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Designing Technology-Intensive Science, Technology, Math, and Engineering Professional Development: Insights from NSF's ITEST Projects

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Introduction

From 2003 to 2008, the National Science Foundation's (NSF's) Innovative Technology Experiences for Students and Teachers (ITEST) program funded 65 projects that provide technology-intensive science, technology, engineering, and math (STEM) professional development (PD) to teachers. These ITEST projects share many common design features and exhibit characteristics of best practices frequently cited in the literature of professional development (Desimone, Porter, Garet, Yoon, Birman, 2002; Garet, Porter, Desimone, Birman, Yoon, 2001; Loucks-Horsley, Stiles, Mundry, Love, Hewson, 2010; Penuel, Fishman, Yamaguchi, & Gallagher, 2007). Penuel et al. (2007).suggest that PD research needs to focus on a specific PD design, so that deeper questions about teacher change can be explored. We are applying Penuel et al's (2007) recommendation to focus on a specific PD design by using NSF-funded ITEST teacher education projects as our study group. As part of a larger study of ITEST projects and teacher participants, this paper describes the results of a survey with past ITEST project teacher participants, sharing their insights on professional development design and impacts of the professional development on their teaching.

In an important study on effective professional development (PD), Garet, Porter, Desimone, Birman, & Yoon (2001) examined a wide variety of PD programs throughout the United States and identified key components of effective efforts. These include the form and duration of the PD; the degree of collective participation by teachers in the same grade, school, or district; the content focus of the PD; the degree of active learning within the PD; and the coherence of the PD to teachers' professional goals. Through surveys and interviews with Principal Investigators (PIs) who designed these programs, we found that ITEST projects exhibit characteristics of best practice frequently cited in the literature of professional development and share a common design that has been implemented in unique ways across projects (Desimone et al., 2002; Garet et al., 2001; Loucks-Horsley et al., 2003; Penuel et al., 2007). In this paper we compare ITEST project teacher participants' insights with those obtained from PIs. Thus, our first research question is as follows: 1) *What do ITEST teachers think were the critical aspects of the PD that had an impact on their classroom implementation and how do they compare to critical aspects identified by PIs?*

In addition to examining the overall PD design, we explore two roles teachers experience with respect to curricular materials during professional development. They are 1) *Teacher as Curriculum Developer (CD)* and 2) *Teacher as Pedagogical Expert (PE)*. These two roles are utilized in varying degrees in all teacher professional development programs. While few programs may employ one role exclusively, there is typically a dominant focus that the professional development provider intends for the program.

When placed in the role of *curriculum developer*, teachers learn content, receive pedagogical support, and then develop their own curricular materials for use with students (e.g., Linn, Songer, Lewis, & Stern, 1993; Singer, Krajcik, Marx, & Clay-Chambers, 2000). They often first explore new STEM content and learn new pedagogical strategies that they use to develop their lessons. This approach involves teachers in the design process. That is, it assumes that (1) teachers can most effectively integrate authentic STEM activities into their curriculum when they have instructional materials tailored to their specific classroom requirements and needs; (2) teachers will develop a deeper understanding of content and student learning goals when they are directly involved in the design process; and (3) teacher-directed curriculum design can increase the likelihood of implementation and of changes in teacher practices (Barab & Luehmann, 2003).

When placed in the role of *pedagogical expert*, teachers learn to use provided curricular materials and/or adapt the materials for use with students (e.g., Lotter, Harwood, & Bonner, 2006; Wiggins & McTighe, 2005). During the professional development, they work through the provided instructional materials, reflecting on the content, and develop plans to adapt and implement these materials into their existing curriculum. This approach builds on pedagogical content knowledge (Shulman, 1987) as well as from the *aligning and implementing curriculum* strategy in Loucks-Horsley et al. (2003) and includes the assumptions that (1) teachers need existing high-quality STEM instructional materials to integrate authentic STEM experiences into their curriculum; (2) learning, discussing and reflecting on these materials can improve teachers' understanding of the content and of how to best to use these materials in their classrooms; and (3) professional development focused on these high-quality existing materials can increase the likelihood of changes in teaching practice (Penuel, McWilliams, McAuliffe, Benbow, Mably, & Hayden, 2009). Thus our second and third research questions are as follows: 2) *How do ITEST teachers describe their role with respect to the curricular materials and how does this compare to PI descriptions?* and 3) *How do teachers in the curriculum developer role differ in their classroom technology implementation compared to teachers in the pedagogical expert role, in terms of continuous and ongoing implementation?*

Methods

Sample and Data Collection

In this paper, we report the results from a survey of teachers who participated in ITEST professional development projects, inquiring into their professional background, classroom practices, teaching philosophy, ITEST professional development experience, and resulting classroom implementation. Our survey instrument contained both selected response and open response questions, which we analyzed quantitatively and qualitatively. We also compare participating teacher responses with those obtained from PIs who designed the projects (Stylinski, Parker, & McAuliffe, 2011).

To obtain our sample of ITEST teachers, we contacted ITEST PIs, asking them to inform their participants about our survey. Teachers completing the survey were compensated for their time. The results from our study are limited by these constraints: 1) our sample is voluntary and not random (we had to rely on PIs to contact teachers from their ITEST projects; some PIs did not inform their teachers of our survey); and 2) the data from teachers are self-report data.[1] Of the 259 teachers who completed the survey, 231 said that they used the ITEST materials in their classroom implementation.

Survey respondents had teaching experience ranging from 1 to 42 years, with an average of 14 years, and included beginning, mid-level career, and experienced teachers (Table 1). Thirty-six percent had taught for more than 15 years.

Table 1: Years of teaching experience

Number of Years	Frequency	Percent
0 to 5 years	41	15.83
6 to 10 years	72	27.80
11 to 15 years	53	20.46
more than 15 years	93	35.91
Total	259	100

Sixty-eight percent of the teachers had earned a Master's degree. 66% of respondents were female; 34% male. The majority of respondents (89%) last participated in ITEST professional development from one to three years ago, with the remaining having participated anywhere from four to eight years ago.

Data

To answer the third research question, *How do teachers in the curriculum developer role differ in their classroom technology implementation compared to teachers in the pedagogical expert role, in terms of continuous and ongoing implementation?,* we used the following teacher survey results: years teaching and years since participating in ITEST PD, the content area of ITEST implementation, the technology applications used in ITEST implementation, and teaching philosophy and professional practices. Teachers identified the content area of ITEST implementation from a list of STEM and other content areas and they identified the technology applications used from a list developed based on applications used in ITEST PD projects. Teachers were also asked questions about their teaching philosophy, their pedagogical practices, and their professional practices.

Differences in classroom practices were measured by responses to two questions**.** The first outcome, "continuous implementation," was built from responses to this question: *In which of the following years did you implement the innovative application of technology?* Teachers were asked to check off each year since participation that they had implemented; those who checked off every possible year were coded as "implemented all possible years" and those who did not check off every possible year were coded as "did not implement all possible years," (Table 2). shows the distribution of responses.

Table 2. Implemented all possible years

	Frequency	Percent
Did not implement all possible years	48	20.8
Did implement all possible years	183	79.2

[1] Another phase of our research involves a comparison study of non-ITEST and ITEST teachers, examining classroom artifacts and additional evidence beyond self-report data.

Total	231	100.0

For the second outcome, "ongoing implementation," teachers were asked to answer yes or no to the following question: *In some way, are you currently implementing what you learned during the ITEST professional development experience?* Table 3 shows the distribution of responses.

Table 3. In some way, are you currently implementing what you learned during the ITEST professional development experience?

	Frequency	Percent
No	31	13.4
Yes	200	86.6
Total	231	100.0

Data Analysis

To address our first two questions, 1) *What do ITEST teachers think were the critical aspects of the PD that had an impact on their classroom implementation and how do they compare to critical aspects identified by PIs?* and 2) *How do ITEST teachers describe their role with respect to the curricular materials and how does this compare to PI descriptions?*, we used descriptive statistics and qualitative methods to analyze the open response questions.

To address the third research, 3) *How do teachers in the curriculum user role differ in their classroom technology implementation compared to teachers in the developer role, in terms of continuous and ongoing implementation?,* we used logistic hierarchical linear modeling to account for the nesting of teachers in ITEST projects.

Setting the Context: The Unique Design of ITEST projects

ITEST projects share many common design features and exhibit characteristics of best practices frequently cited in the literature of professional development. Through surveys and interviews with Principal Investigators (PIs) who designed these programs, we found that ITEST projects also emphasize other unique aspects, such as authenticity (e.g. processes or resources that link experiences or materials to real-world content, context, or activities) and significant participant collaboration (with STEM professionals, peers, and project staff) (Stylinski, et al., 2011). ITEST projects offer long-term (more than 120 hours) professional development, involve students in the professional development experience, and expose participants to *emerging* technologies used by practicing STEM professionals. *Emerging* technologies are technologies that are not widely used in educational contexts such as STEM workplace technologies including geographic information systems, computer modeling programs, and bioinformatics applications. In contrast, *ubiquitous* technologies*,* such as word processing, are commonplace in educational contexts (Cox & Graham 2009). We have also identified an additional category, instructional technologies, that are unique to educational settings. They are specifically designed for use in instruction, such as gradebook programs, assessment programs, and online course management software (Parker, Bonney, Schamberg, Stylinski, & McAuliffe, 2013).

Table 4: Unique design features of ITEST projects

Prepared teachers to use STEM workplace technologies (e.g. emerging technologies in the classroom)
Emphasized authenticity (e.g. processes or resources that link experiences or materials to real-world content, context, or activities)
Involved significant participant collaboration (with STEM professionals, peers, and project staff)
Provided a minimum of 120 hours of professional development, supporting teachers from initial training through classroom implementation
Involved youth in the professional development

Setting the Context: ITEST Survey Respondents

Teachers responding to our ITEST survey sought out professional development opportunities and regularly communicated with their peers about how to teach particular concepts to students. Twenty-six percent of respondents participated in a class, workshop, conference, or webinar with teachers at other schools more than 5 times per year. Thirty-three percent of respondents discussed how to teach a particular concept to a class with teachers at their school several times a year. Our respondents are specifically looking for opportunities to learn about emerging technologies that can enhance their STEM teaching.

ITEST Implementation Practices

In this section, we describe the implementation practices of survey respondents, including rate of implementation, average duration, the emerging technologies implemented, and the content areas in which teachers implemented. Eight-nine percent (231 of 259) of survey respondents indicated that they implemented with students the emerging technology application they learned during their ITEST PD experience.

Table 5: Implementation rate of emerging technology during or after ITEST PD

	Frequency	Percent
Did not implement	28	10.8
Implemented at least once	231	89.2
Total	259	100.0

The percentage of teachers still implementing (94%) was highest in the year after respondents participated in ITEST PD, dropping off each subsequent year. Despite this drop in implementation rates, 87% of survey respondents are currently implementing some aspect of what they learned during their ITEST professional development experience (See Table 3 in the Data section). The most common length of implementation was one to two weeks per year.

Table 6: Average duration of implementation

	Frequency	Percent
Less than 1 week class periods/year	27	11.7
1-2 weeks of class periods/year	78	33.8
3-4 weeks of class periods/year	51	22.1
5-9 weeks of class periods/year	38	16.5
More than 9 weeks class periods/year	37	16.0
Total	231	100.0

Survey respondents most frequently implemented communication tools. We defined communication as using software to share ideas and work with others remotely, such as with wiki's, discussion boards, and web conferences. However, although we included this category in our implementation choices, we consider communication technologies to be *ubiquitous*, rather than *emerging* in classroom settings. So, the top two emerging technologies implemented were numerical data analysis applications and modeling/simulation tools. We defined numerical data analysis as using software to analyze mathematical patterns and relationships, such as with spreadsheets and bioinformatics software. We defined modeling and simulation as using software to represent and manipulate objects, concepts, or systems, such as with Stella or Inspiration software. Gaming tools were implemented the least.

Table 7: Technology tools used (n=231)

	Frequency	Percent
Spatial Data Analysis Tools	82	35.5
Image Data Analysis Tools	76	32.9
Numerical Data Analysis Tools	88	38.1
Field Data Collection Tools	73	31.6
Engineering Design Software Tools	30	13.0
Digital Design Tools	83	35.9
Modeling and Simulation Tools	85	36.8
Programming Tools	53	22.9
Gaming Tools	31	13.4
Virtual Reality Tools	46	19.9
Communication Tools	101	43.7

Classroom implementation of emerging technologies occurred most often in grades 7 and 11 and most frequently in the life sciences.

Two of the subjects taught by teachers (Engineering/Technology and Physical Science/Physics) had statistically significant differences in the duration of ITEST class implementation. While 16% of all teachers implemented for more than nine weeks per year, 28.8% of Engineering/Technology teachers and 27.1% of Physical Science/Physics teachers implemented for more than nine weeks.

Table 8: Percentage of teachers implementing in each content area by duration of ITEST implementation

	Less than 1 week of class periods/year	1-2 weeks of class periods/year	3-4 weeks of class periods/year	5-9 weeks of class periods/year	More than 9 weeks of class periods/year
Life Science/Biology (n=85)	10.6	41.2	17.6	12.9	17.6
Earth/Space Science (n=45)	11.1	33.3	31.1	11.1	13.3
Environmental Science (n=48)	14.6	31.3	25.0	12.5	16.7
Chemistry (n=34)	5.9	23.5	29.4	20.6	20.6
Physical Science/Physics (n=48)**	0	27.1	25.0	20.8	27.1
General Science (n=55)	10.9	27.3	20.0	20.0	21.8
Engineering/Technology (n=66)**	7.6	22.7	19.7	21.2	28.8
Mathematics (n=40)	15.0	32.5	12.5	20.0	20.0
Total (n=231)	11.7	33.8	22.1	16.5	16.0

**chi-square<.001

Findings: Critical Aspects of ITEST Project Design and Impacts on Classroom Implementation

Critical Aspects of ITEST Professional Development as Perceived by Teacher Participants

On a scale ranging from very poor to very good, 75% of ITEST survey respondents rated their professional development experience as very good. When asked to think about their ITEST PD experience (e.g. activities, technologies, interactions), respondents reported the most critical aspects of their ITEST PD to be: 1) learning about the emerging technology itself, 2) learning a pedagogical strategy, 3) collaborating with others (e.g. teachers, STEM professionals, project staff), 4) engaging in authentic activities with respect to science and engineering practices, 5) active/hands-on learning strategies, and 6) the opportunity to practice and plan for classroom implementation. These aspects are consistent with those identified by ITEST project PIs we surveyed and interviewed as well as with best practices frequently cited in the literature of effective professional development (Desimone et al., 2002; Garet et al., 2001; Loucks-Horsley et al., 2003; Penuel et al., 2007). When asked to identify the primary emphasis of their ITEST PD, 62% of PIs surveyed chose technology skills over STEM content knowledge or pedagogical strategies. 22% of PIs chose pedagogical strategies while only 16% chose STEM content knowledge as the primary emphasis of their ITEST PD. Authenticity and collaboration were two critical aspects identified by PIs, aligned with 3) and 4) above (Stylinski, et al., 2011).

Perceived Impact of the ITEST Professional Development Experience on Implementation

The top three ITEST professional development elements that respondents rated as most important to their ability to implement emerging technologies with students were: 1) skilled and supportive project staff (61%), 2) use of high quality materials during training (57%), and 3) opportunities to practice new skills (48%). Respondents also indicated that ITEST professional development had the greatest positive impact on 1) their confidence using emerging technologies with students; 2) their own skill level with using these technologies; and 3) the frequency with which they use emerging technologies with students.

Perceived Value of the Student Involvement During the Professional Development
As part of NSF's solicitation, ITEST projects were required to involve students in the professional development experience. Some projects held summer camps in which teachers mentored students. Others recreated typical classroom settings with teachers using students to try out activities. In other projects, students and teachers worked together in a field setting, collaborating on data collection and analysis. Sixty-three percent of respondents indicated that this out-of-school experience with youth was critical to helping them implement emerging technology applications in the classroom. Similarly, 79% of interviewed PIs said the involvement of youth was a critical part of their professional development design (Stylinski, Parker, & McAuliffe, 2012).

Evidence of Authenticity as a Key Component of Successful ITEST Implementation
In an open-ended response question on our survey, we asked teachers to describe their most effective classroom implementation using the emerging technology of their ITEST professional development experience. We received a range of descriptions; from STEM content-focused implementations supporting subject-area content standards to technology skill-focused implementations emphasizing student-centered learning to highly authentic implementations aligned with STEM inquiry practices. In addition, technology use varied across implementations, with some focused on *emerging* technologies, others focused on *ubiquitous* technologies, and others focused on *instructional* technologies.

For example, one STEM content-focused implementation included using the bioinformatics software to show evolutionary relationships between organisms based on DNA sequence identities. In another, students looked at elodea via probeware to see organelles and investigate membrane response to salt water and distilled water followed by digitally presenting the function of the organelle to which they had been assigned. In another STEM content-based example, students used Alice software to create a 3-D World where they demonstrated their understanding of science concepts. Specifically, they created a training video for sky divers explaining how Newton's Three Laws of Motion are used in skydiving. Other implementations included having students use PowerPoint or other digital presentation software programs to present key science concepts, such as locations of earthquakes and volcanoes and their relationship to plate boundaries. Sometimes a pedagogical strategy was mentioned.

Technology skill-focused implementations were student-centered, but not necessarily STEM content-based or aligned with inquiry practices. For example in the following teacher's implementation description, the focus is on the students learning how to use the GPS tool. The teacher wrote, "With regard to GPS the students did not collect data, rather they entered coordinates to set waypoints which they later used to find hidden objects along a preset route." This next implementation includes learning both GPS and GIS, but does not get to the level of data analysis. The teacher describes, "With a group of students, we visited a buffalo pound site near a few miles out of town. We brought GPS units and marked the location of the items that we found (buffalo bones, teeth and pottery.) After that, we downloaded that data from the GPS units and used the ArcView GIS software to create maps showing the location of the objects. Each student created their own individual map showing the location and type of object found at each location."

Highly authentic implementations align with STEM inquiry practices. For example, one teacher described having students analyze and submit DNA sequences to the National Center for Biotechnology Information (NCBI) database. Another teacher had students use software to model biological molecules and examine the structural differences resulting from genetic mutations. In another implementation, students used a bioinformatics program to analyze sequences from the organism Wolffia australiana, a photosynthetically active duckweed, ultimately putting together a poster which was then presented at a science symposium. Some of these implementations were field-based. For example, in one teacher's class, in response to rising Lyme disease concerns, students developed, organized, and ran a deer population survey on their island community at the request of the local Health Center. They mapped out 3000 randomly generated plot points along 37.5 miles of transects, taught local community members field techniques, and spent a week counting deer pellets. The data was entered into spreadsheets and visually and statistically analyzed to reveal very high local deer populations. In another class, students were taken on field trips to Yosemite where they collected water quality data and macroinvertebrate surveys along the Merced River throughout the watershed. They GPS'd all the locations, used PASCO probeware, water test kits, and digital microscopes to photograph macroinvertebrates. When they returned to school, students made spreadsheets of the class data and uploaded it into a GIS they created, linking the data to each location they visited. Some of the students entered data from past years into spreadsheets so they could be uploaded into the GIS for comparison through seasons and years. We describe these implementations as authentic uses of classroom technology because they: 1) align with the process and nature of STEM inquiry, 2) use pedagogical approaches encouraging student-centered learning, and 3) are relevant to students in terms of having a focus on real-world problems (Parker et al., 2013).

Findings: Curriculum Developers vs. Pedagogical Experts

Teacher Insights

In addition to examining the overall PD design, we also asked teachers about their role with respect to the curricular materials during professional development; they may have been placed in the role of either *curriculum developer* (CD) – where they learn content, receive pedagogical support, and then develop their own curricular materials for use with students or in the role of *pedagogical expert* (PE) – where they learn to use provided curricular materials and/or adapt the materials for use with students. With regard to these roles, 26% of respondents said they were placed in the role of curriculum developer, while 74% said they were placed in the role of pedagogical expert. Teachers in both roles indicated that their content knowledge and technology skills were enhanced, but technology skills were enhanced more for the curriculum developer role while content knowledge was enhanced more for the pedagogical expert role.

Principal Investigator Insights

When asked to select a dominant role that teachers were placed in during the professional development (limited to two choices), about half of surveyed PIs said they had teachers use/adapt provided curriculum materials (53%) and half said they had teachers develop their own curricular materials (47%). 86% agreed that this role was a critical part of their professional development. From the survey's open-response items and the interviews, we did find some variations in reasons for placing teachers in one of these two teacher roles. Specifically, PIs who have teachers adopt/adapt provided curricular materials tended to emphasize that teachers lack the necessary expertise (particularly technical), while PIs who have teachers develop their own curricular materials tended to emphasize that teachers bring the needed expertise (particularly pedagogical skills); make necessary social/environmental connections to the local community; and are more invested in the materials. Both sets of PIs felt their approach provided opportunities for teachers to make necessary classroom connections and to construct new understanding. For a number of projects, there was no clear division between the two roles. For example, some PIs with "developer" teachers provide model curricula as a starting point for creating new materials, while some PIs with "adopter/adapter" teachers helped participants make extensive adaptations to the provided curricula or gave them the option to develop their own materials (Stylinski et al., 2011).

Teacher Role and Implementation Practices

In earlier research focused on the PI survey (not reported here), we found that, while PIs did identify one role or the other, their descriptions of their projects and theoretical frameworks did not cluster around one or the other teacher role (Stylinski et al., 2011). Instead, the analysis found the five unique design features common to ITEST projects (of both roles) described above in Table 5. While we did not find significant differences between those ITEST projects which emphasized one or the other teacher role, we conducted similar analyses with the teacher survey data in order to see if the findings were similar or different. We used logistic hierarchical linear modeling of the teacher data to compare differences in classroom implementation between curriculum developers and pedagogical experts. As described earlier, we used two outcome variables to operationalize implementation. We discuss each in turn.

The first model looked at the probability that teachers used ITEST materials in all years since participating in ITEST professional development. The dichotomous outcome was modeled using logistic regression. When the covariates were added to the model, three covariates were retained (Table 9): the teacher's most recent participation in ITEST professional development, the professional practice of reading literature and attending conferences, and the use of field data collection tools. Teacher role was not a significant predictor of whether or not teachers used ITEST materials in all years since participating in the ITEST PD.

While the first model looked at the probability that teachers implemented the innovative application of technology, the second model looked at the more general question of whether the teacher was currently implementing "what was learned." As with the first set of models, the dichotomous outcome was modeled using logistic regression, and the results are discussed in terms of probabilities (Table 10). Teacher role was a significant predictor of whether or not teachers were currently implementing what was learned in ITEST. Teachers who said they were in the adapter role were more likely to be currently implementing what was used in the ITEST PD, holding all other variables in the model constant, than were teachers who said they were in the developer role. Four covariates were retained in the model: most recent participation in ITEST professional development, and three technology application tools: data analysis, virtual reality, and communication.

Table 9: Logistic Regression of Teacher Role on Implementation Practices

	Implemented ITEST all possible years	Currently using some aspect of ITEST PD
	Coeff (s.e.)	Coeff (s.e.)
Intercept	-0.450 (.69)	1.410 (.61)*
Covariates		
TEACHER CHARACTERISTICS		
Most recent participation in ITEST PD	2.49 (.38)***	1.611 (.36)***
TEACHING PHILOSOPHY		
Reads literature and attends conferences	.456 (.20)*	
TECHNOLOGY APPLICATIONS USED		
Spatial Data Analysis Tools		1.264 (.51)*
Field Data Collection Tools	1.153 (.39)**	
Virtual Reality Tools		-1.017 (.44)*
Communication Tools		.800 (.24)**
Predictor Variables		
Teacher role curriculum developer	0.108 (.41)	-.687 (.31)*

Conclusion

In most classrooms, technology implementation continues to occur primarily with *ubiquitous* technologies. For example, in a review of United States schools' technology use, Gray et al. (2010) reported that the most common computer-related classroom activities were word processing, spreadsheets, graphing, presentations, Internet searches, and student record management. However, in order to engage and prepare the next generation of STEM professionals, teachers and students need to use technology in authentic ways that mirror science and engineering practices (Committee on Conceptual Framework for the New K-12 Science Education Standards, 2012). Furthermore, these authentic uses align with the 21st century skills framework (Partnership for 21st Century Skills, 2009) and help classroom teaching move from more teacher-centered to more student-centered approaches (Chen, 2010; Hsu, 2008; Lu, 2007).

This study shows that long-term, technology-intensive, STEM professional development is effective and has long-lasting impacts. Eighty-nine percent of ITEST survey respondents implemented with students the emerging technology application they learned during their ITEST PD experience. This implementation rate provides strong evidence of the successful design of ITEST projects. Although, the percentage of teachers still implementing dropped off each subsequent year after respondents participated in ITEST PD, 87% of survey respondents are currently implementing some aspect of what they learned during their ITEST professional development experience.

ITEST professional development experiences are thoughtfully designed and executed, resulting in high participant satisfaction, with seventy-five percent of survey respondents rating their overall PD experience as very good. There is a consistency and alignment with the critical aspects of ITEST professional development as described by participating teachers and by PIs. These aspects also parallel those cited in the literature of effective professional development (Desimone et al., 2002; Garet et al., 2001; Loucks-Horsley et al., 2003; Penuel et al., 2007). Skilled and supportive PD staff was the top element rated by survey respondents as most important to their ability to implement emerging technologies with students. Both teachers and PIs felt involving youth in the PD was another essential element critical to helping them implement (Stylinski, et al. 2012).

There is a wide range of approaches that teachers use when implementing emerging technologies into the classroom. These approaches are not mutually exclusive and do overlap. However, we did identify some patterns of implementation. These include teachers whose implementations were STEM-content focused. In these situations teachers used the emerging technology to support the teaching of specific science content, typically directly aligned with science standards. What sets these implementations apart from others is that while students may investigate relationships between variables, the outcome is already known. Chinn and Malhotra (2001) define *authentic scientific inquiry* as the "research that scientists actually carry out." They describe this process as complex and engaging scientists in a different set of cognitive processes than typically takes place with students in classrooms. Chinn and Malhotra (2001) found that what takes place in classrooms are simple experiments, usually investigating one or two variables and often with a known outcome. STEM-content focused implementations included simple experiments as well as "demonstration of understanding" activities where students presented science concepts, such as Newton's Laws, often in creative ways. Another implementation pattern we observed was the technology skill-focused implementation, where the emphasis was on learning technology for technology's sake. These might be fun and motivating, but for the most part, lacked the aspects of scientific inquiry that typify even simple experiments. Last, some teachers' implementations contain elements of *authentic scientific inquiry* as defined by Chinn and Malhotra (2001). These implementations provided students with the opportunity to engage in the practice of science. We are currently developing a framework to place these implementations into a broader context as a way to describe and categorize teacher implementation of technology applications (Parker, Bonney, Schamberg, Stylinski, & McAuliffe, 2013).

Additionally, our findings suggest that the pedagogical approaches typical of a subject matter may influence the length of the implementation of emerging technologies. For example, two of the subjects taught by teachers (Engineering/Technology and Physical Science/Physics) had statistically significant differences in the duration of ITEST class implementation. In both of these subject areas, there is a long history of teachers facilitating inquiry-based, authentic experiences with students. For example, the modeling approach to physics instruction has transformed physics education over the years by organizing course content via a small number of scientific models, engaging students in collaboratively using and constructing models, and involving computers for data collection and analysis (Hestenes, 1987; Wells, Hestenes, & Swackhamer, 1995). Students in modeling classrooms justify their conclusions, compare models with their peers, and learn to clearly articulate their ideas (Jackson, Dukerich, Hestenes, 2008). Students in modeling classrooms do not engage in small two-week units of instruction. Similarly, most engineering/technology classes are likewise organized around larger extended hands-on projects, such as a six-week robotics unit. Thus, It is not surprising that these implementations might be longer.

While the analysis presented here found that those placed in the *Teacher as Pedagogical Expert* model during their PD were more likely to still be implementing what they learned in their ITEST PD than those in the *Teacher as Curriculum Developer* model, we caution readers that these results should be considered in light of a number of limitations. First, as noted in the findings section, while one set of analyses did find significant differences between the two roles, the other analyses, both those presented here and in earlier research, did not find any significant differences. In addition, the sample size and the distribution of teachers across projects (with many projects having fewer than five teachers participate in the study) should be noted. Finally, the division into two different teacher roles was not necessarily an articulated characteristic of the PD, either by the PIs or the teachers; rather, the researchers sought out evidence of the two roles. Future research should articulate the roles clearly in the PD design and then study the resulting teacher classroom practices.

ITEST professional development is a useful model for investigating STEM professional development. However, more research is needed to tease apart the factors that influence classroom implementation patterns, particularly with respect to emerging technologies. What conditions move teachers toward authentic implementations? In our next phase of our research study, we will more closely examine these aspects of classroom implementation.

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