</td>
<td>Sustained increase</td>
</tr>
<tr>
<td>WMU</td>
<td>0</td>
<td>190</td>
<td>90</td>
<td>100</td>
<td>Sustained increase</td>
</tr>
<tr>
<td>UNC</td>
<td>30</td>
<td>190</td>
<td>180</td>
<td>150</td>
<td>Sustained increase</td>
</tr>
<tr>
<td>Cornell</td>
<td>160</td>
<td>300</td>
<td>180</td>
<td>20</td>
<td>Not increased</td>
</tr>
</tbody>
</table>

These results constitute evidence that at most of the sites studied, the PhysTEC award is associated with increased support for physics teacher education, even after the PhysTEC award itself has concluded. Some sites indicate that the PhysTEC award played a significant role in precipitating this support, especially through site visits during which PhysTEC staff communicated the importance of physics teacher education to administrators. Other sites attribute their increased support for physics teacher education to a confluence of many factors, PhysTEC among them.

In this study, funds contributing to physics teacher education are those that support the specific activities in Figure 1. In some cases these activities also benefit all preservice teachers at an institution, or all preservice science teachers, or both inservice and preservice teachers, or preservice physics teachers along with physics undergraduates. For this reason, it is not appropriate to calculate the institutional cost of producing one physics teacher by dividing the funds contributing to physics teacher education by the number of physics teachers produced. Rather, the funding reported benefits the larger physics teacher education program, which in many cases benefits other populations at the same time.

2. Status of programs at studied sites

Seven of the eight PhysTEC legacy sites studied are identified as “sustained” physics teacher education programs, in that they have sustained increases in both teacher production and funding for physics teacher education. Four of the eight studied sites are identified as having thriving physics teacher education programs, in that they have achieved further increases in both teacher production and funding for physics teacher education. One site has not sustained its physics teacher education program. Table III details these results.

Table III. Status of physics teacher education programs at PhysTEC legacy sites. Production status and
Research Findings

Funding status are reproduced from Table I and Table II.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Production status</th>
<th>Funding status</th>
<th>Program status</th>
</tr>
</thead>
<tbody>
<tr>
<td>UArk</td>
<td>Further increased</td>
<td>Further increased</td>
<td>Thriving</td>
</tr>
<tr>
<td>CU-B</td>
<td>Further increased</td>
<td>Further increased</td>
<td>Thriving</td>
</tr>
<tr>
<td>FIU</td>
<td>Further increased</td>
<td>Further increased</td>
<td>Thriving</td>
</tr>
<tr>
<td>SPU</td>
<td>Further increased*</td>
<td>Further increased</td>
<td>Thriving</td>
</tr>
<tr>
<td>UAz</td>
<td>Sustained increase</td>
<td>Sustained increase</td>
<td>Sustained</td>
</tr>
<tr>
<td>WMU</td>
<td>Sustained increase</td>
<td>Sustained increase</td>
<td>Sustained</td>
</tr>
<tr>
<td>UNC</td>
<td>Sustained increase</td>
<td>Sustained increase</td>
<td>Sustained</td>
</tr>
<tr>
<td>Cornell</td>
<td>Not increased</td>
<td>Not increased</td>
<td>Not sustained</td>
</tr>
</tbody>
</table>

* SPU’s record of teacher production is close to the threshold for further increased production and follows the trend of other institutions that further increased teacher production in showing an increasing average over the pre-award, award, and post-award periods.

3. Funding sources

Funding for physics teacher education at the studied sites has issued from a variety of sources over the studied period. Figure 2 shows the distribution of funding for physics teacher education that all sites taken together have received from these sources during the studied period (starting three years before the award at the studied site with the earliest award and continuing to the spring of 2012). Funding activities supporting physics teacher education are shown in Figure 1. When only a fraction of an award is dedicated to these activities, only that fraction of the award is counted as supporting physics teacher education.

The largest fraction of funding for physics teacher education (40%) comes from the studied institutions themselves. This funding primarily supports the personnel who conduct activities benefiting physics teacher education. Personnel contributing to physics teacher education at the studied sites include faculty, TIRs, and other personnel such as graduate researchers and staff.

PhysTEC funding accounts for 14% of the total. PhysTEC funding originates with the National Science Foundation as well as from APS fundraising efforts; subawards are administered by APS.

Direct funding from the National Science Foundation comprises another 37% of the total. Most of this funding derives from the Directorate for Education and Human Resources (EHR), including Discovery Research K-12 and other programs in Research on Learning in Formal and Informal Settings (DRL) and Noyce and other programs in Undergraduate Education (DUE). Some also derives from programs in the Directorate of Mathematical and Physical Sciences (MPS), including Physics (PHY) and Engineering Education and Centers (EEC). This funding supports a variety of activities including scholarships for secondary physics teachers, construction of pathways to become a secondary physics teacher, design and implementation of professional development programs, the maintenance of a Teacher Advisory Group, and other activities.

The other 9% of total funding is from other sources including foundations (e.g., Woodrow Wilson Foundation), the U.S. Department of Education, state Departments of Education, and donations and endowments from individuals.

Overall, the great majority of funding for physics teacher education comes either from the National Science
Research Findings

Foundation or from the local institution. Awards from the National Science Foundation tend to support teachers directly (e.g., scholarships or professional development experiences) or establish new programs at an institution (e.g., construction of pathways to become a physics teacher). Personnel that contribute to physics teacher education at an institution are usually supported by institutional funding. Given the key role that lead personnel play in sustaining physics teacher education at an institution (See next section and also the “1. Champions” section in Part 3 on p. 21), institutional funding is probably a key factor in sustaining increases in physics teacher production.

Sources of funding for physics teacher education

<table>
<thead>
<tr>
<th>Source</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>PhysTEC</td>
<td>9%</td>
</tr>
<tr>
<td>NSF-PHY &amp; EEC</td>
<td>14%</td>
</tr>
<tr>
<td>NSF-DUE (mostly Noyce)</td>
<td>37%</td>
</tr>
<tr>
<td>NSF-DRL</td>
<td>40%</td>
</tr>
<tr>
<td>Institution (mostly personnel)</td>
<td>37%</td>
</tr>
<tr>
<td>Other (DoEd, State, Industry, etc.)</td>
<td>9%</td>
</tr>
</tbody>
</table>

Figure 2. Sources of funding for physics teacher education. The distribution shown is for all funding supporting the activities listed in Figure 1 for all sites during the studied period.

4. Status of personnel at studied sites

Long-term support for physics teacher education at a site is indicated not only by funds supporting physics teacher education, but also by the personnel whose activities constitute the physics teacher education program at that site. (Personnel activities supporting physics teacher education are defined in Figure 3.) These indicators are related: Institutional funding almost exclusively supports site personnel. Personnel contributing to physics teacher education include faculty, Teachers in Residence, and to a lesser extent other personnel such as program staff and graduate researchers.

At all sites, the pre-award average personnel time dedicated to physics teacher education was less than 0.5 FTE, typically corresponding to a small fraction of faculty time spent conducting professional development or outreach activities for physics teachers. During the PhysTEC award, faculty time dedicated to physics teacher education was 0.5 to 1.0 FTE at seven out of the eight sites studied. These are the seven sites that sustained an increase in physics teacher production. At the eighth site, faculty time did not average more than 0.2 FTE in any period, and physics teacher production was not sustained.
Research Findings

In the post-award period, six of the eight sites (six of the seven sites that sustained teacher production) sustained faculty time of at least 0.5 FTE, typically at the same level as the award period. This suggests that about 0.5 to 1.0 FTE of faculty time is appropriate for sustaining physics teacher education at an institution. At several sites, this quantity of faculty time is the total contributed by a team of faculty, though at some sites faculty time is contributed by just one or two people. More detail is available in the individual site reports.

- Recruits secondary physics teachers (directly identifies specific students as potential physics teachers and communicates that to the student)
- Builds pathways to become a secondary physics teacher (designs physics teacher education certification programs)
- Advises preservice secondary physics teachers (academic advising and advice about being a teacher)
- Mentors/inducts inservice secondary physics teachers
- Teaches secondary physics teachers (students who have declared a physics teaching major and/or inservice secondary physics teachers)
- Creates/maintains physics-specific pedagogy classes (such as LA pedagogy courses or science methods courses with specific physics pedagogy content)
- Maintains a Teacher Advisory Group of secondary physics teachers (network of local secondary physics teachers who serve as physics teacher education resources)
- Influences placement of new secondary physics teachers for student teaching
- Leads collaborations with schools and school districts through local school administrators and teacher leaders that benefit secondary physics teacher education
- Promotes secondary physics teacher education (through talks, papers, and/or research specifically about physics teacher education)
- Secures funding and staff for secondary physics teacher education efforts at the institution (i.e., procures grants and/or hires people)
- Makes deals for secondary physics teacher education (negotiates with institution for changes beneficial to physics teacher education)
- PhysTEC site leader

Figure 3. Personnel activities supporting physics teacher education. In most cases only a fraction of an individual's time is spent on these activities.

Table IV shows the average faculty time dedicated to physics teacher education at the studied sites in the pre-award, award, and post-award periods.
Table IV. Average faculty time dedicated to physics teacher education at PhysTEC legacy sites in the pre-award, award, and post-award period. Faculty time is reported in full-time equivalents (FTEs). Teacher production status is reproduced from Table I for reference.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Pre-award faculty time (FTE)</th>
<th>Award-period faculty time (FTE)</th>
<th>Post-award faculty time (FTE)</th>
<th>Faculty time maintained &gt; 0.5 FTE?</th>
<th>Teacher production status</th>
</tr>
</thead>
<tbody>
<tr>
<td>UArk</td>
<td>0.3</td>
<td>1.0</td>
<td>0.9</td>
<td>Yes</td>
<td>Further increased</td>
</tr>
<tr>
<td>CU-B</td>
<td>0.4</td>
<td>0.6</td>
<td>0.6</td>
<td>Yes</td>
<td>Further increased</td>
</tr>
<tr>
<td>FIU</td>
<td>0.0</td>
<td>1.0</td>
<td>1.0</td>
<td>Yes</td>
<td>Further increased</td>
</tr>
<tr>
<td>SPU</td>
<td>0.0</td>
<td>0.8</td>
<td>0.8</td>
<td>Yes</td>
<td>Further increased</td>
</tr>
<tr>
<td>UAz</td>
<td>0.3</td>
<td>0.7</td>
<td>0.7</td>
<td>Yes</td>
<td>Sustained increase</td>
</tr>
<tr>
<td>WMU</td>
<td>0.2</td>
<td>0.6</td>
<td>0.2</td>
<td>No</td>
<td>Sustained increase</td>
</tr>
<tr>
<td>UNC</td>
<td>0.0</td>
<td>0.5</td>
<td>0.5</td>
<td>Yes</td>
<td>Sustained increase</td>
</tr>
<tr>
<td>Cornell</td>
<td>0.1</td>
<td>0.2</td>
<td>0.2</td>
<td>No</td>
<td>Not increased</td>
</tr>
</tbody>
</table>

Teachers in Residence provide substantial benefit to a site by recruiting undergraduates into teaching, teaching methods and content courses to future teachers, influencing placement of new secondary physics teachers for student teaching, and connecting the university to the school system, among other activities specific to local context. PhysTEC awards increased personnel time by supporting a Teacher in Residence either full or part time to conduct some of the activities listed in Figure 3. Most sites sustained a Teacher in Residence in the post-award period, but usually for less than 0.5 FTE. At some institutions, the TIR position evolved; for example, at one institution (UArk) a regional network of teachers took on some of the functions of the TIR, and at another (UAz), clinical faculty with a background in high school physics teaching support all preservice science teachers, rather than primarily physics teachers. Five of the seven sites that sustained teacher production averaged only 0.2 FTE or less of TIR time in the post-award period. These findings suggest that sustaining a TIR part-time may be a feasible solution for sites looking to have some benefits of a TIR without support for a full-time TIR. These findings are detailed in Table V.

Table V. Average Teacher in Residence time dedicated to physics teacher education at PhysTEC legacy
Research Findings

sites in the pre-award, award, and post-award period. TIR time is reported in full-time equivalents (FTEs). Post-award status indicates the status of the TIR position compared to the award period (further details are available in the individual site reports). Teacher production status is reproduced from Table I for reference.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Pre-award TIR time (FTE)</th>
<th>Award-period TIR time (FTE)</th>
<th>Post-award TIR time (FTE)</th>
<th>Post-award status of TIR</th>
<th>Teacher production status</th>
</tr>
</thead>
<tbody>
<tr>
<td>UArk</td>
<td>0.0</td>
<td>1.0</td>
<td>0.0</td>
<td>Evolved</td>
<td>Further increased</td>
</tr>
<tr>
<td>CU-B</td>
<td>0.0</td>
<td>1.1</td>
<td>0.2</td>
<td>Reduced</td>
<td>Further increased</td>
</tr>
<tr>
<td>FIU</td>
<td>0.0</td>
<td>0.7</td>
<td>1.7</td>
<td>Maintained</td>
<td>Further increased</td>
</tr>
<tr>
<td>SPU</td>
<td>0.0</td>
<td>0.2</td>
<td>0.2</td>
<td>Maintained</td>
<td>Further increased</td>
</tr>
<tr>
<td>UAz</td>
<td>0.0</td>
<td>1.0</td>
<td>0.1</td>
<td>Evolved</td>
<td>Sustained increase</td>
</tr>
<tr>
<td>WMU</td>
<td>0.2</td>
<td>1.0</td>
<td>0.2</td>
<td>Reduced</td>
<td>Sustained increase</td>
</tr>
<tr>
<td>UNC</td>
<td>0.0</td>
<td>0.3</td>
<td>0.4</td>
<td>Evolved</td>
<td>Sustained increase</td>
</tr>
<tr>
<td>Cornell</td>
<td>0.1</td>
<td>1.0</td>
<td>0.1</td>
<td>Reduced</td>
<td>Not increased</td>
</tr>
</tbody>
</table>

3 | What features should be prioritized for building sustainable physics teacher education programs?

Two features are common to all studied sites that sustained increased production of physics teachers: a champion of physics teacher education and institutional motivation and commitment. Only one studied site lacks this pair of features, and that site stopped producing physics teachers. These results suggest that in order to sustain increased production of physics teachers, sites need both a champion and institutional motivation and commitment.

1. Champions

All studied sites have at least one champion, defined as one who secures funding and personnel benefiting physics teacher education and negotiates with the institution for changes beneficial to physics teacher education. In other words, every studied site has at least one person who creates, funds, staffs, and institutionalizes physics teacher education at his or her institution. This suggests that the champion is essential.

This study characterizes champions as those who undertake certain activities, rather than those who are “personally committed to physics teacher education,” as in the Report of the Task Force on Teacher Education in Physics. At many of the studied sites, those who lead efforts for physics teacher education do have such personal commitment, which contributes to sustaining their professional focus on physics teacher education over the long term. At some sites, however, champions have a primary commitment to a different cause that includes physics teacher education, such as science teacher preparation or STEM education broadly construed. These champions may be effective advocates for physics teacher education regardless of its primacy in their intentions.

All champions at the studied sites are faculty, consistent with their activities of securing funding and personnel and making institutional deals for physics teacher education. All sites have at least one champion who is a member of the

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2 The full T-TEP report is available at www.phystec.org/taskforce.
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The fact that all studied sites have at least one champion is partly by selection: PhysTEC awards are made only to sites that have effective leadership for physics teacher education. However, for physics teacher education to be sustainable
Research Findings

at a site, the champion must be sustained as well. This sustainability may be attributed to an institution’s support for and recognition of the champion (described below), and its motivation for and commitment to physics teacher education in general.

2. Institutional motivation and commitment

All studied sites that have sustained increases in production of physics teachers have substantial institutional motivation for and commitment to physics teacher education. The one site at which institutional commitment was greatly reduced stopped producing physics teachers.

Institutional motivation to support physics teacher education, as observed in this study, may include fulfilling the institutional mission; serving regional needs; improving the reputation of the institution in the community; supporting strong members of the faculty; and being visible on a national stage. These motivations tend to be more apparent at the dean and provost level than within the disciplinary departments. Specific institutional motivations are described in reports on individual sites. In some cases, institutions support physics teacher education as part of a broader effort to improve STEM teacher education; the numbers of prospective physics teachers at an institution may be too small to merit institutional support for their own sake. As a discipline, however, physics sets a strong example for improving STEM teacher education; its history of discipline-based education research and professional society leadership can motivate institutions to support physics teacher education as a model for other disciplines.

Institutional commitment to physics teacher education is evidenced by funding for physics teacher education programs and personnel, alignment of the institutional mission with physics teacher education, establishment of infrastructure supporting physics teacher education, and support for champions such as promotion, leadership opportunities, and a mandate to dedicate substantial effort to physics teacher education. PhysTEC sites are selected partly on the basis of institutional commitment.

Institutional funding for physics teacher education is mostly in the form of salaries for personnel contributing to physics teacher education. In the case of faculty, institutional support usually consists of a mandate to pursue physics teacher education as part of one’s regular teaching, research, and/or service. In a few cases, faculty lines are created and filled for the specific purpose of supporting physics teacher education. Some institutions fund salaries for undergraduate early teaching experiences in physics, such as learning assistant programs. Occasionally an institution funds a broad effort, such as an institutional center or institute, whose mission supports physics teacher education. At many institutions, the decision to allocate internal resources to physics teacher education happens at the dean and/or provost level, rather than at the department level. This finding suggests a likely pathway to sustainability at other institutions.

Institutional recognition of and support for the champion(s) is crucial for sustaining the leadership of efforts supporting physics teacher education. Institutional recognition and support constitutes positive pressure to continue advancing physics teacher education. The Report of the Task Force on Teacher Education in Physics\(^3\) observed that in most physics teacher education programs, recognition and support for the champion was “minimal and not commensurate with the amount of work involved.” In contrast, this study documents that at sites that have sustained increases in production of physics teachers, champions have substantial institutional recognition and support. At various sites this support has included a mandate to pursue physics teacher education as part of one’s regular duties; funding for programs that support physics teacher education, such as Learning Assistant programs; tenure, promotion, and salary increases; hiring of STEM education colleagues; establishment of infrastructure supporting physics teacher education (such as a STEM education center or institute); and/or appointment to influential positions (such as director of a center or institute). The PhysTEC award itself may increase support to the champion not only through prestige, but also

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\(^3\) The full T-TEP report is available at www.phystec.org/taskforce.
through site visits from PhysTEC staff, which sites report to be very effective for educating administrators about the benefits of supporting physics teacher education.

3. Other features

Many activities contribute to sustaining physics teacher education at legacy sites, such as recruitment, advising, and early teaching experiences. One goal of this study was to determine whether certain activities correspond strongly with sustaining an increase in physics teacher production. Every site that has sustained an increase in production of physics teachers has sustained its program of recruitment, providing evidence that recruitment is necessary for sustaining increases in teacher production. However, overall, the data does not offer strong evidence that any one specific activity holds the key to teacher production. Instead, this study suggests that physics teacher education activities at each site reflect local priorities and opportunities, including the expertise of local personnel.

This study offers a catalogue of specific activities contributing to physics teacher education as a metric by which to compare specific activities conducted at different sites and as a guide for sites seeking to increase their personnel and funding activities in support of physics teacher education. This catalogue is presented in Figure 1 and Figure 3.

In selecting sites for funding and guiding sites in program development, PhysTEC has emphasized “key components” of a physics teacher education program—activities or program structures that PhysTEC deems important for a successful physics teacher preparation program. PhysTEC has particularly emphasized components that do not exist at most universities, rather than reiterating activities that most universities already offer (such as physics courses, education courses, and student teaching). Each PhysTEC site implements all the key components during the award period, but does so in a manner consistent with the local context, taking advantage of institution-specific resources and expertise. PhysTEC key components have evolved over time, as the project gained experience with building effective programs. At the start of this study, the list of PhysTEC key components included the following, as well as other components that were redundant with other research being conducted (e.g., “sustainability”):

- Recruitment
- Teacher in Residence
- Course transformation
- Early teaching experiences
- Learning Assistants
- Teacher Advisory Group
- Induction and mentoring
- Collaboration

Table VI shows the status of the PhysTEC key components at the studied sites. The data does not suggest strong correlations between specific components and a site’s teacher production status. However, the data does support a few generalizations:

- Every site that has sustained an increase in production of physics teachers has sustained (evolved, grown, or maintained) its program of recruitment. Recruitment is probably necessary to increased teacher production.
- The components most likely to be sustained (evolved, grown, or maintained) are recruitment, course transformation, early teaching experiences, and learning assistants. These components were each sustained at seven out of eight sites (though not the same seven for each component). These components tend to benefit the physics department (by drawing students into the department or by improving physics courses), which may partly account for their being sustained.
- The components most likely to be reduced or eliminated are the Teacher in Residence, Teacher Advisory Group, induction and mentoring, and collaboration with local schools. These components were each reduced or
eliminated at three or more sites out of the eight studied. These are the components directly involving inservice teachers and local schools; their benefit to the university (especially the physics department) is less direct.

- Although some sites have reduced the role of their Teacher in Residence, all sites studied have sustained a Teacher in Residence at least part-time over the long term through institutional or external funding, or have found another way to have some of the benefits of a Teacher in Residence (e.g., through an active network of local teachers).

- The four sites that have sustained large increases in teacher production each sustained at least six of the eight components studied, reflecting these sites’ multifaceted approach to physics teacher education. However, a multifaceted approach to physics teacher education does not necessarily correspond to sustaining increases in teacher production: Among sites that have sustained increases in physics teacher production, one has sustained all eight PhysTEC key components, another four, and another only two. The site that has not sustained its production of physics teachers has still sustained four PhysTEC key components.

Table VI. The status of PhysTEC Key Components at the studied sites (evolved, grown, maintained, reduced, or eliminated). Teacher production status is reproduced from Table I for reference.

<table>
<thead>
<tr>
<th></th>
<th>Evolved</th>
<th>Grown</th>
<th>Maintained</th>
<th>Reduced</th>
<th>Eliminated</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recruitment</td>
<td></td>
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<tr>
<td>TIR</td>
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<td>Course</td>
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<td>transformation</td>
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<td>Early Teaching</td>
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<td>Experiences</td>
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<td>Learning</td>
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<td>Assistants</td>
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<tr>
<td>Teacher</td>
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<tr>
<td>Advisory</td>
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<tr>
<td>Group</td>
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<td>Induction</td>
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<td>and</td>
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<tr>
<td>Mentoring</td>
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<td>Collaboration</td>
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<tr>
<td>Teacher</td>
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<tr>
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<td>status</td>
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<tr>
<td>Further increased</td>
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<tr>
<td>CU-B</td>
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<tr>
<td>Further increased</td>
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</tr>
<tr>
<td>SPU</td>
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<td></td>
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<tr>
<td>Further increased</td>
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</tr>
<tr>
<td>UAz</td>
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4 | **Summary**

Most PhysTEC legacy sites have sustained increases in production of physics teachers over the long term. Increased
physics teacher production is associated with long-term funding for activities supporting physics teacher education. Two key features for building sustainable physics teacher education programs are a champion of physics teacher education and institutional motivation and commitment. The defining activities of a champion are to secure funding and personnel benefiting physics teacher education and to negotiate with the institution for changes beneficial to physics teacher education. Institutional recognition of and support for the champion(s) are crucial for sustaining the leadership of efforts supporting physics teacher education. Although many specific activities contribute to sustaining physics teacher education at the studied sites, such activities seem to reflect local priorities and opportunities rather than showing patterns that can serve as a guide for the development of sustainable physics teacher education programs.

References

Site Reports
I. Introduction

The University of Arkansas (UArk) is a research university that is working to sustain and increase its research and teaching accomplishments while improving its image in a region that does not necessarily prize academia. Site leader Gay Stewart is recognized locally and nationally for her physics teacher education efforts. Physics teacher education is regarded as a way for the University to serve the community, which encourages institutional buy-in.

The average output of PhysTEC secondary graduates increased from near-zero before the PhysTEC award to about four per year during the award period (2001-2008), much greater than the national yearly average among institutions with a stated interest in physics teacher education (about one/year). Since the award period the average is about six per year, and is expected to be maintained as a result of the establishment of UAtch (a replication of UTeach). Thus, UArk is among the PhysTEC legacy sites that, during the post-award period, has further increased production of physics teachers. Also, in this period UArk has further increased funding for physics teacher education (see section IV.C). On this basis, UArk is identified as having a thriving physics teacher education program.

II. Sustainability lessons learned

- It is possible for an institution to produce six to eight physics teachers a year over a sustained period.
- In favorable circumstances, a single hardworking faculty member can lead the transformation of physics teaching and physics teacher education at an institution and can sustain that transformation over many years.
- These favorable circumstances include strong relationships between the champion and administrators, and the champion’s mandate from the university to devote a significant fraction of time to physics education issues.
- Supporting physics teacher education can solve significant problems faced by institutions, such as improving the institution’s image in the community.
III. Institutional motivation and commitment

UArk administrators understand themselves as having to work against the perception (by the public and by the state legislature) that universities are “gloriously useless,” in the words of Associate Dean of Arts and Sciences Charles Adams. Institutional buy-in to physics teacher education is attributed to the sense that physics teacher education is practical: It is a means by which the university prepares students for jobs of recognized value, and thus serves the community. The PhysTEC award is now seen as having been the beginning of a new era for UArk: Associate Dean Adams said, “It changed everything,” referring primarily to the university’s image in the community. Physics teacher education at UArk directly serves state interests in that UArk graduates are leading the establishment of STEM-focused high schools recently initiated by the governor. In this context, the success of the UAteach program, which has recruited 71 students in its first year (140% of the most optimistic estimate) is a major public-relations success for the institution. PhysTEC site leader Gay Stewart is also significant in a public relations sense: Provost and Vice Chancellor for Academic Affairs Sharon Gaber recognizes her as a “nationally known charismatic leader who excites students,” improves UArk’s reputation, and proves her worth by securing external funding (she is one of the most successful fundraisers at the institution). The Provost’s support of UAteach is motivated in large part by Gay Stewart’s national recognition and proven track record of obtaining external funding. Overall, the political relevance of physics teacher education and Stewart’s mutually beneficial relationships with administrators are very important to the long-term success of physics teacher education at UArk.

IV. Personnel and funding

A. Champion

Physics teacher education at UArk revolves around PhysTEC Site Leader Gay Stewart. Stewart’s extraordinary leadership in physics teacher education is recognized at every level: from the preservice teachers that she mentors, through every level of university administration, to the national professional communities in which she serves. Stewart was brought to UArk to address student dissatisfaction with physics teaching at UArk that had grown to strike proportions in the 1990s; she and the rest of the leadership team (described below) accomplished this with introductory course transformation. Starting with the PhysTEC award, Stewart has enjoyed a mandate to devote a significant fraction of time to physics teacher education. Her funding success and national recognition (both primarily for physics teacher education) have motivated the UArk administration to support her through promotion and institutional funding.

Stewart supports physics teacher education with a myriad of day-to-day activities as well as larger, longer-term efforts. She energetically recruits LAs, actively encourages them to pursue physics teaching, and connects graduates to professional development and outreach opportunities. She promotes physics teacher education locally by cultivating strong relationships with administrators, making sure they understand the benefit that accrues to UArk through her efforts, and making time to serve their interests by representing UArk at regional events. She pursues funding for physics teacher education, creates programs that make physics teaching more attractive to undergraduates, and supports the other personnel who help make those awards and programs happen. Through her professional relationships and activities, she constantly advocates for physics teacher education.

B. Other personnel

Faculty member John Stewart co-leads physics teacher education projects and contributes substantially to course transformation. Former chair Lin Oliver supported the Stewarts’ efforts during the PhysTEC award period and assisted with introductory course transformation. An extensive and deeply loyal network of physics teachers, many of whom are graduates of UArk’s teacher education program, are available to consult with the UArk team, participate in ongoing professional development, and mentor preservice teachers.
C. Historical development

Before the PhysTEC award period, NSF funding supported course transformation, but in the decade before the PhysTEC award, UArk produced only one physics teacher. No funding or personnel were dedicated explicitly to physics teacher education.

The PhysTEC award (2001-2006) supported a Teacher in Residence and provided some support for Gay and John Stewart. During this time, both Gay and John Stewart dedicated themselves to physics teacher education to a high degree (0.4 FTE for G. Stewart and 0.6 FTE for J. Stewart). Contributions from other faculty and the TIR brought personnel time to approximately 2.2 FTE, supported partly by PhysTEC, partly by Physics, and partly by the dean of the Fulbright College of Arts and Sciences (CAS), in which physics resides. During this period, a Mathematics and Science Partnership (MSP) from the State of Arkansas supported inservice teacher professional development.

Since the award period, funding from both Physics and the CAS for personnel dedicated to physics teacher education (G. and J. Stewart) has been sustained, and new funding has been added: External funding since the award period has supported physics teacher candidates (Noyce, 2007-2013) and inservice physics and physical science teachers (MSP, 2009-2014). Personnel time is currently about 0.5 FTE.

Looking to the future, the establishment of UAteach (the University of Arkansas’s replication of the UTeach program, funded by the Provost, the State of Arkansas, and the National Math and Science Initiative (NMSI), 2012-2016) and a scholarship program in support of the new physics/chemistry and physics/mathematics licensure areas (Noyce 2013-2017) promises even more growth as teacher candidates take advantage of a licensure program within a four-year degree. The 2013 addition of a UAteach master teacher brings personnel time to about 1.5 FTE.

Details of awards and personnel contributing to physics teacher education are presented in Appendix A1. Overall, funds supporting physics teacher education at UArk increased from near-zero before the PhysTEC award to an average of about $290K per year during the award period, substantially more than the amount of the PhysTEC award. Since the award period, funding has averaged about $600K per year, about $580K/year more than in the pre-award period. Thus, UArk is among the PhysTEC legacy sites that, during the post-award period, further increased funds supporting physics teacher education. Personnel supporting physics teacher education also increased from near zero in the pre-award period to about 2.0 FTE during the award, and has averaged a bit below 1.0 FTE in the post-award period.

**Funds supporting physics teacher education at UArk**

![Chart showing funds supporting physics teacher education over time.](chart-url)
University of Arkansas

V. Summary of Key Components

University Physics, the reformed introductory calculus-based physics course sequence, is a primary recruiting tool. The start of UAteach adds a new avenue for recruitment.

There has not been a full-time physics TIR since the PhysTEC award ended, but there is a new full-time master physics teacher for UAteach. The Teacher Advisory Group fulfills other TIR functions.

The LA program provides early teaching experience. LAs serve for course credit, not pay, so the program is highly sustainable. UAteach physics students will have early teaching experiences associated with that program, as well as the first two UTeach replication courses, which immediately place students in middle or elementary classrooms.

A substantial regional network of teachers in physics, physical science, and math contributes to induction and mentoring. The site leader has close relationships with all graduates and maintains active contact. UAteach will establish official mentoring relationships.
Status of PhysTEC Key Components at UArk

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<thead>
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<th>Component</th>
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<td>Recruitment: Promising undergraduates are identified as possible physics teachers and directed into a teacher pipeline.</td>
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<td>Teacher in Residence: Experienced teacher is employed to work with the teacher education program and as a mentor to new teachers.</td>
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<td>Course Transformation: Good pedagogy is modeled in physics classes.</td>
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<td>Early teaching experiences: First- and second-year undergraduates get a low-pressure taste of the challenges and rewards of teaching.</td>
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<td>Learning assistants: Talented undergraduates work with faculty to make large-enrollment classes more collaborative, student-centered, and interactive.</td>
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<td>Teacher Advisory Group: Local teachers improve the teacher education program.</td>
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<tr>
<td>Induction and mentoring: New physics teachers are supported in continuing as teachers.</td>
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<td>Collaboration: Departments collaborate with one another and with school districts to support physics teacher education.</td>
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VI. Highlighted components

A. Course transformation

Introductory physics course transformation has been highly significant at UArk since the 1990s, when Gay Stewart was hired to revitalize physics teaching in a department troubled by student dissatisfaction. The introductory course sequence, University Physics, is substantially lab-based and emphasizes both conceptual and quantitative understanding. The course transformations have been sustained, and are greatly valued in the department for increasing the number of physics majors. University Physics is a valuable starting point for physics teacher preparation in that it makes physics learning accessible to many students and models a form of teaching that translates well to high school physics. The sustainability of University Physics provides a steady supply of students who are interested in and well prepared for physics teaching.

B. Recruitment

Recruitment at the University of Arkansas occurs through Gay Stewart reaching out proactively to every individual with an interest in or talent for physics—and in her eyes, many students have that interest or talent. She rarely directly promotes physics teaching as a student; it is simply one of the possible career outcomes available, treated equally with the other options. Students report that what leads them to consider teaching as a career is Stewart’s high esteem for the profession. Once a student expresses an interest in teaching, proactive advising is extremely significant for recruitment. Stewart helps students navigate program requirements, advocates for qualified individuals, and cuts through red tape on students’ behalf. With her energetic investment in each student’s success, she embodies UArk’s “Students First” motto. In the future, UAt each is expected to be a significant means of recruitment.
Preservice teachers are drawn into both physics and teaching by the experience of first taking University Physics, then helping teach the courses as Learning Assistants. Many who find that they enjoy physics, but don’t want to go into physics research, decide that physics teaching is a good fit as well as a reliable career choice. UTeach students speak movingly about having learned (in University Physics or elsewhere) that everyone can learn physics; as teachers, they hope to bring out that potential in students. Arkansas’s rural poverty is both a challenge and an inspiration: UTeach students hope to show Arkansan children and their parents that in spite of expectations to the contrary, they can succeed academically, even in science. Though recruitment is sustained primarily by Stewart’s activity, the reasons motivating students to go into physics teaching are bigger than Stewart, and can be expected to continue to motivate students in the foreseeable future.

C. Teacher advisory group

Stewart’s personal investment in each physics teacher candidate has, over the years, produced a regional network of energetic, accomplished, and committed physics teachers with a deep loyalty to Stewart. Though there is no formal Teacher Advisory Group, this regional network serves many of the same functions: UArk graduates recruit students into teaching, mentor physics teacher candidates, and participate in inservice professional development. Two of these graduates are helping lead the formation of new STEM-focused high schools. A stable infrastructure of engaged expert physics teachers with strong relationships to UArk helps sustain physics teacher education there.

VII. Sources

This study was conducted through interviews with the following faculty, staff, department chairs, administrators, preservice teachers, and inservice teachers:

Gay Stewart, Professor, Physics
John Stewart, Clinical Associate Professor, Physics
Sharon Gaber, Provost and Vice Chancellor for Academic Affairs
Charles Hansford Adams, Associate Dean, Fulbright College of Arts & Sciences
Julio Gea-Banacloche, Chair, and William F. “Lin” Oliver, former Chair, Physics
Marge Cotton, UTeach Master Teacher
Marc Reif, Teacher in Residence
PhysTEC Graduates
Physics teacher candidates, including new UTeach recruits
I. Introduction

The University of Colorado, Boulder (CU-B) is a large research institution nationally known for overall excellence in STEM education. CU-B is a site that relishes growth and prioritizes institutionalization of programs. Institutional commitment to physics teacher education at CU-B is substantial, though it may take the form of commitments to STEM education improvements that benefit physics teacher education indirectly.

The number of PhysTEC Secondary Graduates averaged one per year in the pre-award period (comparable to the national yearly average among institutions with a stated interest in physics teacher education), increased to an average of two per year during the award (2004-2008), and increased further to about three per year since the award period (see graph of CU-B Secondary Graduates). Thus, CU-B is among the PhysTEC legacy sites that, during the post-award period, has further increased production of physics teachers. Also, in this period CU-B has further increased funding for physics teacher education (see section IV.C). On this basis, CU-B is identified as having a thriving physics teacher education program.

II. Sustainability lessons learned

- Elements of a physics teacher education program can be sustained as part of an overall program of excellence in STEM education.
- The presence of a physics education research group can significantly advance and sustain activities supporting physics teacher education, including course transformation, Learning Assistants (LAs), and courses on the teaching and learning of physics. These items are also well aligned with department priorities.
- Support and recognition of champions depends significantly on departmental incentives for faculty to support physics teacher education. Departmental priority for physics teacher education depends, in turn, on institutional incentives. Without these in place, champions are likely to put their efforts elsewhere.
CU-B is seeking to build a reputation for excellence in STEM education broadly construed. Institutional commitment to physics teacher education at CU-B is substantial, though it sometimes takes the form of commitments to STEM education improvements that benefit physics teacher education only indirectly. For example, the LA program, which was initially supported by grant funding, is now funded significantly by the Provost, who is motivated by the program’s effectiveness in course transformation and teacher recruitment. Many STEM departments at CU-B, including Physics, invest significantly in course transformation: The Physics department accepts Physics Education Research (PER) faculty as full colleagues as part of its long-term commitment to research-based improvement of instruction, and the Physics Chair brings a bag of clickers on recruitment visits to demonstrate interactive engagement to prospective students and their parents. The establishment of the Center for STEM Learning (CSL), which houses STEM Education research awards and seeks to create STEM Education faculty lines to be shared with disciplinary departments, may benefit physics teacher education by supporting and stabilizing constituent programs such as Streamline to Mastery (a Noyce program supporting inservice teacher development). The CU Teach program (a replication of UTeach) involves significant commitment to STEM teacher education by the institution, especially the School of Education, but physics teacher education is not yet a strong part of that program.

A. Champions
Valerie Otero, Steve Pollock, and Noah Finkelstein have championed physics teacher education at CU-B for many years by securing funding and staff and negotiating with the institution for programs benefiting physics teacher education. In recent years, their effort has broadened to building excellence in STEM education more comprehensively, aligned with institutional priorities. Otero and Finkelstein are leaders in establishing the (Provost-funded) CSL, whose mission includes the promotion of “K20 faculty recruitment, preparation, and professional development,” among many other goals. Otero is well recognized both locally and nationally for her leadership of the LA program; she also directs the Colorado Noyce Fellowship program, co-directs the CU Teach program, serves on the National Task Force for Teacher Education in Physics, and promotes physics teacher education through published studies of teacher knowledge and practice and through hundreds of invited talks around the country and around the world. Finkelstein conducts research on teacher education, develops numerous programs to strengthen the teaching identity of the physics department, and engages at a policy level, including testifying before the U.S. Congress on the state of STEM education at the undergraduate and graduate levels and contributing to the efforts of the Association of Public and Land-grant Universities (APLU) in the Science and Mathematics Teacher Imperative. Otero, Pollock, and Finkelstein have all been supported with promotion, awards, and institutional funding for programs.

Over the years departmental, institutional, and intellectual pressures have reduced the effort that lead faculty dedicate to the physics teacher recruitment that PhysTEC emphasizes. The physics department places a high value on course transformation, but does not specifically support Finkelstein and Pollock in championing physics teacher education. Since 2009, Otero has focused significant attention on the Streamline to Mastery and Noyce Teacher Teams programs, intended to support inservice teachers that were recruited through the LA model; as her support of inservice teachers recruited through the LA model has increased, her one-on-one recruitment of LAs into physics teaching has decreased. Though Finkelstein, Pollock, and Otero all continue to significantly benefit physics teacher education, none of them experience their PhysTEC champion role as their top priority.
B. Other personnel

CU-B has a large network of people who contribute to physics teacher education indirectly through course transformation and other STEM education efforts. Personnel who directly support physics teacher education at CU-B include LA co-director Laurie Langdon, who co-creates and maintains physics-specific pedagogy classes for LAs and promotes secondary physics teacher education in the context of LA development; physics faculty member Mike Dubson, who creates departmental pathways for physics teaching; science education faculty member Erin Furtak, who teaches, advises, and mentors physics teachers; and longtime Teacher in Residence (TIR) Steve Iona, who teaches LA pedagogy classes and advises preservice secondary physics teachers.

C. Historical development

Physics teacher education has been a specific interest at CU-B since about 2001. Early efforts in the service of physics teacher education included physics-specific teacher education courses and workshops (in the School of Education). The PhysTEC award (2004-2008) supported a succession of TIRs (Iona, Fuchs, and Tanner). During this period the Physics department acquired Finkelstein (hired in 2003) with the explicit agenda of transforming introductory physics courses; Otero was supported in establishing the LA program, including co-teaching LA pedagogy courses with the TIR; and Pollock directed the LA program within the physics department. External funding (through Noyce and the Teacher Professional Continuum) provided salaries and fellowships to LAs. Since 2008, support for LA salaries has also come partly from disciplinary departments, including physics. The CU Teach program (a replication of UTeach), which began in 2008, represents a significant commitment to STEM teacher education; physics teacher education is not yet a strong part of that program, but some programmatic changes are likely to benefit physics teacher education eventually, such as requiring physics teacher candidates to take the Physics department’s “Teaching and Learning Physics” course. An effort named Integrating STEM (I-STEM) also began in 2008, with the goal of increasing the visibility and impact of STEM education projects around campus, including the LA program, CU Teach, and the community of Discipline-Based Education Research (DBER) faculty.

Since the PhysTEC award period, major support for physics teacher education has come from the Streamline to Mastery program, supporting inservice teachers that were recruited through the LA model; all the participants are physics teachers. In addition, I-STEM has evolved into the Center for STEM Learning (CSL); this Center will create STEM Education faculty lines to be shared with disciplinary departments, possibly benefiting physics teacher education in the future.

Details of awards and personnel contributing to physics teacher education are presented in Appendix A1. Overall, funding supporting physics teacher education at CU-B increased from an average of about $70K per year before the PhysTEC award to an average of about $320K per year during the award period, substantially more than the amount of the PhysTEC award. Since the award period, funding has averaged about $570K per year, about $500K/year more than in the pre-award period. Thus, CU-B is among the PhysTEC legacy sites that, during the post-award period, has further increased funds supporting teacher education. Personnel supporting physics teacher education also increased from an average of about 0.5 FTE in the pre-award period to about 1.7 FTE during the award, and has averaged about 1.3 FTE in the post-award period.
Funds supporting physics teacher education at CU-B

Personnel supporting physics teacher education at CU-B
V. Summary of Key Components

At CU-B, top students in introductory physics courses are recruited into the LA program and potentially recruited into physics teaching. The LA program is growing both campus-wide and in physics; newly transformed courses (including physics for non-scientists as well as middle- and upper-division physics courses) have increased the pool for physics teacher recruitment and broadened the demographics. Otero, who had formerly been a major force for recruitment at CU-B, has significantly reduced her one-on-one contact with potential physics teachers in favor of the induction and recruitment of inservice teachers; recruitment is now led by Langdon, Andrew, and Bunning.

LAs who want to return for multiple terms must demonstrate increasing commitment to a teaching career. A “Teaching and Learning Physics” course is offered to physics education research graduate students and advanced undergraduates considering physics teaching. A “Preparing Future Physicists” series supports graduate student awareness of physics teaching as a profession. A new student group, Teachers of Physics In Training, has 17 members. CU Teach is another recruitment avenue, but has little direct contact with physics; the General Engineering track may turn out to be productive means of recruitment.

LA-supported courses are transformed using *Tutorials in Introductory Physics* and interactive engagement in lectures. At this time, 11 or 12 courses in physics (the majority of the undergraduate sequence) have some research-based transformations implemented in most semesters. In non-LA supported classes good pedagogy includes the establishment of learning goals, student-centered, inquiry-oriented instruction, and assessment of a broad range of outcomes (e.g., conceptual mastery, problem solving, attitudes and beliefs).

Early field experiences are provided in a variety of formal and informal K12 and university settings by the LA program, the CU Teach program, and the Teaching and Learning Physics course. Informal educational partnerships (such as PISEC) provide early field experiences in middle school environments.

Longtime TIR Iona teaches the LA pedagogy course and advises preservice teachers. Though there are CU Teach Master Teachers, they are not physics teachers and rarely interact with the physics department.

For some years a Teacher Advisory Group (TAG) of about 20 regional teachers met monthly, but this has not been sustained due to lack of institutional support (it was voluntary for all involved).

Otero leads programs to mentor and induct teachers through the School of Education, including Streamline to Mastery and Noyce fellowships.

Collaboration between Education, the College of Arts and Sciences, and now Engineering is increasingly strong and substantive through the Center for STEM Learning, and a discipline-based education research (DBER) community reaches into many departments. However, most of these collaborations do not benefit secondary physics teacher education directly.
Recruitment: Promising undergraduates are identified as possible physics teachers and directed into a teacher pipeline.

Teacher in Residence: Experienced teacher is employed to work with the teacher education program and as a mentor to new teachers.

Course Transformation: Good pedagogy is modeled in physics classes.

Early teaching experiences: First- and second-year undergraduates get a low-pressure taste of the challenges and rewards of teaching.

Learning assistants: Talented undergraduates work with faculty to make large-enrollment classes more collaborative, student-centered, and interactive.

Teacher Advisory Group: Local teachers improve the teacher education program.

Induction and mentoring: New physics teachers are supported in continuing as teachers.

Collaboration: Departments collaborate with one another and with school districts to support physics teacher education.

VI. Highlighted components

A. Learning Assistants

CU-B’s LA program, created concurrently with PhysTEC funding, is a centerpiece of its teacher education program. The LA program as a whole is very large, with 100-150 LAs participating from about a dozen departments every year. The program is a national model; universities and colleges around the country benefit from CU-B’s dissemination of LA resources and expertise. LAs take a campus-wide, one-semester pedagogy course taught by one of the LA Program Directors, a TIR, and/or a senior graduate student. In the physics department, the LA program is the main mechanism for course transformation and the primary source for recruiting future physics teachers. Physics now hires thirty to forty LAs each year in a competitive application process. Though most of these LAs are in the introductory courses, an increasing number of upper-division courses also benefit from LA support. Physics LAs who want to become teachers have access to several faculty (including Finkelstein, Pollock, and Dubson) who support careers in physics teaching and will direct them to appropriate faculty in Education (including Otero).
The operation of the large LA program in physics depends critically on the sustained efforts of a few key individuals. Faculty member Pollock recruits students to be LAs by making announcements in physics classes and communicating with undergraduate advisors; interviews LA applicants; recruits faculty to consider applying for LA support; mentors faculty in applying for LA support for their courses; matches LAs with faculty; mentors faculty in making good use of LAs once they have them; and keeps an archive of resources for LA-supported courses that make it easier for faculty to offer quality LA preparation and course materials. Associate Chair Dubson and Science Education Initiative (SEI) Director Perkins also assist with LA administration, and there is good buy-in from the departmental faculty and administration.

B. Course transformation

Course transformation is a high priority at CU-B across campus. Every department that has secured LA support or funding from the SEI, which funds Science Teaching Fellows to collaborate with faculty to transform their courses) has transformed courses in a variety of ways. In physics, introductory courses were transformed concurrently with original introduction of LAs, including tutorials for recitation sections and interactive engagement in lectures using clickers and other Peer Instruction strategies. As physics continues to add new courses that support LAs, course transformation continues to grow, so that now the majority of the undergraduate sequence has some research-based transformations implemented in most semesters. Partly as a result of these efforts, physics has been ranked as the number one department on campus for quality of teaching. Three faculty identified with course transformation have been named as Presidential Teaching Scholars (Pollock, Wieman, and Finkelstein), and Dubson received AAPT’s Award for Excellence in Undergraduate Teaching (2006).

Course transformation is sustained by the LA program, as well as by significant efforts to support Physics faculty buy-in and transfer of improvements among faculty. All faculty members rotate among a wide variety of courses to foster a sense of collective ownership. Postdoctoral fellows from the SEI lead eye-opening faculty discussions in which faculty identify learning goals for each course and agree on assessments appropriate to those learning goals. LAs and other resources for transformation are suggested to faculty as attractive options (which by now have become norms in many courses). New faculty are supplied with extensive (research-based) resources for instruction and paired with veteran instructors of specific courses in an explicit mentoring arrangement, at department expense.

C. Collaboration

Collaboration among departments and colleges/schools is highly visible at CU-B through many efforts co-led by physics, the School of Education, and other STEM disciplines. For example, the LA Program is co-directed by School of Education and former Chemistry faculty (Otero and Langdon); the SEI is directed by Physics faculty (Kathy Perkins) but serves multiple departments; CU Teach is co-directed by School of Education and Biology faculty (Otero and Mike Klymkowsky); and the CSL is co-led by a team of faculty from education and many STEM disciplines. Multiple grants and publications are coauthored by interdisciplinary STEM and education faculty teams. Finkelstein and Otero have a long history of shared program development and funding that has secured their reputations on campus and nationally. However, the extent to which these collaborations directly benefit secondary physics teacher education has decreased since the conclusion of the PhysTEC award. Instead, CU-B leaders are pursuing a broader vision of excellence in STEM education through the interdisciplinary LA program and the Center for Science Learning.

VII. Sources

This study was conducted through interviews with the following personnel:

Noah Finkelstein, Professor, Physics
Valerie Otero, Associate Professor, School of Education; Director, Learning Assistant Program; co-Director, CU Teach
Steve Pollock, Professor, Physics
Mary Kraus, Associate Dean for Natural Sciences
Jackie Sullivan, Associate Dean, Engineering
Laurie Langdon, Co-Director, Learning Assistant Program
Paule Beale, Chair, Physics
Mike Dubson, Associate Chair, Physics
Mike Klymkowsky, Professor, Biology and Co-Director, CU Teach
Kathy Perkins, Associate Professor, Physics and Director, Science Education Initiative
Stan Deetz, Director, Center for the Study of Conflict, Collaboration, and Creative Governance
I. Introduction

Florida International University (FIU) is a young university making a significant investment in STEM Education. FIU’s youth, its origins as a two-year upper-division university, its strength in the sciences, and its search for a community-minded and forward-looking identity all contributed to its ready acceptance of the PhysTEC reforms and initiatives. Through shared program development and effective fundraising, the site leaders have secured their reputations, both on campus and nationally.

The numbers of PhysTEC secondary graduates are increasing, from zero teachers in the pre-award period to one per year in the award period and an average of two per year since the award, greater than the national yearly average among institutions with a stated interest in physics teacher education (about 1/year). Thus, FIU is among the PhysTEC legacy sites that has further increased production of physics teachers during the post-award period. Also, in this period FIU has also further increased funding for physics teacher education (see section IV.C). On this basis, FIU is identified as having a thriving physics teacher education program.

II. Sustainability lessons learned

- STEM education, and by extension physics teacher education, are potentially institution-defining interests.
- Major sustained and even increasing institutional support for physics teacher education is possible. PhysTEC can play a significant role in precipitating such institutional commitment.
- Program changes can align with institutional priorities to generate significant rewards.
- A multidisciplinary STEM education research effort can leverage internal resources.
- Sites can sustain TIRs through teaching and staff positions related to teacher education.
- A physics education research group can significantly advance and sustain physics teacher education program components, including course transformation, LAs, and courses on the teaching and learning of physics. These changes align well with department priorities.
III. Institutional motivation and commitment

FIU is a young university experiencing tremendous growth and quickly developing a strong STEM education identity both in Florida and nationally. Institutional buy-in to the vision of STEM education is attributed to FIU’s youth, its origins as a two-year upper-division university, its strength in the sciences, and its search for a community-minded and forward-looking identity. High-quality teaching, student learning, innovation, and collaboration all feature prominently in FIU’s mission statement. PhysTEC catalyzed interest in physics teacher education, especially during site visits in which PhysTEC leaders met with FIU administrators. The FIU Physics Education Research Group, engagement in the Science and Math Teacher Imperative, and partnership with “100K in 10” solidified institutional participation. Institutional commitment continues to increase as partnerships with school districts begin to bear fruit. Discussions at the Dean and Provost levels confirm that FIU regards physics education as a cornerstone of its STEM achievements so far, and looks to physics education faculty as major stakeholders in future growth and development. FIU established the STEM Transformation Institute, intended to bring together faculty from FIU’s College of Arts & Sciences, College of Education, and College of Engineering and Computing in a collective mission to transform STEM education from preschool to graduate school. The Institute enjoys extremely strong University support at the Dean, Provost, and Presidential levels; it has a name, an infrastructure, a director (PhysTEC site leader Kramer), and an initial budget of $700K for the first three years. Physical spaces for Institute operations opened in 2013. The Institute will house STEM Education research awards and will create STEM Education faculty positions that will be joint between the Institute and the disciplinary science departments. Departments that wish to take advantage of this opportunity will need to decide how to evaluate STEM Education faculty for tenure and promotion, a process which is likely to initiate challenging negotiations within and between departments. These challenges, however, have the potential to increase the value that disciplinary departments place on STEM education, and the value that the physics department places on physics teacher education.

IV. Personnel and funding

A. Champions

Among the FIU faculty, PhysTEC site leader Kramer is the primary “dealmaker,” initiating a wide array of funding proposals, internal agreements, and external collaborations, often working closely with FIU administration for mutual benefit. Kramer’s leadership is recognized with his appointment to direct the new STEM Transformation Institute. Faculty member Brewe is the local expert in Modeling Instruction (a guided-inquiry interactive-engagement method of physics teaching), the primary physics education research advisor, and teaches upper-division teacher education courses; he has an appointment in the College of Education and is an affiliate in the physics department. Kramer and Brewe have a history of shared program development and funding that has secured their reputations on campus and nationally. Both have been supported at FIU with promotion, hiring of new STEM education colleagues, and institutional funding for programs such as the LA program and the STEM Transformation Institute.

B. Other personnel

FIU has a large and thriving team contributing to physics teacher education, including faculty, TIRs, a postdoc, and graduate student researchers at the time of the study. These university personnel are at the hub of an extensive network of learning assistants, preservice teachers, and inservice teachers that enliven the hallways of the physics department. Two highly qualified and very active TIRs, centrally positioned in the physics department, support preservice and inservice physics teachers and inspire LAs to consider the teaching profession. Graduate student and postdoctoral researchers conducting high-quality investigations into teaching strategies, physics course transformation, and learning assistant development contribute to the knowledge base and promote FIU’s programs to the physics education research community.
C. Historical development

Very little of this STEM education activity predates FIU’s PhysTEC award. Before the award period, physics teacher education at FIU was supported to a small degree by CHEPREO (an NSF-sponsored integrated program of research, cyberinfrastructure, and education and outreach encompassing activities at FIU, Florida State University, the University of Florida, the California Institute of Technology, and the Brazilian high energy physics community), which funded Kramer to run Modeling workshops for inservice teachers. Personnel contributing to physics teacher education in the pre-award period were Kramer (Physics) and O’Brien (Education), for a total of less than 0.5 FTE.

The PhysTEC award (2007-2010) established a Learning Assistant program, transformed the secondary science education program (moving it from the College of Education to the College of Arts and Sciences, substantially in physics), and supported the hiring of a succession of TIRs (Wells, Gibert, Crenshaw). The Physics department supported Kramer and Brewe (hired in 2007) in transforming introductory physics courses as part of an overall institutional vision to excel in STEM education; Kramer was also supported by Physics to lead the LA program, and Brewe was supported by the College of Education to teach upper-division teacher education courses emphasizing physics pedagogy. LA salaries during this period were provided by CHEPREO, which funded student “CHEPREO Fellows” to assist with course transformation. When the secondary science education program moved from the College of Education to the College of Arts and Sciences, the first TIR (Wells) was hired by the College of Arts and Sciences to coordinate that program, and has been retained full time in that role. Faculty and staff dedicated to physics teacher education during the award period was 1.5-2.5 FTE.

After the award period ended, funding for physics teacher education at FIU increased. The Physics Department began supporting LA salaries through student fees. Noyce funding supported physics majors in committing to physics teaching. Funding from CHEPREO increased to support not only physics course transformation and Modeling workshops for teachers (run by TIR Jones), but also graduate and postdoctoral researchers in physics education, some of whom conduct research on aspects of the physics teacher education program or have TIR-like responsibilities in their assistantships. In 2012, the Physics department hired former TIR Jones as an instructor for physics courses and Learning Assistant mentor. Faculty and staff dedicated to physics teacher education is now over 3.0 FTE.

Looking to the future, all major funding sources supporting physics teacher education appear secure. Physics Department support is based on permanent student fees. CHEPREO is in progress for a five-year renewal. The Provost is establishing a STEM Transformation Institute (shared by the Colleges of Arts & Sciences, Education, and Engineering) to formalize support for STEM Education, with physics teacher education as a featured component; the Institute will be directed by Kramer and will house an LA Director (Wells) as well as hiring additional STEM Education faculty. A new hire (already identified) will replace Wells as secondary education program coordinator and two new hires will join the STEM Transformation Institute in 2014, increasing physics teacher education personnel time to about 5.0 FTE. Personnel was temporarily reduced as the postdoctoral researcher, Goertzen, relocates to a new position at APS, but a new postdoctoral researcher is expected.

Details of awards and personnel contributing to physics teacher education are presented in Appendix A1. Overall, funds supporting physics teacher education at FIU increased from an average of about $120K per year before the PhysTEC award to an average of about $500K per year during the award period, substantially more than the amount of the PhysTEC award. Since the award period, funding has averaged about $770K per year, about $650K/year more than in the pre-award period. Thus, FIU is among the PhysTEC legacy sites that during the post-award period has further increased funds supporting physics teacher education. Personnel supporting physics teacher education also increased from near zero in the pre-award period to about 2.3 FTE during the award, and has averaged about 3.2 FTE in the post-award period.
Funds supporting physics teacher education at FIU

Personnel supporting physics teacher education at FIU
Recruitment is growing as the benefits of PhysTEC reforms take root. Student enrollment in transformed courses is growing as is the LA program, providing an ever-larger pool of future teachers. Centrally placed TIRs foster conversations about the teaching profession and actively support LAs who express an interest. The TIR coordinates semesterly recruiting sessions that draw 100-150 students.

Nationally-recognized instructional formats are used in introductory courses, and increasingly in upper-division courses. The physics LA program is operating at capacity (45-50 LAs each year). LAs now assist in upper-division courses as well as introductory ones. LA seminars include visits to local high school classrooms.

A local professional network of physics teachers maintains strong ties with FIU, meeting every three weeks with a TIR for mentoring and support. As the number of graduates increases, the network expands. The TIRs have close relationships with all graduates and maintain active contact. Graduates are encouraged to join the Teacher Advisory Group and summer workshops, and are invited speakers in the LA seminar.

There is regular collaboration between TIRs and public schools on professional development workshops and other matters. High administrator turnover within the school district makes it difficult to deepen relationships, and budget restrictions make hiring difficult. However, the new director of the school district has strong ties to FIU and modeling.

<table>
<thead>
<tr>
<th>Status of PhysTEC Key Components at FIU</th>
<th>N/A</th>
<th>Eliminated</th>
<th>Reduced</th>
<th>Maintained</th>
<th>Grown</th>
<th>Evolved</th>
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<tbody>
<tr>
<td><strong>Recruitment</strong>: Promising undergraduates are identified as possible physics teachers and directed into a teacher pipeline.</td>
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<td><strong>Teacher in Residence</strong>: Experienced teacher is employed to work with the teacher education program and as a mentor to new teachers.</td>
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<td><strong>Course Transformation</strong>: Good pedagogy is modeled in physics classes.</td>
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<td><strong>Teacher Advisory Group</strong>: Local teachers improve the teacher education program.</td>
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<td><strong>Induction and mentoring</strong>: New physics teachers are supported in continuing as teachers.</td>
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<td><strong>Collaboration</strong>: Departments collaborate with one another and with school districts to support physics teacher education.</td>
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</tbody>
</table>
VI. Highlighted components

A. Learning Assistants

The Physics LA program is a primary mechanism for physics course transformation and a primary source for the recruitment of future physics teachers. Physics now hires about 60 unique LAs each year (the maximum capacity for the department) in a competitive application process. Physics LAs support transformed courses, traditional labs, and upper-division courses. They take an interdisciplinary pedagogy course (Seminar in Physics/Chemistry/Earth Science Education) taught by STEM Education faculty and staff (e.g., Kramer, Wells, Cochran). They are significantly mentored by a TIR (Jones), who teaches introductory courses and is alert for LAs who show an interest in a teaching career. LAs have no contact with the College of Education until and unless they formally enter a teacher education program.

Before the PhysTEC award period, grant funding supported “CHEPREO Fellows” who assisted with course transformation, paving the way for the physics LA program established by the PhysTEC award. In the post-award period, support for the physics LA program has been mostly internal. Physics LA salaries are paid primarily with departmental student fees (about $120K/year) and secondarily through Noyce fellowships and other grants (about $40K/year). Personnel time dedicated to the LA program is supported with departmental salaries and totals about 1.0 FTE.

The establishment of the STEM Transformation Institute will include the creation of a formal campus-wide LA program directed by Wells. Under this new program, each department will designate a departmental LA coordinator who coordinates with the campus-wide program. Faculty wishing for LA support will apply to their departmental LA coordinator, who will control the funding. Use of the “Learning Assistant” title will be restricted to programs that meet the criteria established by the campus-wide program.

B. Course transformation

FIU’s course transformation centers on Modeling Instruction, a widely disseminated program of high school physics instruction that FIU has adapted for university courses. Modeling Instruction is joined in the physics department by the Open Source Tutorials, which are used in some physics labs, and the Investigative Science Learning Environment (ISLE), another best-practices instructional format introduced to FIU by Brookes. Physics course transformation at FIU is both nationally admired and locally appreciated; most consider it responsible for FIU’s extraordinary increase in the number of physics majors, as well as respectable output of high school physics teachers. Students and faculty believe the transformed courses are especially powerful for first-generation college students and others who may assume they would not succeed in physics.

External funding for course transformation is secured primarily by the education and outreach component of CHEPREO, an especially sustainable ($5M, five-year, renewable) source of external funding whose stability is assured by the value both NSF and FIU place on high-energy physics research. CHEPREO also supports physics education research that studies transformed courses.

Internal funding for course transformation consists of departmental salaries for the personnel that teach transformed courses (stable at approximately 0.5 FTE). Support for the LA program, which is mostly internal, also constitutes support for course transformation. Course transformation is highly valued at the Chair, Dean, and Provost levels for its alignment with FIU’s STEM Education identity, for its association with CHEPREO (a cornerstone of FIU’s research
funding), and for its success in increasing the number of physics majors. Regular faculty in the physics department, however, do not appear to value course transformation efforts as strongly: There is little evidence of physics faculty buy-in to Modeling or ISLE instruction (only physics education personnel teach these courses, though some faculty are making their own improvements to other courses), and some faculty believe that the increase in number of majors corresponds to a decrease in quality. Course transformation might be bolstered by the STEM Transformation Institute if the Institute communicated the value of course transformation to faculty, or if it facilitated the hiring of new STEM Education faculty.

C. Teachers in Residence

Physics teacher education at FIU is significantly supported by very active TIRs who have continual substantive contact with preservice and inservice physics teachers as well as undergraduates who might have an interest in teaching. The original PhysTEC award supported three TIRs for one year each to co-teach the LA Seminar, train and supervise physics LAs, and mentor and advise students with a possible interest in physics teaching. FIU now has one full-time TIR and one former TIR supported entirely with sustainable internal funding from Physics, the College of Arts & Sciences, and the Office of the Provost. Plans for TIRs/Master Teachers in Biology and Mathematics are progressing for Fall 2015.

In 2008, when severe budget cuts motivated the closure of all of the secondary education teacher preparation programs in the College of Education, the secondary science education programs were moved into the College of Arts & Sciences. (This transition was significantly facilitated by PhysTEC-oriented conversations with FIU administration.) The first PhysTEC-funded TIR (Wells), a former lead teacher for an FIU-based high school STEM immersion program, was recruited to help design the new math and science programs, and has been retained by the College of Arts & Sciences as the coordinator for the Science and Mathematics Teacher Imperative. From an office centrally located in FIU’s Physics Learning Center, the program coordinator advises and mentors preservice teachers, supports inservice teachers in maintaining connections to FIU, manages STEM teacher preparation program needs, and coordinates a professional network for student teaching and other placements. Wells will be moving into the STEM Transformation Institute to direct the campus-wide LA program, and another new TIR will replace her as secondary science program coordinator.

In 2010, at the end of the PhysTEC award period, a former TIR (Jones) was hired by CHEPREO as its Education and Outreach Program Coordinator. In that grant-supported role, Jones has supported a local community of high school physics teachers, offered teacher professional development workshops centered on Modeling Instruction, and overseen course transformations in the Physics department. In 2012, the Physics department began supporting the TIR as an instructor at 0.75 FTE (with the balance still coming from CHEPREO). His responsibilities in introductory physics place him in constant contact with undergraduates who might have an interest in teaching, and his long history as a committed, engaged teacher of high school physics is a significant inspiration to many. His centrally located office, next to Wells, positions high school physics teaching at the heart of the FIU Physics Learning Center.
VII. Sources

This study was conducted through interviews with the following faculty, staff, department chairs, FIU administration, graduate researchers, and undergraduate learning assistants:

Laird Kramer, Associate Professor, Physics
Eric Brewe, Assistant Professor, Department of Teaching and Learning
David Brookes, Assistant Professor, Physics
David Jones, Instructor and Teacher in Residence, Physics
Leanne Wells, Teacher in Residence and Coordinator, Secondary Science Education Program
Geraldine Cochran, Physics Education Research Graduate Student
Bernard Gerstman, Chair, Physics
Brian Arriete, PhysTEC secondary graduate
Walter Van Hamme, Associate Director, School of Integrated Science and Humanities and Chair of Physics during the PhysTEC award period
Elizabeth Bejar, Vice Provost
Ken Furton, Dean of the College of Arts & Sciences
Delia Garcia, Dean of the College of Education
Physics Learning Assistants
I. Introduction

Seattle Pacific University (SPU) is a private liberal arts university whose physics faculty share a deep commitment to physics teacher education: For over a decade, every person hired into the physics department has had a teaching and learning priority. Institutional support for physics teacher education is credited to alignment with the mission of the university and with SPU’s historic basis in teacher education.

The average number of PhysTEC secondary graduates increased from about 2.5/year in the pre-award period to three during the award period (2006-2009), and then to about four per year since the award, greater than the national yearly average among institutions with a stated interest in physics teacher education (about 1/year) and an especially impressive result for such a small institution (3000 undergraduates). Thus, SPU is among the PhysTEC legacy sites that has further increased production of physics teachers. Also, during the post-award period, SPU has further increased its funding for physics teacher education (see section IV.C). On this basis, SPU is identified as having a thriving physics teacher education program.

II. Sustainability lessons learned

- Small institutions can produce and sustain large numbers of PhysTEC graduates.
- A team dedicated to physics teacher education enables programs to continue even as personnel may change.
- A physics department can successfully shape its mission around physics teacher education, putting considerable resources toward teacher recruitment and preparation without sacrifice to its undergraduate program.
III. Institutional motivation and commitment

SPU’s physics department decided a decade ago to make physics education its focus as a means of reviving a department at risk and aligning with the university’s emphasis on teaching and service. Since that time, every person hired into the physics department has had a teaching and learning priority. The majority of departmental faculty champion physics teacher education by dedicating substantial time and effort to recruitment, physics-specific pedagogy and methods courses, STEM teacher education program development, and research on teacher learning. Because SPU is a small institution where interpersonal agreements can often take the place of formally negotiated policies, faculty members are relatively free to develop programs and activities that suit their priorities.

Administrators at the Dean, Provost, and President level visibly support the Physics Department’s efforts benefiting physics teacher education, seeing them as well aligned with the mission of the university (“Engage the Culture, Change the World”) and consistent with SPU’s long history in teacher education (SPU’s predecessor institution was originally a normal school for teacher training). At the presidential level, excellence in physics teacher education is seen as contributing to SPU’s distinction as a Christian college excelling in science. Physics Department accomplishments related to physics teacher education are featured at events such as the annual faculty retreat, in the State of the University address, on the SPU website, and in SPU’s alumni magazine. A passionate alumna of the LA program serves as the honorary young alumna on the Board of Trustees. Support for Physics Department efforts is evident in the expansion of the Physics Department from two faculty members to six in about ten years.

The physics LA program is the subject of great attention from the university administration, which admires the program for improving undergraduate education in a cost-effective manner, transforming faculty practices, creating community among students, and improving the image and national reputation of the university. At the provost and dean level, the LA program is particularly valued for improving undergraduate student learning, but the “mission fit” of physics teacher education is acknowledged there as well. In 2014, the university will introduce a campus-wide LA program, funded by the institution and co-led by the Physics Department and the Center for Scholarship and Faculty Development. Both physics LA supervisors are excited to collaborate with faculty in other disciplines and concerned to maintain the quality of SPU’s LA program during such rapid expansion.

IV. Personnel and funding

A. Champions

Physics teacher education at SPU is the outcome of efforts of a team of champions. Two of the most senior faculty members in this small department (Vokos and Seeley) were hired a decade ago for their focus on physics education and have made physics teacher education a priority ever since the PhysTEC award. Seeley is PhysTEC site leader, and Vokos contributes as a significant “dealmaker,” often working with national agencies and SPU administration for mutual benefit. The Energy Project, a $3.7M award to support and study teacher practices of formative assessment in the context of energy in physics (2008-2013), brought tremendous recognition to these Physics Department leaders on a campus not accustomed to research awards. Another faculty member (E. Close) had a joint appointment in Physics and Education until her departure for another institution in 2011; she was especially valued for her service efforts in both departments and contributed to significant programmatic changes benefiting secondary teacher education. These faculty leaders have strongly influenced subsequent hiring of Physics Department faculty and staff supporting physics teacher education. New research faculty members (Scherr and Robertson) are pursuing new funding for physics teacher education and negotiating with the institution for changes beneficial to physics teacher education.
B. Other personnel

Almost everyone in the physics department at SPU is significantly engaged in activities directly benefiting physics teacher education. Faculty, staff, the TIR, and graduate researchers cultivate mutually beneficial relationships with educators all along the continuum of a teaching career, from undergraduates interested in teaching to experienced inservice teachers. On the faculty team, Robertson leads an innovative LA program established by Vokos, Seeley, and department chair Lindberg and significantly developed by H. Close, who left for another institution in 2011. DeWater, SPU’s TIR of nine years, mainly serves elementary teachers, but also advises preservice secondary teachers and teaches physics-specific pedagogy courses; Visiting Master Teachers (VMTs) Lippitt and Williamson mentor future teachers on a part-time basis. Scherr, a faculty-level researcher, promotes physics teacher education with presentations and publications focused on teachers’ content understanding of energy in physics. E. Close, who formerly held a joint appointment in Physics and Education, also departed in 2011, which has decreased the active collaboration between the departments. However, graduate researcher Daane has created a new point of contact: she is enrolled in the School of Education while working closely with advisors Scherr and Vokos in the physics department. A national and international network of collaborators contributes to the group’s research and teaching efforts through the Interdisciplinary Research Institute in STEM Education (I-RISE), an intensive summer internship program through which scholars from diverse backgrounds gather to observe, document, and reflect on professional development courses offered by the Energy Project.

C. Historical development

Very little of this activity predates SPU’s PhysTEC award. A small NSF award in 2003 supported the department in implementing Tutorials in Introductory Physics (and was reportedly the first research grant received by the institution). A Teacher Professional Consortium grant (2005-2008) established a professional development program for inservice teachers, but did not recruit or prepare undergraduates for teaching. In 2005, an award from Boeing partly facilitated the hire of a TIR (DeWater) to prepare preservice elementary teachers.

The PhysTEC award (2006-2009) hired a series of VMTs and, perhaps just as importantly, precipitated a focus on secondary teacher recruitment and education. During this period E. Close, who ascended to a joint faculty position in Physics and Education in 2005, contributed to significant programmatic changes benefiting secondary teacher education. H. Close, formerly a science coach at Seattle Public Schools, also began teaching at SPU in 2005, and co-created the LA program with Seeley in 2008.

Since the award period SPU has seen significant developments in secondary teacher education. A Noyce planning grant (2009-2010) supported the development of a certification program specifically for science and math teachers (the Master of Teaching Math and Science [MTMS] program). Significant research funding was secured to support secondary physics teacher education: The Energy Project, a $3.7M DRK12 award (2008-2013), funded professional development, enabled the acquisition of physics education researchers (Scherr, Daane, and Robertson), and supported the creation of a national network of physics education researchers studying teacher professional development through the I-RISE. The LA program tripled in size and was successfully transferred from its developer (H. Close) to a new faculty member (Robertson). A new faculty member with a strong history in LA and physics teacher preparation (Gray) has been hired into a tenure-track position. A PhysTEC Noyce grant has provided continuing funding for the VMT position and a Student Teacher Immersion Experience program.

Looking to the future, the SPU physics department hopes to sustain its growth and retain its commitment to physics teacher education. Partial TIR funding has been secured from the university. New and continuing SPU administrators (President, Provost, and Dean of A&S) are supportive of Physics Department efforts. While there is some uncertainty associated with the end of the Energy Project, the team is actively seeking funding to continue its efforts.

Details of awards and personnel contributing to physics teacher education are presented in Appendix 1. Overall, funds supporting physics teacher education at SPU increased from an average of about $30K per year before the PhysTEC
award to an average of about $580K per year during the award period, substantially more than the amount of the PhysTEC award. During the post-award period, funding has averaged about $1030K per year, about $1000K/year more than in the pre-award period. Thus, SPU is among the PhysTEC legacy sites that has sustained a large increase in funds supporting physics teacher education. Personnel supporting physics teacher education also increased from near zero in the pre-award period to about 1.0 FTE during the award, and has averaged about 1.5 FTE in the post-award period.
### V. Summary of Key Components

SPU has a thriving LA program whose participants are individually recruited into teaching by faculty who are enthusiastic and well-informed about teacher education.

VMTs mentor preservice and inservice teachers with a small time commitment (about five hours a week).

LAs support the implementation of tutorials and other active-learning strategies in SCALE-UP style classrooms. A recent classroom remodel makes innovative pedagogy more visible.

A large inservice teacher education program supports a strong network of local teachers who advise and support university efforts. About fifteen teachers meet biweekly during the academic year for continuing professional development.

New physics teachers stay in contact with faculty and TIR/VMT for support, though there is no formal mentoring or induction program.

The recent departure of E. Close (who had a joint appointment with a large amount of service) has reduced the programmatic contact between Physics & the School of Education.

#### Status of PhysTEC Key Components at SPU

<table>
<thead>
<tr>
<th>Component</th>
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<td><strong>Recruitment:</strong> Promising undergraduates are identified as possible physics teachers and directed into a teacher pipeline.</td>
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<td><strong>Teacher in Residence:</strong> Experienced teacher is employed to work with the teacher education program and as a mentor to new teachers.</td>
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<td><strong>Course Transformation:</strong> Good pedagogy is modeled in physics classes.</td>
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<td><strong>Early teaching experiences:</strong> First- and second-year undergraduates get a low-pressure taste of the challenges and rewards of teaching.</td>
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<td><strong>Learning assistants:</strong> Talented undergraduates work with faculty to make large-enrollment classes more collaborative, student-centered, and interactive.</td>
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<td><strong>Teacher Advisory Group:</strong> Local teachers improve the teacher education program.</td>
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<td><strong>Collaboration:</strong> Departments collaborate with one another and with school districts to support physics teacher education.</td>
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VI. Highlighted components

1. Recruitment

SPU’s recruitment practices have resulted in a large number of physics teachers being produced by a very small department. Physics faculty and TIRs regard their individualized relationships with students as a primary factor in recruitment: They each know their students well enough to identify specific students as potential physics teachers, and have the kind of mutually respectful relationships in which career suggestions are taken seriously. Because faculty are visibly dedicated to a continuum of physics teacher professional development, students perceive high school physics teaching as valuable among physicists and in society. Champions have supported the construction of a variety of attractive pathways to become a physics teacher, including Noyce scholarships and a Noyce-initiated master’s program specific to math and science teacher preparation.

2. Visiting Master Teacher

SPU originally pioneered the role of a Visiting Master Teacher (VMT) in 2004 as a part-time alternative to Teachers in Residence. The VMT at SPU has a commitment of about 5 hours per week. SPU’s two VMTs, Williamson and Lippitt, are retired physics teachers with decades of classroom experience who mentor future physics teachers, describe the life of a physics teacher based on direct experience, and support student teachers and new teachers in the classroom.

The VMT role at SPU has presented advantages and disadvantages as compared to the full-time TIR role. The small VMT time commitment means experienced teacher mentorship is available to SPU students at low cost. On the other hand, a VMT is not a visible, daily presence on campus and is not very involved in physics department program development.

3. Learning Assistants

The LA program at SPU began with the purpose of supporting implementation of Tutorials in introductory courses, and was shaped by H. Close into a significant experience in its own right. Programmatically the LA supervisors (Close, Seeley, and now Robertson) have had a strong policy of inclusion in order to have a critical mass of LAs working together: Supervisors are not only flexible about logistics but also promote the program as valuable MCAT preparation (in that it deepens content knowledge) and preparation for medical professionals (in that teaching and medicine both involve listening for the purpose of diagnosis). The program is marked by innovative activities such as having LAs interview a peer about a physics concept with the goal of only finding out about their thinking, not “teaching” anything. Such activities are especially appropriate in the SPU student culture, which is strongly service-oriented and particularly values service in the context of deep interpersonal encounter.

SPU’s LA program does not require a ramping up of commitment to physics teacher education in order to continue participation. LAs who become secondary teachers credit Noyce scholarships and H. Close’s mentorship as particularly significant to their decision. With the departure of both H. and E. Close, the Physics Department has lost a significant teacher-educator presence: While the new personnel (Gray and Robertson) greatly value secondary teaching, they are not themselves former secondary teachers. That said, the LA program continues to grow and retains many of the features that were originally significant, including bonding with a cohort of fellow LAs, being entrusted to co-design their pedagogy experience, admiring faculty who are visibly dedicated to a continuum of physics teacher professional development, being valued as junior educators by those faculty, and being supported in and celebrated for applying for Noyce scholarships.
4. Course transformation

Physics courses at SPU are small, with introductory courses typically at about 35 students and upper-division courses often at five to seven students. Physics faculty members are mostly experienced PER consumers and are skilled at taking advantage of the flexibility conferred by small courses. For example, in the introductory courses lecture, tutorial, and lab are integrated into a seamless studio experience, with a schedule of activities determined actively by the instructor in response to students’ developing understanding. Thus, LAs in these courses participate in offering instruction that is in some ways much like a high school physics class. Institutional recognition of physics department pedagogy was recently made visible through a classroom remodel that features SCALE-UP-style architecture and dry-erase tables and walls.

VII. Sources

This study was conducted through interviews with the following personnel:

Lane Seeley, Professor, Physics, and PhysTEC Site Leader
Stamatis Vokos, Professor, Physics, and PhysTEC Site Leader
Eleanor Close, former Associate Professor, Physics and School of Education
Hunter Close, former Lecturer, Physics
Amy Robertson, Assistant Professor, Physics
Kara Gray, Assistant Professor, Physics
Lezlie DeWater, Affiliate Resident Master Teacher, Physics and School of Education
B Lippitt, Visiting Master Teacher
Margaret Diddams, Director, Center for Scholarship and Faculty Development
John Lindberg, Chair, Physics
Rick Eigenbrood, Professor and Dean, School of Education
Kristine Gritter, Assistant Professor and Chair of Undergraduate and Post-Baccalaureate Teacher Education, School of Education
David Denton, Assistant Professor and Chair of Graduate Teacher Education, School of Education
Daniel Bishop, Assistant Professor and Director of Teacher Education and Professional Education, School of Education
Dan Martin, President
Jeff Van Duzer, Provost
Bruce Congdon, Dean, College of Arts and Sciences, and former Provost
Learning Assistants for introductory physics course
Learning Assistants for elementary science methods course
SPU PhysTEC Secondary Graduates
I. Introduction

The University of Arizona (UAz) is a public research university with a successful secondary teacher education program in the College of Science.

The average number of PhysTEC secondary graduates increased from near zero to about two per year during the award period (2001-2008), greater than the national yearly average among institutions with a stated interest in physics teacher education (about 1/year). The production of physics teachers has stayed higher than the baseline in spite of administrative changes that have decreased support for some activities supporting physics teacher education. Thus, UAz is among the PhysTEC legacy sites that has sustained an increase in production of physics teachers. UAz has also sustained an increase in funding for physics teacher education (see section IV.C). On this basis, UAz is identified as having a sustained physics teacher education program.

II. Sustainability lessons learned

- A teacher preparation program housed in the College of Science can produce secondary physics teachers consistently even when the physics department does not have physics teacher education as a priority.

III. Institutional motivation and commitment

Physics teacher education at UAz takes place mainly in the context of a Teacher Preparation Program (TPP) in the College of Science; this program embodies a commitment by the university to serve the state with science teachers. This commitment responds to pressure from the State of Arizona to contribute to public education, and persisted through difficult negotiations (led by champion Levy) to establish teacher education in the College of Science. Some disciplinary departments (including math and biology) have a base of enthusiasm for science teacher education; others (including physics) vary in their support, partly depending on departmental administration. The TPP is modeled on a teacher education program in UAz’s College of Agriculture.

The TPP has sustained its production of secondary physics teachers in spite of changes in physics department administration that reduced departmental support for physics teacher education. Institutional commitment to the program has been sufficient to create a new non-tenure faculty position for the physics teacher education champion to direct the science teacher education program.
IV. Personnel and funding

A. Champions

Physics teacher education at UAz was established, along with teacher education in other sciences, through the championship of Eugene Levy, formerly faculty in the Department of Planetary Sciences, who led the effort to establish a teacher education program in the College of Science from his position as Dean. His commitment to STEM teacher education persisted through difficult negotiations with the College of Education and disciplinary departments who did not prioritize teacher education. These negotiations eventually created faculty lines specifically for discipline-based teacher education; the top applicants were hired into their corresponding disciplinary departments (Ingrid Novodvorsky in physics, Debra Tomanek in biology, and Vicente Talanquer in chemistry). These three faculty members co-created the Teacher Preparation Program in the College of Science.

Among current UAz faculty, PhysTEC site leader Novodvorsky is the strongest force for physics teacher education. Hired into the physics department in 1999, she transferred in 2005 to a non-tenure faculty position in the College of Science that is not vulnerable to shifting priorities in the Physics department. As Director of the Teacher Preparation Program in the College of Science, she is dedicated full-time to science teacher education through a program that is about 25% future physics teachers.

B. Other personnel

Novodvorsky has worked closely with Tomanek and Talanquer to develop, teach, and assess TPP courses. Tomanek directed the TPP from 2000-2005. In 2011, Tomanek became Associate Vice Provost, and was replaced in the TPP by Molly Bolger.

McPherson, Byrum, and Gilbert have all served as TIRs. McPherson is now an Assistant Professor of Practice in the College of Science.

Two physics faculty, Garcia and McCullen, co-led course transformation in the physics department. Garcia is now emeritus, but remains an active advocate for physics teacher education locally and nationally.

C. History

Physics teacher education at UAz has its origins in a collaboration between the College of Education and the interdisciplinary Department of Planetary Sciences in the 1980s, which demonstrated the University of Arizona’s capacity for science teacher education and created enthusiasm among some disciplinary faculty. Levy, originally a faculty member in Planetary Sciences, became Dean of the College of Science in 1993 and made science teacher education a high priority. The faculty hires that led to the TPP in the College of Science are the outcome of Levy’s sustained negotiations with the Provost, the College of Education, and the disciplinary departments, who have often prioritized the production of graduate students over the production of teachers. Physics was among the less enthusiastic of the departments; mathematics and biology had a stronger base of enthusiasm. Nonetheless, Physics accepted Novodvorsky into the department with a focus on physics teacher education.

The appearance of the PhysTEC program in 2000 was a good fit with the TPP. A main goal of UAz’s PhysTEC award (2001-2008) was to transform introductory physics courses. The physics chair at that time supported both physics teacher education and undergraduate physics course transformation. However, course transformation efforts were resisted by faculty who did not want changes implemented in the calculus-based courses.

Since the award period, the departmental climate has changed, partly due to a new chair that is less supportive of physics teacher education. Course transformations have not been sustained; although the algebra-based physics course has collaborative components, as of 2012 the calculus-based course is taught traditionally. Novodvorsky moved into a non-tenure faculty position in the College of Science that is not vulnerable to shifting departmental priorities, and
University of Arizona

supports physics teacher education as Director of the Teacher Preparation Program in the College of Science. Some of UAz’s physics teacher candidates are recruited from astronomy.

Details of awards and personnel contributing to physics teacher education are presented in Appendix A1. Overall, funds supporting physics teacher education at UAz increased from an average of about $40K per year before the PhysTEC award to an average of about $300K per year during the award period, substantially more than the amount of the PhysTEC award. Since the award period, funding has averaged about $200K per year, about $160K/year more than in the pre-award period. Thus, UAz is among the PhysTEC legacy sites that has sustained an increase in funds supporting physics teacher education. Personnel supporting physics teacher education also increased from an average of about 0.3 FTE in the pre-award period to about 1.6 FTE during the award, and has averaged about 0.7 FTE in the post-award period.

**V. Summary of Key Components**

Since some of UAz’s physics teacher candidates come from astronomy, Novodvorsky’s departure from the physics department has not impacted recruitment as strongly as it might have if all recruited students were from physics. Recruitment takes place through advisors in the College of Science, who meet yearly with Novodvorsky to maintain
contact with the TPP. Professors of practice in the TPP also recruit at the new physics major welcome luncheon and in “discovery courses,” in which undergrads develop outreach activities for school groups. The latest area of recruitment is 2+2 programs with community colleges, where some of the coursework is online; it is hoped that this effort will increase the numbers of secondary teacher graduates for communities remote from Tucson. However, the need right now is greatest in biology, chemistry, and math, so this effort may not primarily benefit physics teacher education.

Since 2010, physics TIR functions have been fulfilled by an Assistant Professor of Practice (a retired high school physics teacher) in the College of Science.

TPP courses require early teaching experiences in local schools as early as sophomore year.

Since the end of the PhysTEC award, the Teacher Advisory Group and other inservice mentoring have been significantly reduced. UAz is seeking funding (e.g., $100K in 10) to fund recruitment, induction and mentoring.

Teacher education faculty in a variety of departments connect the disciplinary departments to one another. Since almost every course in the teacher preparation program includes classroom time, TIRs work closely with schools to coordinate placement.

Introductory physics course transformations initiated in the PhysTEC period have not been sustained.

### Status of PhysTEC Key Components at CU-B

<table>
<thead>
<tr>
<th>Component</th>
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<th>Reduced</th>
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</table>
VI. Sources

This study was conducted through interviews with Ingrid Novodvorsky, Director, College of Science Teacher Preparation Program, and Eugene Levy, former Dean of the College of Science.
I. Introduction

Western Michigan University (WMU) is a public research university with a large College of Education, consistently ranked in the American Association of Colleges for Teacher Education’s top 10 producers of professional educators.

The number of physics teacher graduates has been high for at least 14 years (relative to the national yearly average of about 1/year among institutions with a stated interest in physics teacher education), averaging almost four per year in the three years before the PhysTEC award. During the award period (2001-2007), the number of graduates increased to average about six teachers per year. In the period since the award, the average has stayed above the pre-award baseline at about five teachers per year. Thus, WMU is among the PhysTEC legacy sites that has sustained an increase in production of physics teachers. WMU has also sustained an increase in funding for physics teacher education (see section IV.C). On this basis, WMU is identified as having a sustained physics teacher education program. This is particularly notable in the context of greatly decreased enrollment in the College of Education, a depressed local economy, shrinking state population, and difficult employment situation for teachers and others.

II. Sustainability lessons learned

- Longstanding institutional commitment to teacher education can create the conditions for graduating large numbers of physics teachers.

III. Institutional motivation and commitment

Western Michigan University originated as a Normal School with purpose of preparing teachers, and teacher preparation remains a foundation area of the university. The Mallinson Institute of Science Education houses eleven faculty members, all of whom have dual appointments in both the Institute and in a home department (i.e., physics, biology, chemistry, or teacher education). The College of Education and Human Development is committed to the preparation of STEM teachers, and STEM teacher education is aligned with both the college and university strategic plans. A new dean is supporting one of the physics teacher education champions to create a STEM Center, one of whose purposes will be to recruit and prepare more STEM teachers.
Enrollment in the College of Education is significantly decreased in recent years, which may contribute to decreased production of physics teachers. However, most of the reduction is in the elementary education program (reduced by 30-50% in the last seven years); secondary teacher education has seen only a 10-15% reduction. The proportion of physics teacher candidates has been stable.

IV. Personnel and funding

A. Champions

Senior physics faculty member Bob Poel led the effort for physics teacher education at WMU until about 2005, when he became emeritus. Poel was a member of the Mallinson Institute for Science Education and the former Director of the Center for Science Education, which provides professional development to K-12 science teachers. Poel initiated the PhysTEC effort based on WMU’s strong record of content courses for elementary and secondary physics teacher candidates, working with TIRs to develop a mentoring and induction program for physics graduates. He continues to support physics education at the local and national level.

Since Poel’s retirement, physics teacher education is supported as part of STEM teacher education, through partnerships between the STEM disciplinary departments and the College of Education and Human Development. These partnerships are facilitated by Marcia Fetters, who has a joint appointment in the College of Education and Human Development (Department of Teaching, Learning, and Educational Studies) and the College of Arts & Sciences (Mallinson Institute of Science Education). Fetters coordinates secondary teacher education, teaches secondary science methods courses, and directs the Woodrow Wilson Teaching Fellowship program, a national fellowship program to support science and mathematics graduates and STEM career changers in pursuing secondary teaching certification.

B. Other personnel

Physics department faculty rotate through an advising position that supports physics teacher candidates. Al Rosenthal, who served as PhysTEC site leader after Poel, has occupied this advisor position. Rosenthal has also been department chair and is now the physics graduate advisor.

Faculty member Henderson was hired into a joint physics/education position in 2002 and has also been a PhysTEC site leader. Henderson’s research develops theories and strategies for promoting change in the teaching of STEM subjects, including issues related to the diffusion and adoption of research-based instructional strategies. Henderson has developed a physics-specific methods course to strengthen physics teachers’ pedagogical content knowledge; this course is a model for similar courses under development for earth science, chemistry and biology. David Schuster, another faculty member with a joint appointment in physics and the Mallinson Institute, supervises elementary teacher preparation.

A series of TIRs (Freeland, Wood, Semaru, and Isola) were highly visible presences in introductory and intermediate physics courses. Area physics teachers (Mirakovits and others) were active in developing physics workshops for regional science teachers. Mirakovits has also served as a PhysTEC Noyce mentor. These TIR leaders built community through frequent interaction with teacher candidates, student teachers, recent graduates, and area teachers. This Teacher Advisory Group organizes an annual event for area teachers and preservice teachers.

C. History

Before the PhysTEC award period (1998-2000), WMU was already producing an average of five physics teachers per year, a success that is partly attributable to WMU’s strengths as a primary teacher training institution. The PhysTEC award efforts were to reform the introductory course sequence, recruit additional physics and physics education majors and minors, and prepare PhysTEC graduates to use interactive teaching methods. These efforts may have contributed
to the increase in PhysTEC graduates during the award period. Alternatively, they may have mainly benefited the physics department by improving its undergraduate education.

Since the award period, the number of PhysTEC graduates is still high, but has been decreasing. The retirement of champion Poel has decreased the activity supporting physics teacher education at WMU; physics teacher education issues are no longer put before the departmental faculty on a regular basis. Other physics personnel (Rosenthal, Henderson, and Schuster) do not have secondary teacher education as a high priority. Without the TIRs, involvement with local area teachers has decreased, as has credibility with schools. Broader issues may also be affecting WMU’s physics teacher education program. In the last few years enrollment has declined both in WMU generally and teacher education particularly, though most of that decline is in elementary education (30-50% decrease); the number of secondary teacher candidates is relatively stable (5% decrease). Michigan also suffers from a depressed local economy, shrinking state population, and a difficult employment situation for teachers and others.

Details of awards and personnel contributing to physics teacher education are presented in Appendix A1. Overall, funds supporting physics teacher education at WMU increased from near zero before the PhysTEC award to an average of about $190K per year during the award period, substantially more than the amount of the PhysTEC award. Since the award period, funding has averaged about $90K per year, comparable to a PhysTEC award. Thus, WMU is among the PhysTEC legacy sites that has sustained an increase in funds supporting physics teacher education. Personnel supporting physics teacher education increased from near zero in the pre-award period to about 1.6 FTE during the award, and has averaged about 0.3 FTE in the post-award period.
Personnel supporting physics teacher education at WMU

V. Summary of Key Components

Recruitment takes place in the physics department through a physics education track, and in courses in the College of Education and Human Development in which instructors routinely highlight the need for physics, chemistry, mathematics and special education teachers. Future physics teachers are also recruited through the College of Engineering: Engineering advisors frequently recommend math or physics teaching to students unsure about their career choices. The opportunity to maintain a physics identity while pursuing a teaching career tends to be attractive to such students.

TIRs have not been sustained since the PhysTEC award; an attempt to sustain the TIR by adding a line item to the university budget failed when the economy worsened. The TIR-led Teacher Advisory Group that was formed during the award period now meets only once a year.

Course transformations initiated during the PhysTEC award period have been maintained in most cases, except that courses are no longer supported by a TIR.

Induction and mentoring takes place through Noyce and W. K. Kellogg Woodrow Wilson Teaching Fellowships.
Status of PhysTEC Key Components at WMU

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VI. Sources

This study was conducted through interviews with:

Al Rosenthal, Professor, Physics
Charles Henderson, Associate Professor, Physics and Mallinson Institute for Science Education
Marcia Fetters, Associate Professor, Mallinson Institute for Science Education and College of Education and Human Development
University of North Carolina at Chapel Hill

I. Introduction

The University of North Carolina at Chapel Hill (UNC) is a highly ranked research university known as a “Public Ivy” institution for its prestigious undergraduate program. Institutional commitment to physics teacher education is embodied in a departmentally based science teaching program created to serve regional needs.

The output of PhysTEC secondary graduates, which had been zero for decades, increased to an average of one per year during the award period (2007-2011), comparable to the national yearly average among institutions with a stated interest in physics teacher education. Thus, UNC is among the PhysTEC legacy sites that has sustained an increase in production of physics teachers. UNC has also sustained an increase in funding for physics teacher education (see section IV.C). On this basis, UNC is identified as having a sustained physics teacher education program.

II. Sustainability lessons learned

- With institutional support, programs can sidestep departmental resistance to faculty lines focused on physics education.
- Multidisciplinary programs can increase physics teacher education programs’ visibility and sustainability.

III. Institutional motivation and commitment

UNC’s science teacher education program was initiated jointly in 2005 by Biology, Physics, and Education, with assistance from the Provost, to highlight the institution’s contributions to the state. The program, called UNC-BEST (Baccalaureate Education in Science and Teaching), remains departmentally based and institutionally supported. UNC has made a significant commitment to discipline-based teacher education through the Provost’s allocation of “UNC-BEST instructor” lines to the disciplinary departments. UNC-BEST instructors teach discipline-based pedagogy.
courses and support preservice teachers in addition to other department-specific responsibilities. The Physics UNC-BEST program, in particular, is a means by which the physics department shows its value to the state (more so than with traditional physics research).

The status of UNC-BEST instructors as fixed-term, non-tenure-track faculty is an important part of how they function in their departments. Overall, UNC has established good practices for fixed-term faculty: There are clear paths for advancement, and they attend faculty meetings and vote. On the other hand, the pay is relatively low, job security is not guaranteed, and the extent to which they are respected members of the department varies from one discipline to another. (In Physics, most faculty have little interest in the UNC-BEST program; in Biology, in contrast, many faculty collaborate with the UNC-BEST instructor to reform their teaching.) An indicator that these conditions are considered favorable overall is that there has been essentially no turnover in UNC-BEST instructors since the start of the program. The funding model addresses the question of education-oriented faculty members gaining credibility (and getting tenure) in their department; they are reviewed and retained by the department with a clear understanding that their primary role is to support science teacher education.

IV. Personnel and funding

A. Champion

PhysTEC site leader McNeil is the primary “dealmaker,” initiating and managing funding proposals, making agreements with administrators, and leading collaborations with other departments. McNeil was the chair of the department during the PhysTEC award period; some of her activities over the years have been to support the process for the department to approve the pedagogy course, secure resources for course reform (including remodeling in the physics department to create a SCALE-UP classroom), and lead the committee for increasing the number of majors.

B. Other personnel

UNC-BEST instructor Churukian teaches the pedagogy course, supports preservice physics teachers, and prepares graduate and undergraduate teaching assistants. She also mentors faculty to teach transformed physics classes and teaches introductory physics courses. A series of TIRs have co-taught the pedagogy course and recruited and advised physics teachers. Other personnel support the multi-departmental UNC-BEST program, including a coordinator in the School of Education and a steering committee that includes the Dean of the School of Education, an Associate Dean of Arts & Sciences, and chairs or representatives of the disciplinary departments.

C. Historical development

Physics teacher education in the recent era at UNC began with the PhysTEC award. For decades before that time, there was no undergraduate program in physics teacher education at the high school level or even science teacher education beyond the middle school level, either in disciplinary departments or in the School of Education. There was a master’s program, but essentially no students completed it. The current physics teacher education program produces an average of one physics teacher per year.

UNC-BEST began in 2005 (one year before UNC’s PhysTEC award) as a collaboration among Physics, Biology, and Education: Biology recruited teacher candidates from its large population of former premedical students, Physics provided expertise in disciplinary teacher education to Biology, and Education created a new four-year certification program as well as helping with licensure requirements and student teaching supervision. This interdisciplinary team secured support from the Provost for three years of funding for one “fixed-term lecturer” (non-tenure-track faculty) in Biology to teach a pedagogy course, renewable if the Provost judged the program to be a success. At the same time, Physics secured an NSF CCLI award to partially transform its introductory physics courses; later, Physics extended these transformations by instituting a SCALE-UP model.
In 2006, the PhysTEC award kicked off the UNC-BEST program in Physics by supporting a Teacher in Residence and motivating the Provost to support a fixed-term lecturer in Physics (Churukian). Physics also obtained scholarships from the Burroughs-Wellcome Foundation to support UNC-BEST teacher candidates. Faculty and staff dedicated to physics teacher education have been stable since the start of the award period at about 1.0 FTE total for all personnel.

Looking to the future, there is good reason to believe that the UNC-BEST program in general and the physics program in particular are stable. A new Provost (as of July 1, 2013) has declared his support for the program.

Details of awards and personnel contributing to physics teacher education are presented in Appendix 1. Overall, funds supporting physics teacher education at UNC increased from near zero before the PhysTEC award to an average of about $190K per year during the award period, substantially more than the amount of the PhysTEC award. Since the award period, funding has averaged about $180K per year, about $150K/year more than in the pre-award period. Thus, UNC is among the PhysTEC legacy sites that has sustained an increase in funds supporting physics teacher education. Personnel supporting physics teacher education increased from zero in the pre-award period to about 0.9 FTE during the award, and has averaged about 1.0 FTE in the post-award period.
V. Summary of key components

Though there is little active recruitment, students who express interest in physics teaching to regular faculty are referred to the department program advisors (McNeil or Churukian). Few students get an early-enough departmental teaching experience to influence their career choice. However, the pedagogy course, taken by a wide variety of students, includes a significant fieldwork component in which participants spend a minimum of two hours per week teaching in or studying a high school physics classroom.

A part-time TIR is paid by the department to assist with the teaching of the pedagogy course and consult with students and faculty. There is no longer an official Teacher Advisory Group that meets regularly, but local teachers mentor and supervise the field experiences of the students in the pedagogy course.

One out of four sections of the introductory physics course are taught in a SCALE-UP format. Starting fall 2013, all sections will be taught with a mixed lecture-studio format.

The UNC-BEST program is actively coordinated among five disciplinary departments and the School of Education.

<table>
<thead>
<tr>
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<td><strong>Teacher in Residence:</strong> Experienced teacher is employed to work with the teacher education program and as a mentor to new teachers.</td>
<td>○</td>
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<td><strong>Course Transformation:</strong> Good pedagogy is modeled in physics classes.</td>
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<td><strong>Early teaching experiences:</strong> First- and second-year undergraduates get a low-pressure taste of the challenges and rewards of teaching.</td>
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<td><strong>Learning assistants:</strong> Talented undergraduates work with faculty to make large-enrollment classes more collaborative, student-centered, and interactive.</td>
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<td><strong>Teacher Advisory Group:</strong> Local teachers improve the teacher education program.</td>
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<tr>
<td><strong>Collaboration:</strong> Departments collaborate with one another and with school districts to support physics teacher education.</td>
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VI. Highlighted components

A. Course transformation

UNC’s Physics department benefits from the SCALE-UP model of instruction instituted in 2010 in one section of the introductory calculus-based physics course. External funding (NSF CCLI) initiated the transformation. UNC’s implementation of SCALE-UP is small, with only 45 students in the transformed course at a time (25% of enrollment). Churukian assists with instruction for the SCALE-UP courses. There is some transfer of her expertise to specific faculty members who have expressed an interest in modern pedagogy, and a new AAU-funded project will support more formal faculty development. Beginning in the fall of 2013, Churukian will lead a departmental changeover to a lecture-studio model, in which all sections of the introductory course will have two one-hour lectures and two two-hour studios (a combination of laboratory and cooperative-group problem-solving activities) per week. In the long term, McNeil hopes to expand the capacity of the SCALE-UP classroom by remodeling an additional room.

As at many PhysTEC sites, course transformation is significantly responsible for recruitment of physics students into physics teaching. Positive experiences with SCALE-UP draw students into UNC’s Undergraduate Teaching Assistant (UTA) program, and in some cases, from there to teacher candidacy. A pedagogy course that is offered for upper-division credit in the physics department is populated by physics majors/minors, non-physics majors, UNC-BEST students, and an occasional physics graduate student with an interest in teaching. The pedagogy course includes a significant high school fieldwork component and meets part of the licensure requirements for North Carolina public school teaching.

B. Collaboration

Eight years into the UNC-BEST program, there are UNC-BEST instructors in a total of five disciplinary departments (Physics, Biology, Chemistry, Geosciences, and Math). Each UNC-BEST instructor teaches a pedagogy course for that department’s UNC-BEST students. (UNC-BEST instructors also have other responsibilities, depending on the department.) Education provides UNC-BEST with a program coordinator. A steering committee includes the Dean of the School of Education, an Associate Dean of Arts & Sciences, and chairs or other representatives of the disciplinary departments. During the initiation of the program, there was substantial active collaboration among the participating departments to establish expectations and requirements. At this time, the program is well established and the personnel are experienced with one another, meaning that the collaboration, while still important, operates in the background.
VII. Sources

This study was conducted through interviews with the following faculty, staff, department chairs, administrators, preservice teachers, and inservice teachers:

Laurie McNeil, Professor, Physics, and PhysTEC Site Leader
Alice Churukian, Lecturer, Physics
Ted Oakley, Teacher in Residence
Chris Clemens, Chair, Physics and Astronomy
Mike Crimmins, Senior Associate Dean for Natural Sciences and Mathematics, College of Arts & Sciences
Bill McDiarmid, Dean, School of Education
Cathy Scott, UNC-BEST Coordinator, School of Education
Bill Kier, Chair
Steve Matson, former Chair
Vicki Bautch, incoming Chair, Biology
Peter Mucha, former Chair, and Rich McLaughlin, interim Chair, Mathematics
Allen Glazner, Chair, Jonathan Lees, incoming Chair, and Kevin Stewart, Associate Professor, Geological Sciences
David Smith, Lecturer, Physics
UNC-BEST students and graduates: Erik MacIntosh, Addie Jo Schonewolf, Mary Clements, Dave Gaston, Todd Anderson-Goldsworthy
I. Introduction

Cornell University is an Ivy League land-grant university, part public and part private, with a historical mission of educational breadth and practical impact as well as excellence.

The number of PhysTEC secondary graduates did not increase during the award period (2007-2011), and the teacher education programs at Cornell have all been terminated: although one more graduate will complete the program in 2014, no more graduates are expected since there is no longer a mechanism for certification at this institution. Neither physics teacher production nor funding for physics teacher education has been sustained at Cornell.

II. Sustainability lessons learned

- It is possible to sustain some elements of a physics teacher education program with little funding or other institutional support.
- The physics teacher education program can be entirely eliminated from an institution as part of broader strategic planning.

III. Institutional motivation and commitment

Cornell has a 100-year history of teacher education, and the Cornell Teacher Education Program was one of the few in the nation to focus solely on the preparation of science teachers. Cornell’s School of Education was located in the state-supported College of Agricultural and Life Sciences; during a period of state budget cuts, it was reduced to a department, and then eliminated entirely in 2012. In the near future, when the current cohort of student teachers graduates, the licensure program will be terminated as well. There is no longer any means to certify teachers in physics (or any other subject) at Cornell. The decision to close the Education Department was made as part of a university-wide strategic planning effort.
The Physics Department at Cornell is internationally renowned for research, and has prioritized the production of physics graduate students rather than physics teachers. However, individual faculty have made significant contributions to physics teacher education, especially in the form of course transformations. For example, Cornell is the site of the first student response system to be installed as part of the infrastructure of a lecture hall.

IV. Personnel and funding

A. Champions

The champion of physics teacher education at Cornell, Thorne, is a determined and independent leader who takes the national need for physics teacher education seriously. As a PhysTEC site leader his emphasis was on raising awareness and changing the attitudes of students and faculty regarding careers in high school teaching. Concurrent with the PhysTEC award, he secured funding from the Provost to recruit physics undergraduates into Cornell’s teacher education program. He established an informative and attractive website, collaborated with business students to create a “This Is Physics” marketing campaign, and prioritized site leader and TIR relationships with students for recruitment. He also established Undergraduate Teaching Assistant (UTA) program (similar to an LA program) and continues to maintain it, both to support transformed courses in the physics department and with the hope that undergraduates may pursue a teaching career through other means (e.g., at another institution or through an alternative certification program).

B. Other personnel

Two TIRs, Overhiser and Alderman, have served physics teacher education at Cornell for at least two years each. They have supervised the UTA program, taught the associated pedagogy course, recruited students into teaching through university events, and supervised preservice teachers. Though Overhiser has returned to the high school classroom, he still teaches a pedagogy course at Cornell.

Trumbull, faculty in the School (then Department) of Education, led science teacher education since before the PhysTEC award. She retired when the Department closed in 2012.

C. History

Before the PhysTEC award, there was little support for physics teacher education at Cornell, though an average of two teachers per year graduated with at least a physics minor. Cornell secured a PhysTEC award in 2007 with the aim of tapping the teaching potential of its large numbers of excellent physics and physical science students. The PhysTEC award supported TIRs, established the UTA program, and funded recruitment efforts.

Since the award period, the university’s teacher certification programs have all been eliminated. Cornell’s TIRs will be hired by Ithaca College to supervise Noyce scholars there. Course transformations in physics have been sustained along with the physics UTA program, with participating UTAs now earning credit instead of pay.

Cornell still supports an education minor through which students can complement a science major with coursework and fieldwork in secondary science education. Students with the education minor may go on to obtain certification at nearby Ithaca College. A two-year Noyce grant awarded to the Cornell Teacher Education Program in 2012 will be repurposed to improve the education minor.

A Physics Teacher Institute supported by the Cornell Laboratory for Accelerator-Based Sciences and Education provides professional development and community to inservice physics teachers.

Details of awards and personnel contributing to physics teacher education are presented in Appendix A1. Overall, funds supporting physics teacher education at Cornell increased from an average of about $160K per year before the
PhysTEC award to an average of about $300K per year during the award period, substantially more than the amount of the PhysTEC award. Since the award period, funding has averaged about $180K per year, about the same as before the PhysTEC award. Thus, Cornell has not sustained an increase in funds supporting physics teacher education. Personnel supporting physics teacher education increased from about 0.2 FTE in the pre-award period to about 1.3 FTE during the award, and has averaged about 0.3 FTE in the post-award period.

V. Summary of Key Components

At this time, no personnel conducts direct recruitment, i.e., directly identifies specific students as potential physics teachers.
Overhiser continues to fulfill some of the functions of a Teacher in Residence (e.g., by teaching the pedagogy course for UTAs), but has primarily returned to the high school classroom.

UTAs are recruited broadly from anyone who has taken introductory physics. UTAs were initially supported by PhysTEC funds, but are now offered only course credit for their service: a one-credit pedagogy course does not count toward graduation credit, but serves to document the teaching experience. About 45 UTAs serve six different introductory courses each semester. UTAs are mentored by experienced UTAs as well as a high school physics teacher from the region. UTAs are encouraged to pursue careers in teaching through degree programs at other institutions or alternative certification programs.

A Physics Teacher Institute supported by the Cornell Laboratory for Accelerator-Based Sciences and Education provides professional development and community to inservice physics teachers. Teachers from the Institute interact with preservice teachers at events. Local physics teachers also mentor UTAs.

### Status of PhysTEC Key Components at Cornell

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<tr>
<th>Component</th>
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<th>Maintained</th>
<th>Grown</th>
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<td><strong>Course Transformation:</strong> Good pedagogy is modeled in physics classes.</td>
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<td><strong>Early teaching experiences:</strong> First- and second-year undergraduates get a low-pressure taste of the challenges and rewards of teaching.</td>
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<td><strong>Teacher Advisory Group:</strong> Local teachers improve the teacher education program.</td>
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<tr>
<td><strong>Collaboration:</strong> Departments collaborate with one another and with school districts to support physics teacher education.</td>
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<td>☐</td>
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</tbody>
</table>

### VI. Sources

This study was conducted through interviews with:

- Rob Thorne, Professor, Physics
- Jim Overhiser, Teacher in Residence
Appendices
This appendix includes data for each study site on (1) personnel contributing to physics teacher education (odd-numbered tables) and (2) awards contributing to physics teacher education (even-numbered tables).

**Personnel tables**
In Personnel tables, a dagger (†) designates a champion and an asterisk (*) indicates a PhysTEC-funded TIR. Personnel activity codes are as follows:

1. Recruits secondary physics teachers (directly identifies specific students as potential physics teachers and communicates that to the student)
2. Builds pathways to become a secondary physics teacher (designs physics teacher education certification programs)
3. Advises preservice secondary physics teachers (academic advising and advice about being a teacher)
4. Mentors/induces inservice secondary physics teachers
5. Teaches secondary physics teachers (students who have declared a physics teaching major and/or inservice secondary physics teachers)
6. Creates/maintains physics-specific pedagogy classes (such as LA pedagogy courses or science methods courses with specific physics pedagogy content)
7. Maintains a Teacher Advisory Group of secondary physics teachers (i.e., a network of local secondary physics teachers who serve as physics teacher education resources)
8. Influences placement of new secondary physics teachers for student teaching
9. Leads collaborations with schools and school districts through local school administrators and teacher leaders that benefit secondary physics teacher education
10. Promotes secondary physics teacher education (through talks, papers, and/or research specifically about physics teacher education)
11. Secures funding and staff for secondary physics teacher education efforts at the institution (i.e., procures grants and/or hires people)
12. Makes deals for secondary physics teacher education (negotiates with institution for changes beneficial to physics teacher education)
13. PhysTEC site leader

FTE: Average fraction of time dedicated to the above-specified activities contributing to physics teacher education.

Years: Years spent contributing to physics teacher education (as defined above), beginning whenever such activities began and ending in Spring of 2012.

**Award tables**
In Award tables, awards are described by their source and the National Science Foundation program that issued the award, where applicable.

Award sources are listed in the following categories:

- NSF (National Science Foundation)
- PhysTEC (Physics Teacher Education Coalition)
- Fdtn (Foundation, e.g., Woodrow Wilson Foundation)
A1. Personnel & Funding

- Individuals (donations and endowments)
- Local (local institution—departments, colleges, Provost)
- DoE (Department of Education)
- State DoE (State Department of Education)

Award activity codes are as follows:

1. Funds recruitment of secondary physics teachers (pays for activities in which specific students identify as potential physics teachers)
2. Funds salaries for undergraduate early teaching experiences in physics (i.e., physics Learning Assistant programs) in which participants are actively recruited into secondary teaching
3. Funds scholarships for secondary physics teachers (e.g., Noyce)
4. Funds construction of pathways to become a secondary physics teacher (pays for faculty and staff to design physics teacher education certification programs)
5. Funds advising of preservice secondary physics teachers (pays for faculty and staff to advise preservice teachers both academically and about being a teacher)
6. Funds mentoring/induction of inservice secondary physics teachers
7. Funds teaching/professional development of secondary physics teachers (students who have declared a physics teaching major and/or inservice secondary physics teachers)
8. Funds creation or maintenance of physics-specific pedagogy classes (such as LA pedagogy courses or science methods courses with specific physics pedagogy content)
9. Funds a Teacher Advisory Group of secondary physics teachers (i.e., a network of local secondary physics teachers who serve as physics teacher education resources)
10. Funds a Teacher in Residence or Visiting Master Teacher (an experienced secondary physics teacher who works part-time or full-time with any aspect of the physics teacher education program)
11. Funds the development of resources benefiting secondary physics teacher education (e.g., professional development materials specific to secondary physics teachers, observational assessment instruments for evaluation and support of secondary physics teachers, diagnostic tools to be used by secondary physics teachers with their students)

%: Average percentage of the award dedicated to the above-specified activities contributing to physics teacher education.

$k$: Amount of the award, in hundreds of thousands of dollars.

Years: Years during which the award contributed to physics teacher education (as defined above), beginning whenever such activities began and ending in Spring of 2012.
A1. Personnel & Funding

1 Florida International University (FIU)

Table 1.1 Personnel contributing to physics teacher education at FIU

<table>
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<tr>
<th>Name</th>
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Table 1.2. Awards supporting physics teacher education at FIU

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A1. Personnel & Funding

### University of Arkansas (UArk)

#### Table 2.1. Personnel contributing to physics teacher education at UArk

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<thead>
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<th>Name</th>
<th>Role</th>
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## 4 | Seattle Pacific University (SPU)

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A1. Personnel & Funding

6 | University of Arizona (UAz)

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7. Western Michigan University (WMU)

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### A1. Personnel & Funding

#### 8 | Cornell University

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Table 8.2. Awards supporting physics teacher education at Cornell

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</tbody>
</table>
A2. Quantitative Questionnaire

Overview
PhysTEC is conducting a study on the sustainability of teacher education programs. As a PhysTEC Legacy Site, your institution is in a special position to help us understand how teacher education programs have been maintained, grown, or productively evolved over many years. The study will be conducted by means of a site visit and collection of quantitative data. This questionnaire requests quantitative data documenting specific outcomes at your site. We are grateful for your participation.

Instructions
Please use the attached data sheet to produce a year-by-year account of the following, beginning three years before the start of the PhysTEC award and continuing to the present. (Information previously reported to PhysTEC appears on the data sheet.)

1. PhysTEC Secondary Graduates [N]
2. Physics Learning Assistants [N]
3. Personnel [Position, names, %FTE dedicated to PhysTEC program, years served]
   a. PhysTEC Faculty and Staff
   b. Teacher-in-Residence
4. Program funding
   a. Internal Funding [$]
   b. External Funding [$]
5. Any additional data you would like to share with PhysTEC, especially if it represents an area of strength for teacher education at your institution

Please produce this account in advance of the site visit. At the site visit, the PhysTEC Sustainability Consultant (R. Scherr) will discuss the data with you in order to fully understand the information represented.

Data sheet

<table>
<thead>
<tr>
<th>1. PhysTEC Secondary Graduates</th>
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<tbody>
<tr>
<td>Baseline</td>
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<tr>
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<td>Year 0 (2004-2005)</td>
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<tr>
<td>Project</td>
</tr>
<tr>
<td>Year 1 (2005-2006)</td>
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<td>Year 2 (2006-2007)</td>
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<td>Year 3 (2007-2008)</td>
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<tr>
<td>Post-funding</td>
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<tr>
<td>Year 4 (2008-2009)</td>
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<tr>
<td>Year 5 (2009-2010)</td>
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<tr>
<td>Year 6 (2010-2011)</td>
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<tr>
<td>Year 7 (2011-2012)</td>
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</tbody>
</table>

Definition of PhysTEC Secondary Graduate: Any student who has graduated from a PhysTEC Institution and (a) has a major or minor in physics, OR (b) has completed coursework equivalent to a major or minor in physics, AND (a) has certification to teach high-school physics, OR (b) has completed a teacher education program.

Comments on Secondary Graduates data:
2. Physics Learning Assistants

<table>
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<tr>
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<td>Year -1 (2003-2004)</td>
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<td>Year 6 (2010-2011)</td>
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<td>Year 7 (2011-2012)</td>
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</table>

**Definition of Physics Learning Assistant:** Any student who facilitates learning in an undergraduate physics course, receives formal pedagogical instruction, and is encouraged to enter a teacher preparation program.

**Comments on Learning Assistant data:**

<table>
<thead>
<tr>
<th>3a. PhysTEC Faculty and Staff</th>
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<tr>
<td>Position</td>
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**Definition of PhysTEC Faculty and Staff:** Any university faculty or staff member in physics or education engaged in any aspect of the PhysTEC program. Engagement is measured by the %FTE that each PhysTEC faculty or staff member dedicates to the PhysTEC program.

**Comments on PhysTEC Faculty and Staff data:**

<table>
<thead>
<tr>
<th>3b. Teacher-in-Residence</th>
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</table>
### Definition of Teacher-in-Residence:

Any experienced secondary physics teacher employed at a PhysTEC Institution to work part-time or full-time with any aspect of the PhysTEC program.

### Comments on Teacher-in-Residence data:

<table>
<thead>
<tr>
<th>Name</th>
<th>%FTE</th>
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<th>Comments</th>
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</table>

### Definition of Internal Funding:

Funding originating at the PhysTEC institution that supports one or more of the PhysTEC Key Components. This could include salary or course release time for faculty or staff, stipends for teachers or students, funds for recruiting or events, or any other direct support of the PhysTEC program.

### Comments on Internal Funding data:

<table>
<thead>
<tr>
<th>Source</th>
<th>Description</th>
<th>Amount</th>
<th>Years</th>
<th>Comments</th>
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| 4a. Internal funding | 4b. Internal funding |
A2. Quantitative Questionnaire

<table>
<thead>
<tr>
<th>Source</th>
<th>Description</th>
<th>Amount</th>
<th>Years</th>
<th>Comments</th>
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</table>

**Definition of External Funding:** Funding originating outside the PhysTEC institution that supports one or more of the PhysTEC Key Components.

**Comments on External Funding data:**

Finally, we invite you to share any additional data you would like us to be aware of, especially if it represents an area of strength for teacher education at your institution.
A3. Site Summary Survey

Overview
PhysTEC is conducting a study on the sustainability of teacher education programs. As a PhysTEC Legacy Site, your institution is in a special position to help us understand how teacher education programs have been maintained, grown, or productively evolved over many years. The study will be conducted by means of a site visit and collection of quantitative data. This document is a survey intended to provide PhysTEC with an overview of the programs that are being sustained at your site. We are grateful for your participation.

Instructions
This document describes areas in which your institution may be active that would be of interest for this study. These are organized in terms of PhysTEC’s Key Components. To prepare for the site visit, please summarize briefly whether each of these Key Components has grown, been maintained, productively evolved, been reduced, or been eliminated since the period of PhysTEC funding.

After completing this summary, we will arrange for a conversation between the PhysTEC Sustainability Consultant (R. Scherr) and a member of your institution’s leadership team for teacher education. The Consultant and your site’s representative will select a few Key Components to be the focus for your institution and create a plan for the site visit.

Key Components

RECRUITMENT:
Promising undergraduates are identified as possible physics teachers and directed into a teacher pipeline.

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<th>Maintained</th>
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<th>Reduced</th>
<th>Eliminated</th>
<th>NA</th>
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</thead>
</table>

Summary:


TEACHER IN RESIDENCE/MASTER TEACHER:
Experienced teacher is employed to work with the teacher education program and as a mentor to new teachers.

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<tr>
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<th>Evolved</th>
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</table>

Summary:
### COURSE TRANSFORMATION:

Good pedagogy is modeled in physics classes.

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</table>

**Summary:**

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### EARLY TEACHING EXPERIENCES:

First- and second-year undergraduates get a low-pressure taste of the rewards and challenges of teaching.

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<tr>
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<th>Reduced</th>
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</thead>
</table>

**Summary:**

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### LEARNING ASSISTANTS:

Talented undergraduates work with faculty to make large-enrollment classes more collaborative, student-centered, and interactive.

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<thead>
<tr>
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<th>Reduced</th>
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</table>

**Summary:**

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### TEACHER ADVISORY GROUP:

Local teachers improve the teacher education program.

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</table>

**Summary:**

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A3. Site Summary Survey

**INDUCTION AND MENTORING:**
New physics teachers are supported in continuing as teachers.

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</table>

*Summary:*

**COLLABORATION:**
Departments collaborate with one another and with school districts to support physics teacher education.

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</table>

*Summary:*
A4. Site Visit Protocol

Overview
PhysTEC is conducting a study on the sustainability of teacher education programs. The goal is to understand how teacher education programs have been maintained, grown, or productively evolved over many years at PhysTEC Legacy Sites. The study will be conducted by means of site visits and collection of quantitative data. This document is the comprehensive protocol for site visits.

Part I. Key Components, Key Questions, and Prompts for Reflection
This first part of the protocol is organized in terms of PhysTEC’s Key Components. For each particular site, site leaders will work together with the Evaluator (R. Scherr) to identify a few especially successful Key Components for that site. These Key Components will be the focus of investigation for that site. The subsidiary questions (bulleted) will serve as prompts for reflection on and discussion of the focal Key Components in the site visit.

RECRUITMENT
How are promising undergraduates identified as possible physics teachers and directed into a teacher pipeline?

- How are brand-new undergraduates invited to consider physics teaching?
- By what means do you communicate with existing undergraduates to recruit them into teaching?
- Do you have a website or brochure providing information about your teacher preparation program?
- What advising is offered to undergraduates considering physics teaching?
- To what extent do undergraduate advisors know about and promote your teacher preparation program?
- To what extent do experienced teachers promote teaching careers to your undergraduates?
- To what extent do graduates of your program promote teaching careers to your undergraduates?
- To what extent do your physics classes model engaging, interactive teaching?
- Do your undergraduates have access to an authentic early teaching experience?
- Do you offer a four-year physics degree plan that includes teacher certification?
- Are your undergraduates offered scholarship support to get a teaching certificate?
- What impact is your program having on teacher production and retention?
- What data demonstrate the success of your program?

TEACHERS-IN-RESIDENCE/MASTER TEACHERS
How is classroom wisdom applied to the tasks of identifying, training, and supporting teachers of physics?

- To what extent does an experienced teacher among your personnel:
  - recruit new teachers?
  - recruit, select, and train learning assistants?
  - supervise field experiences?
  - mentor preservice and beginning teachers?
  - teach methods classes?
  - teach content classes?
  - redesign existing course curricula and develop new courses?
  - design and give professional development workshops?
A4. Site Visit Protocol

- give workshops and presentations at local schools and at state, regional, and national meetings?
  - Do you retain your master teachers for some time or is there a turnover?
  - How did you find your current master teacher?
  - How would you recruit another master teacher, if the current one were unable to serve?
  - How is your master teacher currently funded? How have past master teachers been funded?

### COURSE TRANSFORMATION

*How is good pedagogy modeled in physics classes?*

- To what extent are research-based curricula and methods used in your physics classes?
- How do faculty learn about innovative and effective pedagogical techniques?
- How are course developments transferred between faculty?
- How does administrative or management infrastructure support continued course transformation?
- Is data collected on student performance?
- Do you have a physics course designed especially for elementary teachers?
- Is good pedagogy apparent in preservice teachers’ field experiences?
- What standardized content assessments do you administer?
- How are faculty encouraged to participate in content assessments?
- What data demonstrates the success of your program?
- To what extent are course reforms transferable?
- How do you help faculty believe in and practice interactive teaching methods?
- Are interactive physics and science pedagogy courses required or recommended for preservice teachers?

### EARLY TEACHING EXPERIENCES

*How do first- and second-year undergraduates get a low-pressure taste of the rewards and challenges of teaching?*

- Do you have a Learning Assistant program?
- Do you have a program that supports peer teaching?
- Are preservice teachers placed in local school classrooms?
- Are student teachers exposed to multiple grade levels?
- Do practicing teachers participate in the design of your teacher education program?
- Does an experienced teacher help coordinate early teaching experiences?
- Does an experienced teacher help secure student teaching placements?
- Does an experienced teacher mentor preservice teachers during student teaching?
- What data demonstrates the success of your program?
LEARNING ASSISTANTS

How do talented undergraduates work with faculty to make large-enrollment classes more collaborative, student-centered, and interactive?

- How are Learning Assistants (LAs) recruited?
- How do LAs enhance your courses?
- What is the content of the LA pedagogy course?
- How are LAs supported and mentored?
- How are LAs compensated?
- How is your LA program funded?
- How do you encourage LAs to enter a teacher certification program?
- What data demonstrates the success of your program?

TEACHER ADVISORY GROUP

How do local teachers improve your teacher education program?

- Do local teachers have a forum to provide advice and expertise to departmental faculty?
- Does your program provide a network for local teachers?
- Does your program provide a means for preservice teachers to learn from experienced working teachers?
- Do practicing teachers participate in the design of your teacher education program?

INDUCTION AND MENTORING

What structures support new physics teachers in continuing as teachers?

- What mentoring do new teachers receive?
- Do you have an experienced teacher in your program that supports new teachers?
- Do you have a network of local teachers that support new teachers?
- Are new teachers part of any professional network?
- How do you keep track of teachers that go through your program?
- Is electronic communication used to stay in touch with distant mentees?
- Do new teachers have a forum for common planning time?
- Do new teachers get ongoing professional development?
- Is there standards-based evaluation for new teachers?
- Are preservice and beginning teachers invited to professional association meetings?
- Do you sponsor a student chapter of a teacher support organization such as NSTA?
- Is there a local masters’ program that emphasizes induction and mentoring?
- Are new teachers formatively assessed using tools such as the RTOP?
- Is teacher mentoring part of your LA program?
- Does an experienced teacher in your program mentor his or her replacement?
A4. Site Visit Protocol

- Do graduates of your teacher education program mentor preservice teachers?
- What impact is your program having on teacher production and retention?
- What data demonstrates the success of your program?

COLLABORATION

How do departments collaborate with one another and with school districts to support physics teacher education?

- How do physics and education faculty work together for teacher education?
- How does your institution partner with school districts for teacher education?
- Does your physics department recruit future teachers?
- Does your physics department train future teachers in content-specific pedagogy?
- Does your education school offer a content-specific course in teaching methods?
- Does a content-specific methods course count toward both a physics degree and a teaching certificate?
- Do school districts offer practice teaching experiences that promote inquiry teaching?
- Does an experienced teacher in your program serve as a bridge between your physics department and school of education?
- Does an experienced teacher in your program use his or her connections in local school districts to improve teacher preparation, induction, and mentoring?
- Do joint committees and working groups include physics and education faculty, faculty from other STEM disciplines, school district administrators, and/or university administrators?
- Do physics and education faculty work together on articles, presentations, workshops, or grants?
- Do practicing teachers participate in the design of your teacher education program?
- Do you connect with local teachers through teacher professional development workshops?
- Does your program have relationships with local two-year colleges?
- What data demonstrates the success of your program?

Part II. Mechanisms for Sustaining Teacher Education at the Study Site

The goal of the study is to determine the mechanisms by which teacher education at the site has been maintained, grown, or productively evolved, especially regarding the Key Components in which the site has been successful. For each focal Key Component, the Evaluator will pose comparative and causally-oriented questions such as those listed below. These questions are likely to be especially site-specific, and can be expected to require sensitive reflection on the part of both the site and the investigator.

FOR SPECIFIC ACTIVITIES:

Comparisons

- How is this similar to or different from what it was before your PhysTEC funding?
- How is this similar to or different from what it was during your PhysTEC funding?
- What has changed, and what has been maintained?
A4. Site Visit Protocol

Sustainability mechanisms

- By what means did that change occur?
- How has this kept going?
- Is this part of departmental infrastructure?
- Is the administration involved in this?
- Is this permanent?
- Where does the money for this come from?

Staffing

- Who made this happen?
- Who keeps this going?
- Does this have a champion?
- Does this have community involvement?
- What is your motivation or incentive for doing this?
- Is your effort sustainable?
- What sustains you?

OVERALL PROGRAM:

Department

- What resources has the department committed to teacher education?
- Is teacher education part of the mission of your department?
- Is teacher education discussed at faculty meetings?
- Do departmental faculty support teacher education? Do they recommend the program to their students?
- Do departmental faculty have the sense that teacher education is an important part of their department’s activity?

Institution

- What resources has the administration committed to teacher education?
- Is teacher education part of the mission of your institution?
- Do key administrators visibly support teacher education?
- Are there regular conversations between site leaders and higher-level administrators about the teacher education program?
- Does your institution devote faculty time to teacher education?
- Does your institution devote academic credit to teacher education?
A4. Site Visit Protocol

**Funding**

- What internal funding have you secured to support your program?
- What external funding have you secured to support your program?
- How is your Teacher-in-Residence or master teacher funded?
- What factors were critical in securing program funding, with regard to each funding source?

**Staffing**

- Does the program have a champion or champions? If so, who?
- What is the champion’s role?
- What has the champion done to build departmental/institutional support for teacher education?
- How has program staffing changed over time?