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STEM Learning and Research Center

Engaging Teachers in Supporting Next Generation STEM Learning

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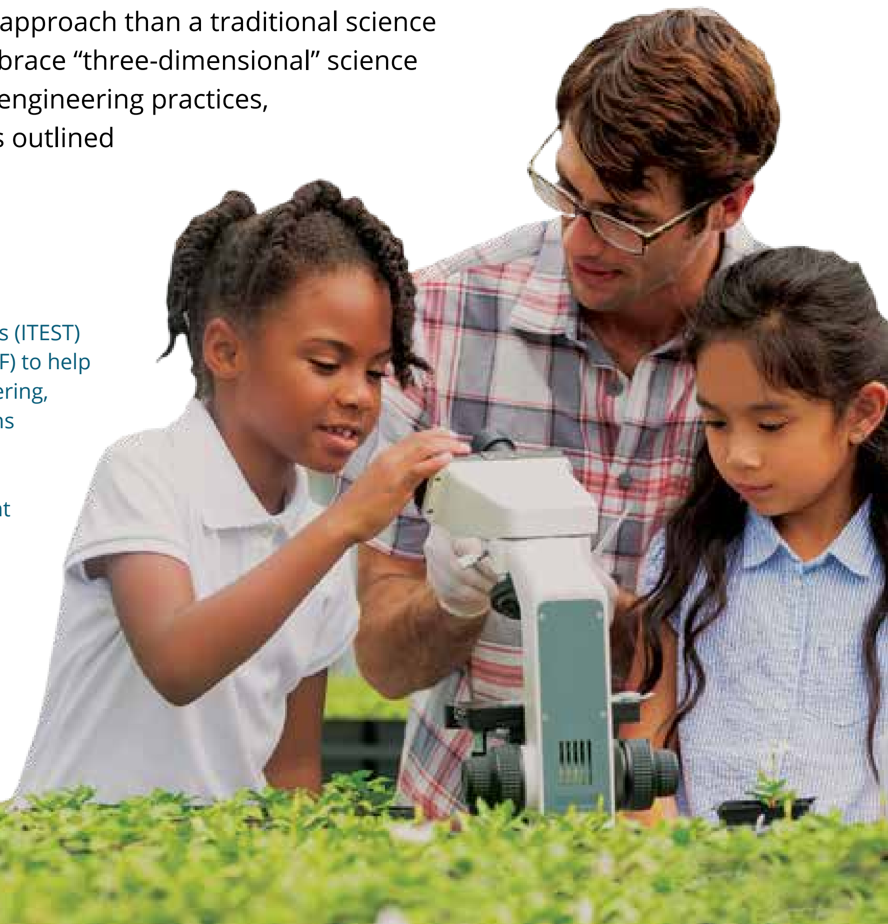
Exploring underwater robotics, mapping fossil finds, and collecting and sharing data with the National Weather Service—such student learning experiences are everyday fare in ITEST projects, but radical departures from "business as usual" in science and math classrooms and afterschool activities.

ITEST projects may draw on scientific concepts, disciplines, and technological tools with which teachers have no prior experience. ITEST projects may also involve inquiry science, which requires a very different pedagogical approach than a traditional science lab activity. And many recent ITEST projects now embrace "three-dimensional" science learning—learning that brings together science and engineering practices, crosscutting concepts, and disciplinary core ideas, as outlined in the new Next Generation Science Standards.

The Innovative Technology Experiences for Students and Teachers (ITEST) program was established by the National Science Foundation (NSF) to help ensure the breadth and depth of the science, technology, engineering, and mathematics (STEM) workforce, in direct response to concerns and projections about the growing demand for and current shortages of STEM professionals in the United States. The STEM Learning and Research (STELAR) Center at Education Development Center, Inc., in partnership with the Goodman Research Group, Inc., assists ITEST principal investigators (PIs) and evaluators to design, refine, and evaluate their ITEST projects and to effectively synthesize and disseminate project findings.



In this synthesis, we explore the minority of projects primarily designed around professional learning for teachers, out-of-school-time educators, and/or pre-service teachers.

ITEST projects typically support teachers in taking on new roles by incorporating programming for teachers within their projects. As noted by Parker, Stylinski, Darrah, McAuliffe, and Gupta (2010), in order to enable changes in teaching practice, the transformative strategies that ITEST projects strive for must address not only gaps in teachers' knowledge and practice, but also their attitudes and beliefs about teaching STEM and incorporating technology into practice.

To accelerate dissemination of educator learning models in ITEST projects, the ITEST program has called for reflection on best practices and lessons learned in response to this question: ***"What instructional and curricular models can effectively engage teachers to use and integrate technologies so as to enhance student understanding of STEM-related occupations?"*** In this paper, we address this question by taking a closer look at teacher-centered projects. In the majority of ITEST projects, educator learning occurs within a primary focus on student learning. In this synthesis, we explore the minority of projects primarily designed around professional learning for teachers, out-of-school-time educators, and/or pre-service teachers.

This is not STELAR's first look at teacher learning. In 2010, we led the development of a special issue of the *Journal of Technology and Teacher Education*,[1] which included a set of articles authored by project teams that reported on teacher learning in their work as well as the results of a study of professional development in over 40 ITEST projects.

For this synthesis, we took a different approach. We reviewed over 200 publications related to approximately 110 projects, and identified a set of publications related to 9 projects that truly centered on professional learning and outcomes for teachers. In summarizing those publications here, we aim to provide a different lens on ITEST professional learning while also sharing developments since 2010 with the community and the field. Across the publications included in this summary, we report on three common topics: changes over time in professional development delivery methods; teachers working alongside STEM professionals; and learning for pre-service teachers.

1 *Journal of Technology and Teacher Education*, April 2010, available at The Learning Technology and Library website (https://www.learntechlib.org/p/33209).

Implications of various formats for professional development

Prior to 2008, ITEST required that projects structure their professional development components to include a summer institute for teachers, as described in the 2007 program solicitation:

> Teachers should receive an appropriate level of professional development to enhance their skills in incorporating information technologies into their core STEM courses. Teachers should then be provided with an opportunity to put into practice what they have learned, by working with students (grades 7–12) in a summer laboratory experience. (NSF, 2007, I. Introduction, ¶9)

After the program's requirements for teacher professional development changed, one project team conducted research to examine teacher and student outcomes in the summer institute format as compared to a continuous approach through the academic year. As part of the Harnessing the Power of Data project (2009–2013), the project team compared a professional development offering for middle- and high-school teachers delivered during a two-week summer institute to another grant-funded professional development program offered monthly and bimonthly during the school year. Teachers and students from both formats showed improvement in all areas assessed. The team found that the format of the professional development did not affect student outcomes. However, the team also found that teachers who participated in the professional development throughout the academic year implemented authentic lessons with students at a higher rate than did the summer institute group (Claesgens et al., 2013).

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This paper is based on a review of over 200 publications collected from research.gov and the STEM Learning and Research Center (STELAR) website, along with additional resources related to newer projects. The publications reviewed relate to approximately 110 of the 325 ITEST projects funded from the program's inception in 2003 to 2015. The publications originally appeared in sources from a wide range of disciplines (from maritime technology to women's studies) and an array of formats (research journals, practitioner-focused magazines and newsletters, and conference presentations and posters). The publications reviewed also contain widely ranging levels of detail, and the connection to a given ITEST project may be direct or tenuous. Many include descriptions of project implementation or implementation plans. A smaller portion describe targeted outcomes, evaluation methods, and findings.

The variety of sources reflects the diversity of ITEST grantees' backgrounds, specialties, and professional communities, as well as the diversity of local contexts for which projects are designed. ITEST projects build on the strength found in bringing together diverse professionals in the goal of broadening participation in STEM careers, but this strength also presents challenges; because ITEST PIs come from a range of academic disciplines, the nonprofit sector, or formal or informal learning arenas, their work, and how they report on it, varies widely. By summarizing available publications, STELAR hopes to facilitate learning across the various professional communities that together comprise the ITEST community.

More projects have started blending in-person training with online professional development components.

Since 2008, projects have had greater flexibility around implementing the professional development approach they thought would work best in their contexts. As an example, more projects have started blending in-person training with online professional development components. Below, we discuss three projects that used such blended formats. Two chose a blended format to address the challenges of working with teacher participants spread across very rural areas; one employed this approach to scale up a project at four sites in different geographic regions.

Combining in-person and online professional development to reduce barriers

In rural areas of the United States, distance can prevent teachers from being able to participate in professional development—and can prevent students from access to innovative STEM experiences.[2] The Arctic Climate Modeling Program (2005–2009) involved collecting data from school-based weather stations in the Bering Strait region of Alaska. The project design added online professional development components, anticipating that solely offering in-person professional development would reduce participation. Further, the project used a teacher leader model to reach teachers who could not participate in meetings at locations other than their schools. The team's strategy paid off: although the project initially planned to involve only a subset of teachers in the district, all teachers ended up participating (Bertram, 2010).

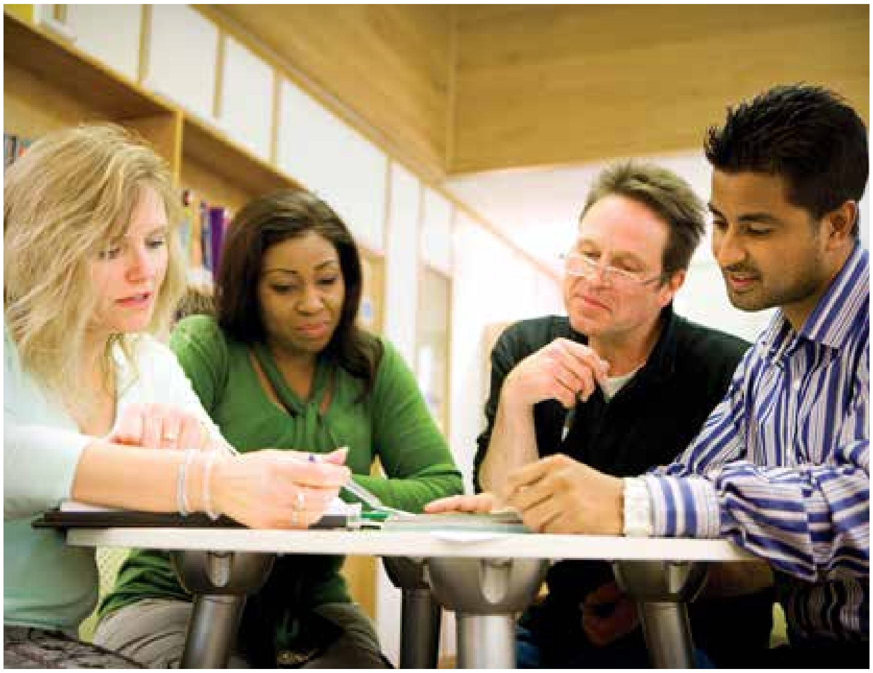
In Eastern North Carolina, the Photonics Leaders II project (2008–2011) also used a blended approach to work with teachers in an underserved rural area. The professional development, for grades 6–12 teachers of subjects that involve physics concepts, combined a three-day intensive, in-person training with a subsequent two-day online experience focused on optics and photonics—the behavior and study of light (Gilchrist, Hilliard-Clark, & Bowles, 2010). The project found that teachers

2 The two projects described in this section are also featured in a related paper on promising strategies for broadening participation in ITEST projects. In that paper, we focus on access to innovative STEM learning experiences for students in remote, underserved areas, where teachers and students alike may experience an opportunity gap in STEM learning experiences.

who participated in the blended-format professional development demonstrated knowledge gains in physics and photonics content areas. Participating teachers reported that they would use the proposed activities in their classrooms and that the project's activities would engage students and promote learning that connects to the real world. Teachers also indicated that the hands-on experiments and demonstrations could easily be done and would fit well in their curriculum. In addition, more than three-quarters indicated that they would share the activities and information with their colleagues.

The project team later found that teachers' subsequent activities were consistent with what they had reported they would do. Participating middle and high school teachers implemented optics and photonics content and inquiry-based strategies in their classrooms, professional learning communities, and extracurricular programs (Gilchrist, 2014; Gilchrist et al., 2010; Gilchrist, Hilliard-Clark, Bowles, & Carpenter, 2014). These findings suggest that blended professional development can support teachers' learning of new science content, pedagogical approaches, and Web-based technology strategies.

Another project used a combination of in-person and online professional development to connect participating teachers from any location around the country. The [Build IT Underwater Robotics Scale Up for STEM Learning and Workforce Development] project (2009–2015) focused on making an underwater robotics curriculum more accessible to experienced technology education and engineering teachers. At a one-day in-person workshop, teachers built robots and completed challenges. Follow-up online modules had asynchronous and synchronous



components focused on engineering concepts and curriculum implementation (McGrath & Sayres, 2012).

The project team had anticipated that the professional development would be most successful with participating technology teachers, whose prior knowledge and experience they thought would prove advantageous. In fact, they found that the program was successful with technology teachers *and* with teachers of other STEM subjects. The team also found that the shorter one-day teacher training was as effective as a week-long training when paired with Web-based follow-up (Lowes & Tirthali, 2013).

These projects suggest that blended formats can mitigate barriers to teacher participation. Some evidence also suggests that professional development that takes place in smaller doses during the school year may offer advantages over summer institutes in supporting more frequent implementation of ITEST-supported lessons throughout the year (Claesgens et al., 2013).

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Bringing teachers and STEM professionals together

Local STEM professionals can serve as role models for students and be a resource for teachers as well.

In some ITEST projects, teachers work not only with a university-based research team but also alongside STEM professionals from industry or the nonprofit sector. Having direct contact with STEM professionals and their practices can improve teachers' STEM career awareness and help them share with their students realistic, first-hand information about the concepts, approaches, and tools that various professionals use every day.

The Scaling Up STEM Learning in the VCL project (2009–2014) featured pairs of teachers working with STEM professionals from a range of fields to develop an in-class activity that the STEM professionals would lead while visiting the classes. In the same project, project staff developed short videos about each STEM professional role model for students to view in class. The videos described the STEM professionals' work and also highlighted the relevant math content. For example, when an architect in a video talked about the role of geometric solids in his work, he was pictured in front of a house with a digital overlay of the solids (Ware & Stein, 2013).

In another project, EcoScienceWorks (2009–2014), middle school science teachers in Maine worked with Audubon environmental educators and the project team to develop a curriculum that integrated computer simulations into their teaching. This project took advantage of Maine's existing statewide one-to-one laptop program to improve computer-based science learning. Curriculum goals were to guide the use of the computer simulations and to include an allied field experience that would give students a hands-on activity in ecology. Over two week-long summer curriculum institutes, teachers developed a curriculum that supports five targeted simulations in ecology based on Maine ecosystems, and a programming module called *Program a Bunny*. Through their participation in the project, all the teachers recognized how experiential learning could take place in the field as well as with the simulation software and simple programming challenges. The project team reported finding positive gains in teacher technology skills, new knowledge regarding the use of simulations in teaching, positive changes in pedagogy, and increased content knowledge (Allan, Erickson, Brookhouses, & Johnson, 2010).

Local STEM professionals can serve as role models for students and be a resource for teachers as well. Given the emphasis on STEM practices in the new Next Generation Science Standards, opportunities for teachers to partner with STEM professionals may be an important component of capacity building moving forward.

Building the capacity of pre-service teachers

While most ITEST projects focus professional development efforts on in-service teachers or out-of-school-time (OST) educators, ITEST-related professional learning has also been integrated into the coursework of pre-service teachers. This section highlights three projects that involved pre-service teachers. In all three cases, pre-service teachers engaged in and facilitated open-ended, inquiry-centered experiences. As the open-ended nature of inquiry science can take even veteran science teachers out of their comfort zone, these projects took the view that future teachers would be more likely to implement such experiences in their classrooms if they felt knowledgeable and confident in facilitating them.

In the Fablab Classroom project (2010–2015), researchers identified effective ways of integrating advanced manufacturing technologies, such as 3D printing, into the K-12 curriculum and prepared pre-service and in-service teachers to deliver project-based learning[3] activities. For instance, participating pre-service teachers built windmills to generate the energy necessary to lift a geometric solid. In this way, pre-service teacher activities were modeled on those of their future students. Participants in the project exhibited significant pre-post gains in technology skills, increased self-efficacy regarding technology integration, and greater STEM career interest and awareness (Alexander, Knezek, Christensen, Tyler-Wood, & Bull, 2014). To support this work, the University of Virginia developed a Laboratory School for Advanced Manufacturing (Lab School) in collaboration with the Charlottesville and Albemarle school systems. The Lab School provides a permanent testbed for this work and a site in which pre-service and in-service teachers can observe and participate in best practices.

The Urban Ecological Challenges project (2009–2014) introduced pre-service

3 It is worth clarifying that while many ITEST projects use the term *problem*-based learning, the Fablab Classroom team describes its core activities as *project*-based learning. In both cases, learners typically design and complete a multi-step process that may involve several cycles of testing and revision. Problem-based learning can additionally emphasize that the design responds to a defined problem, and some use the term to signify real-world applications and/or the more hands-off role of the teacher, whose role is to facilitate an open-ended design process. See the STELAR data brief for more information.

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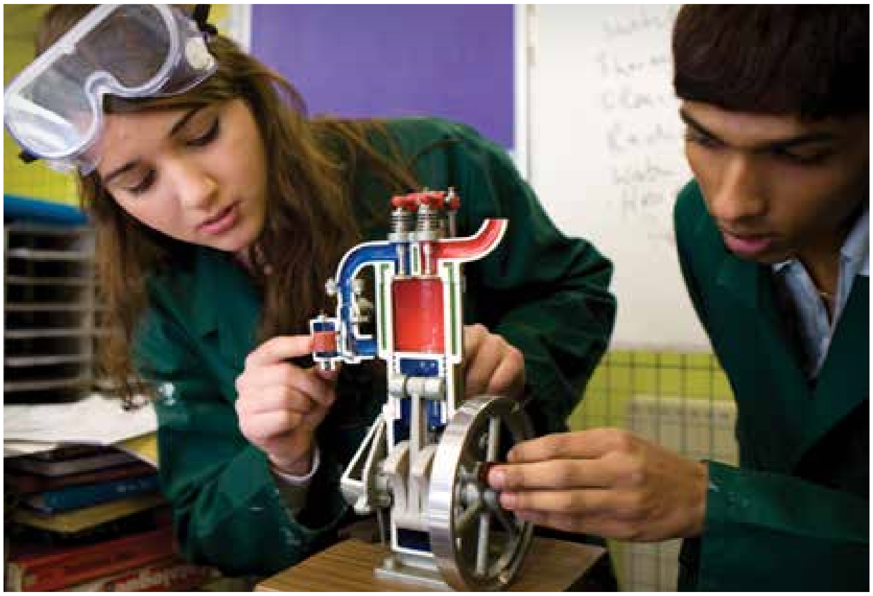
teachers to urban ecology concepts, Geographic Information System (GIS) mapping technology and tools, and inquiry-based approaches to addressing urban ecology issues. The team found that as the pre-service teachers' content knowledge improved, so did their understanding of how to use the technology to support science learning, and their confidence in their ability to do so. However, the pre-service teachers encountered some difficulty with the scientific process. The team members found that they had not devoted enough time in their training activities for teachers to gain a thorough grasp of inquiry approaches, given their limited prior experiences with them (Barnett, Houle, Mark, Strauss, & Hoffman, 2010).

Another project that involved inquiry science with pre-service teachers, Communities Educating Tomorrow's Scientists (COMETS, 2007–2011), engaged pre-service teachers throughout a semester-long instructional methods course (Cartwright, 2012). Many pre-service teachers involved in COMETS had little prior experience with science instruction. Having noted that teacher training programs often lack adequate practicum hours, this project partnered with local afterschool programs in an under-resourced urban area in West Virginia. By facilitating lessons in afterschool settings, participating pre-service teachers gained more student teaching hours overall, started their practicum training much earlier, and, perhaps most importantly, gained expertise with and deeper knowledge of concepts and practices they may not have otherwise encountered in their training, and sought out ways to overcome the typical barriers associated with teaching science (Cartwright, Smith & Hallar, 2014). Pre-service teacher participants also benefited from the support of in-service teacher mentors; mentors observed pre-service teachers leading instruction during afterschool and summer programming, provided feedback, and met regularly with the pre-service teachers (personal communication with Kea Anderson Vogt, May 2013).



Partnerships involving local OST providers in ITEST work can bring together OST programs for youth and pre-service teacher training programs to mutually benefit all involved. Cartwright (2012) pointed out that afterschool programs are often under-resourced, and pre-service teachers benefit from practice in the afterschool environment to gain experience with inquiry science. Offering opportunities for teachers to practice the concepts, skills, and tools their students will later experience has long been a strategy recommended by the ITEST program, including in the early years, when the program required that projects support teacher learning by providing opportunities to practice new approaches during summer institutes (Parker, Malyn-Smith, Reynolds-Alpert, & Bredin, 2010).

Incorporating teachers' perspectives and needs into project design and professional development

Since teacher participation for the duration of a given project is so important to its success, in terms of both potential research contributions from study findings and learner programming, projects can benefit greatly from seeking teacher input and showing responsiveness to teachers' needs.

Findings from Scaling Up STEM Learning in the VCL demonstrate the importance of designing professional development with teachers' perspectives and contexts in mind. At the start of the professional development, the project team interviewed teachers, using open-ended questions regarding their use of technology in the classroom, their overall perceptions, and the inclusion of STEM role models as part of the project. During follow-up interviews a year later, researchers found that teachers' perspectives at the outset of the programming—regarding such interrelated factors as Internet connectivity in their classrooms, students' access to the Internet and devices outside of school, and their own experiences with their counties' one-to-one programs—affected how they implemented the intervention. Given the role of these contextual factors, the project team recommends treating a new technology as "an embedded artifact," and addressing in training not only technical competency but also the contextual factors that may limit the use of any new technology (Ware & Stein, 2014).

Offering stipends and other incentives

Given that teachers have many demands on their time and can face other barriers as well in implementing new approaches and using new tools and curriculum, projects use myriad strategies to make implementation more feasible for teachers. Some projects have offered graduate course credit as an incentive for participating teachers (Stanley & Almquist, 2008).

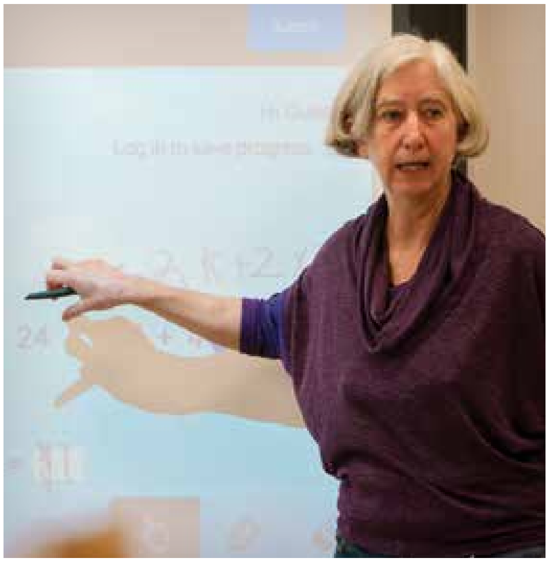
Another strategy is to offer stipends to teachers, as one project did upon completion of all steps of the project (Gilchrist et al., 2010). COMETS, the project in which pre-service teachers facilitated inquiry science activities in afterschool programs, also offered stipends to teachers (Cartwright, 2012). To ensure that all trained teachers have the resources needed to implement the curriculum, some projects offer stipends for the equipment or supplies needed to carry out classroom activities—either a single stipend for this purpose, or in addition to other stipends (Lowes & Tirthali, 2013). Participants in one project that used stipends for equipment (where the teachers purchased electronic equipment to build solar ovens) reported that those funds were what made implementation of the project feasible.

Pre-service teachers benefit from practice in the afterschool environment to gain experience with inquiry science.

Looking ahead

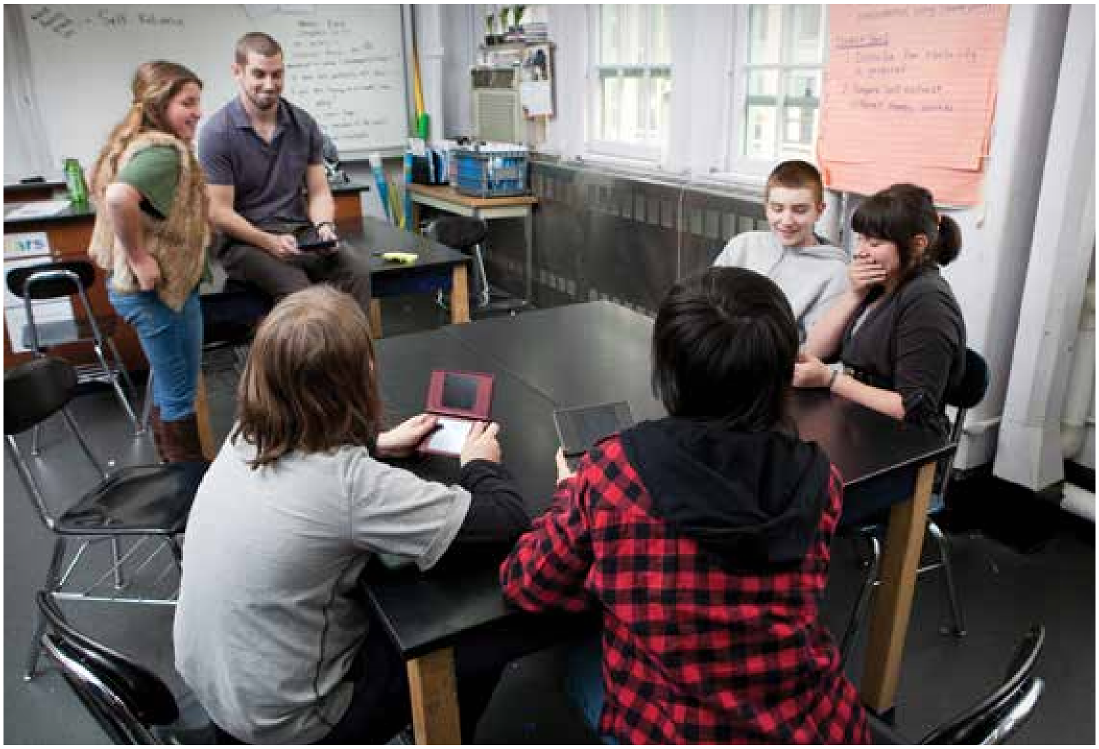
To successfully implement ITEST-based lessons with their students, teachers and OST educators need sufficient support.

Professional learning in ITEST projects typically involves content knowledge, experience with new technologies and tools, and new pedagogical approaches. To successfully implement ITEST-based lessons with their students, teachers and OST educators need sufficient support across all three areas. Taking participants' perspectives, capacity, experience, and contexts carefully into account in the planning phases can help projects understand areas in which teachers may need additional support.



The ITEST portfolio shows a range of approaches to professional development. Several projects have teachers learn as they will teach by offering hands-on activities and field experiences as components of professional learning. Project teams may combine online and in-person formats to encourage participation and gain efficiency in underserved areas.

Project teams may include summer institutes or partner with OST providers to offer opportunities for teachers to practice facilitating ITEST learning activities. Finally, strategies for reducing barriers to teacher participation, including through incentives such as stipends or course credit, can help project teams recruit and retain teacher participants.



Projects featured in this synthesis

(in the order that they appear):

1. The POD Project: Harnessing the Power of Data (2009-2013; DRL-929846)
2. Arctic Climate Modeling Program (2005–2009; DRL-0525277)
3. Photonics Leaders II (2008-2011; DRL-833615)
4. Build IT Underwater Robotics Scale Up for STEM Learning and Workforce Development (2009-2015; DRL-929674)
5. Scaling Up STEM Learning in the VCL (2009–2014; DRL-0929543)
6. EcoScienceWorks (2009–2014; DRL-0525221)
7. Fablab Classroom (2010-2015; DRL-1030865)
8. Urban Ecological Challenges (2009–2014; DRL-0833624)
9. Communities Educating Tomorrow's Scientists (COMETS; 2007-2011; DRL-736067)

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