Effective Strategies of Teacher Professional Development Focused on Geospatial Technologies[1]

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Introduction

To meet the needs of our global economy and to help students achieve competitive workforce skills, classrooms need to support the exploration of real-world problems and issues (Alberts 2013). This is especially relevant for Earth science, environmental science and social studies courses. Such authentic investigations would align well the new Next Generation Science Standards and Common Core State Standards, which emphasize science and engineering practices, problem solving and evidence-based reasoning (http://www.nextgenscience.org/, http://www.corestandards.org/).

Working with technology in ways that better match computer literacy skills and applications in today's workplace is an important component of these investigations. Such real-world technology applications include robotics, computer modeling and simulations, digital animation and multimedia production, biotechnology, and geospatial technologies. In addition to providing the tools to tackle authentic problems and questions, these applications expand opportunities for teachers to introduce students to careers across science, technology, engineering and math (STEM) fields (Ejiwale, 2012) and to use student-centered inquiries and constructivist practices (e.g., Krajcik et al. 2000, Varma et al. 2008). Geospatial technology (GST) can be a particularly effective tool for exploring real-world issues because it allows visualization and analysis of local, regional and global landscapes and supports community-based activities (e.g., Bodzin, 2008, National Research Council, 2006).

Despite these benefits, many teachers are still implementing technology in the classroom in limited ways (e.g., SIIA 2012, Bebell et al. 2004, Wright & Wilson 2012). Because they are novel to the K-12 classroom, GST and other real-world technology applications may present significant challenges for teacher professional development and classroom implementation including steep learning curves and the daunting task of gaining confidence and skill at guiding students through complex activities within the constraints of the K-12 environment.

Intensive professional development (PD) focused on increasing teachers' skills and comfort with using technology in innovative ways offers one possible way to increase its use in the classroom. As part of a larger study, we are exploring the design of teacher professional development focused on real-world applications of technology, teachers' perception of these experiences, and any subsequent changes in teaching practices. Here we present a portion of our research focused on GST-based training and classroom implementation.

In this study, we applied Penuel et al.'s (2007) recommendation to focus on a specific professional development design by using the National Science Foundation's Innovative

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Technology Experiences for Students and Teachers (ITEST) "comprehensive" projects as our study group. These teacher professional development projects are ideal because they immerse teacher in an extensive training on one or more real-world technology applications (including GST) to promote interest in STEM and STEM careers. With this study group, we asked the following questions:

- How common are GST projects within the ITEST program?
- What are critical aspects of these GST-based PD projects?
- Did teachers from these PD experiences implement GST in their classroom?

Methods

We reviewed abstracts of ITEST comprehensive projects funded between 2003 and 2012 (provided on the ITEST Learning Resource Center website, http://itestlrc.edc.org/). We used these abstracts to identify and describe projects that had a significant GST focus. We excluded projects that were limited to GPS or remote sensing.

We conducted semi-structured phone interviews with principal investigators (PIs) from 31 ITEST projects awarded between 2003 and 2008; 11 of these were GST projects. PIs were recruited through an online survey sent to all those funded during this period. We used findings from this survey along with commonly cited professional development practices to develop the PI interview protocol. We coded the interviews, applying grounded theory by first creating preliminary codes based on responses; we then synthesized the results to determine the most frequent responses.

With the help of ITEST PIs, we recruited 259 teachers to complete an online survey; this included 89 teachers from six GST-ITEST projects. We used the PI survey and interviews to develop this survey, which asked teachers to reflect on their professional development experience and to discuss their classroom implementation. We determined the mean response for relevant multiple-choice items (see McAuliffe et al 2013).

Results

GST-ITEST Professional Development

The NSF ITEST program was initiated in fall 2003. Between its inception and October 2012, 39 of about 200 funded projects included geospatial technologies. Twenty-seven had a significant teacher PD component and the rest focused on youth in informal education settings. GST-ITEST teacher PD projects were funded throughout this period, although there were fewer projects in later years (Table 1). Most of these projects fit within environmental science (24); other disciplines were computer programming (1), bioscience (1), and computer games and simulations (1). Environmental science topics were quite diverse including paleoecology, urban ecology, watersheds, and climate science.

Table 1: ITEST GST projects funded each year between 2003 and 2012

Year funded	Number of GST-ITEST projects – teacher focused	Number of GST-ITEST projects – youth focused
2003	3	1
2004	5	1
2005	8	0
2006	1	3
2007	1	4
2008	5	2

2009	3	1
2010	1	0
2011	0	0
2012*	0	0

*Only a few ITEST projects had received their award when these data were collected.

Among other interview questions, we gave ITEST PIs a list of professional development strategies and asked them to identify and discuss those critical to their project design. The rating of these strategies was fairly similar for ITEST PIs overall and GST-ITEST PIs. GST-ITEST PIs did place somewhat greater emphasis on the local context and proximity to practice. Below we discuss the top five strategies.

Table 2: Percentage of interviewed PIs who identified the following strategies as critical to their technology-based teacher professional development

Strategy	GST-ITEST PIs	ITEST PIs
Collaborations	100%	97%
Focus on a particular pedagogical approach	91%	91%
Out-of-school experience	82%	74%
Proximity to practice	82%	72%
Authentic inquiries	73%	73%
Local context	64%	53%
Teacher as expert	64%	78%
STEM career connections	55%	66%
Focus on STEM content knowledge	45%	44%
Differentiated instruction	36%	53%
Collective participation	36%	41%

<u>Collaboration</u>

The most frequently mentioned strategy was collaboration, which we defined as two or more individuals in the professional development working in significant ways towards a common goal. Several had teams work as equals, drawing on the expertise of other teachers and other participants (community members, STEM professionals, students and project staff). As described by one GST-ITEST PI,

> *The nonhierarchical learning [in our project] was extremely important...the [summer] students and the teachers were learning in a peer-to-peer format. So, there weren't teachers teaching kids…trying out things on the kids. It was everybody was learning the same thing at the same time on the same exact level.*

GST-ITEST PIs and other ITEST PIs supported structure and functioning of these collaborative interactions in various ways: having teachers work together on science research and game design; discussing ideas and sharing information; writing and revising materials; peer-reviewing and trouble-shooting materials and teaching; managing shared resources such as equipment; and co-teaching with other teachers and project members. One GST-ITEST PI even gave select teachers additional training on curriculum development so they could function as more effective team leaders. These PD structures were often designed to promote long-term collaborations. For example, one GST-ITEST PI used "Sustainable Learning Community," describing the benefits,

> *Teachers had a [support network] within their own building, within their own community, that they could go to [when they trying to implement and] who had similar trainings and a similar summer intensive experience.*

Another used a "Cascading Leadership Model" with each group of past teacher participants mentoring new participants; the PI felt that by using this approach, "[These] communities-of- practice [among the teachers] will…organically evolve."

Focus on a particular pedagogical approach

Inquiry-based learning and problem-/project-based learning were frequently mentioned pedagogical approaches among all ITEST PIs and ITEST-GST PIs. Since ITEST projects centered on real-world technology applications within the context of STEM topics, it is not surprising that these approaches were critical components of many professional development designs. One ITEST-GST PI explained how they integrated scientific inquiry into their professional development:

> *We constructed our activities… all as inquiry activities. For instance, when we were teaching [the teachers] the GIS skills, we gave them a problem to solve that would require at them to look collectively at numerous different layers of data and analyze various associations between data layers to answer the question. We made it a compelling question, like where would you find this type of dinosaur.*

GST-ITEST PIS and other ITEST PIs noted that they chose inquiry because it was an efficient way to introduce STEM content and the targeted technology and because it illustrated how technology could be used to expand students' critical-thinking and problem-solving skills. Many remarked that teachers often lack skill in guiding students through this type of active hands-on learning, and thus it was critical for the staff to model ways to support inquiry-, problem-, and project-based learning and for teachers to experience these approaches as learners. As a GST-ITEST PI described,

> *[The] opportunity to experience [an investigative] case as learners, collect their data, come up with an evidence-based conclusion and present that evidence to their peers was a strategy of allowing them to spend time with the content, make sense of the content, and then share whatever their understandings of that case was about.*

The other commonly mentioned pedagogical approach was place-based education. This approach aligns well with the authenticity and local-context strategies, as projects had teachers and students apply real-world digital tools within their own social, environmental and cultural settings. Cultural context was a foundational piece of at least one GST-ITEST project, in which the Native American community defined the learning priorities for the project, and the students gathered the requested information (e.g., water quality report) and shared their findings with the whole community.

Out-of-school experience

All ITEST PD projects were required to include an extended out-of-school experience, or "youth institute," as part of the teacher training. Typically these institutes occurred for one to three weeks over the summer and involved teams of middle and high school teachers working together and interacting with small groups of teenagers. Although mandatory, this informal education experiences were highly valued by the ITEST PIs, especially GST-ITEST PIs. Many surveyed teachers also cited the youth institute as a critical element of the professional development (62% of all surveyed ITEST teachers and 60% of GST-ITEST teachers). Both PIs and teachers reported these experiences offer the opportunity to practice and improve skills with the technology and related curricular materials *before* tackling these in the classroom and *without* the typical classroom restrictions. As one GST-ITEST PI noted,

> *Taking them out of the school building and just immersing them in these weeks…helped them be able to focus on just one thing rather than having to deal with all the other rigors of a school year, and the things that are after them in the classroom…just focus on their own learning.*

Another highlighted how the youth institute offered a chance for teachers to "play" with GST and new concepts and skills:

> [*Y]ou are not all stressed out about how you are going to implement it within a classroom type of environment. It…gives you a chance to be very thoughtful, and reflective, and just explore what may or may not work. If it doesn't work, oh so be it … it gives you a chance to actually fail by using the technology in a safe environment.*

Both PIs and teachers highlighted the benefits of exploring possible problems, challenges and questions that might occur in the classroom, giving teachers confidence and a clear view of how the targeted technology could be implemented. The youth institute also helped teachers gained a better understanding of how teenagers interact with technology and how these interactions differ from their own struggles. For example, one GST-ITEST PI reported,

> *Teachers were impressed by how easily students adapted to the technology and ran with that, and until they had worked with the students they did not understand that…Without that interaction, I think at least some of the teachers would have doubted that their students were going to be as excited about the technology as they eventually were.*

The opportunity to practice was particularly important as many PIs encouraged their teachers to move towards more student-centered teaching; that is, teachers giving up some control and allowing youth to drive the direction of research or design activities. Indeed, many GST-ITEST PIs encourage teachers to have a mentoring and partnering role with youth during the summer institutes (Table 3).

Table 3: Percentage of interviewed PIs and surveyed teachers who identified the following dominant roles with youth during the ITEST PD. Both PIs and teachers could select more than one dominant role.

	GST-ITEST PIs	ITEST PIs	GST-ITEST teachers	ITEST teachers
Teacher as mentor	55%	68%	61%	68%
Teacher as instructor	55%	39%	46%	42%
Teacher as partner	45%	42%	40%	45%
Teacher as student	27%	23%	25%	31%

Proximity to practice

Many ITEST PIs reported that a close eye to proximity to practice (professional development activities and materials focus on preparing teachers for classroom implementation) helped ensure the targeted technology was used in the classroom. This was particularly important as GST and other technologies are typically unfamiliar to classroom teachers, and many lack teaching experience with these tools. PIs applied this strategy by "consciously modeling," as one GST-ITEST PI coined, the pedagogical practice that they were promoting and by leading teachers in regular discussions and reflections on their planned classroom implementation. Many PIs reported that the youth institute provided a key component of this proximity-to-practice strategy.

Authentic inquiries

We defined authentic inquiries as interactions, activities and resources in the professional development that link to real-world content, contexts, or processes. By making this alignment, projects promoted a deeper understanding of STEM culture, process, and concepts and created opportunities to make their own novel discoveries. As one GST-ITEST PI noted,

> *It was an opportunity for both teachers and students to a gain better understanding of how scientists conduct their work. They had to come up with a scientific question and to conduct their own little research projects. They needed to see how it really happens in the field rather than read about in the Pollyanna world of textbooks.*

Some projects directly involve STEM professionals, who hosted field trips, supervised teacher science research, mentored teachers as they worked on curricular materials, and assisted with classroom implementation. These professional helped sustain collaboration and implementation beyond the professional development and personalized the STEM process and STEM career pathways. In addition to careers, this authenticity strategy overlaps with local context, as GST-ITEST PIs supported exploration of local fossil beds, schoolyard ecological features, nearby lobster hatcheries and other community features and issues. In one GST-ITEST project, teams of teachers, students and community members worked together on a local project:

> *We asked the kids…what are the major research stewardship issues in your community and had them…drive that conversation, which…helped the teachers see where the interest really lay [sic] for the students.*

GST-ITEST Teachers

Of the 91 surveyed GST-ITEST teachers, almost all implemented one or more technology applications from their PD experience at least once (Table 4). Most of these teachers used the technology application in their classroom during their PD and in the next couple years. There was then a sharp decline three, four and five years after the PD, even taking into consideration the number of teachers for whom this is applicable (i.e., for whom it has been 3-5 years since their PD). These implementation trends were slightly better than those reported for the entire teacher survey group (n=259). Of those who implemented, most used the targeted technology in their classroom for one week to one month (Table 5).

Table 4: Percentage of surveyed teachers who implemented technology from their PD experience in their classroom

Implemented...?	GST-ITEST teachers *Yes†*	ITEST teachers *Yes†*
At some point (n=259)	95%	89%
During PD*	87% (n=82)	87% (n=222)
Immediately after PD	96% (n=76)	94% (n=196)
2 years after	82% (n=56)	71% (n=133)
3 years after	63% (n=27)	50% (n=80)
4 years after	50% (n=18)	36% (n=59)
5 years after	25% (n=12)	24% (n=49)

*Some projects did not have teachers implement during the yearlong PD.
†This number increases because many teachers only recently completed their PD and thus they have had only one or two years to implement their technology.

Table 5: Percentage of surveyed teachers who implemented the PD technology in their classroom over below number of weeks (n=86)

	GST-ITEST teachers
Less than 1 week of class periods/year	13%
1-2 weeks of class periods/year	43%
3-4 weeks of class periods/year	24%
5-9 weeks of class periods/year	10%
More than 9 weeks of class periods/year	9%

While GST-ITEST teachers faced a number of challenges when implementing their PD-based technology into the classroom, less than a quarter cited these as significant (Table 6). The most common barriers were related to school policy; fewer resulted from software, hardware or technology support limitations. It was suprising that the level of collegiality was a top barrier, while opportunities for teacher collaboration was the lowest ranked barrier.

Table 6: Percentage of surveyed teachers who selected the two highest levels (4 and 5) on five-point scale from no barrier (1) to significant barrier (5) to implementing technology from their PD (n=259)

	GST-ITEST teachers	ITEST teachers
Standardize testing requirements	22%	19%
Level of collegiality at your schools	21%	21%
Amount of time to implement with your students	19%	15%
Level of flexibility to decide the order and content of topics taught	19%	18%
Access to technology in computer labs	18%	17%
Amount of time to plan for implementation	16%	11%
Level of administrative support	14%	12%
Access to necessary software	14%	17%
Access to technology in your classrooms	11%	10%
Level of project follow-up support during classroom implementation	11%	11%
Level of parental support	11%	9%
Access to STEM experts	7%	5%
Teaching to standards	5%	7%
Opportunities to collaborate with other teachers	3%	6%

When asked to identify technologies used in their most successful classroom implementation (as defined by teachers), 73% listed spatial analysis. The other teachers who were trainined on GST either did not use GST at all or used it only for visualization. During this self-described successful implemention, teachers often integrated other technologies – particularly field, image, numeric and communication tools (Table 6). Their spatial applications centered MyWorld GIS, ArcGIS, and Google Earth (plus GPS options), while non-spatial tools included wikispaces, blogs, website design, and podcasts/vodcasts. Teachers' descriptions of this implementation addressed topics in earth science (e.g., hurricanes and weather patterns), ecology/biology (e.g., oyster reef healf, impervious surfaces and stormwater runoff, habitats of zoo animals, migration of marine mammals), space science (Mars and the Moon), social studies (Egypt history, historic events fires and population changes, distribution of food zones, marriage and divorce rates), and math (central tendency).

Table 6: Percentage of GST-ITEST teachers using spatial analysis and one of the other technologies listed below.

Using spatial analysis and...	GST-ITEST teachers
Field data analysis tools	70%
Image data analysis tools	48%
Numeric data analysis tools	44%
Communication tools	42%
Digital design tools	21%
Modeling and simulation tools	17%
Virtual reality tools	16%
Programming tools	11%
Gaming tools	6%
Engineering design tools	3%

Conclusions

Our findings indicate that GST provides a compelling way to integrate investigations of real-world problems and issues into K12 classroom. NSF has awarded a large number of GST education projects, impacting hundreds of teachers and students throughout the nine years of the ITEST grant program.

Geospatial technology use in schools has dramatically evolved since its first introduction in the 1980s and early 1990s and the launch of GIS day in 1999. Early adopters struggled with complex desktop software programs, immense file sizes, and limited technological support. Now, user-friendly applications allow even novices to acquire, visualize and analyze spatial data layers. Shifts to more and faster web delivery of software and data coupled with the growing number of wired U.S. classroom has significantly broadened access to GST and other real-world technology applications. Indeed, in this web-centric environment, teachers and students expect to seamlessly blend GST with other online technologies, including uploading field data remotely, examining data using mobile devices, integrating maps into multiple-media productions, and sharing GST findings on blogs, Facebook and other web-based distribution channels.

Our findings provide evidence of this evolution in GST in the classroom. GST-ITEST teachers frequently used multiple technologies, combining GST with digital tools for field data collection, image data analysis, numeric data analysis and communication. While they faced significant barriers, almost all were able to implement their ITEST training into the classroom—even two years after the PD. Fewer faced significant technological barriers that have been cited in the past (e.g., Kerski, 2003; National Research Council, 2006). However, challenges associated with school policy remain; these include pressure associated with standardize testing, inflexible curriculum structure, and lack of collegiality. The latter requires more exploration, as opportunities to collaborate with other teachers was not a major barrier. Overall, these findings point to a tension between the time required to engage students in real-world activities that parallel professional STEM practices (multiple weeks) and time available to prepare for and guide students through these investigations.

While many important technological challenges have been conquered (or at least subdued), effectively using GST as a teaching tool in the classroom requires technological pedagogical content knowledge (TPACK), which considers how teachers use the unique affordances of technology to transform content and pedagogy for learners (Mishra & Koehler, 2006). Teachers with high levels of TPACK understand how to effectively select and use appropriate technology applications (like GST) that will help their students understand specific content using an appropriate pedagogical approach. Effective use also requires a deep understanding of the practices of STEM professional who regularly apply GST and other technologies. Our findings illustrate how GST-ITEST PIs designed their PD to prepare teachers for technology classroom implementation, placing significant emphasis on collaboration, a focus on a particular pedagogical approach, out-of-school experiences, proximity to practice and authentic inquires. Also critical were focusing on the local context, treating teacher as experts, and STEM career connections—all of which could fit within authenticity and collaboration.

As described in earlier papers (Stylinski et al. 2011, 2012), many of these strategies parallel best practices regularly reported in the literature on effective PD practices. These include collaboration, proximity to practice, differentiated instruction, a focus on STEM content knowledge, and collective participation (Desimone et al., 2002; Collins, 2010; Garet et al., 2001; Loucks-Horsley et al., 2003; Penuel et al., 2007). Additional cited strategies are extend duration, alignment with education standards and active learning; although not included in the interview, these were also common in ITEST teacher PD projects. The NSF ITEST grant program required the first two strategies (e.g., PD had to include 120 contact hours). Evidence of active learning was apparent through the focus on inquiry and problem-/project-based learning, involving teachers in developing and adapting curricular materials (Stylinski et al. 2011), giving them an opportunity to try out pedagogical skills and materials during the out-of-school youth institute, and allowing time for discussion and reflect on their teaching and learning.

GST-ITEST PIs also designed their PD around strategies that are either not commonly cited in the literature or not emphasized in more traditional efforts. This included expanded collaborations, focusing on a particular pedagogical approach (inquiry, problem/project-based learning, place-based learning), out-of-school experiences and authentic inquiries. All four strategies intertwine in terms of purpose and approach. GST-ITEST PIs (and other ITEST PIs) sought to extend collaborative efforts to include STEM professionals, local citizens, and students as team members and to use technology to support and sustain collaboration. These deeper and broader collaborations often occurred in the out-of-school summer experiences. Working with students outside of formal school settings and in non-traditional roles (mentor and partner) allowed teachers to acquired a better understanding of youth's relationship with technology, develop their skills in student-centered teaching and inquiry-based and problem-/project-based learning through practice, and gain confidence for subsequent classroom implementation. Others have identified similar benefits of these low-stake settings (Saxman et al. 2010, Luehmann 2007), however the integration of informal education experiences into classroom teachers' professional development is not common. Finally, the focus on inquiry and problem/project-based learning aligns well with authentic STEM practices and with a focus on the local environmental and social context—both a natural fit for GST investigations.

Overall, while we have made significant progress in the integration of GST into K-12 classrooms, teachers continue to need support to effective use this technology, especially in light of the new Next Generation Science Standards and Common Core State Standards. We need to address of support teachers' and students' deep explorations of real-world relevant issues and questions within the constraints of the classrooms. We need to explore ways to support collaborations among diverse community members inside and outside the classroom. We need to better understanding how out-of-school experiences can help teachers develop skills and confidence to use GST and other related in their classrooms. Finally, we need continue to explore ways to use GST and other technologies to effectively prepare students for the workplace and instill an identity as lifelong STEM learners. We will provide additional insight in our larger study as we examine and describe the quality of ITEST teachers' classroom implementations of GST and other technologies.

References

Alberts, B. (2013) Prioritizing science education. *Science 340*(6130), 249.

Bebell, D., Russell, M., & O'Dwyer, L. (2004). Measuring teachers' technology uses: Why multiple-measures are more revealing. *Journal of Research on Technology in Education, 37*(1), 45–63.

Bodzin, A. M. (2008). Integrating instructional technologies in a local watershed investigation with urban elementary learners. *The Journal of Environmental Education, 39*(2), 47-57.

Collins, A. (2010). The science of teacher development. *Education Week*, *30*(13), 36-27.

Desimone, L. M., Porter, A. C., Garet, M. S., Yoon, K. S., & Birman, B. F. (2002). Effects of professional development on teachers' Instruction: Results from a three-year longitudinal study. *Educational Evaluation and Policy Analysis, 24*(2), 81–112.

Ejiwale, J. (2012). Facilitating teaching and learning across STEM fields. *Journal of STEM Education: Innovations and Research, 13*(3), 87-94.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38*(4), 915–945.

Kerski, J. (2003). The implementation and effectiveness of geographic information systems technology and methods in secondary education. *Journal of Geography, 102*(3), 128-137.

Krajcik, J., Blumenfeld, P., Marx, R. W., & Soloway, E. (2000). Instructional, curricular, and technological supports for inquiry in science classrooms. In J. Minstrell & E. H. Van Zee (Eds.), *Inquiring into inquiry learning and teaching in science*. Washington, DC: American Association for the Advancement of Science.

Loucks-Horsley, S., Love, N., Stiles, K. E., Mundry, S., & Hewson, P. W. (2003). *Designing professional development for teachers of science and mathematics* (2nd ed.). Thousand Oaks, CA: Corwin Press.

Luehmann, A. L. (2007) Identify development as a lens to science teacher preparation. *Science Education*, *91*(5), 822-839.

McAuliffe C., Parker, C. & Stylinski C. (2013) Designing Technology-Intensive Science, Technology, Math, and Engineering Professional Development: Insights from NSF's ITEST Projects. *National Association for Research in Science Teaching Conference.* Rico Grande, Puerto Rico.

Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record, 108*(6), 1017-1054.

National Research Council. (2006). *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum*. Washington, D.C.: National Academies Press.

Penuel, W. R., Fishman, B. J., Yamaguchi, R., & Gallagher, L. P. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American Educational Research Journal, 44*(4), 921–959.

Results from the SIIA vision K-20 Survey. (2012): The Software & Information Industry Association, MMS Education.

Saxman, L. J., Gupta, P., & Steinberg R. N. (2010) CLUSTER: University-science center partnership for science teacher preparation. *The New Educators, 6*, 280-296.

Stylinski, C.D., Parker, C. & C. McAuliffe (2012) Integrating Informal Education Experiences in K-12 Technology-Intense Teacher Professional Development. *American Education Research Association Conference*, Vancouver, BC.

Stylinski, C.D., Parker, C. & C. McAuliffe (2011) Examining real-world IT-immersion teacher education experiences through the lens of two teacher roles. *National Association for Research in Science Teaching Conference*, Orlando, FL.

Wright, V. H., & Wilson, E. K. (2011). Teacher's use of technology: Lessons learned from the teacher education program in the classroom. *Southeastern Regional Association of Teacher Educators (SRATE) Journal, 20*(2), 48-60.

Varma, K., Husic, F., & Linn, M. (2008). Targeted support for using technology-enhanced science inquiry modules. *Journal of Science Education and Technology*, *17*(4), 341-356.