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Professional Development Integrating Technology: Does Delivery Format Matter?

Abstract

The goal of the two Power of Data (POD) projects was to increase science, technology and math skills through the implementation of project-based learning modules that teach students how to solve problems through data collection and analysis utilizing geospatial technologies. Professional development institutes in two formats were offered to encourage teachers to implement the modules. We compared teacher learning, teacher implementation, and student learning from the two different professional development formats to examine how each format supported teachers to implement the modules, and, ultimately, improve student understanding. Teacher surveys, content and technology assessments, classroom observations, student assessments, and student work samples were analyzed for comparison between a two-week summer institute and monthly meetings held throughout the academic year. Teachers and students from both formats showed improvement in all areas assessed, yet there was not a large effect on student outcomes based on the delivery format between the professional development sessions.

Introduction

A common goal of professional development (PD) is to improve student learning, but there are many mediating factors between teacher experiences during the PD, levels of implementation, and subsequent student learning in the classroom. Technology further complicates implementation due to factors such as teachers' content knowledge, support at the school site, and classroom resources (Mumtaz, 2000; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011). The purpose of this study is to examine how two different PD formats support teachers to implement technology into classrooms to improve student understanding. The assumption is that changes in student understanding are only observed after teachers implement the professional development intervention, so if student understanding is to increase, we must first improve teachers' understanding and skills as needed to change classroom practices.

The two Power of Data (POD) projects sought to increase science, technology, and math skills through learning modules that teach students how to solve problems through data collection and analysis utilizing geospatial technologies. The PD team included geology faculty, science teacher professional developers, geospatial technology experts, evaluators and science education researchers. The focus of the POD PD was to improve teacher pedagogy through the use of ArcGIS software technology, while purposefully alleviating barriers to implementation of new technology. During the PD institutes, time was spent emphasizing student projects related to claims and evidence, data collection, and presentation using geospatial technology. With equivalent information presented and resources afforded to each set of teachers during PD, the question remained: Did the delivery format of the teacher PD institute affect teacher and student program outcomes? To answer this question we compared teacher learning, teacher implementation, and student learning from two different PD formats. One form of the PD was provided through an intensive two-week summer institute (SI), and the other utilized monthly or bimonthly meetings throughout the academic year (AY).

Keywords: professional development, technology, implementation, geospatial technology, project based instruction

POD Professional Development Model

The POD PD model was based on research on best practices in professional development for teachers in which technology is integrated into the classroom instruction (Flick & Bell, 2000; Kerski, 2003; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003; National Research Council [NRC], 2007; Parker, Carlson, & Na'im, 2007; Ringstaff & Kelley, 2002). Research on models of teacher change includes the following variables to account for levels of implementation: teachers' beliefs and attitudes (Lawless & Pellegrino, 2007; Mumtaz, 2000), fears of failure (Lawless & Pellegrino, 2007; Mumtaz, 2000), comfort level (Barnett & Mark, 2010; Lawless & Pellegrino, 2007; Kubitskey, Fishman, & Marx, 2002; Trautmann & MaKinster, 2009), and pedagogical content knowledge (Gess-Newsome, 2002; NRC, 2007). Barriers to implementation are further increased when technology is involved (Cuban, Kirkpatrick, & Peck, 2001; Lawless & Pellegrino, 2007). Additionally, research suggests that the capacity of technology to improve student learning depends more on teacher pedagogy, content knowledge, and instructional goals than the design of the technology itself (Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011). Therefore, the POD PD was developed to support teachers to implement effective pedagogy, alleviate barriers to implementation, and use the technology in the classroom based on the research. Based on the literature review, the following consolidated categories were examined:

1. teacher learning of content, pedagogy, technology, and teacher satisfaction following the professional development;

2. teacher implementation of content and pedagogy presented in the projects;
3. barriers and pathways of this implementation; and
4. student learning.

These categories both informed the design of the POD PD model and the data that were gathered to determine the effectiveness of the PD. Each category will be discussed in terms of the research on the topic and how it was addressed in the POD PD design below.

Teacher Learning

Features of PD that have positive effects on teachers' self-reported knowledge and skills and changes in classroom practice include: active learning, opportunities to collaborate with colleagues, time for metacognitive activities, and alignment with curricula and other professional development experiences (Garet, Porter, Desimone, Birman, & Yoon, 2001; Baylor & Ritchie, 2001; Mumtaz, 2000). Within projects that integrate technology, the greatest influence on teacher practice occurs when teachers participate in professional learning experiences in which they are: 1) provided technology-enhanced teaching materials; 2) required to implement with some freedom to customize the materials to their individual context; and 3) provided time with colleagues to reflect upon the experience. The PD must also provide support so that teachers are able to use evidence of student learning to improve their teaching practices (Gerard, Varma, Corliss, & Linn, 2011; Trautmann & MaKinster, 2009). Additionally, one of the critical factors that determines the effectiveness of a professional learning experience is participant satisfaction (Guskey, 2000). As teachers have an opportunity to build their knowledge of content and skills with technology, their morale increases (Baylor & Ritchie, 2002; Garet et al., 2001). Therefore, the focus of the POD PD design was on teacher learning and satisfaction with the PD to lead to implementation in the classroom.

The PD was designed in a manner to scaffold teacher learning. All teachers who attended received twelve books on the topics of: teaching and learning with geographic information systems (GIS) software, effective science and math pedagogy, formative assessment strategies, and research on teaching and learning. The teachers also received 1) six sets of Vernier LabQuest data collection devices with GPS and soil moisture and temperature measurement capabilities and 2) site licenses for ArcGIS with extensions and Logger Pro software.

During the PD, teachers experienced lessons as learners first, before implementing the lessons in their classrooms. The goal was that they would know what to expect in terms of struggles their students might experience, while increasing their own confidence, content knowledge, and technical skills. Teachers received lessons to implement that could be taught immediately, or that could be modified to better meet their instructional needs. Participants were given time to plan how they would implement these lessons, and were provided an online space where they could discuss implementation, ask questions of each other about difficulties, and share successes. Following the institutes, monthly discussion board questions were posed to the teachers to encourage collaboration amongst participants.

Implementation

Implementation is considered the key step between teacher PD and student learning. Factors that affect implementation include teachers' content knowledge, support at the school site, and classroom resources. When implementing technology-enhanced lessons, the first year is typically spent overcoming barriers, such as issues with hardware and software, suggesting that programs of duration of more than one year are most effective in changing teacher practice (Gerard et al., 2011). Implementation and integration of technology is also influenced by a teacher's openness to change (Baylor & Ritchie, 2002). Activities that focus on specific content, are tied to relevant school reform efforts, promote student-centered teaching, and are aligned to curricula are more likely to be viewed positively by participants as more applicable to their classrooms (Baylor & Ritchie, 2002; Desimone, Porter, Garet, Yoon, & Birman, 2002; Garet et al., 2001; Guskey, 2002). Strong educational technology leaders, such as those that value and utilize technology and include the use of educational technology in school plans, can increase teachers' perceptions of student content acquisition (Baylor & Ritchie, 2002). To address these factors, both PD formats were designed to alleviate fears, reduce costs, provide teachers with planning time, and create support at the school site. PD recruitment efforts focused on two areas: 1) support at the school site; and 2) the teacher's openness to and experience in teaching with technology in the classroom.

Because technology was added on top of the already high demands of new pedagogies involved in student-centered and project-based instruction, barriers to implementation, whether perceived or actual, were anticipated. To mitigate these effects, several supports were in place before, during, and after the PD institutes. To ensure support at the school level, pairs of teachers from the same school were invited to apply, with the preference of one Career and Technical Education (CTE) teacher and one science or math content teacher. The idea was that the CTE teacher might have more confidence with technology and/or project-based instruction, and the content area teacher more confidence with the science or math subject matter. Teachers were asked to confirm basic technology skills such as navigating to files, saving files, and downloading data from the Internet. They were also asked to provide examples of their teaching that included inquiry–based lessons, technology and subject integration, and collaborations with other teachers. Those who had more experience or who had a partner at their school were selected over those with less experience with technology and inquiry-based pedagogy or with no partner.

All accepted participants confirmed they had access to a Windows-based computer lab necessary to run ArcGIS software and other basic system requirements. Additionally, all participants were required to provide a signed memorandum of understanding from their school or district information technology (IT) department representative. The memorandum was crafted by our technology lead and described specific recommendations for the lab. It included details on storing and maintaining data, loading software, and deadlines by which the lab would need to be ready to use. Additionally, PD and technical staff were available to answer questions and assist with software installation and troubleshooting.

Study Overview

A review of research on the effectiveness of technology-integrated and science, technology, engineering, and math (STEM) PD tends to support the notion that context and content within the professional learning experiences are more important than format of the PD activities. However, the majority of these studies are based on teacher self-report rather than student outcomes (Garet et al., 2001; Guskey, 2002; Guskey, 2003; Kennedy, 1998; Mumtaz, 2000). Yet, self-report is not enough if we want to improve student learning in STEM classes following PD. Our focus then was to examine the effect that technology-integrated, project–based learning modules have on the learning of secondary students following PD.

The study design was based on Guskey's (2000) evaluation of teacher PD, which describes "five critical levels of information." In Guskey's model, the emphasis is on teacher learning, implementation, and student learning. The five levels for PD evaluation are:

1. participants' satisfaction,
2. participants' learning,
3. organizational support and change,
4. participants' use of new knowledge and skills, and
5. student learning outcomes.

Each level increases in complexity and influences the success of each higher level. In other words, the first four levels affect the fifth level. The premise is that effective PD (Levels 1 and 2) coupled with administrative support (Level 3) can influence teachers' classroom practices (Level 4) which then change student learning outcomes (Level 5) thereby influencing changes in teachers' beliefs and attitudes (Guskey, 2002).

The original intent of both POD projects was to provide on-going professional learning experiences throughout the academic year (AY) based on research surrounding best practices for professional learning (Darling-Hammond & McLaughlin, 1995; Darling-Hammond & Richardson, 2009). However, due to the constraints of offering PD beyond our local region, an intensive summer workshop was the next best option to serve our out-of-region teachers. With all else being equivalent concerning the information that was presented and the resources afforded to the participants, did the delivery format of the teacher professional development affect teacher and student program outcomes? To answer this question, data were collected on teacher learning, teacher implementation, and student learning from each of the two different professional development formats based on Guskey's model. The study presented here did not use an experimental design. The comparison was between the two PD models. In an effort to more clearly understand the relationship between the professional development and its impact on student learning, data from several sources were collected and analyzed. These included data related to teacher learning and satisfaction following the PD, what was implemented in the classroom and to what level, and, most importantly, measures of student learning. Each will be discussed below.

Study Participants

This study summarizes results from 38 teachers who participated between the two POD PD programs. Teachers in the academic year (AY) program were from schools in one southwestern state, while teachers from summer institute (SI) program were from schools in the entire southwest region. Participant demographics varied to some degree across programs. While both PD formats included teachers at high school (HS) and middle school (MS) levels, the majority of the participants were high school science teachers. Teacher demographic data are shown in Table 1.

From the original 38 teachers, a total of 238 students from 24 teachers' classrooms (16 in SI and 8 in AY) agreed to participate in this study focused on the connection between PD and student outcomes.

Teacher Learning and Satisfaction

At the conclusion of each PD session, teacher participants were asked to complete an online survey, an assessment covering content and spatial reasoning, and a GIS performance assessment. Participant satisfaction was measured with a survey which used a Likert scale with ratings 1-5 as poor, fair, average, very good, and outstanding. All participants from both AY and SI formats ranked the institute as *very good*, score of 4, to *outstanding,* score of 5.

POD project staff developed a content assessment to assess participants' changes in understanding of science content, scientific analysis, and spatial analysis. The specific categories (and number of questions) covered in this assessment were Earth science content (17), general science content (3), data analysis involving charts and/or maps (5), making claims

Table 1: Demographics of Teacher Participants by Percentage

	Summer Institute (SI) (*n* = 23)	Academic Year (AY) (*n* = 15)
Teaching Level		
Middle School	13%	27%
High School	87%	73%
Content Area		
CTE	30%	27%
Mathematics	9%	13%
Science	57%	47%
Social Studies	4%	7%
Special Education	0%	7%
Classroom Demographics		
Native American	2%	31%
Latino/Hispanic	35%	6%
Caucasian/Other	63%	63%

Table 2: Level of GIS Proficiency

Level	Definition
Level 0	Inability to use the map or data to obtain information to answer the question.
Level 1	Able to use the map and/or data to obtain information to answer the question.
Level 2	Able to use the map and/or data to obtain information to answer the question and to create a basic map adding points, lines and polygons to the map to represent geographic features.
Level 3	Able to use the map and/or data to obtain information to answer the question and create a basic map, add points, lines and polygons to the map to represent geographic features and symbolize geographic features based on levels of variability in data across a region (choropleth map).
Level 4	Able to use the map and/or data to obtain information to answer the question and create a basic map, add points, lines and polygons to the map to represent geographic features, symbolize geographic features based on levels of variability in data across a region (choropleth map) and create a layout with a graphic (bar graph or pie chart) and/or include other graphical representations to communicate ideas.

based on evidence from maps produced in ArcGIS software (5), and spatial analysis (10). Pretest data were gathered prior to the implementation of the program and post-test data were gathered at the last meeting of each institute. Mean content scores improved for almost all participants across both programs. A Mann-Whitney U test was conducted to evaluate whether there was a difference in teachers' content understanding between the two programs, as measured by a post program content assessment. The results of the test were not significant, $z = -1.68$, $p = 0.10$; the teachers in both the AY and SI PD learned an equivalent amount of content based on the post-test.

A geospatial performance assessment was administered pre- and post-institute to teacher participants. This assessment measured participants' abilities to use the ArcGIS software. Ability levels were defined from 0 through 4 in terms of proficiency as shown in Table 2.

Participants in both institutes showed growth in GIS skills from pre- to post-institute (Figure 1). Results for the SI participants were higher than those in the AY institute. All participants took the GIS performance assessment on the last day of their respective institute rather than at the same time in the academic year of implementation.

Figure 1

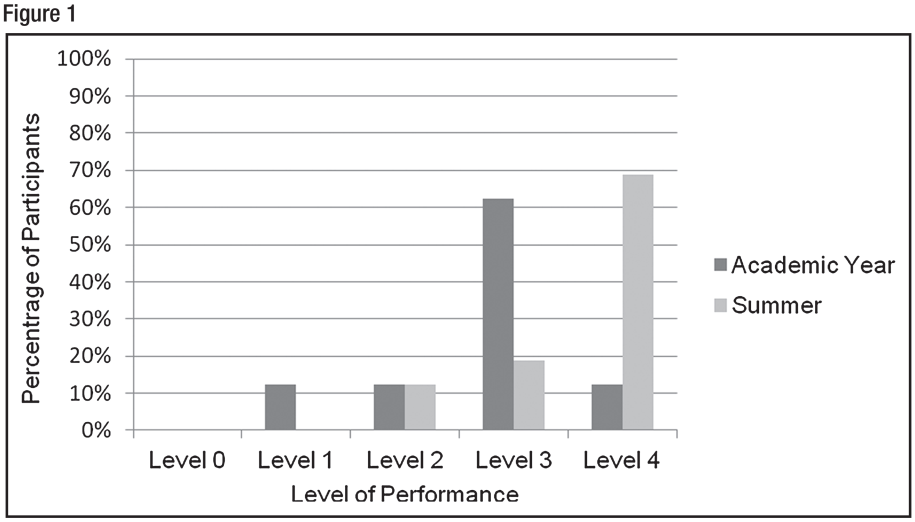

Figure 1: Comparing level of geospatial performance between programs at the end of professional development.

Overall results for both groups are shown in Table 3. The groups are very similar showing high satisfaction and improved learning following the professional development. Without larger numbers of participants in each group to compare, we have general trends but are reluctant to make any stronger claims.

Organizational Support

In order to ensure support for teachers during implementation, recruitment efforts focused on pairs of teachers at the same school site. However, when participants returned to their respective schools, IT and administrator support varied. Data on technology support were collected informally through inquiries, emails, phone calls, discussion board postings, and formally through surveys. Some schools had more support and access than others before they even began implementation, but the problems installing software were similar across the two formats of PD. Regardless, all teachers had the software installed and ready to use within four months of the PD sessions (Table 4).

Implementation

Levels of implementation were measured using multiple data sources and multiple researchers to triangulate patterns and themes (Creswell & Miller, 2000). Data sources included surveys, classroom observations, and collection of classroom artifacts to describe both the quantity and quality of implementation following the POD PD institutes. Because teachers must implement lessons in order for student achievement to improve, data were collected on the level of classroom implementation. All teachers in the study who completed the AY program implemented at least one lesson, while only 81% of the SI participants implemented a lesson.

For those 24 teachers who implemented at least one lesson, results of implementation were further examined to determine which teachers implemented which types of lessons – a lesson out of a book with data provided, a general project designed by POD program staff with data provided, or a project with students collecting their own data. Results

Table 3: Means on Post PD Teacher Questionnaire and Assessments

	Summer Institute (SI) (n = 16)	Academic Year (AY) (n = 8)
Satisfaction with Institute[a]	4.6	4.5
Content Assessment[b]	32.4	29.9
GIS Performance Assessment[c]	3.5	2.8

[a] Based on a 5-Point Scale (1-5)
[b] Based on a 40-Point Scale (1-40)
[c] Based on a 4-Point Scale (1-4)

are reported based on the "highest" level of project implemented by the teacher in their classroom in Table 5. For those teachers who implemented lessons, the lessons were similar in nature when compared across the two PD formats.

To attempt to quantify the quality of implementation, classroom observations were conducted using a modified instrument based on Inside the Classroom Observation and Analytic Protocol (Horizon Research, Inc., 2000). To enable comparisons across projects, common sections of implementation from the protocol were chosen as a focus (Table 6). Observers were looking for evidence of high quality teaching, based on the degree of student-centered teaching as opposed to direct instruction, and the degree to which inquiry was valued and encouraged.

Comparing the means of the observation scores on the six common items (Table 6), the scores are very consistent. The average score of the teachers in the SI was 9.1 and the average score of the teachers in the AY was 10.1.

Student Understanding

The measure of effective teaching is improved student understanding. Measures of student understanding from this study included pre- and post- tests and student artifacts gathered from the teachers following implementation of the units. In both projects, students increased their content understanding over the course of the project, as measured by the 40-question pre-post content assessment. This was the same test administered to their teachers.

For students whose teachers had participated in the SI project, there was a significant increase in achievement from pre-test to post-test, $t(145) = -5.37$, $p < .001$, Cohen's d = .44. In the AY project, there was also a significant increase in achievement from pre-test to post-test, $t(93) = -5.59$, $p < .001$, Cohen's d =.56. Nonetheless, there was no significant difference in student content understanding regardless of whether their teachers participated in AY or SI institutes as measured by a content post-assessment, $t(238) = .614$, $p = .540$. In other words, there was not a significant difference in student achievement between the AY and the SI programs.

Student understanding was also evaluated in terms of student work samples submitted. Teachers were instructed to implement two project-based learning modules, which required students to use GIS to understand a scientific concept through examination of data and to use GIS to visually represent claims based on data. A variety of student work samples were submitted, including worksheets, paper and pencil assignments, paper assessment maps, projects, fieldwork, authentic projects, and analysis reports. Note that although 238 students from 24 teachers completed the pre- and post-tests, only 161 student work samples from 9 teachers in the SI model and 8 teachers in the AY model were submitted for further analysis.

POD project staff developed a rubric to score student work samples on use of data or GIS, content application, and claims and evidence (Table 7).

Student work demonstrated that ArcGIS was utilized to varying degrees and the quality of student work products varied. Student artifacts were categorized as either resulting from implementation of: 1) a basic lesson - usually a worksheet provided in PD; 2) a general project that POD project staff designed for the unit; or 3) an authentic project where students gathered data and attempted to solve a real-world problem. Project scores by type of work submitted are listed in Table 8.

In general, any type of student project yielded higher overall scores in all areas compared to basic lessons. However, more teachers implemented authentic, relevant projects in the AY program (63%) than in the SI program (44%).

Findings: Summer Institute (SI) vs. Academic Year (AY)

Implementation is integral for PD to lead to student learning outcomes. The

Table 4: Organizational Support

Summer Institute (SI) (n=23)	Academic Year (AY) (n=15)
Participants	
23 teachers 12 schools represented 11 teams	15 teachers 8 schools represented 7 teams
Software Installation	
June or July PD October 2010 (4 months following PD) 10 schools installed 1 school not installed 1 school never installed or perceived as no access only using Macs and ArcView 3x	September PD January 2011 (4 months following PD) 7 schools installed 1 school dropped out
Partnerships and Level of Participation	
10 teams both partners fully engaged during institute 1 single teacher with no partner 1 teacher lost partner, due to illness 1 team – partner disengaged	4 teams both partners fully engaged for entire AY institute 1 single teacher with no partner 1 teacher lost partner towards the end 1 team dropped out halfway through the year 2 teams – partner disengaged 1 team partner had health issues and missed several classes, but finished program

Table 5: Highest Level of Project or Lesson Implementation in the Classroom by Teacher Partners

	Summer Institute (SI) (*n* = 16)	Academic Year (AY) (*n* = 8)
No implementation	3 (19%)	N/A
Basic lesson	2 (13%)	2 (25%)
General project	4 (25%)	1 (13%)
Authentic project	7 (44%)	5 (63%)

focus of this research was to see how the format of the professional development, AY vs. SI, affected student learning. With the focus on student learning, the types and quality of student products were measured as evidence of the effectiveness of the PD. Indicators showed that both PD formats yielded similar learning outcomes for both teachers and their students.

Teacher Outcomes

1. There were high levels of teacher satisfaction with PD in both formats.
2. Teachers in both formats improved GIS skills and content knowledge at a similar level.
3. A number of teachers in both formats were able to implement lessons using GIS that demonstrated exemplary teaching practices.

Student Outcomes

1. Students significantly improved content knowledge as measured by an achievement test in both formats, with no difference in achievement between the formats.
2. Student work demonstrated ArcGIS was utilized to varying degrees and the quality of student work products varied, but the means for the student work samples did not vary significantly.
3. Lessons with authentic problems promoted a higher level of student engagement.

Overall, there were few observed differences between the teachers who participated in the two PD formats or the overall measures of student learning.

Insights on Implementation

Teachers and students showed improvement in all areas assessed, but there was not an observable effect on student understanding based on the delivery format of the PD. However, the PD format may affect levels of implementation, which is important if the assumption is that changes in student understanding are only observed after teachers implement interventions learned during PD. One difference between the formats was that classroom implementation was higher in the AY program. In the SI program, using initial participant numbers, 43% did not complete all requirements (attend all PD sessions and implement at least one lesson), compared to 20% in the AY program who did not complete requirements. A higher number of AY participants implemented lessons in their classrooms following PD. It seems that the structure of the PD model had little impact on student or teacher learning, but follow-up meetings in the AY group did provide teachers support and incentive to complete the program and therefore implement lessons with students.

Additionally, teachers in both PD formats were encouraged to not only implement technology-integrated lessons with data provided, but also to implement a project-based lesson, and then to facilitate a site-based, authentic project surrounding their individual schools and communities. In this study, the rate of implementation of any lessons during or following PD was higher with the AY program, with 100% (8/8) implementation rate compared to 81% (13/16) implementation rate for the SI program. The lower implementation rate in the SI program was surprising, because the SI teachers had the opportunity to plan the implementation before their school year started, presumably helping to better integrate the lessons into their regular teaching agendas.

Additionally, there appeared to be a slightly higher average application of science content in the student projects submitted by AY participants. Implementation of authentic projects did not necessarily yield higher GIS, content, and inquiry skills, but if a structured lesson was provided preceding an authentic one, an improvement was observed in the second product. Based on anecdotal evidence from project participants, students who investigated authentic problems and collected their own data were more engaged and involved in project activities than those who were solving general problems or completing lessons out of a text, which may explain the differences in student content scores on their projects. Here are responses from a teacher regarding her submission of student work for analysis:

> "As can be seen from the Power Points submitted to you, there were quite a few projects that did not include GIS maps at all. Generally, they do not care." – *Teacher in SI program, following general project implementation*

> "The students were very interested in this project because it was a real world application of classroom information. They saw that their research

Table 6: Domains and Items Common to Both POD Project Observation Protocols

Implementation
The instructional strategies were consistent with investigative mathematics/science. The teacher appeared confident in his/her ability to teach mathematics/science. The teacher's questioning strategies were likely to enhance the development of student conceptual understanding/problem solving (e.g., emphasized higher order questions, appropriately used "wait time," identified prior conceptions and misconceptions).
Mathematics/Science Content
Students were intellectually engaged with important ideas relevant to the focus of the lesson. Appropriate connections were made to other areas of mathematics/science, to other disciplines, and/or to real-world contexts.
Classroom Culture
The climate of the lesson encouraged students to generate ideas, questions, conjectures, and/or propositions.

Table 7: Rubric for Scoring Student Work Samples

Level	Access/Use of data/ArcGIS	Content	Claims and Evidence
1	Get and display information from any source.	Specific facts collected/ presented but unrelated to science concept. Can't tell what content was to be learned.	Claim without any supporting data as evidence or explanation.
2	Get and display information from ArcGIS.	Science concept mentioned but not applied.	Claim with explanation but no supporting data/ evidence.
3	View ArcGIS data (build layout, layers, table).	Science term/fact applied.	Claim with any supporting data as evidence
4	Use evidence map/visual to illustrate a claim. Make sense of data, show patterns, clearly present information.	Science concept applied to the situation and discussed more generally.	Discusses more than 1 piece of evidence to support claim.
5	Create evidence map/visual representation of data from scratch to illustrate claim.	N/A	Claim with own or class collected data/experiments, more than one listed as evidence to support this claim and evidence was used to make a decision.

> and ideas for repair and prevention could have a positive impact on their school. In addition, they were equally excited about using the LabQuests. This was an opportunity for them to collect real data in the field." – *Same teacher in SI program following site based authentic assignment*

Teachers in the SI PD were required to have students create presentations that included data as evidence for claims about the most preferred time to visit a city, based on weather and climate present at different times of the year. The differences observed between SI student projects seemed to depend on how the lessons were presented to students, what the teachers expected from the student work, and what the teachers were emphasizing in the grading or evaluation of the work. Since the AY PD was implemented following the SI, assessment and creation of rubrics that emphasized claims and evidence and application of science content was incorporated into the AY PD. The AY teachers were provided time and instruction on assessing student learning that included examining student work to ensure that the project required a focus on science content over geography, which seemed like an important modification in the PD to support classroom implementation.

Generally, teachers and students showed improvement in all areas assessed, but there was not a measurable effect on student understanding until implementation was more closely examined. The AY format supported higher levels of implementation following PD with higher fidelity. It seems that examining implementation levels in conjunction with the student work samples submitted provided better insights as to how to support teachers to implement project-based learning modules using geospatial technologies.

Summary

Lessons learned from our study contribute to the growing body of evidence that geospatial technology supports student learning and provides an opportunity for students to learn through examining authentic problems. However, even when teachers were satisfied with the PD and were provided technology support, many factors affected the level of implementation in the classroom. **Our findings suggest that the structure of the PD model had little impact on student or teacher learning, but follow-up meetings in the AY group did provide teachers support and incentive to implement lessons with students at a higher rate than the SI group.**

Several other mitigating factors may have contributed to the increased implementation rates seen in the AY group. Teachers in the AY program had monthly, face-to-face, follow-up support as they implemented their lessons. This appears to have been a critical factor for teachers as they taught new lessons integrating geospatial technology. Additionally, the AY participants were asked to present what they had implemented at their final PD meeting and possibly felt more self-imposed pressure to actually implement the lessons, which is a crucial link to expecting change in classrooms (Guskey, 2002). There were also monetary incentives tied to attendance and implementation of the lessons in the AY group, which were not present with the SI group.

Loucks-Horsley et al. (2003) assert that on-going support is vital for science and math PD, and this may be especially critical for teachers utilizing new technology in teaching (Trautmann & MaKinster, 2009). Creating teacher accountability measures beyond the PD institute was not obvious to us until this study. Therefore, a hybrid model of PD, with incentives, that includes both face time and year-round support, may be the best model to encourage high levels of implementation as participants learn to integrate new technology into their teaching.

Cheng and Hanuscin's Taxonomy of Hybrid Professional Development Model (2012) outlines a continuum of PD models in which technology is utilized to support teacher learning, with technology integration levels ranging from "high/interactive" to "low/information based". In the high/

Table 8: Average Student Rubric Scores in Each Area by Assignment Type

	Summer Institute (SI) (*n* = 118)				Academic Year (AY) (*n* = 43)			
	n	GIS	Content	Claims	n	GIS	Content	Claims
Basic lesson	2	1	2	1	22	2	2	1
General Project	41	2	2	3	9	3	3	2
Authentic Project	75	4	1	2	12	2	3	3

interactive model, online interaction is essential to the program. In the low/information model, the main delivery method is face-to-face; online technology plays a minor role. Further recommendations for increasing the effectiveness of hybrid PD from the research community include: offering some asynchronous activities to enable a more learner-centered, personalized experience for teachers (Fritschi & Wolf, 2012); building a shared vision to promote ownership of the project goals and to encourage structured collaboration on common projects (Fritschi & Wolf, 2012; Ocker & Yaverbaum, 1999; Owston, Wideman, Murphy, & Lupshenyuk, 2008; Vrasidas & Zembylas, 2004); providing mentors and regular feedback on authentic, job-embedded tasks (Boling, Florida, & Martin, 2005; Johnson, 2001; Ocker & Yaverbaum, 1999; Owston et al, 2008; Vrasidas & Zembylas, 2004); facilitating metacognitive activities for participants to reflect on the experience (Owston et al., 2008; Vrasidas & Zembylas 2004); and providing some face-to-face time together before working collaboratively online (Johnson, 2001; Ocker & Yaverbaum, 1999; Owston et al., 2008). Based on these recommendations, a hybrid format for PD should include some face-to-face interactions to initiate participants into the project and allow for relationship-building that will continue online.

The online portion of the PD should be closer to the "high" end of Cheng and Hanuscin's proposed spectrum, with a mixture of asynchronous activities that meet participant needs, and synchronous interactions in the form of webinars or break-out rooms where the technology becomes "invisible" or at least secondary to the professional learning that occurs, to allow a more face-to-face authenticity to the online environment (Fritschi & Wolf, 2012; Owston et al., 2008; Vrasidas & Zembylas 2004). The tools within which the online environment is conducted must be reliable, and teachers must be supported while learning and using the new collaboration tools (Boling, Florida, & Martin, 2005; Ocker & Yaverbaum, 1999). With this in mind, the delivery format may actually matter if teachers' participation in PD can develop knowledge and skills, and then be followed by the use of technology to enhance year-long interactions and accountability to the project.

Teachers must implement knowledge and skills learned during PD in their classrooms for student learning to occur. Professional development providers must support and encourage implementation in classrooms. One way to do that might be to make teachers accountable to the project, and therefore feel obligated to implement some of what was learned in PD in their classrooms. If face-to-face meetings are not possible, a hybrid model might help accomplish this goal.

Even when teachers apply knowledge and skills learned during PD in the school year immediately following the PD experience, there is no guarantee they will continue to implement once support from the PD project ends. Although the POD PD projects have ended, we are currently conducting additional research to determine what instructional practices from PD are persisting one to two years following participation in PD. In addition, we are working to describe contexts that encourage, support, and maintain the use of geospatial technologies and project based instruction when the PD institutes and participant support end.

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