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Executive Summary

This study focused on the sustainability of 16 PhysTEC Comprehensive Grants funded from 2010-2015 ("Comprehensive II sites"). Evaluation questions included whether the number of physics teacher graduates increased, and sustained, what PhysTEC activities were sustained, and what factors contributed to sustainability. This period spans 5 different requests for proposals. Funding amounts were typically $300,000 over 3 years, plus a recommended 3-year institutional match; UTeach replication sites were funded at a lower level. Data gathered included archival documents, graduation data, a written survey, and a series of interviews, including completion of the Physics Teacher Education Program Analysis (PTEPA) Rubric. The desired outcomes included:

- Institutional capacity and culture for physics teacher education (PTE), such as leadership, resources, structure, and policy, and
- Sustained PTE program outcomes, such as graduation and an effective PTE program.

Sites were rated as "unsustained," "mixed," "sustained," or "grew."

The full report includes a diverse and rich data on outcomes across institutions, as does the full report summary. This executive summary provides only a very brief overview of the study.

Comprehensive II legacy sites often sustain their outcomes -- all but two sustained their outcomes to some degree, with meaningful outcomes and lasting impacts of the grant. All have a functional PTE program. More than half (9 institutions) are rated with high sustainability.

Comprehensive II legacy sites grow and sustain their graduation rates on average.

Teacher graduation increased by 1/year on average and this increase was sustained on average (1.3 teachers/year pre-funding, 2.2 teachers/year during-funding, 2.4 teachers/year during the sustainability period). For those sites which experienced an overall gain in graduation rate (N=11 sites) the average increase is 2 teachers/year. Gains and graduation rates were also overall higher for sites rated as sustained. Future teachers represented about 10% of undergraduate majors, on average, and about half of future teachers were certified through post-baccalaureate pathways.
PhysTEC supported strong culture, norms, and capacity for PTE and created strong PTE programs. In many cases, the most important outcome was stated as being the supportive culture for teacher education. Site leaders were overall proud of the results of the grants, and the quality of education provided for teacher graduates. Based on the PTEPA Rubric, PhysTEC supported many improvements in PTE programs, such that Comprehensive II sites rival the strength of thriving programs in terms of program structure and practices. LA programs, curricular changes, and recruitment practices were commonly mentioned durable outcomes, and institutionalization of LA programs was somewhat common. Students at former PhysTEC sites also receive quality preparation regardless of site sustainability: All sites including “unsustained” sites) were found to have strong ratings in the PTEPA “Knowledge and Skills” standard -- this standard includes physics content and pedagogy, and field experiences. Additionally, nearly all sites experienced growth in PTEPA ratings during PhysTEC funding, regardless of sustainability level, showing that Comprehensive grant funding improved PTE programs.

Successes promote a positive feedback loop and provide “proof of concept.” Often, success bred success; the PhysTEC grant enabled site leaders to establish “proof of concept” that PTE was viable: There was interest among students, demand for courses, graduation numbers could increase, and Teachers in Residence (TIRs) and Learning Assistant (LA) programs could be valuable for the department. LA programs supported a strong culture for teacher education, which then supported the LA program. The institutional match period helped establish the value of these program elements and create funding and routine to support them.
Most activities were maintained for most sites, especially LA programs. Overall, it is remarkable how many activities and structures were maintained across sites. Sustainability plans from the grant were upheld and in all but two cases the institutional match commitment was upheld. For most areas of the PTEPA Rubric, activity maintained or increased since PhysTEC for at least 80% of sites. LA programs were maintained at 13 out of 15 sites with an LA program; PhysTEC created or helped to maintain all these programs. External funding and human resources (e.g., full time equivalent, number in the team, TIR) were often reduced. The TIR position was maintained for over half of institutions (N=9), usually in a regular departmental position (such as lecturer or lab coordinator). About half of current TIRs were part-time. Most TIRs who were sustained included coordinating an LA program as part of their duties, demonstrating that LA programs can be an effective part of a sustainability plan, even if only indirectly related to PTE.

Human and financial resources are related to sustainability. Unsustained sites lacked champions, resources, and capacity for PTE. The two unsustained sites did not have a champion, and there were also very few resources allocated to PTE (e.g., funding, people, and FTE). Sites with greater levels of sustainability had generally higher levels of internal and external funding, greater numbers of PTE leaders and team members, and greater FTE spent by faculty. Local teacher salaries were not related to sustainability level, nor was the year of funding. UTeach replication sites experienced mixed sustainability results, with the Master Teacher not typically serving as a good replacement for a PhysTEC TIR.

Sustainability increased with the number of majors and with postbac pathways. Department size was higher for the 9 more well-sustained sites (average 33 majors/year) compared to the less sustained sites (average 21 majors/year), and these sites also grew more (+15-16 majors/year on average compared to +8 majors/year). The percentage of majors choosing to become teachers also increased with the sustainability level (8-9% for lower sustainability compared to 10-11% for well-sustained sites). Well-sustained sites tended to include a post-baccalaureate pathway as one of the main ways in which students achieved certification, and more students graduated through these pathways than through undergraduate-only routes.

Site capacity is necessary but not sufficient for sustained outcomes; the addition of institutional culture is a hallmark of the exemplary institutions. Each site was rated on their capacity and culture for PTE based on their leadership, institutional culture, and resources. All those rated as sustained were at least “medium” capacity. Thus, “medium capacity” may be a threshold for good results. Among the 9 sites that were rated as sustained, 4 were identified as truly exemplary; these were marked by stronger institutional climate and program collaboration and rated as “high capacity.” Sites that were sustained but not exemplary appear to have maintained their programs and outcomes as a result of the efforts of champions, rather than due to broader commitment to the cause. Thus, “high capacity” including a strong institutional
climate may be needed for exemplary results. Five sites had strong capacity and strong PTE programs, but low graduation rates; these were denoted as "mixed." Mixed sites (5 institutions) had generally good PTE programs but reduced graduation rates. These sites were typified by engaged champions but lacked supportive structure and institutional culture. When asked what helps keep things going at the site, we found that drivers of sustainability include people, money, structure, culture, and routine: The effort of champions, money, formalized structures, and culture change are critical. In many cases, having enough time to establish programmatic success enabled the establishment of value, and routines, to support continuity.

I thus conclude that:

- PhysTEC Comprehensive Sites achieve meaningful results for institutions, and the nation.
- PhysTEC supports organizational capital and a healthy ecosystem for PTE at institutions.
- It is difficult to maintain leadership, time, and effort, leading to fragility.
- Culture, including structure and routine, can help with sustainability.
- Motivated people, site capacity, and institutional culture are important, but insufficient on their own. Exemplary results require all elements of the model below to be exemplary: Motivated people, structure, and culture, likely with good connection to structures which support undergraduate education broadly.

About this study

This study was commissioned to assess sustainability of the latest round of PhysTEC Comprehensive sites. This was an intensive mixed-methods study requiring over 30 days of person-effort on the part of the evaluator alone. The findings are thus quite robust and rich.

Evaluation questions

1. Did the number of physics teacher graduates increase? Was this increase sustained?
2. What factors contributed to success in sustainability? What challenges to sustainability were encountered?
3. Which of the activities initiated by the PhysTEC grant are being sustained?
4. What is the future outlook for sustaining PhysTEC activities longer term?

Evaluation methods

Multiple data collection methods allowed the evaluator to gain a rich understanding of each site, while minimizing site leader time as much as possible. However, each site leader was still required to contribute at least 4 hours of time to the effort. We are all grateful for their effort.

<table>
<thead>
<tr>
<th>Evaluation method</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Document review</td>
<td>Reviewed RFPs, MOUs, annual reports, proposals, etc.</td>
</tr>
<tr>
<td>Graduation data</td>
<td>PhysTEC-collected graduation data was analyzed for each site and across sites.</td>
</tr>
<tr>
<td>Written survey</td>
<td>Each site leader was asked to identify some quantitative and qualitative data about their site, including listing outcomes resulting from the grant in an “outcomes harvesting” approach.</td>
</tr>
<tr>
<td>Orienting interview</td>
<td>1+ hour interview with site leader(s) to learn the story of their site, about teacher graduates over time, and hear the factors they believe are important in their site’s success (or lack thereof).</td>
</tr>
<tr>
<td>PTEPA interview</td>
<td>2+ hour interview to complete the PTEPA instrument, including rating change during, and since, PhysTEC in key areas.</td>
</tr>
<tr>
<td>Stakeholder interviews</td>
<td>1 hour interview with 2-3 additional stakeholders to validate findings and collect additional information. Typically, these included the physics chair and the education partner.</td>
</tr>
</tbody>
</table>
This information was collected within a “Dashboard” which collected information across all 16 sites.

Created products

The products created from this effort are:
1. This internal PhysTEC analysis report
2. An external, public version of this report with site names removed.
3. Individual “internal site reports” for each site, with key outcomes, a site narrative, and evaluative recommendations. Provided in PDF and Word format for ease of sharing.

Confidentiality

Confidentiality within PhysTEC was not promised for participating sites. All interviewees were told that information they shared would be viewable by (1) the site leaders and (2) the PhysTEC PMT. The site leaders are provided the “internal site report” and can decide what, if anything, to share further among stakeholders at their site. The PhysTEC PMT can view a private analysis report, and internal site reports, with sites identified. This public version of this report has all identifying information removed.

Which institutions participated?

This study focused on the 16 sites which were funded during the 2nd NSF PhysTEC grant, plus the Campaign Funds funded sites. Funding initiated from 2010-2015, and typically lasted 3 years. Funding amounts were typically $300,000 in total, except at UTeach replication sites (typically half that amount). Sites included are listed below.

1. First RFP (2009)
   a. California State University, Long Beach
   b. Middle Tennessee State Un.
   c. Towson University II
   a. Boston University
   b. Virginia Tech
3. Third RFP¹ (2011)
   a. Alabama, University of
   b. Arizona State University
   c. University of Missouri - Columbia
   a. Georgia State University
   b. James Madison University
   c. University of Central Florida
   d. University of Cincinnati
5. Fifth RFP (2014)
   a. Rowan
   b. Texas State
   c. UNC/Mines
   d. West Virginia U

¹ The third RFP is when the RFP was in its near final form, with a clearly defined period of sustainability.
What is a sustained PhysTEC site?

To understand what “success” would look like for site sustainability, I did some work to define this construct more specifically for PhysTEC sites. I sought guidance from the international development community. USAID defines sustainability as: “The ability of a local system to produce desired outcomes over time. Discrete USAID-funded interventions contribute to sustainability when they strengthen the capacity of the system to produce valued results and be both resilient and adaptive in the face of changing circumstances” (ADS 201, see Definitions). They identified categories of both Learning, and Sustainability, with sustainability split into individual, organizational, and institutional sustainability.

Valued outcomes

From this definition and our evaluation questions, I arrived at two main **valued outcomes** related to physics teacher education (PTE), resulting from PhysTEC grants: Capacity, and Sustained Outcomes. These are defined below, and each site was rated globally on this outcome, taking all factors into account holistically.

### Capacity & culture for PTE

*Institutional capacity & culture for PTE should be strong now, regardless of where it was immediately after the grant.*

**Includes:**
- Institutional culture and commitment.
- Leadership and resources
- Structure and policy

**Measured by:**
- PTEPA standards 1 and 2.
- Number and FTE of leaders, existence of champion, funding.
- Stated outcomes.
- Interviews across all stakeholders.
- Department size

**Global rating:**
- Low / medium / high (3 levels)

### Sustained PTE Outcomes

*PTE program outcomes should be at least as strong now as they were post-grant.*

**Includes:**
- PTE program strength.
- PTE program growth and resilience.
- Number of future physics teachers.

**Measured by:**
- PTEPA standards 3-6.
- Changes in PTEPA since the grant.
- Stated outcomes.
- Activities sustained.
- What keeps things going / resilience.
- Certification pathways.
- Graduation data.

**Global rating:**
- Unsustained / mixed / sustained/ grew

While both are valued outcomes, I decided that “sustained PTE outcomes” were the primary **dependent variable** by which I would examine results, treating “capacity” as a dependent variable.
Theoretical model

I have found that the findings from this study dovetail well with a model developed by Allie Lau and collaborators\textsuperscript{2} to identify factors which contribute to high use of active learning in introductory courses. They find that motivated people with knowledge and opportunities are necessary but insufficient to generate high use of active learning; these people must operate within (and develop) a supportive culture for active learning. They find that people and culture develop iteratively in high active-learning departments. They also find that establishing high use of active learning takes intentional effort over a sustained period.

I have adapted their model of factors contributing to “active learning” instead for factors contributing to “PTE” within departments. Their model, adapted for PTE, is shown below. I suggest that all items in the grey box represent “capacity,” and the desired result is the “sustained PTE outcomes” -- which includes both the quality of the PTE program and the number of graduates it maintains. Based on my recommendation (from the results of this PhysTEC study), Lau et al added an indicator arrow showing that this positive outcome further reinforces the culture in a positive feedback loop. I will return to this model again in the conclusions section.

Findings (1): How many sites were sustained?

Overall, were PhysTEC site activities and outcomes sustained? This section examines outcomes across sites.

All sites have a functional PTE program.

As a baseline measures, all site leaders were asked:
- Do you currently have a PTE program?
- To what extent do you feel your PTE program is functional?
- To what extent do you feel your PTE program is thriving?

All sites have a PTE program. For the two who indicated that they only “sort of” have a PTE program this is because there is a pathway to certification that does not reside solely within the institution. Three PTE programs became more established during PhysTEC, moving from “no” to “sort of” or “sort of” to “yes.”

Site leaders feel that their PTE programs are at least moderately functional, and somewhat thriving.

See graphs below. As a baseline measure, this suggests that legacy PhysTEC institutions have functional PTE programs, which is more than can be said for most physics departments.

These self-ratings only somewhat corresponded with the evaluator ratings (next page) -- the sites which I rated as “unsustained” tended to rate themselves very low on the “thriving” scale. Otherwise, self-ratings were not necessarily a good proxy of sustainability.

But to better understand sustainability, let’s look at the global ratings of “capacity” and “sustained outcomes” which were the outcomes of this study.
All but two sites are sustained, and over half are well-sustained.

Out of 16 sites, 9 were well-sustained; rated as “sustained” or “grew” in the global ratings. Only 2 were rated as “unsustained.”

Those which were rated “sustained” (N=5) were rated as having a strong PTE program (based on standards 3-6), changes in the PTEPA indicating that most areas sustained or grew since PhysTEC, having adequate pathways to certification, and maintaining the number of graduates over time. These were solid programs that had managed to keep most if not all the interventions from PhysTEC.

Those which were rated as “grew” (N=4) had significant changes since PhysTEC that increased the strength of the PTE program, certification pathways, PTEPA ratings, or number of graduates.

Those which were rated as “mixed” (N=5) typically had strong PTE programs which had maintained over time, but graduation numbers were extremely variable and had dropped since the grant; most “mixed” sites experienced a drop-off in teacher graduates of 1 to 2 teachers/year since the grant ended. Unlike the Unsustained sites, however, Mixed sites maintained most of the PTE program elements put in place during the grant and with one exception, graduation numbers did not drop as precipitously as the “unsustained” sites.

Those which were “unsustained” (N=2) retained few of the interventions from PhysTEC; grant outcomes had not been maintained, champions were no longer present or were uninvolved, and few people in the department were involved in PTE. Both sites had significant structural and/or financial barriers to progress.

Holistically, I suggest that approximately 12-14 out of the 16 sites, or 75% of the sites which were funded achieved outcomes which are worthy of the grant funding. I would like to emphasize that meaningful changes happened at these institutions, with worthy outcomes and lasting impacts.

Sites report time and money being spent on PTE.

The average current internal funding spent on PTE is approximately $100,000, with 2 PTE leaders and 2 PTE non-leaders, spending about 0.5 faculty FTE and 0.3 TIR FTE. These numbers vary by sustainability level, as will be described later in the report, but overall there is continued effort and resources being directed towards PTE -- though somewhat minimally at the 2 Unsustained sites.
Three-quarters have at least medium capacity for PTE; half have high capacity for PTE.

Regardless of sustained outcomes, half of studied sites were rated as “high” capacity for PTE, based on funding, leadership and champions, number of people involved in PTE, time for engagement in PTE, department size, and PTEPA standards 1 (institutional commitment) and 2 (leadership and collaboration).

**Summary**

**Comprehensive II legacy sites often sustain their outcomes** -- all but two sustained their outcomes to some degree, with meaningful outcomes and lasting impacts of the grant. All have a functional PTE program. About half (9 institutions) are doing very well, rated with high sustainability, and 4 of these growing further since the grant and truly thriving. The 5 programs that were not fully sustained did typically maintain their program structures but not graduation rates. The majority (12) are rated as having at least medium capacity in their PTE program, and most report continued effort and resources dedicated to PTE. The average current internal funding spent on PTE is approximately $100,000, with 2 PTE leaders and 2 PTE non-leaders, spending about 0.5 faculty FTE and 0.3 TIR FTE. Thus, the vast majority of former PhysTEC-funded sites have functional PTE programs, many of which are truly thriving -- more than can be said for most physics departments.
Findings (2): How many teachers are graduating?

In this section I examine the findings related to teacher graduation rates at the Comp II sites. This addresses the evaluation question, “Did the number of physics teacher graduates increase? Was this increase sustained?” The period of PhysTEC funding is taken as the “funded +1” period -- Funded years 1-3 plus the first post-funded year.

Teacher graduation increased by 1/year on average; this was sustained.

Below are teacher graduation rates\(^3\) over time. The sustained increase of +1 teacher/year mirrors the results analyzed across all Comprehensive sites in a 2019 evaluation report, which found that Comprehensive sites increased teacher graduation rates by +1 teacher/year, which was statistically significant.\(^4\) There was no drop after funding ended, on average, resulting in an average total gain from pre-to-post funding of +1 teacher (rounding to the nearest whole number of teachers).

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\(^3\) Rates are averaged across all 16 sites and plotted over the time period for which we have graduation data for at least 14 of those sites. When this data is analyzed for the 7 sites for which there is graduation data through PF7 we find evidence of even longer-term sustainability (pre-funding: 1.3 teachers; during-funding: 1.9 teachers; post-funding: 2.5 teachers).

\(^4\) The 2019 study also found that this result was statistically significant even when controlling for background variables (department size, pre-funding graduation rates). That study also found no clear differences in graduation rates between Comp I and Comp II funded sites.
Two-thirds of sites increase their graduation rates by 2 teachers/year.

Not all sites increased the graduation rates pre-to-post; 11 sites increased the overall number of teachers, for a “hit rate” of 69%. These 11 sites increased their graduation rates by 2 teachers/year pre-to-post, on average, to an average during the sustainability period of 2.6/year (see inset, right). (These 11 sites are not the same as those which were classified as sustained/grew, as that classification considers the site as a whole, not just graduation rates.)

This finding is again similar to that of the 2019 Funded Site Graduation Report. The other 5 increased no net gain in graduation rates, with two experienced reductions in graduation rates of 1-2 teachers. Because results are similar to the 2019 study, I do not replicate the cost/benefit analysis therein (showing that small grants are cost effective); those results should hold.

Graduation rates are higher for well-sustained sites.

Below are the graduation rates for sites, organized by the “sustained outcomes” rating. The trend is positive for well-sustained sites (both “grew” and “sustained”), “mixed” sites increase but then lose some of these gains, and “unsustained” sites return to baseline. Additionally, the current graduation rate (during the sustainability period) is higher for the more sustained sites. This pattern is somewhat by design, as graduation rates were considered when creating the sustainability ratings. However, these averages obscure the extreme year-to-year variability; see next page.

---

5 For this chart and those below, the graduation rate of one of the “unsustained” sites during the sustainability funding was interpolated due anomalous post-funding year 2 data for each one (5+ club). Since there are two sites in this category it is particularly sensitive to anomalies, and the interpolated data better matches the trendline.
<table>
<thead>
<tr>
<th>Category</th>
<th>Graphs</th>
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<tbody>
<tr>
<td>Unsustained sites</td>
<td><img src="image1.png" alt="Graphs" /></td>
</tr>
<tr>
<td>Mixed sustainability</td>
<td><img src="image2.png" alt="Graphs" /></td>
</tr>
<tr>
<td>High sustainability</td>
<td><img src="image3.png" alt="Graphs" /></td>
</tr>
<tr>
<td>Grew further</td>
<td><img src="image4.png" alt="Graphs" /></td>
</tr>
</tbody>
</table>
Graduation rates increase more for well-sustained sites.

To analyze the changes in graduation rate over time, I analyze the change from “during” funding to “post” funding, to calculate the overall pre-to-post-funding change in graduation, below.

The overall pre/post increase is positive for all groups of sites except for the unsustained sites. Overall, 2 decreased, and 3 maintained graduation rates compared to pre-funding rates. Somewhat by design, the change during sustainability (i.e., the difference between during-and-after funding rates) is highest for those sites which were sustained or grew.

The data, however, is extremely messy at the level of individual sites. To provide an overall picture of graduation rates within the four categories of sustainability these are provided as anonymized snapshots below. The period of PhysTEC funding is shown as a reference rectangle.

The “sustainable outcomes” categorization does not always clearly follow the graduation data as the categorization is considering activities at the site holistically, including whether there were anomalous graduation years, and the overall PTE program strength. Additionally, the “grew” sites are earlier in their funded periods, so the “grew” rating is typically an educated opinion based on past performance and exemplary program strength.

---

6 Sustainability ratings were made by a global inspection of graduation rates over time (taking into account anomalous years), as well as maintenance of the PTE program as a whole.
7 For this chart, the anomalously high post-funding year for the unsustained site is maintained.
Future teachers are about 10% of the physics department majors.

Based on the recommendation of a site leader, I calculated the percentage of the physics department that is counted as a teacher graduate. The average was 10% and the median was 8%. This number was remarkably robust. This analysis supports a rule of thumb that 10% of the majors might be expected to become future teachers; a rule of thumb that was cited to me by a few physics department chairs. This rule of thumb originated in an AIP Career Statistics survey, which are studies of in-service teachers. Note, however, that not all future teachers originate within the undergraduate major; a sizable fraction follows a post-baccalaureate pathway.

Post-bac certification makes up approximately half of future teachers.

Graduation data from the Comp II sites was analyzed for the 2021 Graduate Pathway Analysis evaluation report. Like all PhysTEC institutions, postbac certification makes up a significant portion of PhysTEC graduates at Comprehensive II sites. On average, 42% of students at these sites received an undergraduate certification, compared to 47% receiving postbac certification as a standalone program or an add-on to an undergraduate program.

I also investigated which pathway accounted for most graduates. For only N=4 does the undergraduate pathway account for most of their graduates. For the other 12 sites, half use primarily a post-bac pathway, and half use a combination of undergraduate and post-bac pathways.

---

8 I used the average number of teacher graduates in the sustainability period (from PF2 through the most recent year for which there is data), divided by the average department size (i.e. graduating undergraduate majors) in the sustainability period (using IPEDS data through AY 2019-2020).
Summary

**Comprehensive II legacy sites grow and sustain their graduation rates on average.** Teacher graduation increased by 1 teacher/year on average, and this increase was sustained on average. The data, however, is messy and idiosyncratic. Teacher graduation rates increased from 1.3 teachers/year pre-funding to 2.2 during funding and 2.4 during the sustainability period. For those sites which experienced an overall gain in graduation rate (N=11 sites) the average increase is 2 teachers/year. These increases contribute significantly to addressing the national physics teacher shortage.

**Well-sustained sites experience sustained graduation rates of 3-4 teachers/year.** Well-sustained sites (those which “sustained” or “grew”) had overall higher teacher graduation rates: 2.5 teachers/year for “sustained”, and 3.8 teachers/year for “grew” sites. Growth in teacher graduation rates was also higher at these well-sustained sites, with overall pre-post growth of 1.1 and 2.1 teachers/year at “sustained” and “grew” sites, respectively. Only “unsustained” sites experienced no average growth from pre-to-post funding, though both “unsustained” and “mixed” sites experienced a decrease in graduation rates, on average, after funding ended.

**Future teachers represent about 10% of the undergraduate majors at departments.** The number of majors, and the fraction of majors who choose teaching, increases for more successfully sustained sites.

**About half of teachers at an institution are certified through a postbac pathway, on average.** On average, 42% of students at these sites received an undergraduate certification, compared to 47% receiving postbac certification as a standalone program (30%) or an add-on to an undergraduate program (17%).
Findings (3): What outcomes were observed?

To address the evaluation questions regarding sustainability, we must first understand the current status of Comp II sites; what do these programs look like, and what do they feel were the outcomes of the grant? What challenges do they face? In this section I review outcomes:

- Statements of the success of the grant, and significant outcomes
- Quantitative resource data
- PTEPA Rubric results
- Written outcomes

Note that 15 out of 16 sites completed the PTEPA, and results were validated across stakeholders. These results will also be used for an inter-rater reliability study of the PTEPA, and rubric revisions.

Overall outcomes

Comp II site leaders were asked “Do you feel like your PhysTEC grant was a success?” and “what are you most proud of?” This section outlines these global responses.

Site leaders overall feel that the PhysTEC grant was a success.

Regardless of sustainability level, the overwhelming response was “yes,” the PhysTEC grant was a success. Site leaders described a variety of reasons why they felt it was a success, including sustaining PhysTEC-initiated activities, sustaining the TIR, changes in departmental and institutional culture, laying the groundwork for future grants and collaborations, establishing viable certification pathways, and increasing the number of graduates. That said, 4 site leaders indicated mixed feelings about their success because they weren’t yet achieving the kinds of graduation numbers they had hoped for, or because they felt performance pressure during PhysTEC. Site leaders had many suggestions for PhysTEC as a project, which will be discussed later.

Site leaders are most proud of their graduation rates, and PTE programs.

Across the board, site leaders indicated that they were most proud about the number of teachers they have been able to graduate, the quality of the preparation they are able to give those teachers, and institutionalization of key elements of PTE. For example:

- “This is a great place to become a physics teacher.”
- “Getting the 5+ club twice was a feather in the cap.”
- “We have the best TIR ever, and an LA program.”
- “Having sustained 1-2 teachers/year after being flatline for a decade is noteworthy. That’s a dozen well-qualified physics teachers out there in the field.”
- “I see individuals discovering their own well of dedication to the (teaching) profession.”
- “We have a 4-year certification path, with physics students in that path.”
Comprehensive II sites approach the thriving programs on PTEPA results.

When taken as a whole, the Comp II sites PTEPA results approach those of the thriving programs; 73% of all PTEPA items were rated at least Benchmark for Comp II sites, which is comparable\(^9\) to the 78% of items rated at least Benchmark for the Thriving Programs study (see http://phystec.org/thriving). In many individual standards and components, Comp II results meet or exceed those from the thriving programs.

Sites experienced broad increases in PTEPA ratings during PhysTEC.

Site leaders were asked to indicate whether PTEPA ratings had increased during PhysTEC. Across the PTEPA, the majority of sites reported increases during the grant. This shows that PhysTEC grants support broad improvements in culture, capacity, and programs. The fewest sites reported increases in component 3D (streamlined and accessible programs), standard 4 (knowledge and skills), and standard 6 (assessment).

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\(^9\) This results and others were not tested for significance. The Standard Error of the Mean is used as a visual judge of distribution spread, but is not the appropriate metric to test for significance due to lack of a random sample.
Institutional capacity & culture outcomes

Here I review results from a set of stated outcomes. Site leaders were asked to state (1) the most significant outcome of the grant, and (2) to list up to 5 outcomes in each of 4 areas of valued outcomes. In addition to the most significant outcome, site leaders named a set of outcomes in each of the 4 areas: Capacity and commitment, structures and policies, collaborations and partnerships, and PTE programs and practices. These results were coded for common themes.

In the beginning of this report, I outlined a theoretical framework that indicated that people, culture, and structure lead to sustained teacher graduation numbers and strong PTE programs - and vice versa. This model is outlined in abbreviated form below, along with the key variables in each area.

First, I will outline the results related to the first part, “institutional capacity and culture.”

**PhysTEC often helped support a positive culture for teaching; this was seen as the most important outcome for a majority of sites.**

When asked what the most significant outcome was for their site, 9 out of 16 sites spontaneously mentioned a supportive culture for teaching or teacher education as the most significant outcome (N=7 in the physics department, and N=2 among higher administration). The statements were remarkably similar to one another, indicating overall that teaching is now seen as a viable career option and students will find faculty support for their decision. A few specifically mentioned that physics faculty have greater awareness and understanding of the needs of future physics teachers.

Another key outcome was that PhysTEC helped support institutionalization of programs, especially LA programs.

A total of 5 out of 16 sites mentioned institutionalization of an LA program as the most significant outcome of the grant, and one site mentioned two other institutionalized programs or positions which were key. Embedding such a program into institutional practices and routines represents strong program capacity.
PhysTEC supported across-the-board improvements in institutional capacity and culture.

Across all sites, site leaders were able to name an average of 4-5 outcomes for each of the 3 categories related to institutional capacity and culture: capacity and commitment, structures and policy, and collaboration and partnerships. About half of those outcomes were identified as “key” or critical outcomes in each area.

There were more outcomes in institutional commitment and norms than in policy or collaboration.

The category “capacity and commitment” stood out from the other 2 categories of outcomes in that the average N of outcomes per site across sites was higher than in other categories (5 outcomes compared to 3-4), and in that the average percent of “key” outcomes was higher than for others (59% compared to 45% on average). “Capacity and commitment” tend to include changes such as support for PTE in the physics department, funding for programs, norms supporting PTE, and administrative support. Thus, we can conclude that PhysTEC supports changes in culture supporting PTE -- but it supports even more changes, and more important changes, in capacity and commitment for PTE (compared to structures/policy or collaborations/partnerships.)

I coded the written outcomes casually by topic (see below).

<table>
<thead>
<tr>
<th>Top institution capacity &amp; culture outcomes (out of 15 max)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Topic</strong></td>
</tr>
</tbody>
</table>
| LA programs | 2.4 | ● Requests for undergrad LAs is now routine  
● The LA program is now permanent and supported by the university. |
| Education/physics connection | 2.1 | ● Physics MS candidates have done their thesis in physics ed.  
● More collaborative grants between colleges. |
| Certification/pathway | 1.4 | ● New dual physics/math major with flexible pathway.  
● The institution has a functional 4-year certification program. |
| Curriculum | 1.3 | ● Physics teaching concentration is now one of four stated career pathways for a major.  
● New education courses are part of teaching minor. |
| K-12 connections | 1.2 | ● We have informal collaborations with local districts for preservice teaching.  
● Monthly on-campus meetings with area HS teachers. |
LA programs were the most commonly named cultural outcome of PhysTEC, followed by education/physics connections.

LA programs were named most commonly (about 2 times per site on average). Sites indicated that the LA program was now embedded in institutional practices and routines, supported by faculty, and/or sustained by resource allocation. As indicated earlier, institutionalization of LA programs was named as the most significant outcome by many sites. Education/physics collaborations were the next most commonly named outcomes, including collaborative grants or other touchpoints between the colleges.

Also commonly named were certification/pathway changes, curriculum changes, and connections to K12. Other outcomes named by at least one site included a supportive culture for PTE, grants and scholarships (plus 3 sites specifically indicated that future grant-funded projects were one of the most significant outcomes), TIR (plus 2 sites indicated that the TIR position was the most significant outcome), advising, undergraduate program improvement, partnerships, recruitment activities, leadership, and cross-STEM discipline collaboration. There were few notable differences between well-sustained and less well-sustained sites.

Comprehensive II sites PTEPA results have room for growth in areas of institutional commitment and leadership.

When taken as a whole, the Comp II sites PTEPA results are similar to thriving programs (see right), in that they have a similar percentage of items rated at least Benchmark in all PTEPA standards except standards 1 (Institutional Commitment) and standard 2 (Leadership and Collaboration.) Standard 6, Assessment, is also somewhat lower for Comprehensive II sites than for Thriving Programs.

In particular Resources (1C), Program Team members (2A) and Program Team Attributes (2B) have fewer items rated at least Benchmark among Comp II sites than among thriving programs. Additionally, “Communication to Stakeholders” (6C) has fewer items rated at least Benchmark among Comp II sites. These results suggest that Comp II sites develop a wide variety of strong PTE program structures, but perhaps only the strongest develop strength in standards 1 and 2, plus communication to stakeholders.
Most sites have solid PTE programs with good teacher graduation rates.

As indicated earlier in this report, all sites have a functional PTE program, with time and money spent on PTE. Most sites increased physics teacher graduation rates sustainably since beginning PhysTEC funding, though the level of increase varied across sites. Many site leaders are proud of these graduation rates, and of the existence of their PTE programs. PTE programs were strengthened during PhysTEC as measured by the PTEPA, which showed increases for most sites across most components or standards. Current PTEPA ratings (see above) show strength in a wide variety of PTE program practices and structures.

LA programs are a common area of strength in the PTE program.

Institutionalization of LA programs was noted earlier as a marker of enhanced institutional capacity and culture for PTE. LA programs also strengthen the PTE program itself, by offering early teaching experiences, recruiting future teachers, and providing a community to engage those interested in teaching. When site leaders were asked to name outcomes of the grant for their PTE program, “LA programs” were mentioned by about half of the respondents; see below. There were no notable differences between well-sustained and less well-sustained sites on these outcomes.

Top PTE program outcomes (out of 5 max)

<table>
<thead>
<tr>
<th>Topic</th>
<th>Average N/site</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curriculum</td>
<td>1.2</td>
<td>● Pre-service teachers take pedagogy courses we developed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● Physics pedagogy course offered on a regularly scheduled basis.</td>
</tr>
<tr>
<td>LA program</td>
<td>0.6</td>
<td>● Most future physics teachers work as LAs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● Recruitment has increased through participation in the LA program.</td>
</tr>
<tr>
<td>Recruitment</td>
<td>0.6</td>
<td>● Recruitment has increased via the Noyce grant.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● Posters and slides which highlight the benefits of teaching.</td>
</tr>
</tbody>
</table>

Curricular changes and recruitment were common outcomes.

As shown by the table above, curricular changes were mentioned about once per site on average, usually mentioning the pedagogy course created and/or maintained under PhysTEC. As a counterpoint, however, on PTEPA ratings the fewest sites reported increases in standard 4 (“knowledge and skills”) compared to other standards. Many sites mentioned recruitment activities as a lasting outcome of the grant, such as posters, career seminars, and promoting the program through events.
Challenges

Site leaders were asked what their biggest local challenges were. Responses are analyzed here.

The most common challenge is the effort and personnel required to keep the program going.

The most prominent theme was that it takes a great amount of effort, and engaged faculty, to keep PTE going. Challenges with effort and personnel were mentioned by N=8 out of 15 sites. This effort requires dedicated positions (e.g., LA program director, TIR, PTE program director), constant work and effort, and onboarding and engaging faculty members so they are aware of the PTE program. Since PTE doesn’t often fall directly within any one person’s formal job duties, this can be difficult. Example statements include:

- The constant work to do with faculty [to improve perceptions]
- The energy it takes to keep things moving.
- It’s not anybody’s job, it’s a side gig.
- We need an LA director position so that we do not lose [the long-time TIR].
- I wish we had more faculty involvement. If any of us left, I don’t know how we would continue.

Given that the unsustained sites are those which lost the time and focus of a champion, this challenge points at the inherent fragility of PTE efforts.

The other common challenge is in licensing requirements, including time to degree.

This was mentioned by N=5 out of 15 sites. Two mentioned that students decide to pursue teaching late, two mentioned emergency certification as a challenge, and others mentioned certification requirements or time to degree as challenges.

Other challenges included perceptions of teaching as a profession (N=4), funding (N=2), retirements (N=1), and recruitment challenges (N=2).
Summary

Site leaders are overall proud of the results of PhysTEC, and feel it was a success. Site leaders feel the grant was a success due to sustaining activities and positions, changes in culture, and laying the groundwork for future grants. In many cases, PhysTEC offered the chance to institutionalize changes by creating a “proof of concept” and allowing time for changes to become entrenched. Site leaders were proud of their PTE programs, including the quality of education they are able to provide to future teachers, and the number of teacher graduates.

I posit that institutional capacity and culture support sustained PTE outcomes, and vice versa.

PhysTEC supported institutional capacity and culture for PTE -- especially norms. This statement is supported by multiple strands of evidence. Most site leaders (N=9) mentioned a supportive culture for teaching (or for teacher education) as the most significant outcome of the grant. The other common significant outcome was the entrenchment of key programs (usually an LA program) into institutional culture and practice. Site leaders were also able to name 4-5 outcomes for each of 3 areas related to institutional capacity and culture, with about half of those outcomes identified as key outcomes. They were able to name even more outcomes (5 compared to 3-4) in “capacity and commitment,” due to changes such as faculty and administrative support and changing norms. Thus, PhysTEC supports changes in culture and norms supporting PTE (compared to structures, policy, or collaborations).

Sites have strong PTE programs which were enhanced during the PhysTEC grant. Based on PTEPA rubric results, Comprehensive II sites approach the “thriving” physics teacher education programs, with 73% of PTEPA items rated at least Benchmark (compared to 78% for thriving programs). Comp II results also rival those of the thriving programs at the standard and component level. Most sites reported increases in each area of the PTEPA, showing across-the-board enhancement of PTE, with some exceptions. LA programs, curricular changes, and recruitment practices were the most commonly mentioned durable outcomes.

Institutionalization of LA programs was related to both culture and quality of PTE. LA programs were often institutionalized during PhysTEC, indicating a culture of support for physics education and/or teacher education. Those same LA programs enhanced the quality of PTE, and of undergraduate physics education. The strength of those LA programs then further enhanced the cultural support for physics teaching and/or physics teacher education in a positive feedback loop. This is evidenced by the fact that LA programs were named both as important cultural outcomes for sites (average of 2 outcomes/site) and as enhancements to the PTE program (average of 0.6 outcomes/site). LA programs were named by 5 as the most significant outcome.
The most common challenge is effort and personnel, followed by licensing requirements. Many champions indicated that it’s hard to keep PTE going, requiring great effort and engagement of faculty. While best if done as part of a dedicated position, usually this isn’t anybody’s “real” job. Many also mentioned that licensing requirements and time to degree, including students choosing late to pursue teaching, is a challenge.
Findings (4): What was, and was not, maintained

To address the evaluation question, “which of the activities initiated by the PhysTEC grant are being sustained,” in this section I review aspects of the grant activities which stayed, or did not stay, after grant funding. These include:

- Ratings of PTEPA changes over time
- Written statements of sustainability compared to the sustainability plan
- Qualitative interviews
- Tabulation of results for LA programs and TIRs

**Things that were maintained**

Most areas of the PTEPA were maintained.

Below are shown the percentage of sites reporting that each area of the PTEPA was maintained or increased. Those maintained by a larger percentage of sites than average are highlighted. Most areas of the PTEPA are reported as maintained or increased by most sites. The two areas which tended to decrease were **resources** (1C) and **team members** (2A), which I will discuss later in the report.
Institutional climate, team attributes, collaboration, and recruitment further increased for many sites.

In the graph above, institutional climate (1A), team attributes (2B), and collaboration (2C), increased since PhysTEC for 30% or more of sites. These increases are notable since they are so critical for a positive culture and capacity for PTE. Additionally, recruitment activities (3B) increased for many sites; recruitment is important for a strong PTE program.

Sustainability plans were upheld, and most activities maintained.

For each site I reviewed the sustainability plans and/or institutional commitments for the 3-year sustainability period. These sustainability plans were upheld with two exceptions; upper administration did not maintain the TIR funding in one case, and in the other case the TIR funding was not able to be used due to lack of suitable candidates. In two cases the sustainability plan was upheld, but not maintained past the 3-year commitment due to budget constraints, eliminating both the TIR and LA programs. Overwhelmingly, however, key elements of the grants, including coursework, LA programs, recruitment events, and some form of TIR in most cases, were maintained. Out of N=16 sites, when asked “what fell away after the grant ended,” 9 out of 16 sites indicated that almost nothing fell away; 5 sites indicated that everything from the grant was maintained, and 4 named only minimal changes.

Most sites maintained internal funding and the number of PTE leaders. Only some maintained the FTE, and the number in the PTE team.

Below is a graph of institutional resources that maintained or grew across N=16 sites. Internal funding tended to maintain, as did the number of PTE leaders. Faculty and non-faculty FTE, and the number in the PTE team, was mixed. Other areas decreased and will be discussed later.
Things that fell away

Funding, resources, and human resources are most commonly reduced.

The evidence for this statement comes from the PTEPA, and quantitative data on resources.

**PTEPA data.** Below are shown the percentage of sites reporting that each area of the PTEPA decreased since PhysTEC. Resources (1C) and team members (2A) were not maintained for 30-50% of sites. As will be discussed later, this reduction typically indicated a decrease in funding, and/or the TIR position. Also sometimes falling away were rewards and recognition (1B), collaboration (2C) and mentoring (5), reported by 3 sites each.

**Quantitative resource data.** Below is a graph of institutional resources that decreased since PhysTEC for N=16 sites. External funding was the most common area of decrease, often due to loss of the PhysTEC grant itself. However, areas related to human resources such as the size of the PTE team, faculty, non-faculty and TIR FTE also decreased -- often due to loss or reduction of the TIR position.
Most commonly not maintained was the TIR position and/or duties.

9 out of 16 sites (56%) maintained the TIR position or duties and 7 eliminated the TIR position. In some of those cases the position was eliminated due to budget constraints, for others they tried to hire the TIR permanently, but they returned to teaching. Only one institution did not honor the commitment for 3 years of TIR funding post-PhysTEC, but this role was able to be filled in another way. Out of the 9 maintained TIRs, 4 had their duties reduced due to an FTE reduction and/or changing job duties. Of the 9 maintained TIRs, almost half (N=4) were part time, and most (N=3) had been part-time during the grant. The TIR sustainability is further explored below.

I used additional questions and to best understand the sustainability of the TIR. Results are below.

### Well-sustained sites (sustained/grew)

<table>
<thead>
<tr>
<th>Site</th>
<th>TIR now?</th>
<th>TIR full-time? (now/then)</th>
<th>TIR seen as critical?</th>
<th>TIR work with LAs?</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>No/no</td>
<td>Yes</td>
<td>Yes</td>
<td>Rotating part-time TIR, fills lecturer position to teach LA pedagogy course.</td>
</tr>
<tr>
<td>2</td>
<td>Yes</td>
<td>No/yes</td>
<td>Yes</td>
<td>No</td>
<td>Part-time TIR maintained through external grants to run NSF grant; future uncertain.</td>
</tr>
<tr>
<td>3</td>
<td>No</td>
<td>--/ Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Not maintained through institutional match period because couldn’t agree on candidate.</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>Yes/Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Energetic TIR maintained as lab coordinator, with a fraction of the original TIR duties.</td>
</tr>
<tr>
<td>5</td>
<td>No, but wanted to</td>
<td>--/ Yes</td>
<td>No; useful</td>
<td>No</td>
<td>Wanted to hire but TIR returned to classroom; then lost leverage to hire TIR permanently.</td>
</tr>
<tr>
<td>6</td>
<td>Yes</td>
<td>Yes/Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Maintained as instructor teaching intro physics, pedagogy courses, leading LA program</td>
</tr>
<tr>
<td>7</td>
<td>Yes; 2</td>
<td>No/No</td>
<td>No; useful</td>
<td>Yes</td>
<td>Maintained as lab coordinator part-time with some original duties, including training LAs.</td>
</tr>
<tr>
<td>8</td>
<td>No</td>
<td>No/no</td>
<td>No</td>
<td>No</td>
<td>Not maintained through institutional match period, not seen as great loss. Champion undertook original TIR duties and leads LAs.</td>
</tr>
<tr>
<td>9</td>
<td>Yes; several</td>
<td>No/No</td>
<td>Yes</td>
<td></td>
<td>Several part-time TIRs aintained as adjunct faculty teaching courses, running early field experiences, advising.</td>
</tr>
</tbody>
</table>
**Less well-sustained sites (mixed/unsustained)**

<table>
<thead>
<tr>
<th>Site</th>
<th>TIR now?</th>
<th>TIR full-time? (now/then)</th>
<th>TIR seen as critical?</th>
<th>TIR work with LAs?</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No</td>
<td>--/ Yes</td>
<td>Yes</td>
<td>No</td>
<td>UTeach Master Teacher was plan for sustainability, but no Master Teacher in Physics</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
<td>--/ Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Maintained through institutional match period as instructor line, then dropped.</td>
</tr>
<tr>
<td>3</td>
<td>No</td>
<td>--/ Yes</td>
<td>No</td>
<td>No</td>
<td>UTeach Master Teacher was plan for sustainability, but no Master Teacher in Physics</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>Yes/Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Maintained as lecturer to teach methods course and direct LA program</td>
</tr>
<tr>
<td>5</td>
<td>No</td>
<td>--/ No</td>
<td>No; useful</td>
<td>No</td>
<td>Was maintained for a few years post-grant to recruit, supervise, mentor; discontinued when student numbers dropped.</td>
</tr>
<tr>
<td>6</td>
<td>Yes</td>
<td>Yes/Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Maintained as lecturer to teach pedagogy course and run LA program</td>
</tr>
<tr>
<td>7</td>
<td>Yes</td>
<td>Yes/ Yes</td>
<td>Yes</td>
<td>No</td>
<td>Same person maintained as UTeach Master Teacher, established connection to physics. Continues to recruit and mentor.</td>
</tr>
</tbody>
</table>

TIRs are most commonly maintained through a position which fits within the departmental structure: lecturer, instructor, or lab coordinator.

Examining the table above, TIRs are often maintained through a position which is already typically part of the physics department, and a portion of that position or the courses taught are part of the PTE program.

**TIR duties often include coordinating or supporting the LA program, which may help sustain their position.**

Examining the table above, as well as the qualitative study results, in many cases the TIR is maintained in order to teach the LA pedagogy course and/or direct the LA program. A total of 8 out of 16 TIRs worked with the LA program, and 6 out of the 9 TIRs that were maintained
worked with LAs. In contrast, only 2 out of the 7 discontinued TIRs worked with LA programs. The strong support for the LA program among faculty and administrators is often a key part of maintaining the TIR position, as the TIR provides the human resources and pedagogical expertise needed to support the LA program. It is worth noting that an LA program coordinator does not need to be a TIR -- for a site having difficulty identifying a TIR, they might consider who else could be useful in running an LA program.

**Sustainability of the TIR is only a little more likely at well-sustained sites.**

In the table above, 6 out of 9 well-sustained sites (67%) maintained their TIR, compared to 3 out of 7 less well-sustained sites (43%). These results are not particularly striking and suggest that the TIR, while valuable, is not necessarily what makes or breaks a site’s sustained success.

**Well-sustained sites tended to have part-time TIRs.**

Well-sustained sites were more likely to have part-time TIRs (N=4 out of 6 sites that maintained their TIR) than were less well-sustained sites (N=0 out of 3 sites that maintained their TIR). It is unclear how this could be related to site sustainability, but it may indicate more flexible thinking on the part of these successful site leaders. It also suggests that part-time TIRs can be highly impactful.

### Learning Assistant (LA) programs

*Due to the centrality of LA programs across the sites, I also compiled results related to the LA program sustainability and roles at the sites, and how it was maintained when it was maintained. Note the role of the TIR in continuing the LA program at many of these sites.*

#### Well-sustained sites (sustained/grew)

<table>
<thead>
<tr>
<th>Site</th>
<th>LA program created during PhysTEC?</th>
<th>LA program maintained?</th>
<th>LA program relationship to PTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No, existed</td>
<td>Yes, <strong>TIR teaches pedagogy course</strong></td>
<td>Indirect; supports strong undergraduate physics teaching.</td>
</tr>
<tr>
<td>2</td>
<td>No; expanded</td>
<td>Yes</td>
<td>Indirect; supports strong undergraduate physics teaching.</td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>Yes; stipend paid through <strong>A&amp;S soft money requests. Not expensive.</strong></td>
<td>Useful; Creates community and lets them offer pedagogy course</td>
</tr>
<tr>
<td>4</td>
<td>No; <strong>Institutional funds</strong></td>
<td>Institutionalized</td>
<td>Critical; future teachers work as</td>
</tr>
<tr>
<td>Site</td>
<td>LA program created during PhysTEC?</td>
<td>LA program maintained?</td>
<td>LA program relationship to PTE</td>
</tr>
<tr>
<td>------</td>
<td>-----------------------------------</td>
<td>------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>No; existed</td>
<td>Yes; <strong>internal funding</strong>. Support grew.</td>
<td>Useful; internship experience</td>
</tr>
<tr>
<td>2</td>
<td>Yes</td>
<td>No; TIR also discontinued and they recruited LAs and taught pedagogy.</td>
<td>Critical; Internship experience in HS classrooms and community building.</td>
</tr>
<tr>
<td>3</td>
<td>No; does not exist</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>Yes; supported through <strong>course fees</strong> and coordinated by <strong>TIR</strong>. Chair supporter after attending LAA workshop.</td>
<td>Important; recruits students to teaching and gives community</td>
</tr>
<tr>
<td>5</td>
<td>Yes</td>
<td>No; was maintained by <strong>internal funding</strong> for 7 years but then discontinued during COVID.</td>
<td>Important; supported early teaching experience and sustained interest, recruited.</td>
</tr>
<tr>
<td>6</td>
<td>Yes</td>
<td>Yes; maintained through <strong>external monetary gift</strong>. <strong>TIR</strong> teaches pedagogy course and runs LA program.</td>
<td>Important; early teaching experience, sustains interest, recruits.</td>
</tr>
<tr>
<td>7</td>
<td>No; existed</td>
<td>Yes; <strong>champions</strong> teach pedagogy as part of course load. PhysTEC helped maintain it.</td>
<td>Unclear</td>
</tr>
</tbody>
</table>

**Less well-sustained sites (mixed/unsustained)**

<table>
<thead>
<tr>
<th>created just prior</th>
<th>during PhysTEC. Expanding in STEM.</th>
<th>LAs, LA connects to the TIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Yes</td>
<td>Yes; funding for <strong>supplemental instructors</strong> repurposed for LA stipends</td>
</tr>
<tr>
<td>6</td>
<td>Yes</td>
<td>Yes; LAs given <strong>course credit</strong>, <strong>TIR</strong> leads it and teaches pedagogy course.</td>
</tr>
<tr>
<td>7</td>
<td>Yes</td>
<td>Yes; LA stipend through <strong>federal work study</strong>, pedagogy taught as <strong>overload. TIR coordinates</strong>.</td>
</tr>
<tr>
<td>8</td>
<td>No; existed</td>
<td>Yes; paid by <strong>Provost</strong>. Courses regular part of <strong>champion load</strong>.</td>
</tr>
<tr>
<td>9</td>
<td>No; existed</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Half of sites created LA programs as part of PhysTEC: all but two were maintained.

Examining the table above, 8 sites created LA programs as part of PhysTEC (though most of the other 8 enhanced or expanded their existing program). Only 2 (25%) did not maintain that LA program. While both of these programs lamented the loss of the LA program, which was seen as important, only one felt it was really critical. This finding suggests that LA programs are particularly durable outcomes of PhysTEC grants, as suggested elsewhere through this report.

LA programs are continued through a variety of creative funding mechanisms, and often a TIR position, enabled by broad buy-in.

Examining the table above, a wide range of funding strategies are used, from soft money requests, federal work study, provost funding, course fees, and an external gift. Pedagogy courses are taught by TIRs or champions, either as part of their regular teaching load or sometimes as overload. In interviews it was apparent that these creative measures were only possible because faculty and/or administrators were strongly supportive of the LA program -- they had seen how important it was for the undergraduate program.

The LA program often is only indirectly related to PTE.

Only in about 5 cases was the LA program explicitly and clearly related to PTE, in that future teachers served as LAs and the LA program served as a supportive community and professional home for those interested in teaching. In 9 cases it was indirectly or weakly linked to PTE; its primary purpose was to support excellence in undergraduate education. Through creating a thriving LA program, however, site leaders were able to hire a TIR, provide a pedagogy course, or other elements important for supporting future physics teachers.
Summary

The majority of activities were maintained for the majority of sites. Overall it is remarkable how many activities and structures were maintained across sites. Sustainability plans from the grant were upheld and in all but two cases the institutional match commitment was upheld. For most areas of the PTEPA, activity maintained or increased since PhysTEC for at least 80% of sites. Institutional climate, team attributes, and collaboration were elements of culture which often increased since PhysTEC. In the PTE program, recruitment activities often increased since the end of the grant. Many institutional resources were maintained on average, including internal funding, the number of PTE leaders, faculty and non-faculty FTE were maintained for at least 10 out of 16 sites.

External funding often was not maintained. The most common area that was not maintained was external funding. While internal funding maintained for 13 out of 16 sites, external funding was only maintained for 6. On the PTEPA, over 30% of sites reported decreases in “resources,” which includes funding, personnel, and space.

Human resources are often reduced since PhysTEC. Several measures of human resources were often reduced -- on the PTEPA, about 50% of sites report a reduction in the number of people on the PTE team (as evidenced both by the PTEPA data and quantitative resource data). Faculty FTE was only maintained for 10 sites, and TIR FTE was only maintained for 6 sites. Thus, while the number of PTE leaders is generally maintained, the amount of time they have to spend on PTE is often reduced, and the number in their support team is also reduced. This is often due to the loss of the TIR.

The TIR position and/or duties are often eliminated or reduced -- but this is not always a problem. A total of 9 sites maintained the TIR, and 7 eliminated the TIR position. Only 5 out of the 9 maintaining the TIR maintained them as the original job described; the other 4 reduced their FTE or had other primary job duties. Additionally, 4 were maintained as part-time TIRs, most of whom had been part-time during PhysTEC. However, in some cases losing the TIR was not a drastic loss, and sites which sustained their PhysTEC activities were only slightly more likely to have sustained their TIR as well. Thus, a TIR may be valuable, but not necessary. Additionally, well-sustained sites were more likely to have part-time TIRs, showing that even a part-time position can be very valuable.

TIRs are often maintained through a regular departmental position. Most maintained TIRs were in regular positions such as lecturer, instructor, or lab coordinator, with a portion of their duties dedicated to TIR-like jobs.

TIR sustainability may be helped by including LA programs within their duties. In most cases the TIR’s current job included directing or coordinating the LA program, and/or teaching the pedagogy course. During PhysTEC, half of TIRs worked with the LA program, usually recruiting LAs, mentoring them, and teaching the pedagogy course. Such duties may help maintain the TIR position for some sites -- 66% of maintained TIRs worked with the LA program, in contrast to only 28% of discontinued TIRs.
LA programs were almost always maintained; broad support for the LA program helped enable many elements of PTE to maintain. Only 2 sites studied did not maintain their LA program; all other 13 sites with an LA program maintained that program. Not all of these programs were created by PhysTEC (8 new programs were created), but PhysTEC helped to institutionalize or maintain most of the existing programs. Qualitatively, I heard that institutional support for the LA program created an internal drive to keep the LA program going, often leading to finding a way to hire the TIR to run it and/or to teach the pedagogy course. A wide range of funding strategies were used to support the LA program, from soft money requests, federal work study, provost funding, course fees, and an external gift. While the LA program was often only indirectly related to PTE, having such a program created many benefits supporting PTE, such as hiring a TIR, teaching a pedagogy course, and providing a community for future teachers.
Findings (5): What are the factors related to sustainability of a site?

“What factors contributed to success in sustainability? What is the outlook for sustaining PhysTEC activities longer term?” To address these evaluation questions I investigate quantitative data, interview data, and PTEPA data to identify possible key factors. The sections of this part of the report were generated empirically (i.e., organized by the themes in the data itself).

Overall

Well-sustained sites have higher overall PTEPA ratings.

The percent of items rated at least Benchmark level, taken across all items on the PTEPA and averaged across sites in a category, is well-related to the sustainability rating (see below), with more “grew” sites achieving at least Benchmark level on more items on average (86%) than other types of sites (71%, 75%, 47%, respectively). “Mixed” and “sustained” sites are similar on this measure, demonstrating the strength of “mixed” sites PTE programs (despite less consistent graduation numbers). Exemplary ratings account for most of the differences.

These findings support the validity of the sustainability global ratings as well as suggesting that PTE program strength is supported by broad strength on the PTEPA Rubric. Note that PTEPA ratings were only loosely considered when making global sustainability categorizations.

When investigating the PTEPA items grouped into standards, there is not a clear trend by sustainability level. The one exception is that Unsustained sites have a clearly lower percentage of items rated at least Benchmark, compared to other types of sites, across several standards (see Appendix). However, I do not believe the PTEPA standards hold together well as
constructs, and so I instead investigate the component-level results in the analyses which follow.

Well-sustained sites tend to maintain strength in the PTEPA.

Above are shown the percentage of sites which sustained or improved areas of the PTEPA, separated by those which were “unsustained”/“mixed” versus “sustained”/“grew”. Less sustained sites were less likely to indicate that a particular area was maintained (or improved). This is somewhat by design, as sustainability of PTEPA ratings were taken into consideration when making global sustainability ratings.

**Unsustained sites**

*Looking first at the two unsustained sites, what characterized these sites?*

Lack of champions and resources were hallmarks of unsustained sites.

“Unsustained” **sites did not have a champion.** On the pre-interview questionnaire, site leaders were asked whether their PTE program currently had a leader or champion. Both of those who answered “no” were the “unsustained” sites. Additionally, those who had been originally involved in PTE did not have positional power (e.g., non-tenure track instructors). “Unsustained” sites often mentioned the lack of a champion as something that kept the site from maintaining activities.
“Unsustained” sites reported very few resources; low funding for PTE, few people in the PTE team, and little or no FTE spent on PTE. They also reported reduction in almost all areas of institutional resources since the end of PhysTEC.

Low capacity for PTE, and low PTEPA ratings were also characteristic.

“Unsustained” sites had low PTEPA ratings. PTEPA ratings for “unsustained” sites were lower than other levels of sustainability (i.e. fewer items rated at least Benchmark) in all areas except Knowledge and Skills for Teaching Physics (Standard 4).

“Unsustained” sites were also all rated as having low capacity for PTE, based on the leadership, institutional climate, and resources: Two out of the four sites rated as “low capacity” were also rated as “Unsustained.”

“Unsustained” sites are at smaller departments. As will be shown below, “unsustained” sites tended to be at smaller physics departments (average size during sustainability period = 20 majors), with small growth.

_External factors_

Local teacher salaries were not related to sustainability.

Mid-career salary shows no relationship to the level of sustainability. This finding holds when salary is averaged across all institutions in a category, as well as in inspection of salary levels at individual sites (i.e., some of the lower salaries occur at institutions with higher sustainability), and using an index$^{10}$ that takes into account the cost of living.

PhysTEC RFP was not related to sustainability.

“Unsustained”, “mixed,” and “sustained” sites responded to a variety of PhysTEC RFPs, suggesting that no RFP was particularly effective. The one exception is that many sites in the “grew” category responded to the 5th and final RFP (funded by Campaign funds). However, this also means that the “grew” category includes many tentative ratings, as these sites are currently in their 3rd year post-funding. The RFP was in its’ near final form by the 3rd RFP (2011), with a clearly defined sustainability period, and I consider it to be in a mature form as of the 4th RFP (2012).

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$^{10}$ (Average of First year salary + mid-career salary)/ median home price. All data from GFO, based on the local region around the institution.
Teacher graduates and certification

The number of majors, and the fraction of majors becoming teachers, increases for well-sustained sites.

One hypothesis I wanted to test was whether the larger number of future teachers at successful sites could be related to the size of the department. (Department size was previously found to not be a significant predictor of teacher graduation rates in the 2019 graduation rate study.) The department size, and growth in department size, (as judging by the number of majors) do increase for more sustained sites.\footnote{11} But so does the number of teachers as a percentage of the department. Thus, it seems that more successful sites may be drawing from a larger pool of majors and have a stronger undergraduate department. But more successful sites are also able to draw a slightly greater percentage of these majors into teaching. Once again, note that not all future teachers come through the undergraduate major.

Well-sustained sites typically make strong use of post-bac licensing.

Sites had a mixture of certification pathways (e.g., undergraduate, post-baccalaureate) which certified students to teach physics, physical science, general science, etc. These certification pathways were well-mixed across sustainability levels and most (but not all) sites included multiple pathways to certification. However, when examining the most commonly used certification pathway at sites, I find that only one of the “sustained” or “grew” sites had the undergraduate pathway as the main pathway used by students for achieving certification; most of these sites included a post-baccalaureate pathway as another common way (or the only way) of achieving certification.

\footnote{11} The growth as a percent of the department does not show the same upward trend across sustainability categories, however; it varies between 30-50\% of the department with no clear trend.
Less-sustained sites rely primarily on undergraduate pathways.

I analyzed the certification pathways in the 2021 Graduate Pathway Analysis, and further broke down the percentages according to levels of sustainability. A greater percentage of graduates of “Unsustained” and “mixed” sites, on average, achieved certification through an undergraduate-only pathway (65% and 63%, respectively) compared to “sustained” (22%) and “grew” (6%). At “sustained” sites the majority of graduates (60%) are certified through a postbac-only route; at “grew” sites most graduates (59%) are certified through an undergraduate + postbac pathway.

Again, these percentages are taken as an average across sites.

![Comp II sites by sustainability level](chart)

Institutional climate and policy

“Grew” sites are extremely strong in components of the PTEPA related to climate and collaboration, plus program evaluation.

Component-level PTEPA results were generally similar across sustainability levels. However, in several components, the “grew” sites had many more items rated at least Benchmark than did other categories of sites, meeting or exceeding Thriving programs:

- **Institutional climate and support** (1A): 96% of items rated at least Benchmark
- **Program collaboration** (2C): 91% of items “”
- **Program evaluation and improvement** (6B): 100% of items “”

Additionally, more of the “grew” sites report having further improved component 1A since PhysTEC (N=3 out of 4 sites), compared to other sustainability categories (N=2 out of 12 sites). This finding suggests that institutional climate may be key to exemplary performance.
Institutional commitment is surprisingly weak at “sustained” sites.

Components measuring institutional commitment (standard 1) have fewer items rated at least Benchmark for “sustained” sites compared to “mixed” or “grew” sites, including items measuring climate, rewards, and resources. (See image at right, showing PTEPA ratings for “sustained” sites). In fact, these components have similar average ratings between “sustained” and “unsustained” sites. This finding mirrors my overall impression of “sustained” sites; that they had maintained their PTE programs because of the efforts of champions, and entrenching PTE program practices within the department, rather than due to a broader commitment on the part of the institution or the department. Thus, institutional commitment may be what differentiates sites which sustain their activities from those which continue to grow and improve -- despite the efforts and commitment of champions at those “sustained” sites.

PhysTEC supported more structural outcomes at well-sustained sites.

This result pertains to the written outcomes analyzed in section 3 and was the only clear distinction between levels of sustainability for the outcome data. Well-sustained (sustained and grew) named more outcomes in structure/policy (4 on average) compared to less well-sustained (unsustained and mixed) sites (3 on average), and a larger fraction of those outcomes were named as key at well-sustained sites (65% compared to 13%). Structural outcomes often included certification pathways and tracks, advising policies, and putting a course “on the books.” This finding suggests that a key to sustainable outcomes may be to have cultural outcomes “baked-in” to policy and procedure.

Well-sustained sites can point to many things keeping the PTE program going.

When asked what keeps things going, those which were “sustained” or “grew” were typically able to name a wide variety of elements keeping things going, from culture to structure to champions. “Mixed” and “unsustained” sites had fewer things they could name, showing a potential lack of resiliency.
Leadership, capacity, and resources

Leader turnover and champion positional power are not clearly related to sustainability.

This doesn’t mean these factors are unimportant, but that they are not necessary.

- Half of sites experienced leader turnover (8 out of 16). These 8 sites were spread across the levels of sustainability.
- Champions with positional power were spread across all levels of sustainability, except for completely unsustained sites in which there was a lack of champions and a lack of positional power. Among the 9 Sustained or Grew sites, 5 had champions without real positional power. That said, champions with positional power were able to “grease the skids” at their institutions; it was a helpful, but not necessary, condition.

Well-sustained sites have access to greater resources and human capital.

Resources are a chicken-and-egg issue (more resources lead to success, and success leads to greater resources), but sustained sites clearly have access to greater resources: Sites with greater sustainability generally have higher internal and external funding, greater numbers of PTE leaders and team members, and greater FTE spent by faculty. At Grew sites, for example, the median number of PTE leaders is 3, and the median number of PTE non-leaders is 4. I also note that, qualitatively, the champions at well-sustained sites typically have strong leadership qualities.

Well-sustained sites tended to maintain or grow the human capital available for PTE since the end of the grant.

How have resources changed since PhysTEC ended? Since PhysTEC ended, the more successful sites maintained or increased the leadership and human capital available for PTE:

- The number of PTE leaders is typically maintained or increased at “mixed,” “sustained,” and “grew” sites (and decreased at “unsustained”).
- The number of non-leader PTE team members typically decreased at “unsustained” and “mixed”, ad maintained or grew at “sustained” or “grew” sites.
The faculty FTE available for PTE typically decreased at “unsustained” and “mixed” and maintained at “sustained” or “grew” sites. The non-faculty FTE available for PTE typically maintained at “mixed” and “sustained” sites and grew at “grew” sites.

Having a TIR is not clearly related to sustainability

While TIRs were clearly influential, TIRs are not consistently related to sustainability levels either in terms of whether they were maintained, or if they were seen as critical. There are successful sites which rejected the TIR model, and less successful sites which maintained strong TIRs in their roles. Qualitatively, however, successful sites had a strong champion and/or someone who could play some sort of TIR-like role, even if the TIR itself wasn’t maintained. Both Unsustained sites lamented the loss of a TIR.

Well-maintained sites are more likely to maintain the “team” on the PTEPA.

The early graph on the percent of PTEPA items that are maintained or increased showed that program team members rating (Component 2A) decreased at only 44% of the “sustained” or “grew” sites compared to 67% of “unsustained” or “mixed” sites. Program team attributes (Component 2B) maintained or increased since PhysTEC at 67% of sites which Sustained or Grew, but at only 33% of “unsustained” or “mixed” sites. The other areas will be discussed elsewhere in the report. This shows an overall reduction of human resources.

Well-sustained sites are more likely to be part of an engaged team.

To further elucidate the nature of leadership at sustained vs. unsustained sites, I list the champions and their qualities at different levels of sustainability, below. While the positional power of champions varies across the board, “sustained” and “grew” sites seem to more often have a team focused on PTE. The one exception (indicated as “sort of”) is a site which I expect to see a decrease in numbers over time due to recent loss of champions.

<table>
<thead>
<tr>
<th>Site sustain level</th>
<th>PTE champion?</th>
<th>Leadership position?</th>
<th>Team?</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsustain</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Unsustain</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td>Yes</td>
<td>Yes; chair</td>
<td>No</td>
<td>PER group, but many education responsibilities, so champion(s) not focused on PTE</td>
</tr>
<tr>
<td>Mixed</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>TIR and faculty member, deeply engaged</td>
</tr>
<tr>
<td>Mixed</td>
<td>Yes</td>
<td>Yes; assoc. chair</td>
<td>No</td>
<td>Lone PTE champion, but has good partners in physics and education</td>
</tr>
<tr>
<td>------------</td>
<td>-----</td>
<td>-------------------</td>
<td>---------</td>
<td>------------------------------------------------------------------</td>
</tr>
<tr>
<td>Mixed</td>
<td>Yes</td>
<td>Yes; program director</td>
<td>No</td>
<td>Champion holds a leadership position but not in the department. Lacks strong physics champion.</td>
</tr>
<tr>
<td>Mixed</td>
<td>Yes</td>
<td>Yes; program director</td>
<td>Yes</td>
<td>Strong, change-savvy leaders as part of strong team</td>
</tr>
<tr>
<td>Sustain</td>
<td>Yes</td>
<td>Yes; chair</td>
<td>Yes</td>
<td>Strong, senior cross-disciplinary team.</td>
</tr>
<tr>
<td>Sustain</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Strong, cross-disciplinary team of lecturers.</td>
</tr>
<tr>
<td>Sustain</td>
<td>Sort of</td>
<td>Yes</td>
<td>No</td>
<td>Champion is chair but not truly a champion.</td>
</tr>
<tr>
<td>Sustain</td>
<td>Yes</td>
<td>Yes; chair</td>
<td>Yes</td>
<td>Team of TIR and chair.</td>
</tr>
<tr>
<td>Sustain</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Strong, cross-disciplinary team of faculty.</td>
</tr>
<tr>
<td>Grew</td>
<td>Yes</td>
<td>Yes; assoc. chair</td>
<td>Yes</td>
<td>Team of TIR and faculty member.</td>
</tr>
<tr>
<td>Grew</td>
<td>Yes</td>
<td>Yes; dean</td>
<td>Yes</td>
<td>Champion is PER faculty.</td>
</tr>
<tr>
<td>Grew</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Champions are PER faculty.</td>
</tr>
<tr>
<td>Grew</td>
<td>Yes</td>
<td>Yes; program director</td>
<td>Yes</td>
<td>Team mostly in physics.</td>
</tr>
</tbody>
</table>

**Capacity is high at sites which Grew -- but is strong at other sites as well.**

Each site was rated on their capacity for PTE (low/medium/high), as judged by institutional capacity and individual leadership (see [Valued Outcomes](#)). All sites which were rated as “grew” were also rated as “high capacity.” All “unsustained” sites were rated as “low capacity.” Otherwise, ratings are mixed across levels. Note, however, that both of the “low capacity” sites that were in the “mixed” and “sustained” levels could be said to be riding on past successes; I expect these sites to become less sustained over time if their capacity does not increase. This finding suggests that capacity for PTE is necessary but not sufficient for achieving good results; but “medium capacity” may be a threshold for good results, and “high capacity” is necessary but insufficient for exemplary results.
Improvement in the PTE program is not related to sustainability.

Nearly all sites experienced positive growth in PTEPA ratings during funding (i.e., a greater percentage of items rated at least Benchmark). This growth was not clearly related to whether activities and outcomes were sustained.

All sites, including “unsustained” sites, are strong in Knowledge and Skills.

When investigating standard-level and component-level ratings, Unsustained sites are consistently lower than other types. A notable exception is in Knowledge and Skills for Teaching Physics (Standard 4), which includes physics content knowledge, pedagogy courses, and practical K-12 school experiences. Unsustained sites, and indeed all other sustainability levels, rated on par with Thriving programs. This finding suggests that students at former PhysTEC sites receive a quality preparation in physics teacher education.

“Mixed” sites have overall strong PTE programs.

“Mixed” sites have PTEPA results which rival or exceed those of stronger programs (e.g., Thriving, “sustained” or “grew” programs). Notably, PTEPA components measuring institutional commitment and leadership are overall strong at Mixed sites. Exceptions are program collaboration (component 2C), mentoring and community support (component 5B), and program outcomes (Component 6A), which are lower among “mixed” sites than “sustained” or “grew.”

All well-sustained sites maintained PTE program structures and outcomes.

None of the sites rated as Sustained or Grew reported any decrease in PTEPA ratings since PhysTEC ended in standards 3-6 (assessing recruitment, coursework and preparation, mentoring, community, and assessment).

“Recruitment” is an area of strength for “grew” sites, and weakness for poorly sustained sites.

Component-level PTEPA results were generally similar across sustainability levels. However, in several components, the Grew sites had many more items rated at least Benchmark than did other categories of sites, meeting, or exceeding, Thriving programs:

- Recruitment opportunities (3A): 100% of items rated at least Benchmark
- Recruitment activities (3B): 95% of items “”
- Early teaching experiences (3C): 90% of items “”
When looking at changes over time, these areas were maintained for both “grew” and “sustained” sites. By comparison, 1-3 of the “mixed” and “unsustained” sites experienced decreases in any of these areas. This was especially true for recruitment activities (component 3B; 65% of less well-sustained sites maintaining activities, versus 100% of well-sustained sites) and mentoring (standard 5; 50% maintaining versus 100% of well-sustained).

**UTeach is not necessarily a good sustainability plan.**

Three of the institutions were UTeach replication sites. All of these were in the “unsustained” or “mixed” groups, and one of the two Mixed UTeach sites is close to being Unsustained. I learned a lot about the UTeach model and how it does and doesn’t dovetail well with the PhysTEC grant, but with only N=3 it is difficult to make strong statements. Some findings include:

- **Physics department ownership.** UTeach collaboration with the physics department varies widely from institution to institution, compared to a PhysTEC program which is run out of physics. When UTeach comes along, the ownership by the physics department has the potential to wane, resulting in less control and engagement over PTE.
- **Physics department TIR connection.** PhysTEC TIRs have a stronger connection to the physics department than a physics UTeach Master Teacher. A PhysTEC TIR may maintain this connection as they transition to a Master Teacher role if it was already well-established. However, if there is no Master Teacher with a physics background, the PTE program may lose a critical element.
- **LA program.** UTeach Master Teachers do not typically play a role in an LA program, which was shown earlier to be a key part of supporting a healthy ecosystem for PTE.
- **Recruitment.** UTeach Master Teachers do not always play a strong recruitment role; often cited as a critical role for PhysTEC TIRs.

**What keeps things going**

*While discussing key outcomes at individual sites, leaders were asked “what keeps this going?” Below are the findings from this analysis.*

**Champions, established positions, and money keep things going at sites.**

The most commonly mentioned thing that keeps things going are the efforts of **champions**. This was mentioned by 12 out of 16 sites, with Unsustained sites indicating that the lack of a champion is what kept things from being maintained. Another common theme was **positions** -- positions could include institutionalizing a TIR position, creating a position, having a faculty champion serve in a key role such as pedagogy course instructor, or having a PER group. Having a TIR often helped to keep an LA program going, and vice versa. **Money** was also mentioned, which took different forms at different sites, such as Noyce grants, a fixed budget for the PTE program, or funding for an LA program from the provost, course fees, or a private donor. Both positions and money were mentioned by 9 out of 16 sites. These findings held
across all levels of sustainability, with unsustained sites typically being hampered by one or more of these 3 elements.

Structural elements also kept things going, including institutionalized programs, LA programs, and certification pathways.

The next most common items were structural aspects. These included structures or institutionalization, such as UTeach structure, creation of formalized structures to house the PTE program or institutionalization of programs. LA programs were a structure mentioned often, as were certification pathways. Six (out of 16) mentioned each of these areas (structure, certification, LA programs). Notably, a few people mentioned that the LA program itself maintains the PTE program because it drives the continuation of the pedagogy course or the maintenance of the TIR position.

Culture change, including inertia and routine, is another driver of continuity.

Culture change was often mentioned as keeping things going (N=6), including a greater support for teaching as a career in physics. Several people (N=4) also mentioned that inertia or routine keeps things like course reforms, LA program requests, and graduate assistant requests. A key aspect of PhysTEC was establishing these routines beyond the timeframe of institutional memory.

Other things that were mentioned as maintaining PTE were that the program helped fulfill a local need (e.g. to draw more engineers; N=4, there was a supportive administrator (N=4), the program had established its value and viability and thus was self-sustaining (N=2), or PTE fit within the institutional mission (N=2).
Summary

Unsustained sites lacked champions, resources, and capacity for PTE. Recalling that only 2 sites did not sustain their activities, what characterized these two outliers? Notably, they did not have a champion, and there were also very few resources allocated to PTE (e.g., funding, people, and FTE). These unsustainable sites also reported reduction in all these areas since the end of PhysTEC. Unsustained sites also had very low PTEPA ratings, were rated as “low” capacity for PTE based on leadership, institutional climate and resources, and tend to be at smaller departments.

While external factors were not clearly related to sustainability, sustainability increased with the number of majors and with postbac pathways. Local teacher salaries were not related to levels of sustainability, nor was the year of funding (i.e., year of PhysTEC RFP). However, the department size did increase for more well-sustained sites compared to “unsustained” or “mixed” (42 majors graduated/year for “grew”, versus 25, 22, and 20 for “sustained”, “mixed” and “unsustained” respectively). “Sustained” and “grew” sites also experienced greater growth in their major since funding ended (+15-16 majors/year on average compared to +8 majors/year). The percentage of majors choosing to become teachers also increased with the sustainability level, at 8%, 9%, 10% and 11% for each increasing level of sustainability, respectively. Well-sustained sites (those which “sustained” or “grew”) tended to include a post-baccalaureate pathway as one of the main ways in which students achieved certification, and more students were graduated through these pathways than through undergraduate-only routes.

Site capacity and culture is necessary but not sufficient for sustained outcomes. Each site was rated on their capacity and culture for PTE based on their leadership strength, institutional culture, and resources. All “grew” sites were rated as “high capacity,” most “sustained” and “mixed” sites were rated medium or high capacity and all “unsustained” sites were rated low capacity. Thus, “medium capacity” may be a threshold for good results, but “high capacity” is necessary but insufficient for exemplary results.

Exemplary sites have overall strong programs, as judged by the PTEPA. “Mixed” sites have overall intact PTE programs but experience other difficulties. Sites which “grew” have higher overall PTEPA ratings (86% rated at least Benchmark) than “sustained,” “mixed,” or “unsustained” sites. However, ratings between “sustained” and “mixed” were similar in this metric. “Mixed” sites have PTEPA results which rival or exceed those of stronger programs (e.g. Thriving, Sustained, or Grew programs). This suggests that the PTE programs at “mixed” sites are structurally strong, but they are not achieving high graduation rates or there is some other noted dysfunction from the evaluation keeping them from reaching “sustained” status. This also suggests that PTEPA ratings can only differentiate at the edges of the scale (exemplary versus non-functional programs); the PTEPA alone cannot differentiate solid and weaker programs, and neither can graduation rates or site leaders’ self-ratings. However, when taken as a whole, these measures can help distinguish institutions.

Institutional climate and policy seem to differentiate sustained sites from truly thriving ones. Several points of evidence support this statement. First, the sites which “grew” were...
very strong in “institutional climate and support” (PTEPA 1A) and “program collaboration” (PTEPA 2C) with over 90% of items rated at least Benchmark. “Program evaluation” was also highly rated at these sites. In addition, more of the “grew” sites reported further improvement in PTEPA 1A since PhysTEC ended. In comparison, at “sustained” sites, the components in the PTEPA standard “Institutional commitment” were rated at similar levels as “sustained” and “unsustained” sites. Thus, “sustained” sites may have maintained their programs and outcomes as a result of the efforts of champions, rather than due to broader commitment to the cause. Truly exemplary sites may be differentiated by enhanced institutional commitment.

**Sustainability may be enhanced by structural outcomes, and overall resiliency.** Among the written outcomes, sites which “sustained” or “grew” named more outcomes in structure and policy compared to less well-sustained sites and named more of these outcomes as key. These structural outcomes were often the same things that kept things going, such as certification pathways, advising policies, and putting a course on the books. Additionally, those at “sustained” or “grew” sites were typically able to name a wide array of things that keep the PTE program going (from culture, to structure, to champions), showing more overall resiliency than “mixed” or “unsustained” sites.

**Well-sustained sites maintain the PTE program structures and practices; recruitment and mentoring often fall away at less maintained sites.** *None* of the sites rated as “sustained” or “grew” reported *any* decrease in PTEPA ratings since PhysTEC ended in standards 3-6 (assessing recruitment, coursework and preparation, mentoring, community, and assessment). Sites which “grew” had particularly strong ratings in “recruitment opportunities,” “recruitment activities,” and “early teaching experiences.” Less well-sustained sites (“mixed” and “unsustained”) reported more across-the-board decreases on the PTEPA since PhysTEC, but especially in recruitment activities (component 3B) and mentoring (standard 5).

**Well-sustained sites maintain greater human and financial resources, including a number of leaders and a PTE team.** Sites with greater levels of sustainability had generally higher levels of internal and external funding, greater numbers of PTE leaders and team members, and greater FTE spent by faculty. Many of these metrics maintained or grew since PhysTEC for “sustained” and “grew” sites, and often decreased at the other sites. On the PTEPA, the program team members and team attributes components (2A and 2B) decreased at 67% of “unsustained” or “mixed” sites compared to 44% of well-sustained sites. “Sustained” and “grew” sites are more often part of a team focused on PTE. Leader turnover, champion positional power, or having a TIR, was not clearly related to sustainability levels.

**Students at former PhysTEC sites receive quality preparation regardless of site sustainability.** All sites including “unsustained” sites) were found to have ratings in the PTEPA “Knowledge and Skills” standard which rivalled those of thriving programs -- this standard includes physics content and pedagogy, and field experiences. Additionally, nearly all sites experienced growth in PTEPA ratings during PhysTEC funding, regardless of sustainability level, showing that Comprehensive grant funding improved PTE programs.

**UTeach is not necessarily a good sustainability plan.** With only 3 UTeach replication sites, it is difficult to make strong statements. However, all UTeach replication sites were in the “unsustained” or “mixed” groups, and I observed that physics department ownership, and TIR
connection, was often reduced in UTeach sites. UTeach Master Teachers did not offer a good replacement for a PhysTEC TIR, typically, because they have less connection to the physics department and engage in less recruitment. A UTeach Master Teacher also would not typically be engaged with an LA program which, as reported earlier, can be an important part of a healthy PTE ecosystem.

**Drivers of sustainability include people, money, structure, culture, and routine.** When asked what keeps a particular outcome going, there were some common themes, listed here in order of decreasing frequency. One was the effort of champions, and often the institutionalization of a position for that champion (such as a TIR or including PTE courses within a faculty course load). Money, including grant funding, were named as useful. Structures were commonly named, such as formalized PTE program structures, LA programs, or certification pathways. Lastly, culture change kept things going, such as support for teaching careers, or inertia and routine. Several people mentioned that the length of the PhysTEC grant, and the 3-year institutional match period, was critical for establishing the culture and routine necessary to argue successfully for the structures, people, and money needed to maintain the program.
Findings (6): What is PhysTEC’s contribution, and how can it be improved?

**Major contributions of PhysTEC**

*When discussing key outcomes at sites, site leaders were asked “What is the contribution of PhysTEC to this outcome?” Below are the results of this analysis across N=15 sites.*

PhysTEC helped by providing resources to establish a program.

PhysTEC funding provided necessary resources to hire TIRs (mentioned by N=10), start or further establish an LA program (N=10), and/or develop coursework (N=6). These activities were very important for establishing the PTE program in various ways; a TIR typically provided boots-on-the-ground to build out the program, the LA program provided a structure and community for in which future teachers could engage while providing value to the undergraduate curriculum, and coursework development would not have been possible without external resources. These activities (and thus the funding supporting them) were thus critical for building out programs and establishing that proof-of-concept.

PhysTEC established proof of concept for PTE at institutions, leading to future activity and funding.

A very common theme was that having the PhysTEC grant allows the institution to establish proof of concept for PTE (mentioned by N=9). Site leaders could demonstrate success, allowing them to argue for continuation of the program. Site leaders mentioned that it legitimized PTE, or created credibility, created a critical mass of students to continue the program, and allowed them to demonstrate success to the administrators. A total of 5 site leaders mentioned specifically that PhysTEC paved the way to future funding (e.g., Noyce) by establishing credibility with the NSF and local partnerships.

PhysTEC helped by creating impetus and accountability for the work.

Another theme was that getting the PhysTEC grant provided a reason to work on PTE. Having the grant helped champions to prioritize PTE, but also created partnerships and impetus to collaborate (N=6), getting the attention of stakeholders through the institutional commitment. For a few, the grant provided impetus and accountability (a “carrot”) for creating a viable certification pathway. One mentioned that PhysTEC “nucleated” activity at their site. Two explicitly mentioned that the institutional match requirement was critical -- but interviews demonstrated that the 3-year institutional match was often key to establishing the PTE activities as normal and routine.
Leaders’ recommendations for PhysTEC

Interviewees were also asked if they had any recommendations for PhysTEC based on their experience. These are reported below. Note that many people took the opportunity here to reiterate their appreciation for PhysTEC, and how effective the model is. I report common themes but not the frequency of these themes because I do not expect the list at each site to be exhaustive.

“Engage us further after funding ends.”

The most common theme was a desire to be kept engaged with PhysTEC and connected to other sites through information-sharing or events. “We’re all busy people, doing this on the side,” said one, “if we know we’ll do a phone call every few months, we’ll spend a little time thinking about what we’re doing.” Four specifically mentioned that they found the evaluation interview valuable for reigniting the project in their mind or helping them identify future directions. “This interview helps us see how far we’ve come, we have so much potential,” said one. Some examples of desired engagement include:

- Have a “jobs” section of the PhysTEC newsletter for sharing job postings (i.e., PTE program positions, or HS teaching positions).
- Offer opportunities to apply for continued funding, $5K-15K.
- Circle back to past recipients to prime activities (e.g., through evaluation interviews like this one, or by contacting administration).
- Offer feedback to legacy sites, as was done during the grant.
- Offer quarterly or annual Zoom meetings among legacy sites to provide a peer network.
- Offer budget for legacy sites to attend the PhysTEC Conference.

“Please don’t micromanage us and lighten up the reporting.”

One common theme was that the reporting was rather onerous, and probably excessive. “Initially we felt micromanaged, but while annoying, maybe that made things happen,” said one. Another was unhappy that the original PI was asked to step down from the grant. Another said that the amount of work was not made clear at the start. Two mentioned that the MOU was tedious, rigid, and confining, without allowing flexibility on how to achieve their goals, or with a long list of items to attend to. Two specifically felt they could have done the same work without as much management. However, another said “it’s eating your spinach, but not unreasonable. I needed the support and structures.”

“Don’t require the TIR to rotate if it is working out.”

Two sites specifically mentioned that they were urged to rotate the TIR after one year. However, having a consistent TIR reduces time burden for the PI, and can lead to later institutionalization of the position. For cases where the TIR is not working out, or the TIR wants to return to the
classroom, rotation does allow a graceful way to change over; otherwise, sites should be allowed to maintain a successful TIR.

“Emphasize the importance of the TIR, including at UTeach sites.”

A few sites mentioned that they realize now that the TIR is key; while PhysTEC emphasized this, they wanted to underline that the importance of the TIR should be communicated to sites. For those sites who are unable to identify a suitable TIR during the grant or sustainability period, engage in focused brainstorming on who might be able to fill this role locally. UTeach Master Teachers were often not a good sustainability plan, as they are located outside of the physics department; educate physics leaders at UTeach replication sites about the distinction between TIRs and Master Teachers so that they can either advocate for hiring a physics TIR or insure that the Master Teacher is adequately connected to the physics department and discipline. One TIR-turned-Master-Teacher indicated that the TIR role was too ill-defined compared to the Master Teacher role. I wonder if having a more well-defined TIR role, especially, at UTeach sites, would help with sustainability.

“Keep the institutional match requirement, and help institutions leverage it.”

A few leaders mentioned that the institutional match period was crucial for establishing a sustainable program. One mentioned that having a “fade-out” of funding might have been helpful. Another indicated that it was important for the site leader to leverage this appropriately: “The best time to get (institutional resources) is in leveraging the cost-share. It’s easier to make an ask of an administrator that is associated with bringing in money than after the fact.

“Focus on in-service teachers too.”

Several sites mentioned that in-service teachers are a critical component of addressing the teacher shortage. A few ways that in-service teachers were seen as important were:

- Fund sites to offer professional development for general science teachers to teach physics, including offering a certificate program. This was done at several institutions with large impact, including the Modeling Physics program at Arizona State.
- Encourage in-service teachers to promote physics teaching as a career.

“Attend to state requirements and state advocacy, too.”

Several people mentioned that the biggest challenge is in state requirements. Teacher certification requirements often increase time to degree. Additionally, lackluster requirements for high school science have resulted in elimination of physics, and thus physics teaching positions, at the high school level. In some states there are not that many physics vacancies. Another asked if APS includes campaigns to encourage HS students to take physics. One indicated that universities ought to band together to lobby the state legislature against poor quality, for-profit teacher preparation mills.
A few other idiosyncratic suggestions were made:

- **Include the physics department chair on requests** for deliverables, and reports (such as teacher graduation numbers). One chair specifically mentioned that they could have more easily intervened if they had realized that things were not being maintained post-grant.

- **Engage with local science coordinators.** One education partner mentioned that their local science coordinator was a critical partner and could be very useful in influencing HS-level teaching. I agree that these could be very useful partners.

- **Create PhysTEC replication grants through foundation funding.** One site leader suggested that PhysTEC has a strong working model and could be multiplying sites more rapidly if they worked through foundations rather than through NSF. Some that they mentioned were Toyota Foundation and Pom Wonderful. They also mentioned that UTeach often funds local sites through partial funding from a local (e.g., state specific) foundation, and that UTeach's development staff was able to broker this.

- **Promote PhysTEC as a brand name.** One indicated that PhysTEC has developed a strong name and brand and should promote its association with good projects. For example, any project in association with NASA is branded as such; the same could be done with PhysTEC. (I noted that one site was still using the PhysTEC name on their program and wondered if it was OK to use this “brand,” indicating the uncertainty about branding).

- **Focus on the physics department as a whole.** One mentioned that to get research universities on board, PhysTEC must support impacts on the department.

- **Budget for the full team to attend the conference.** Since the conference is so influential, ensure the full team can attend.
Summary

PhysTEC provided resources to start the program, enabling proof-of-concept to maintain it. Site leaders indicated that the funding from PhysTEC was essential, allowing them to hire TIRs, establish an LA program, and/or develop coursework. It also created impetus and accountability for moving things forward, both for champions and their education counterparts. Through this activity, PTE was legitimized, generating credibility, creating a critical mass of students in the program, allowing leaders to demonstrate success and argue for continued support. In many cases (N=5) PhysTEC funding paved the way for future funding from the NSF.

Site leaders request post-funding engagement, and less management. Site leaders would like to continue their connection to PhysTEC and to have opportunities to continue to grow their work. Many also requested less management during the grant, including allowing them to choose whether to rotate a TIR. They also suggest emphasizing the importance of the TIR, and helping leaders strategically leverage the institutional match period.

Site leaders also request focusing on other externalities. Other areas site leaders would like PhysTEC to focus on are in-service teachers, state requirements, and state advocacy.
Full Report Summary

This study was commissioned to assess sustainability of the latest round of PhysTEC Comprehensive sites. This study focused on the 16 sites which were funded during the 2nd NSF PhysTEC grant, plus the Campaign Funds funded sites. Funding initiated from 2010-2015, and typically lasted 3 years. Funding amounts were typically $300,000 in total, except at UTeach replication sites (typically half that amount). This was an intensive mixed-methods study requiring many person-days of effort. The findings are thus quite robust and rich.

Evaluation questions include:
1. Did the number of physics teacher graduates increase? Was this increase sustained?
2. What factors contributed to success in sustainability? What challenges to sustainability were encountered?
3. Which of the activities initiated by the PhysTEC grant are being sustained?
4. What is the future outlook for sustaining PhysTEC activities longer term?

Evaluation methods included document review, graduation data, a written survey, an orienting interview, a PTEPA Rubric interview, and stakeholder interviews. We are very grateful for the site leaders’ effort in enabling this data collection.

I focus on two main desired outcomes from the grants, which are bidirectional in their causality. Each site was rated globally on each outcome based on all data.

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<tr>
<th>Capacity &amp; culture for PTE</th>
<th>Sustained PTE Outcomes</th>
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<td>Institutional capacity &amp; culture for PTE should be strong now, regardless of where it was immediately after the grant.</td>
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<th>Global rating:</th>
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Overall, were PhysTEC site activities and outcomes sustained?

**Comprehensive II legacy sites often sustain their outcomes** -- all but two sustained their outcomes to some degree, with meaningful outcomes and lasting impacts of the grant. All have a functional PTE program. More than half (9 institutions) are truly thriving, rated with high sustainability, and 4 of these growing further since the grant. The 5 programs that were not fully sustained did typically maintain their program structures but not graduation rates. The majority (12) are rated as having at least medium capacity in their PTE program, and most report continued effort and resources dedicated to PTE. The average current internal funding spent on PTE is approximately $100,000, with 2 PTE leaders and 2 PTE non-leaders, spending about 0.5 faculty FTE and 0.3 TIR FTE. Thus, most former PhysTEC-funded sites have functional PTE programs, many of which are truly thriving -- more than can be said for most departments.
Did the number of physics teacher graduates increase? Was this increase sustained?

Comprehensive II legacy sites grow and sustain their graduation rates on average. Teacher graduation increased by 1/year on average, and this increase was sustained on average. The data, however, is messy and idiosyncratic. Teacher graduation rates increased from 1.3 teachers/year pre-funding to 2.2 during funding and 2.4 during the sustainability period. For those sites which experienced an overall gain in graduation rate (N=11 sites) the average increase is 2 teachers/year. These increases contribute significantly to addressing the national physics teacher shortage.

Well-sustained sites experience sustained graduation rates of 3-4 teachers/year. Well-sustained sites (those which “sustained” or “grew”) had overall higher teacher graduation rates: 2.5 teachers/year for “sustained”, and 3.8 teachers/year for “grew” sites. Growth in teacher graduation rates was also higher at these well-sustained sites, with overall pre-post growth of 1.1 and 2.1 teachers/year at “sustained” and “grew” sites, respectively. Only “unsustained” sites experienced no average growth from pre-to-post funding, though both “unsustained” and “mixed” sites experienced a decrease in graduation rates, on average, after funding ended.
Future teachers represent about 10% of the undergraduate majors at departments. The number of majors, and the fraction of majors who choose teaching, increases for more successfully sustained sites.

About half of teachers at an institution are certified through a postbac pathway, on average. On average, 42% of students at these sites received an undergraduate certification, compared to 47% receiving postbac certification as a standalone program or add-on to an undergraduate program (see right).

What were the outcomes of the PhysTEC grants?

Site leaders are overall proud of the results of PhysTEC, and feel it was a success. Site leaders feel the grant was a success due to sustaining activities and positions, changes in culture, and laying the groundwork for future grants. In many cases, PhysTEC offered the chance to institutionalize changes by creating a “proof of concept” and allowing time for changes to become entrenched. Site leaders were proud of their PTE programs, including the quality of education they can provide to future teachers, and the number of teacher graduates.

I posit that institutional capacity and culture support sustained PTE outcomes, and vice versa.

PhysTEC supported institutional capacity and culture for PTE -- especially norms. This statement is supported by multiple strands of evidence. Most site leaders (N=9) mentioned a supportive culture for teaching (or for teacher education) as the most significant outcome of the grant. The other common significant outcome was the entrenchment of key programs (usually an LA program) into institutional culture and practice. Site leaders were also able to name 4-5 outcomes for each of 3 areas related to institutional capacity and culture, with about half of those outcomes identified as key outcomes. They were able to name even more outcomes (5 compared to 3-4) in “capacity and commitment,” due to changes such as faculty and administrative support and changing norms. Thus, PhysTEC supports changes in culture and norms supporting PTE (compared to structures, policy, or collaborations).

Sites have strong PTE programs which were enhanced during the PhysTEC grant. Based on PTEPA rubric results, Comprehensive II sites approach the “thriving” physics teacher education programs, with 73% of PTEPA items rated at least Benchmark (compared to 78% for thriving programs). Comp II results also rival those of the thriving programs at the standard and component level. Most sites reported increases in each area of the PTEPA, showing across-the-
board enhancement of PTE, with some exceptions. LA programs, curricular changes, and recruitment practices, were the most commonly mentioned durable outcomes.

PTEPA results: Comp II sites (% of items at least Benchmark)

Institutionalization of LA programs can support both the culture and quality of PTE. LA programs were often institutionalized during PhysTEC, indicating a culture of support for physics education and/or teacher education. Those same LA programs enhanced the quality of PTE, and of undergraduate physics education. The strength of those LA programs then further enhanced the cultural support for physics teaching and/or physics teacher education in a positive feedback loop. This is evidenced by the fact that LA programs were named both as important cultural outcomes for sites (average of 2 outcomes/site) and as enhancements to the PTE program (average of 0.6 outcomes/site). LA programs were named by 5 as the most significant outcome.

The most common challenge is effort and personnel, followed by licensing requirements.
Many champions indicated that it’s hard to keep PTE going, requiring great effort and engagement of faculty. While best if done as part of a dedicated position, usually this isn’t anybody’s “real” job. Many also mentioned that licensing requirements and time to degree, including students choosing late to pursue teaching, is a challenge.

**Which of the activities initiated by the PhysTEC grant are being sustained?**

**Most activities were maintained for the majority of sites.** Overall, it is remarkable how many activities and structures were maintained across sites. Sustainability plans from the grant were upheld and in all but two cases the institutional match commitment was upheld. For most areas of the PTEPA, activity maintained or increased since PhysTEC for at least 80% of sites. Institutional climate, team attributes, and collaboration were elements of culture which often increased since PhysTEC. In the PTE program, recruitment activities often increased since the end of the grant. Many institutional resources were maintained on average, including internal funding, the number of PTE leaders, faculty and non-faculty FTE were maintained for at least 10 out of 16 sites.

![Bar chart showing most sites maintained or increased most PTEPA areas since PhysTEC.](chart)

**External funding often was not maintained.** The most common area that was not maintained was external funding. While internal funding was maintained for 13 out of 16 sites, external funding was only maintained for 6. On the PTEPA, over 30% of sites reported decreases in “resources,” which includes funding, personnel, and space.
Human resources are often reduced since PhysTEC. Several measures of human resources were often reduced -- on the PTEPA, about 50% of sites report a reduction in the number of people on the PTE team (as evidenced both by the PTEPA data and quantitative resource data). Faculty FTE was only maintained for 10 sites, and TIR FTE was only maintained for 6 sites. Thus, while the number of PTE leaders is generally maintained, the amount of time they have to spend on PTE is often reduced, and the number in their support team is also reduced. This is often due to the loss of the TIR.
The TIR position and/or duties are often eliminated or reduced -- but this is not always a problem. A total of 9 sites maintained the TIR, and 7 eliminated the TIR position. Only 5 out of the 9 maintaining the TIR maintained them as the original job described; the other 4 reduced their FTE or had other primary job duties. Additionally, 4 were maintained as part-time TIRs, most of whom had been part-time during PhysTEC. However, in some cases losing the TIR was not a drastic loss, and sites which sustained their PhysTEC activities were only slightly more likely to have sustained their TIR as well. Thus, a TIR may be valuable, but not necessary. Additionally, well-sustained sites were more likely to have part-time TIRs, showing that even a part-time position can be very valuable.

TIRs are often maintained through a regular departmental position. Most maintained TIRs were in regular positions such as lecturer, instructor, or lab coordinator, with a portion of their duties dedicated to TIR-like jobs.

TIR sustainability may be helped by including LA programs within their duties. In most cases the TIR's current job included directing or coordinating the LA program, and/or teaching the pedagogy course. During PhysTEC, half of TIRs worked with the LA program, usually recruiting LAs, mentoring them, and teaching the pedagogy course. Such duties may help maintain the TIR position for some sites -- 66% of maintained TIRs worked with the LA program, in contrast to only 28% of discontinued TIRs.

LA programs were almost always maintained; broad support for the LA program helped enable many elements of PTE to maintain. Only 2 sites studied did not maintain their LA program; all other 13 sites with an LA program maintained that program. Not all these programs were created by PhysTEC (8 new programs were created), but PhysTEC helped to institutionalize or maintain most of the existing programs. Qualitatively, I heard that institutional support for the LA program created an internal drive to keep the LA program going, often leading to finding a way to hire the TIR to run it and/or to teach the pedagogy course. A wide range of funding strategies were used to support the LA program, from soft money requests,
federal work study, provost funding, course fees, and an external gift. While the LA program was often only indirectly related to PTE, having such a program created many benefits supporting PTE, such as hiring a TIR, teaching a pedagogy course, and providing a community for future teachers.

What factors contributed to success in sustainability? What is the outlook for sustaining PhysTEC activities longer term?

**Unsustained sites lacked champions, resources, and capacity for PTE.** Recalling that only 2 sites did not sustain their activities, what characterized these two outliers? Notably, they did not have a champion, and there were also very few resources allocated to PTE (e.g., funding, people, and FTE). These unsustained sites also reported reduction in all these areas since the end of PhysTEC. Unsustained sites also had very low PTEPA ratings, were rated as “low” capacity for PTE based on leadership, institutional climate, and resources, and tended to be at smaller departments.

**While external factors were not clearly related to sustainability, sustainability increased with the number of majors and with postbac pathways.** Local teacher salaries were not related to levels of sustainability, nor was the year of funding (i.e., year of PhysTEC RFP). However, the department size did increase for more well-sustained sites compared to “unsustained” or “mixed” (42 majors graduated/year for “grew”, versus 25, 22, and 20 for “sustained”, “mixed” and “unsustained” respectively). “Sustained” and “grew” sites also experienced greater growth in their major since funding ended (+15-16 majors/year on average compared to +8 majors/year). The percentage of majors choosing to become teachers also increased with the sustainability level, at 8%, 9%, 10% and 11% for each increasing level of sustainability, respectively. Well-sustained sites (those which “sustained” or “grew”) tended to include a post-baccalaureate pathway as one of the main ways in which students achieved certification, and more students were graduated through these pathways than through undergraduate-only routes.
Site capacity and culture is necessary but not sufficient for sustained outcomes. Each site was rated on their capacity and culture for PTE based on their leadership strength, institutional culture, and resources. All “grew” sites were rated as “high capacity,” most “sustained” and “mixed” sites were rated medium or high capacity and all “unsustained” sites were rated low capacity. Thus, “medium capacity” may be a threshold for good results, but “high capacity” is necessary but insufficient for exemplary results.

Exemplary sites have overall strong programs, as judged by the PTEPA. “Mixed” sites have overall intact PTE programs but experience other difficulties. Sites which “grew” have higher overall PTEPA ratings (86% rated at least Benchmark) than “Sustained,” “mixed,” or “unsustained” sites. However, ratings between “sustained” and “mixed” were similar in this metric. “Mixed” sites have PTEPA results which rival or exceed those of stronger programs (e.g., “thriving,” “sustained,” or “grew” programs). This suggests that the PTE programs at “mixed” sites are structurally strong, but they are not achieving high graduation rates or there is some other noted dysfunction from the evaluation keeping them from reaching “sustained” status. This also suggests that PTEPA ratings can only differentiate at the edges of the scale (exemplary versus non-functional programs); the PTEPA alone cannot differentiate solid and weaker programs, and neither can graduation rates or site leaders’ self-ratings. However, when taken as a whole, these measures can help distinguish institutions.

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Students at former PhysTEC sites receive quality preparation regardless of site sustainability. All sites including “unsustained” sites were found to have ratings in the PTEPA “Knowledge and Skills” standard which rivalled those of thriving programs -- this standard includes physics content and pedagogy, and field experiences. Additionally, nearly all sites experienced growth in PTEPA ratings during PhysTEC funding, regardless of sustainability level, showing that Comprehensive grant funding improved PTE programs.

UTeach is not necessarily a good sustainability plan. With only 3 UTeach replication sites, it is difficult to make strong statements. However, all UTeach replication sites were in the “unsustained” or “mixed” groups, and I observed that physics department ownership, and TIR connection, was often reduced in UTeach sites. UTeach Master Teachers did not offer a good replacement for a PhysTEC TIR, typically, because they have less connection to the physics department and engage in less recruitment. A UTeach Master Teacher also would not typically be engaged with an LA program which, as reported earlier, can be an important part of a healthy PTE ecosystem.

Drivers of sustainability include people, money, structure, culture, and routine. When asked what keeps a particular outcome going, there were some common themes, listed here in order of decreasing frequency. One was the effort of champions, and often the institutionalization of a position for that champion (such as a TIR or including PTE courses within a faculty course-load). Money, including grant funding, were named as useful. Structures were commonly named, such as formalized PTE program structures, LA programs, or certification pathways. Lastly, culture change kept things going, such as support for teaching careers, or inertia and routine. Several people mentioned that the length of the PhysTEC grant, and the 3-year institutional match period, was critical for establishing the culture and routine necessary to argue successfully for the structures, people, and money needed to maintain the program.
What was PhysTEC’s contribution to success?

PhysTEC provided resources to start the program, enabling proof-of-concept to maintain it. Site leaders indicated that the funding from PhysTEC was essential, allowing them to hire TIRs, establish an LA program, and/or develop coursework. It also created impetus and accountability for moving things forward, both for champions and their education counterparts. Through this activity, PTE was legitimized, generating credibility, creating a critical mass of students in the program, allowing leaders to demonstrate success and argue for continued support. In many cases (N=5) PhysTEC funding paved the way for future funding from the NSF.

Site leaders request post-funding engagement, and less management. Site leaders would like to continue their connection to PhysTEC and to have opportunities to continue to grow their work. Many also requested less management during the grant, including allowing them to choose whether to rotate a TIR. They also suggest emphasizing the importance of the TIR, and helping leaders strategically leverage the institutional match period.

Site leaders also request focusing on other externalities. Other areas site leaders would like PhysTEC to focus on are in-service teachers, state requirements, and state advocacy.
Conclusions and discussion

In this section I will discuss the meaning and interpretation of these findings.

**PhysTEC Comprehensive Sites achieve meaningful results for institutions, and the nation.**
I would like to emphasize the strength of formerly funded PhysTEC Comprehensive sites; all but two were rated as sustained to some degree, and about half are truly thriving. These sites spend time and money on PTE and have functional PTE programs -- more than can be said for most physics departments. On average these sites also grew and sustained their graduation rates by 1.3 teachers/year, and those which did increase their graduation rates did so by 2 teachers/year on average. Even at sites without enhanced graduation rates, their capacity for effective PTE is much higher than it was before the grant; they are poised for success. The PTE programs are, overall, stronger at all these institutions than it was before the grant. In the cases of the most exemplary sites, their PTE programs and institutional commitment is off the charts. The outcomes which were observed align quite well with PhysTEC’s values -- e.g., institutional commitment, leadership, culture, and structure. This suggests that the PhysTEC model is overall working. Site leaders, PhysTEC, and its funders, should be very proud of these achievements.

**PhysTEC supports organizational capital and a healthy ecosystem for PTE at institutions.**
I found evidence for across-the-board improvements to PTE, including institutional capacity and culture, resources, leadership, collaboration, recruitment, mentoring, and assessment. The majority of activities were maintained for most sites. Many sites institutionalized LA programs which provided a recruitment cool and community for future teachers in many cases, and in other cases supported a strong undergraduate physics program and enabled support of a TIR and/or pedagogy course. PhysTEC thus created intellectual and organizational capital that is important for PTE, as well as activities that provide a supportive ecosystem for PTE to thrive, now or in the future.

**It is difficult to maintain leadership, time, and effort, leading to fragility.**
The most common areas that fell away were the time and personnel to focus on PTE. TIRs were maintained at 9 out of 16 sites, but 4 of these 9 were in a reduced capacity. Many leaders spoke of the difficulty of continuing to work hard to support PTE, including continuing to onboard faculty, without it being their “real job.” PER faculty were sometimes valuable for this effort, but not every PER faculty has time or interest to focus on PTE. Focused time and effort was often difficult, and without it, the work either languished or weakened. Unsustained sites were typified by a lack of leadership, resources, and institutional support. The need for champion efforts can lead to fragility of PTE programs. When a “hero effort” is required, things can also fall apart. Structural supports can help; see below.

**Culture, including structure and routine, can help with sustainability.**
These challenges can and were overcome by culture, including structure, policy, routine, and institutional support. Dedicated funding, positions, including PTE in formal duties, LA programs, policies, and routine were helpful in maintaining activities, as were strong institutional climate and collaboration. Many of these structural supports are part of the normative supports for undergraduate education. These supports, when present, can help reduce the “hero effort” required of PTE.

**Motivated people, site capacity, and institutional culture are important, but insufficient on their own. Exemplary results require all elements of the model to be exemplary.**

I return to the theoretical model described earlier. Across this evaluation I found strong support for this model. Motivated people are important, but not sufficient for site sustainability; without a champion, efforts languished. If people can generate structures and begin to establish cultures that support PTE, the success and proof of concept of the PTE program can feed back into the program’s continued success and cultural support. I have also added **threats** to the model below. Both unsustained and mixed sites were hampered by severe threats, such as budget cuts and personnel loss. All sites experience threats, and some are able to mitigate those threats, and some are not. These threats are often outside the control of motivated people and are often unable to be mitigated despite best efforts and strategy. I place it within the “opportunities” bubble since opportunities and threats are often two sides of the same coin (e.g., a retirement might be an opportunity if it eliminates an intransigent faculty, or it might be a threat if it eliminates a willing champion).

I found evidence that site sustainability increased overall as more elements from the model were added. Without a motivated person, the site was unsustained. If there were motivated
people, and adequate PTE programs, but local structures or lack of opportunities keep them from achieving better results, results were “mixed”. Sites were “sustained” when capacity and culture were overall strong, including motivated people, good opportunities, and supportive structures for PTE -- in other words, good intellectual and organizational capital. However, truly exemplary results (“grew” sites) were observed when the institutional climate was exceedingly strong and leaders mediated opportunities strategically to generate that structure and culture. For well-sustained sites, the PTE outcomes (number of graduates, and the quality of preparation of those graduates) did appear to feed back into the culture and structure for PTE by demonstrating success and establishing proof-of-concept and value.

In other words:

1. Few elements of this mode + threats → Unsustained site with low capacity
2. Mostly motivated people → Mixed results, but good PTE program
3. Mostly motivated people + structure → Sustained results with many graduates
4. Motivated people + structure + culture → Exemplary (“grew”) results

Or in graphical form:

This model represents merely a hypothesis. While it is supported by the data, this is in correlational form only, and we cannot infer the causality suggested by this diagram.

Based on this study, here are some examples of each of these key elements:
<table>
<thead>
<tr>
<th>Key elements for supporting PTE</th>
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<tbody>
<tr>
<td><strong>Motivated people</strong></td>
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<tr>
<td>Champions</td>
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<tr>
<td>PTE team</td>
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<tr>
<td>TIR (may be part-time)</td>
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<tr>
<td>PER faculty</td>
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<tr>
<td>Advisors</td>
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<tr>
<td>Instructors, especially of intro course</td>
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<tr>
<td>Education partners, especially with physics backgrounds, including teacher of Methods course, university supervisor, advisor, UTeach director</td>
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<tr>
<td>Local K12 partners, including district science coordinator</td>
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<tr>
<td>Program alumni</td>
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<tr>
<td>Department chair</td>
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<tr>
<td>Administrators, especially with education backgrounds</td>
</tr>
<tr>
<td><strong>Opportunities/Threats</strong></td>
</tr>
<tr>
<td>Funding (internal and external), including Noyce and existing funding streams (e.g., for SIs or grad students)</td>
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<tr>
<td>3-year institutional match period</td>
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<tr>
<td>Retirement/hiring/turnover in department or administration</td>
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<td>Champion power</td>
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<td>Global pandemics</td>
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<tr>
<td>State-level certification requirements</td>
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<tr>
<td>Department needs (students, TAs)</td>
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<tr>
<td>Size of major</td>
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<tr>
<td>Grants (e.g., Noyce, S-STEM, GFO)</td>
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<tr>
<td>Recognition from APS or others</td>
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<tr>
<td>Local need for physics teachers</td>
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<tr>
<td>Success of PTE program</td>
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<td>Credibility or reputation of PTE program and team</td>
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<td>Recruitment pools</td>
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<table>
<thead>
<tr>
<th><strong>Structure</strong></th>
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<tr>
<td>LA program</td>
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<td>Positions (for TIR, instructor, etc.)</td>
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<td>Courses “on the books”, and listed</td>
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<td>Teaching assignments</td>
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<td>Certification pathways, including dual certification and post-bac</td>
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<td>Counting education credits in physics</td>
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<td>Teaching concentration in physics</td>
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<td>BA in physics</td>
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<td>Graduate assistantships</td>
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<tr>
<td>Noyce grants</td>
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<td>UTeach</td>
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<td>Advising structure</td>
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<tr>
<td>Active learning in physics curriculum</td>
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<tr>
<td>Intro physics reforms</td>
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<tr>
<td>Events (e.g., outreach, open houses, workshops)</td>
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<td>Committees</td>
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<tr>
<td>Local programs* (e.g., outreach, in-service programs, PET, Modeling)</td>
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<tr>
<td><strong>Culture</strong></td>
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<td>--------------------------------</td>
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<tr>
<td>Funding decisions, resource allocation, hiring decisions</td>
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<tr>
<td>Faculty awareness of need for PTE</td>
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<td>Perceptions of teaching among students/faculty</td>
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<tr>
<td>Faculty or admin support* in physics and/or education</td>
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<tr>
<td>Use of active learning in physics</td>
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<td>Routine and norms</td>
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<td>“Proof of concept” for PTE program</td>
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<td>Collaboration between education and physics</td>
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<td>Community for pre-service physics teachers</td>
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<tr>
<td>Community for in-service physics teachers</td>
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<tr>
<td>Institutional mission / history of teacher education</td>
</tr>
<tr>
<td>Student demand for courses / interest in teaching</td>
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</table>

*For reformed teaching, PTE, disciplinary teacher preparation, and/or LA program.
In the best cases, PhysTEC “lifts all boats” in the department. PhysTEC often helped the department support teaching excellence, through using the TIR as an instructional coach for faculty, supporting a thriving LA program, using PTE candidates as well-trained TAs in undergraduate courses, and generating conversations about educational outcomes. There are many institutional mechanisms to support active learning (such as teaching evaluations and course assignments), but fewer available to support PTE specifically; thus, it may be valuable for PTE to “hook onto” the existing institutional mechanisms supporting teaching excellence and a thriving undergraduate program. For example, rather than generating a conversation about how to support an undergraduate pathway to teaching certification only, a broader conversation about career pathways and concentrations in the major might be easier. This suggests a broadened model, below, showing PTE as part of the ecosystem of undergraduate education within the department.

Recommendations were made to PhysTEC based on these results, including in areas of PhysTEC strategy, support for funded and legacy sites, and data collection and evaluation. Key recommendations include continuing to offer Comprehensive grants, determining how to support the common postbac pathways, strategically supporting undergraduate improvement within physics departments, and engaging legacy sites. Recommendations for supporting sustainability among funded sites are also provided.