Integrating Informal Education Experiences in K-12 Technology-Intense Teacher Professional Development[1]

Cathlyn D. Stylinski†, Caroline Parker†† and Carla McAuliffe†††
†University of Maryland Center for Environmental Science, ††Educational Development Center, †††TERC

Paper presented at the 2012 American Education Research Association Conference
Vancouver, BC April 13-17

ABSTRACT

Using technology in ways that parallel professional applications offers many benefits but also significant challenges for K-12 classrooms. Our study explored approaches and perspectives of technology-intense teacher professional development projects that incorporated informal education experiences to meet these challenges. During these experiences, teachers typically served as mentors to youth as they worked on real-world technology applications. Some projects did emphasize a more typical classroom instructor role, while others promoted partnerships between teachers and youth. Overall, most project leaders and teacher participants felt these experiences were a critical component of the professional development and identified many benefits including opportunities to practice-teach; reflect on teaching and gain confidence without typical constraints of the classroom; develop a deeper understanding of students' relationship with technology; and try out more student-centered approaches. These findings align with other studies highlighting the benefits of these low-stakes environments for reform-based teaching.

INTRODUCTION

Real-world applications of professional technologies, such as robotics, computer simulations, digital animation, biotechnology, and geospatial technologies, offer many benefits for K-12 classrooms including engaging students in authentic research and design activities and promoting interest in science, technology, engineering, and mathematics (STEM) careers. However, technology use in the classroom is still quite limited with teachers primarily using computers for administrative purposes, drills or Internet searches (e.g., Bebell et al. 2004, US Department of Education 2003). These low-level uses of computers are typically associated with teacher-centered practices (Ertmer et al. 1999) and do not substantially alter a teacher's approach to instruction (Dexter et al. 1999).

[1]This material is based upon work supported by the National Science Foundation under Grant Number #0833524. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Real-world technology applications in particular present significant challenges for teachers 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 classroom. Only a few studies have explored how best to prepare teachers to incorporate real-world technology applications into their K-12 curriculum (e.g., Vrasidis & Glass 2005).

A potentially effective training approach is to have teachers practice professional applications of technology in low-stakes environments such as summer camps and after-school programs. These and other free-choice learning venues allow children and adults to learn about STEM in ways that are voluntary, non-assessed, and under the control of the learner (Falk et al. 2007). As such, they offer the opportunity for K-12 teachers to explore more learner-driven pedagogical approaches without the constraints of typical classrooms. Our study explores approaches and perspectives of technology-intense teacher professional development that incorporated informal education experiences. This study is part of a larger effort examining the impact of teacher education focused on real-world technology applications on classroom teaching practices.

THEORETICAL FRAMEWORK

Integrating informal education experiences into teacher education aligns with frequently cited practices of effective professional development (e.g., Supovitz & Turner 2000, Garet et al. 2001, Penuel et al. 2007). Specifically, these experiences provide an opportunity for teachers to participate in inquiry, questioning, and experimentation; to collaborate with peers; and to reflect on teaching practices as they work together to guide youth through STEM research and design activities. Ideally, these out-of-school endeavors also provide good proximity to in-classroom practice; that is, these activities align with and can be transferred to teachers' classrooms.

Museums and other informal science environments have a long history of supporting K-12 education, including teacher professional development (Bevan et al. 2010). These institutions and organizations are particularly well suited to expand teachers' STEM content knowledge, as well as their understanding of inquiry and their ability to use inquiry in the classroom (e.g., the Exploratorium's Institute for Inquiry for K-8 teachers). Many focus on using their physical resources, including interactive exhibits, in their teacher professional development projects (e.g., Yu and Yang 2010). Only a few fully immerse teacher participants in informal education practices to develop their inquiry skills. For example, the CLUSTER program, co-led by the City College of New York and the New York Hall of Science, has potential pre-service teachers interact directly with visitors to develop their skills in engaging audiences, extracting prior knowledge, and prompting discussion (Saxman et al. 2010).

Overall, out-of-school experiences provide a low-stakes collaborative environment for teachers to try out new understanding, skills, and materials and to experiment with more inquiry-driven approaches (Luehmann 2007). However, as Luehmann notes, few

pre-service teacher programs exploit these practice opportunities; they are likely even less common in in-service teacher professional development. Low-stakes informal education experiences might be particularly important for both pre- and in-service teachers tackling challenging real-world applications of technology.

In addition to building on this research related to informal education environments, our study applied Penuel et al.'s (2007) recommendation to focus on a specific professional development design by using projects funded through the National Science Foundation's *Innovative Technology Experiences for Students and Teachers* (ITEST) program as our study group. These teacher professional development projects were ideal for our research because they all focused on one or more real-world technology applications and shared a common design, including having an extended out-of-school experience, or *youth institute,* as part of the 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. Our study targeted the 65 ITEST projects awarded between 2003 and 2008.

METHODS

To explore approaches and perspectives of these technology-intense teacher professional development projects, we collected two forms of data—semi-structured phone interviews with ITEST project principal investigators (PIs from 31 projects) and an online survey completed by teacher participants from the pool of 65 ITEST projects (219 teachers). The PI interview protocol and teacher survey were developed from a prior project survey with ITEST PIs. The teacher survey consisted of Likert-scale items, multiple-choice items, and open-response items, and it asked teachers to reflect on their professional development experience. To address validity and reliability, we had an expert panel review the instrument and a subset of ITEST teacher participants pilot a draft survey and provide feedback. We coded interview and survey questions that focused on the youth institute, applying grounded theory by first creating preliminary codes based on responses, and then synthesized the results to determine the most frequent responses.

RESULTS

Dominant teacher role

From an earlier online survey with ITEST PIs, we identified four possible roles that teachers had with youth during the informal education youth institutes—*instructor* (teachers practice-taught with youth in ways that were similar to traditional in-school practices), *mentor* (teachers guided youth as they tackled scientific investigations and design projects), *partner* (teachers worked as equals with youth), and *student* (teachers were taught by youth). Our current data have revealed that interviewed PIs and surveyed teachers selected a similar ranking of roles that occurred during these out-of-school experiences (Table 1). The roles are described in the next sections.

Table 1: Dominant roles that teachers had with youth during the ITEST professional development as identified by interviewed PIs and teacher participants. Both PIs and teachers could select more than one dominant role.

Dominant role with youth	% of interviewed ITEST PIs (n=31)	% of surveyed ITEST teachers (n=219)
Teacher as mentor	68%	68%
Teacher as partner	42%	45%
Teacher as instructor	39%	42%
Teacher as student	23%	31%

Mentor role

Both groups identified *mentor* as the most dominant role. This aligns with the focus of many projects on inquiry and problem- or project-based learning. Indeed, as these PIs commented, their professional development was designed to ensure teachers practiced and reflected on this type of teaching during youth institutes:

- *It's not so much…just talking to the students, but actually working with the students to discover something or to learn how to do something.*
- *You are not just preaching, you are facilitating the learning process.*

Many teachers reacted positively to this role, as these responses indicate:

- *I found that having the experience of mentoring a particular group [of youth] and observing the interaction between the other teachers and their groups was an essential part of my preparation. The mindset/actions of the students during their experience help me to prepare ways to help them through times when they would becomes frustrated during the process and keep them motivated to move forward and complete their task.*
- *This was one of, if not the, most important aspect as a teacher. It allowed me to judge [youth's] prior knowledge and [to] develop the curriculum. [The] mentoring approach allowed me to continuously adapt the curriculum and learn the new innovative decisions the students were using.*

Instructor and Partner roles

Somewhat less common during the youth institutes were *instructor* and *partner* roles. Those PIs who emphasized *instructor* used this role to gauge teachers' understanding and to give teachers a full trial run with curricular materials before returning to the class. According to one PI:

> *The teachers, having developed curricular materials and having taught them to fellow teachers, still would not necessarily have a full perspective of how those materials would be received in a classroom, and so we chose to provide the teachers with an opportunity to see how students would respond to the curricular materials that they developed.*

By contrast, some ITEST PIs sought a significant shift in the teacher-youth relationship and thus had teachers and youth learning together as partners and drawing on each other's expertise. Not surprising, youth in the out-of-school time appreciated this

opportunity to be the drivers of the investigations. In addition to supporting youth engagement, PIs said they selected this approach because it ultimately improved classroom implementation and sustainability. As described by a PI, this role has the potential to shift teaching practice:

> *[Teachers said] this experience changed their teaching in the classroom…because they had never really allowed…kids to work in teams [or allowed themselves] to…work with kids as equals…learning with them. It just really transformed their teaching.*

Several PIs said the partnership approach was a fundamental component of the professional development design, as this example demonstrates:

> *The nonhierarchical learning was extremely important. So, during the summer institute, the students and the teachers were learning in a peer-to-peer format. So, there weren't teachers teaching kids, there weren't teachers trying out things on the kids. It was everybody was learning the same thing at the same time on the same exact level. And, in most cases the students actually ended up teaching the teachers.*

Student role

Partnerships often led to the role reversal cited above with teachers in the position of student and the youth serving as the instructors. In these cases, youth applied their greater comfort with technology to help teachers learn new applications. Both PIs and teachers reported this approach was quite effective for teachers and youth. For example, one PI reflected, *It was just magical to see…[it] was very, very valuable to [teachers]…to be able to look at their kids in that way and learn how to let them take on that role*.

As indicated in Table 1, many ITEST professional development designs integrated multiple roles for their teacher participants. For example in one project, youth taught teachers to build virtual worlds and then teachers and youth would work collaboratively to design a world that could be used in the classroom. Some projects assigned these roles, while others had teachers determined the appropriate role or roles with institute youth. In at least one case, the use of multiple roles aligned quite well with local community practices:

> *In [our] culture …sometimes you are the expert, sometimes you are the learner, sometimes we are equals, and there is that recognition that that's community and that's how we learn.*

Benefits of Youth Institutes

A majority of interviewed PIs and surveyed teachers felt these informal education experiences were critical to the professional development and subsequent implementation of the targeted technology in the classroom (Table 2). The most common benefit of these out-of-school experiences cited by both PIs and teachers was the opportunity to practice and improve skills with the technology and related curricular materials outside the constraints of the classroom. Other frequently mentioned

advantages were that they set the stage for teachers to move towards student-centered teaching; they increased teachers' confidence using the targeted technology and curricular materials; and they gave teachers a better understanding of how teenagers interact with technology and how these interactions differ from their own struggles. Some PIs and teachers also cited the opportunity to learn with and from other teachers, to teach immediately after learning, and to take advantage of youth participants' familiarity with new technologies, as well as their feedback on new curricular materials. These are described in more detail in the next sections.

Table 2: Perspectives of interviewed PIs and teacher participants on whether inclusion of the youth institute was a critical component of the teacher professional development design. PIs' responses were open-ended and thus resulted in an intermediate response. Teachers were limited to "yes" or "no."

Inclusion of youth institute in the teacher professional development	Percentage and number of interviewed ITEST PIs (n=31)	% of surveyed ITEST teachers (n=219)
Critical element	74%	62%
Possibly a critical element	19%	--
Not a critical element	10%	38%

Practice

PIs and teachers highlighted the benefits of having time to explore possible problems, challenges and questions that might occur in the classroom and to reflect on their teaching without constraints of the classroom environment and with all the needed resources and support. As several PIs explained:

- *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.*
- *There is this learning curve that requires practice, and I think giving the teachers that whole week of being out there and practicing was really critical. They wouldn't find the time on their own to really work on this kind of stuff. So once they were up-to-speed, it was easier for them to do something in their classrooms.*
- *It gives you a chance to play, and you 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.*

Teachers also highlighted these benefits of practicing outside of the classroom, reporting for example:

- *It helped us to understand what activities would work best with students and which may need some adaptation for classroom implementation.*

- *These interactions with students outside the classroom before I implemented the program helped me to see the possible problems and difficulties I might encounter and made me think of possible solutions.*
- *Being able to interact with the youth and to observe them working with the technology was very helpful in understanding how to approach the lessons in my own classroom. It also gave me insight into where my weak points were as far as the technology and teaching the technology. Once I got back into the classroom, it was much easier to integrate the technology into my lessons.*

Student-centered teaching

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. This focus is not surprising given the dominance of the mentor role. As suggested above, PIs described the youth institutes as providing teachers a safe supportive environment and the time to practice and reflect on pedagogical approaches that had youth (in the institute) and students (in the classroom) work with technology in ways that are similar to professional technology applications (inquiry, problem-based learning):

- *It was really [helpful] to practice the skills of being a good mentor because the good mentor's job is to really help their research team shine, and not be a provider of information all the time, provider of answers.*
- *If a teacher is used to teaching a certain way, and … you have them do something different, teach differently or to teach new material, you need to practice in a more comfortable setting.*
- *If you just throw them back in the classroom…they will fall back on much more didactic methods…[T]eachers are [under] tremendous pressure, and they are less likely to adapt methods like inquiry-based unless they really recognize in another format, the summer experience for instance, that they do work and the students do learn better by these mechanisms.*

Teachers echoed this, as these two comments revealed:

- *Working with the students gave me insight on how students thought about certain tasks and how to present problem-based learning to the students.*
- *The out-of-school experience demonstrated to me the amount of direct instruction that would be needed versus the amount of time to allow the students to be self-directed.*

This approach also relieved teachers of the pressure of trying to be the experts of everything. This was particularly important for these ITEST projects because teachers typically did not have extensive knowledge of the targeted professional technologies. As described by one PI,

> *One of the hurdles that we did deal with was teacher thinking that "when it comes to a technical competence, I must possess all of the technical competence*

or I can do nothing with it." And, here is yet another way to demonstrate in these mentoring activities that you don't have all the technical competence, and frankly you are not about to have all the technical competence.

PIs encouraged this shift in teaching practices through discussions, reflections and firsthand experiences during the youth institutions. However, PIs were quite aware that such changes in teaching practices take time, as described by this project leader,

We hope that they are going to…completely embrace [an] inquiry-based…problem-based approach. But again, we know from the research that…it often takes more than five years for teachers to become comfortable with these kinds of new pedagogies.

Confidence

PIs regularly pointed out how essential the out-of-school experiences were to boosting teachers' confidence with the new technologies and teaching approaches:

- *They needed almost literally physical handholding to get through some of their initial fears about trying this new stuff. And, some of those people ended up being my top teachers as part of the project. But, it was really not something they were going to do on their own, and I think having the face-to-face [youth] experience was crucial for that.*
- *All of those things were brand new, and in some cases quite challenging. So, this was creating a sense of…confidence in the teachers that they could effectively do this back with a larger group of students.*

Teachers agreed that the out-of-school experience gave them a view of how the technology could be implemented and how it would work with the students. Many indicated that it provided evidence that classroom implementation was achievable and thus increased the probability that they would use the ITEST technology and materials in their classrooms:

- *Observing the students working on the projects that would be implemented in the classroom allowed me to determine what they would struggle with, what they would be excited about, and what would surprise them. Thus it gave me a dry run of how this might look in a classroom.*
- *I was amazed to see how well the lessons and activities actually worked with the [institute youth], and how quick most of them were to become comfortable with the software; much more quickly than we as teachers acclimated to the system. The summer project "proved" to me that this was realistic to try with students of all age and ability levels, and also made me more comfortable with my own skills, abilities, and shortcomings.*
- *Working side-by-side with [youth] strengthens [our] investment in the new skills, and makes us more likely to actually use them in school.*

Youth relationship with technology

The youth institute might have been particularly valuable to these technology-intensive teacher professional development efforts because it enhanced teachers' understanding of how students interact with technology and how real-world technology applications

(including gaming) can be used in a learning context. As described by one PI, it was quite valuable to have teachers observe firsthand the level of engagement and greater ease with which teenagers negotiated new technologies:

> *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.*

Teachers echoed this perspective, as these comments illustrate:

- *I know my limitations with technology. These kids are not afraid to lose something or make mistakes with technology. They also have shown me things that the phone or computer can do that I did not know. Kids are also more creative and don't sweat the little things. Many times in game creation they see the big picture and don't sweat how to get there. They just go back and refine how to get to the spot that they want to change.*
- *It generated excitement, made me aware of students' exposure, understanding and familiarity with technology that they make connections with daily. It showed their ease and comfort level with various technologies that is part of their world.*

Other Benefits

In line with the *Partner* and *Student* roles described above, an important benefit of the youth institute was that PIs could take advantage of youth participants' greater comfort with technology to encourage teachers to allow these teenagers to play a more active role in learning and teaching. Indeed, PIs mentioned several instances where youth had to patiently correct the teachers. For example, one PI observed, *Teachers would be struggling a little bit to show a student how to do something and then the students would go, "Oh no, you just do that" [and would] start clicking away.* Youth participants also often played a fundamental role in developing or refining classroom curricular materials and provided important feedback on curriculum and teachers' teaching, as two teachers noted:

- *The students I worked with had been trained in the software and programs that we were going to use to create our forums. They helped me perfect the knowledge I already had and gave me the information that I needed on the topics that I did not know. They also gave input on if my students would enjoy the forum or would have any issues working with it.*
- *It is always valuable to have students provide input in the learning process. Having students work along with us as we completed tasks provided opportunities to evaluate our own teaching styles.*

In some cases, youth from institute also provided feedback and technical help back in the classroom. When this occurred, PIs felt this extension of the partnership was critical to implementation, as this comment indicates:

> *The teachers could actually go to the kids to say "hey, how did that code work or what button am I supposed to press when I am trying to do this map?" And then,*

> *the kids actually went back to the teachers and said "hey, I thought we were going to be doing this, how come we haven't done it in class yet?" So, it made them accountable for implementation during the school year.*

Surveyed teachers agreed about the value of this input back in the classroom. For example, a teacher participant remarked, *Students saw me in a relaxed environment during the summer and had to remind me a few times during the year to stop playing with the robots and allow them to explore "play" with the robots*.

Many interviewed PIs and surveyed teachers also highlighted the value of working with other teachers during the youth institute. These experiences provided the opportunity to observe other teachers, be observed, and reflect on both. Some projects even videotaped the teaching for deeper reflection. Additionally, several PIs and teachers remarked on the value of teaching immediately after learning new content and skill.

Challenges of Youth Institutes

All but two PIs reported that the most of teachers were comfortable teaching and guiding youth in these informal learning environments. PIs suggested problems were infrequent because both their youth and teacher participants were quite motivated and committed to the experience, because they (PIs) sought to fully engage both groups in the learning, and because teachers had all needed resources, including extensive support. There were also likely fewer issues because many of summer experiences were more similar to familiar in-school settings than a true free-choice-learning environment. One notable exception was a project led and hosted by a museum that struggled to integrate classroom teachers with their informal education staff and practices. This PI reported that teaching and learning in a museum environment was foreign to their teacher participants and that they faced significant challenges in involving these teachers in more student-centered learning and in bridging in-school and out-of-school practices.

Additionally, many PIs admitted that they had some teacher participants who did struggle to work with youth in less didactic ways and to allow youth to take responsibility for their own learning. For example, a PI reported,

> *Some [teachers] are very invested in a particular way of doing things, and they are also uncomfortable letting go off their authority, their authority over the content, over the knowledge, over the facts, and the concepts and so on*.

In contrast, several of the surveyed teachers stated that they were not sufficiently prepared for the more student-centered institutes; that there was not sufficient time to explore changes in their teaching practices; or that were simply too many teachers for the number of youth participants.

Additionally, several PIs and teachers reported difficulty translating the out-of-school experience to in-school teaching. As noted, the summer youth were often more motivated than typical classroom students, and extensive technology and teaching resources were available during the institution that are often lacking in the classroom

(e.g., extensive bandwidth, regular technology support, absence of firewalls). In other words, the youth institutes effectively provided a safe and supportive environment to try out new teaching styles but once back in the classroom, teachers had to contend with numerous challenges. As one PI described it, *they have got the PA going off, they have got like a thousand things going on, they can't get access to computers, [and] they have thirty plus students that they are working with*.

In part because of this disconnect, about a quarter of interviewed PIs and a third of surveyed teachers felt the youth institute were not critical to their technology-intense professional development. According to one PI,

> *It is a very artificial environment … although there is great value in teachers being able to practice with any group of students, I think there is some question as to how applicable it would be for their own classrooms just because of the artificial nature of it.*

A few PIs and teachers felt the youth institutes simply were not necessary and that the project staff addressed the essential elements. As one PI noted,

> *About a third of our teachers were really good. And, all that really mattered to them was bringing this new knowledge into them. …Once they had that new knowledge, they were perfectly capable of adapting that to their classroom on their own, and they were then fine because they were excellent teachers.*

DISCUSSION

These findings provide additional evidence of the value of integrating informal education experiences into classroom teachers' professional development, despite the significant cost and time associated with this. Both ITEST project leaders and teacher participants felt these experiences were critical to their training. They pointed to many benefits including opportunities to practice-teach; reflect on teaching and gain confidence without typical constraints of the classroom; develop a deeper understanding of students' relationship with technology; and try out more student-centered approaches. Saxman et al. (2010) also found out-of-school interactions with informal audiences enhanced their participants' confidence, as well as improved their understanding of scientific inquiry. These authors identified similar key aspects of these interactions including time for reflection and discussion about teaching practices.

Our findings align with a recent report from the Center for the Advancement of Informal Science Education that stated informal education environments offer distinct affordances such as low-stakes settings, collaborative learning, group- and learner-directed activities, and opportunities for sustained relationships and on-going professional development (Bevan et al. 2010). Likewise, Luehmann (2007) described how out-of-school experiences provide opportunities for teachers to try out inquiry-based instructional strategies with small groups of students, with support from peers and mentors, with less academic accountability, and with fewer institutional hurdles. She suggested these experiences are necessary to support reform-minded teachers who focus on students' science understanding and application rather than simply the

acquisition of information. Liberman (1995) also emphasized the value of out-of-school environments for teacher professional development, stating that, *If reform plans are to be made operational–thus enabling teachers to really change the way they work–then teachers must have opportunities to discuss, think about, try out and hone new practices*.

As indicated by the focus on student-centered teaching and mentor/partner roles, ITEST projects sought to have teachers work with applications of technology in ways that parallel professional STEM use. Most teachers lack firsthand experiences with scientific inquiry, and out-of-school interactions with youth provide a useful way to promote teachers' understanding of and skill with authentic science practices. These interactions provide opportunities to mentor students pursuing authentic questions and issues with a real purpose and using scientific tools in appropriate ways (Bevan et al. 2001). They also parallel real-world STEM practices in that they promote collaborative work, drawing on different team members' expertise (Stylinski et al. 2011). This collaborative work can also help deepen teachers' understanding of scientific inquiry, as well as support success with reform-based practices (Luehmann 2007). For technology-intense professional development, it is particularly effective to expand these collaborations to youth participants who may have greater comfort, although not necessarily greater expertise, with learning new technologies. Indeed, as our findings suggest, integration of informal education experiences into teacher education can dramatically shift the relationship that teachers have with students, working at times with them as equal team members and thus further supporting inquiry-based teaching.

However, our study also points to several challenges associated with integrating out-of-school experiences into classroom-teacher professional development. The most significant is forming a clear bridge between learning and teaching in out-of-school and in-school environments to ensure to the transfer of more student-center pedagogical practices to the classroom. One strategy might be to apply more formal approaches to the more flexible out-of-school settings. For example, Saxman et al. (2010) found it quite useful to structure their out-of-school interactions around the 7E instructional model that is often used in K-12 curriculum.

Overall, more research is needed on informal-formal collaborations (Bevan et al. 2001). In particular, we need to understand strategies that are most effective in helping teachers transfer informal education practices to in-school teaching. Additional studies are also needed on outcomes that are achieved when integrating these experiences into teacher professional development, including how this changes teaching practices. We are continuing to explore this in our larger study as we examine teachers' classroom practices and use of technology stemming from their ITEST professional development experiences.

References

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.

Bevan, B. with Dillon, J., Hein, G.E., Macdonald, M., Michalchik, V., Miller, D., Root, D., Rudder, L., Xanthoudaki, M., & Yoon, S. (2010) *Making Science Matter: Collaborations Between Informal Science Education Organizations and Schools. A CAISE Inquiry Group Report*. Washington, D.C.

Dexter, S. L., Anderson, R. E., & Becker, H. J. (1999). Teachers' views of computers as catalysts for changes in their teaching practice. *Journal of Research on Computing in Education, 31*(3), 221.

Falk, J. H., Storksdieck, M., & Dierking, L. D. (2007). Investigating public science interest and understanding: evidence for the importance of free-choice learning. *Public Understanding of Science, 16*(4), 455-469.

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.

Liberman, A. (1995) Practices that support teacher development. *Phi Delta Kappan, 76*(8), 591-597.

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

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.

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., & McAuliffe C. (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.

Supovitz J. A. & Turner, H. M. (2000) The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching, 37*(9), 963-980.

Yu, J.-C. & Yang, H.-Y. (2010) Incorporating museum experience into an in-service programme for science and technology teachers in Taiwan. *International Journal of Technology and Design Education 20*, 417-431.