What Happens After the Professional Development: Case Studies on Implementing GIS in the Classroom

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Abstract
This paper describes a series of case studies of teachers implementing geospatial technologies, such as geographic information systems (GIS), global positioning system (GPS), and remote sensing in the classrooms. Each of the teachers had participated in one of a series of professional development workshops at James Madison University. We analyze the classroom implementation using the framework developed by the Apple Classrooms of Tomorrow (ACOT) project. We find that teachers with a background and interest in project-based learning are effective in implementing geospatial technologies with their students. We discuss our findings and suggest possibilities for further research.

19.1 Introduction

Trying to master technology is like shooting at a moving target; Moore's Law suggests that the information processing capacity of modern computers doubles about every 18 months (Moore, 1965). It is no longer possible for one to know all there is about technology given technology's propensity to change so quickly. A set of skills learned one year may serve teachers well for one or two years, but those skills can quickly become outdated in as little as three or four years. As cellular phones, digital cameras and camcorders, computers, GPS navigation units, and other electronic devices become more commonplace in consumers' lives, today's students have mounting expectations that these devices (and more) will debut in tomorrow's classrooms. The implication is that teachers will not only recognize these devices, but also have a plan to effectively utilize them to promote inquiry, learner engagement, collaboration, and problem solving in their classrooms.

In our roles as both teachers and technophiles, we are engaged in ongoing conversations about technology's role in learning and teaching, and we understand it takes time for technology's impact to be realized in the classroom. Of this, Cuban (1996) writes,

> This persistent dream of technology driving school and classroom changes has continually foundered in transforming teaching practices. Although teachers have slowly added a few technologies to their repertoires, techno-reformers have seldom been pleased with either the pace of classroom change or the ways that teachers have used new machines (¶ 3).

Time alone, however, is insufficient cause for cultivating and sustaining change; reform efforts must be accompanied by intentional activities that scaffold teachers' design, development, implementation, and assessment of technology-based tools that hold significant potential and appeal for enhancing student learning. Our contribution to that effort is represented through our teacher professional development initiatives: VISM (Visualization in Science and Mathematics, 1999-2004), GODI (Great Outdoors, Digital Indoors, 2001-2004), GRASP (GIS/GPS Related Activities for Student Progress, 2005-2007), and Rural STEM (Science, Technology, Engineering, and Mathematics, 2005-2009), along with a unique dual-enrollment effort with high schools focused on GIS called the Geospatial Semester (2005-present). Each of these projects focused on national or regional audiences and featured geospatial technology as the centerpiece (VISM included other tools with a broader focus on scientific visualization).

In each project, teachers came to James Madison University (JMU) for face-to-face workshops and we provided additional follow-up support in the succeeding academic years. While each project had a slightly different focus, the teachers all had an opportunity to learn about geospatial technologies and their classroom applications. In each project we have done long term follow-up to learn more about how teachers integrate geospatial technology into their classroom. As we describe below, we are beginning to see deeper pedagogical implications that speak to active, engaged learners who are involved in authentic, inquiry-based problem solving. Such methodologies promote informed decision making, collaborative problem solving, and multi-sensory/multi-modal learning opportunities. Selected teachers who participated in these projects are the subjects of the case studies in this chapter.

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Comment: Evidence? *Given in the cases below*

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19.2 Theoretical Framework

According to the National Staff Development Council (NSDC), teacher professional development may be an important factor that can impact student achievement (NSDC, 2006). Much of what is held up as technology training for teachers distills to one-shot interventions that focus more on mouse clicks, keystrokes, and menus than on substantive considerations of how to teach with technology. Before- and after-school training models represent reasonable responses to the rigid structure of school days, yet they often lack a context that sets technology utilization within considerations of student learning. Software and hardware training are important first steps, but their value is best realized when they are coupled with sustained opportunities for teachers to create products, to collaborate with peers, and to reflect upon their successes and challenges within the parameters of their classroom, content, and learners.

The design and implementation of our teacher professional development efforts were influenced by the historical research on

Barry Fishman 8/14/09 12:36 PM
Comment: These are all good general references about teacher learning from PD, but I don't know that any of them do any "work" for you. Unless there are specific features of these theories that bear upon your work, I would just cut them. Hall and Hord's CBAM is closest, as it influenced the ACOT work. *Agreed and deleted.*

Apple's Classrooms of Tomorrow (ACOT) program. ACOT is a widely recognized taxonomy of the stages through which teachers progress as they integrate technology in the classroom. We viewed the ACOT model as a reasonable framework on which to examine and advance the evolution and progression of teachers' utilization of geospatial tools that might lead to a more contemporary climate of change—one that is commensurate with the potential these tools bring to bear on authentic, inquiry-based learning.

The ACOT program was a "research-and development-collaboration among public schools, universities, research agencies, and Apple Computer"…that "set out to investigate how routine use of technology by teachers and students would affect teaching and learning" (Sandholtz, Ringstaff, & Dwyer, 1997, p. 3). While much of the early ACOT research focused on student and classroom changes, the Stages of Concern (Sandholtz, Ringstaff, & Dwyer, 1997) was an attempt to examine the transformation in teachers who utilized technology in their classrooms along a continuum of five stages. Teachers, they note, progress through various stages as they become more familiar with technology and move towards more learner-centered, constructivist approaches to instruction.

In applying this model to the question of teacher success in incorporating geospatial tools, we posited that teachers would go through a similar set of stages in adopting these new and relatively advanced technological tools into their own practice. Our interpretation of the ACOT framework for geospatial technologies in the classroom identified four stages of tool use by teachers: Entry, Adopt, Adapt, Innovate (Charles & Kolvoord, 2003). A model was developed called the VISM matrix which applied the four stages to four different kinds of scientific visualization tools resulting in a table of activities that were representative of the four stages. It was proposed based on conversations with the instructors over the duration of the VISM project, and updated in successive years of teaching the workshop as the instructors gained additional experience teaching the tools to practicing teachers.

Entry describes a level of competence with the tool and ability to apply it at the workshop and during any follow-up sessions. *Adopt* means that the teacher has taken a lesson/activity prepared by someone else and implemented it with little or no

Thomas R Baker 8/13/09 9:36 PM
Comment: It's not clear to me why you chose to use ACOT. *We've edited the paragraph to address this concern*

Thomas R Baker 8/13/09 9:36 PM
Comment: ACOT's use of 'routine' is interesting. Is using a "professional-grade" software, like ArcGIS, consistent with a "routine use"? *Yes. The ACOT research applies to technology adoption in general and is not tool specific.*

Barry Fishman 8/14/09 12:42 PM
Comment: Can you tell us how this is related to the CBAM? Not relevant w/deletion above.

Thomas R Baker 8/13/09 9:36 PM
Comment: I wonder how this "golden ring of constructivism" has change in the last two decades since ACOT started? In other words, is this still a national priority? *We take Tom Baker's question as a rhetorical one and we've not addressed it in our edits.*

Barry Fishman 8/13/09 9:36 PM
Comment: What makes this a "matrix"? *The stages are laid out in columns and rows—a matrix. …We've added text to clarify this*

substantive change with students to teach a content-based lesson. *Adapt* implies that the teacher has taken a lesson/activity prepared by someone else and made substantive changes to it to meet their particular classroom needs. *Innovate* means that the teacher has created original activities/lessons to meet a classroom objective. In the case of geospatial technology, we consistently found that Innovate meant that teachers created their own project using an original data set/source. We further describe some of these projects in the cases below.

The above categories were employed to describe and consider how teachers used scientific visualization tools in the years subsequent to their initial workshop experience and to track the stages of teacher development in using that technology. The focus was not necessarily that all teachers should move to the Innovate stage; effective adaptations of the tools in such a way that student learning was enhanced were equally valued. We proposed this as a path that teachers might follow based on the ACOT model, and then compared that to our actual experience over the years.

Thomas R Baker 8/13/09 9:36 PM

Comment: No inquiry component at this phase? *Mike. Good point. No inquiry…except that these activities/lessons tended to be project based as described in the cases.*

19.3 Prior Assessment Work

Post workshop assessment data from the various projects indicated that all of our teacher professional development efforts were well-organized learning experiences that were highly valued by the participants. The programs' leadership, instructors, instruction, and tools all earned average ratings of 4.5-5.0 on a 5-point scale. We surveyed Project VISM teachers' use of the tools using the VISM matrix mentioned above. We collected surveys from about half of the 118 VISM participants responding two to five years after the workshop; we conducted interviews and/or one day classroom visits with 25% of the teachers. Because some of the participants retired from teaching by the time of the follow-up surveys and interviews, the response rate from active teachers in the project was higher: over 55% for the surveys and nearly 30% for the interview/visits. Surveys were also conducted for GODI, GRASP, and Rural STEM—both pre- and post-workshop as well as one or more years out from participants' initial training. From these assessments we know that use of the tools was widespread. More than half of the VISM respondents used at least one of the tools at the Adapt or Innovate

Thomas R Baker 8/13/09 9:36 PM

Comment: This section begins to describe the context of the programs from which these educators emerged. I want to know more about the overall efficacy of these programs so that I can determine (as the reader) whether I think the case studies are representative. The info will also paint a richer, more complete story of your efforts. *We have edited to include more details on program efficacy.*

level. Those who only Adopted the tools can be divided into those who Adopted one activity and those who Adopted several activities--the latter being a wider application of the tool.

Of the four tools taught to the participants in the VISM project, geospatial technology was the one most used. Data suggested that this was because of the power of geospatial thinking to be applied across the curriculum. At the workshop teachers informally noted the wide applicability of geospatial technology as compared to the other tools. We also noted the availability of training resources for geospatial technology beyond the project for continued professional development. Rural STEM participants were to implement four to six activities during the subsequent school year. No stipulations were placed on the level or sophistication of the activities recognizing that participants had varying levels of knowledge and experience with both technology and teaching. Eighteen months after they completed their initial training, all Rural STEM participants had implemented at least one geospatial activity, and 6 of them (30%) had achieved the target 4-6 activities.

In the surveys, teachers consistently noted developing further skills in geospatial technology without project-related follow-up. Two to five years after the workshop, more than four times as many VISM teachers (42% of the active teachers) said that they were more or equally competent with geospatial technology than those (9% of the active teachers) who said they were less competent with the technology compared to the end of the workshop. They improved their skills by purchasing geospatial technology-related classroom-ready curriculum support materials, attending additional workshops focused on geospatial technology, or revisiting workshop notes. GODI, GRASP, and Rural STEM teachers all reported making changes in their classroom teaching as a direct result of their participation in the program; three-quarters of them reported that their participation had improved their teaching methods.

Across all programs, teachers consistently noted obstacles to their use of the tools. First and foremost was the lack of time to develop classroom ready activities and sufficient space in the curriculum to teach these new activities. The demands of No Child Left Behind (NCLB) and high stakes testing were obstacles to implementing geospatial technology projects. Other significant

Thomas R Baker 8/13/09 9:36 PM
Comment: What percentage of participants does this represent? *We've clarified numbers and percentages throughout this section*

obstacles were changes in teaching assignments and personal life, and changes in hardware and software access at their school placement that meant that often they had to negotiate adequate computer time for students to do their project work.

Teachers also noted indirect effects of their professional development experience. Ninety-seven percent reported that they are were better equipped to learn and use other technology tools or resources besides geospatial technology in their teaching as a result of participating in the VISM workshop. Seventy-one percent reported that it raised their status in school and/or district as a technology leader. Seventy percent of GODI participants indicated they either revised or restructured their existing content, 75% introduced new technologies into their classes, and 63% increased their use of existing technologies.

Thomas R Baker 8/13/09 9:36 PM
Comment: What the results of educaotrs and your proposed four stages? What percentages of educators in your follow-up surveys were in the various stages? *We address this above.*

The results from these surveys and follow-up interviews have clear limitations. They rely on teacher self-report data, there was no use of a random sample group design, and there is no direct student learning data. However, they start to outline the impact of our professional development initiatives. In the next section, we highlight the work of seven teachers to explore in detail how the tools introduced in the workshops play out in the classroom.

19.4 Teacher Case Studies

Thomas R Baker 8/13/09 9:36 PM
Comment: How were these educators picked to serve as case studies? Who do they represent (e.g. are these typical results)? Can you tie the collection of case studies or individual case studies to ACOT or your four phases? *We've edited this paragraph to address this concern.*

In this section, we feature in-depth looks at teachers from the different professional development projects and explore the evolution of their classroom use of geospatial technologies over time. The teachers were a sample of interest, representing different grade levels and geographical regions of the country as well as interesting cases of implementation of geospatial technologies.

Case	Gender	Years of Experience	Discipline	Grade Level	Location	Level of use
1	M	7	Ecology	High School	Rural-VA	I: geospatial projects
2	F	10	Social Studies	High School	Rural-VA	I:geospatial projects
3	F	8	Biology and Earth Science	High School	Rural-VA	I: geospatial projects
4	M	28	Technology	Middle	Rural-	A:

			Education	School	NY	geospatial activities
5	F	16	Science	Middle School	Rural/Urban- PA and VA	A: geospatial activities
6	M	30	Science and Technology Education	Middle School	Suburban - IN	A: geospatial activities
7	M	30	Geoscience	High School	Urban/Suburban- AZ	I: geospatial projects

A: Adapt I: Innovate

Table 19.1. Summary of case study teachers.

Teacher #1 (GODI and GRASP) – Teacher #1 teaches at a rural high school near a small city in Virginia. He has taught Ecology for seven years. He graduated from a major research university with degrees in Psychology and Biology and then moved on to a Master of Teaching in Science Education.

Barry Fishman 8/13/09 9:36 PM
Comment: What's an "M.T."? *Expanded.*

While Teacher #1's training was focused on Biology, he was assigned to teach Ecology and felt like he wanted to "break out of the worksheet world" that was the primary pedagogy for that class.

A year after he began teaching, a colleague suggested that Teacher #1 participate in the GODI project to learn about geospatial technology. Teacher #1 saw the workshop as a hands-on opportunity to learn new technologies. He particularly liked the focus on GPS and curricular lessons applied to Shenandoah National Park. He perceived the professional development as focused on case studies and with components that would easily fit in to his classes. The lab-related focus gave him possibilities for things that his students could do rather than "read and watch". His reflection was that the tools he learned offered "a blank canvas and more paint".

Teacher #1 has a strong project-based focus in his classroom. In frequent classroom observations, his students are engaged and able to work independently using the technology tools. Teacher #1 has created an innovative series of projects for the teachers and is clearly in the Innovate stage of use of geospatial technology.

In the subsequent year, Teacher #1 received some district funds to purchase some GPS units and he began to implement the tools in his classes. During this year, there were monthly follow-up sessions with the GODI project and Teacher #1 felt that these sessions were important to keep his appetite for the tools healthy, kept his enthusiasm high, and allowed him "to venture out of the shallow end" in using the tools.

Teacher #1 was later involved in two other projects (one in American Studies and another at the University of Kansas) that continued to allow him to build his skills. He also transitioned to ArcGIS 8 during this time period, making him feel like he was staying up to date with the tools.

At this point, Teacher #1's skills were significant enough that he was asked to contribute as an instructor to a state-wide professional development in geospatial technology, done in parallel with the adoption of a state-wide site license for ArcGIS. His performance in that role was very strong. He also participated in Project GRASP. At this point, he felt that his technical skills were strong and his classroom applications were solid, but in this new project, he was able to help teach others and that allowed him to continue to hone his teaching skills.

His classroom application evolved to participation in the Geospatial Semester. The Geospatial Semester is a dual enrollment effort between high schools and James Madison University. Students learn about GIS and do locally-based projects using GIS and earn college credit as they finish their high school degrees. This was a brand-new effort at his school and allowed him to create and teach a year-long class that focused solely on geospatial technology and allowed students to pursue extended geospatial projects. He has participated in this project for the last three years. His students have done very high quality work, including a project for the Nature Conservancy exploring the permeability of land in sub-watersheds in Albemarle County.

In thinking back on his geospatial technology professional development (PD) experiences, he had the following thoughts:

- Follow-ups are critical to combat atrophy, to try new things, to keep technical skills sharp and they avoid the "appetizer only, no dinner" syndrome. That is, you don't get enough in a workshop to fully implement a new tool/technique.

Barry Fishman 8/13/09 9:36 PM
Comment: Can you tell us more about the Geospatial Semester? You refer to it again in later cases, but I don't know what makes it special/unique. *Done*

- In PD workshops, the balance between instruction and time to experiment is critical to avoid the "cookbook mentality". This dichotomy is needed and important.
- Overarching projects showing connections and offering a continuum of ideas are critical.
- The opportunity to keep learning in follow-up sessions is of utmost importance.

Afternote – Teacher #1's burgeoning geospatial technology skills have led him to leave full-time teaching to take a GIS position in an environmental engineering company. His company has integrated part-time teaching (the Geospatial Semester) as a part of his position, in part to support continuing professional development. This highlights an interesting and significant difference between the software training typically found in industry and the broader emphasis on professional development between K-12 schools.

Teachers #2 and #3 (GRASP) – Teacher #2 teaches at a rural high school in an isolated valley in Virginia. She has taught for ten years at the same school, primarily in Social Studies (World History, U.S. History, Sociology, Economics, Geography and now GIS). She majored in History and Political Science and minored in Education at a small liberal arts college.

Teacher #3 teaches at a rural high school (different school, but the same district as Teacher #2) in an isolated valley in Virginia. She has taught for eight years at the same school, primarily Ecology, as well as Biology and Earth Science. She majored in Biology and minored in Philosophy and Religion at a small liberal arts college. She also completed all of the education minor except for student teaching. She worked for a couple of years in the banking industry prior to taking a teaching job.

Teacher #2 and Teacher #3 have known each other for most of their lives and are long-time friends. Teacher #2's first geospatial technology professional development was in a community college class that she took for personal interest and for professional recertification credit. There were other teachers in the class and she enjoyed the experience, but due to no software availability at her

Bob Kolvoord 8/13/09 9:18 PM
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Thomas R Baker 8/13/09 9:36 PM
Comment: Does this event suggest this former educator may not have approached GIS in education with the same interest level, motivation, or intent? I'm not certain but it seems logical that he may not represent the typical educator. I'm not suggesting removing the case study, only presenting a question. *This educator continues to teach the geospatial semester on a part-time basis as he works full-time in GIS. There was no inkling in our observations that he would likely leave the classroom until a few months before he made the decision. This is not an unusual storu – others involved in GIS training have reported similar experiences.*

Barry Fishman 8/13/09 9:36 PM
Comment: Too subtle – I don't know what the "difference" is. Can you spell it out? *We have expanded the sentence to clarify*

school at the time, she did not implement the technology in her classroom.

Teacher #3 had no prior geospatial technology experience. Parent and administrative interest led to a desire to adopt the Geospatial Semester. Due to their experience and project-based focus (see below), Teacher #2 and #3 were solicited to offer the course and despite concerns about not having enough knowledge/background, they agreed. Teacher #2 and #3 agreed to participate in professional development (GRASP) to prepare for offering the Geospatial Semester.

Both Teacher #2 and #3 have a focus on project-based learning. They emphasize hands-on learning and both wanted to offer a class that let students move beyond the highly constrained Virginia standards-based courses that predominate the high school offerings. Teacher #3 reports that her classroom style is based on the philosophy that "kids learn more by doing".

Teachers #2 and #3 joined the GRASP PD workshop mid-way through the year. In this particular set of workshops, teachers completed an initial two-day introduction during the late summer, attended monthly follow-up sessions, and finished with an extended, in-depth three days of classes during the following summer. While these teachers missed the introductory portion of the workshop, they were highly motivated to catch up as they were preparing to offer the Geospatial Semester classes in the following year.

Regular bi-weekly classroom observations and student work products have shown that both teachers have been extremely successful in the Geospatial Semester. In observations of their classes, they have created a powerful project-based learning environment and their students have both built solid technical skills and applied them in community-based projects. In fact, Teacher #3's students won the statewide mapping contest in 2008 sponsored by the Virginia Association for Mapping and Land Information Systems (VAMLIS).

Teacher #2 reports that the process has been exciting and she has developed a comfort level with not knowing and with instilling in the students a willingness to try and experiment. She's found that students don't lose respect in this situation, but rather they are excited for the opportunity (the students appreciate her honesty and the chance to work together).

Teacher #3 reports that she appreciated the follow-up support that was available via e-mail and visits. She also noted that her comfort level was increased by her perception that the workshop instructor was someone with whom she could work. She reports that the GIS class is the one class where she felt like she knew the least and felt comfortable admitting ignorance. She also felt like the students saw her modeling lifelong learning and the fast-changing world of technology.

At the end of the professional development workshop, participants had to develop lesson plans to integrate geospatial technology in their classes. Teacher #2 and #3 asked if they could develop a plan and pacing guide for their Geospatial Semester class. They did that planning and both report that this plan was a huge support in going through the first and second year of the class.

The two teachers were in regular contact as they've offered the GIS class and they had done joint projects. They also offer each other support as they hit technical snags. Teacher #2 felt like the ongoing support from JMU was important, as was the technical and administrative support in her school. She feels that her efforts are valued and the school is willing to support the effort (even in situations with slightly lower enrollment).

Teacher #2 and #3 both started in the Adopt stage, but moved quickly (within the first 6 months) to the Adapt stage and were beginning to Innovate at the end of their first year. In their second year, they continue to work at all three stages (Adapt, Adopt, Innovate) in different parts of the class, and as needed. Their student projects are clearly in the Innovate stage.

Thomas R Baker 8/13/09 9:36 PM
Comment: Can you elaborate on the matierals they developed? *We don't have sufficient space to do this for each teacher and so we're disinclined to just do it in this instance.*

Teacher #4 (Rural STEM) teaches in a rural middle school in central New York. He has taught for 28 years. He initially earned an Associates Degree and worked in the business world for 6 years before returning to a regional state university in New York for a degree in Industrial Arts (he later earned a Masters in Technology Education). He has worked in the same district for his entire career (with the exception of two short periods where he served as a professional developer for a regional consortium for a year, and as a curriculum developer working with a local nuclear plant).

His entrée into geospatial technologies was when his wife bought him a GPS. He was very interested, but never quite figured out the GPS. He saw an e-mail solicitation regarding the Rural STEM workshop and it piqued his interest. He had lots of prior experience with professional and curriculum development, but no real sense of geospatial tools.

Teacher #4 found the Rural STEM summer workshop experience to be very valuable. He was particularly engaged with the social interaction with teachers from across the country. He did find the work challenging and reported that at times his “head was spinning”.

Teacher #4 did not immediately implement the technology upon returning home, but rather took a very different tack. He began a series of activities to be an advocate for the technology in his home district. He began by writing a grant for additional GPS units and by meeting with his superintendent who supported a regional conference visit. Teacher #4 also made a cold call to the GIS instructor at a local community college that led to the development and offering of a short (two-day) workshop by the community college for district teachers from his district. This all happened prior to Teacher #4 ever using the technology with his students. In fact, in the first year, due to challenges getting the software installed, he only did GPS-based activities in the spring, but these were at the Adapt level. We observed these activities and while they had some elements of existing lessons, they had novel elements as well. Teacher #4 saw the first year as an introduction and he finished it by attending additional professional conferences.

Teacher #4 participated in a summer follow-up workshop at JMU and then returned home to do presentations at a professional conference, return to the local community college for additional training, and organize and lead a curriculum development workshop for his district in his second year of implementation. While the quality of the output from the workshop was quite variable, he felt that it was an important experience for teachers in his district.

Teacher #4’s main focus in the fall of the second year was in organizing and executing a “GIS Day”, a day-long event at the school involving all the students and 17 staff members, along with GIS professionals, community members, and representatives from local government. This activity was part of the work that Teacher #4 did to “plant the seed” and build awareness. In the spring, he worked with 6th grade gifted students to do a Geospatial Enrichment class and along with the GPS activities, started to implement geospatial technology. The activities were both at the Adopt and Adapt stage. During this time, he also worked with the local community college and a high school teacher to set up an articulation agreement so that a GIS class taught at the high school could earn college credit.

At the end of the second year, he again returned to JMU for a follow-up session. He also continued his conference attendance with a visit to the ESRI International Users Conference and work with a local Institute. He again organized professional development for teachers in partnership with the local community college. The largest effort was devoted to leading a professional development group that planned, organized and executed a staff development day devoted entirely to geospatial technologies. Each teacher in the district was introduced to geospatial technology in a staff development day in October.

As the new school year began (year 3 after the workshop), Teacher #4 again organized GIS Day, though a smaller version than the previous year, executed the professional development day listed above, and expanded his geospatial technology teaching to 5th and 8th graders as well as to more of the 6th grade class. The GIS activities continue to be at an Adopt/Adapt level and the GPS activities are at an Innovate level. He continues to mentor fellow teachers and act as an advocate for geospatial technologies in his district. He is also helping to develop some GIS-based alternative energy curricula, but has yet to use them in his classroom.

Teacher #5 (Rural STEM) has taught for 16 years in both Pennsylvania and Virginia at all grade levels, though most of her experience has been at the middle school/junior high level. She has primarily taught science, though much of her work has been in special education classrooms. She holds a B.S. in Elementary and Special Education from a land grant university, as well as a certification in high school Earth Science in Virginia. She is currently pursuing a Master’s degree in Geosciences. Her previous teaching job was in a middle school in a rural county in Virginia where she taught science for 5 years in a regular classroom. She moved and changed positions this year and she is currently teaching high school science in an inclusion classroom in an urban high school on the other side of Virginia.

Teacher #5 came to geospatial technologies accidentally. She attended an NSTA conference and chose to go to a keynote session being given by a faculty member in the department at JMU where her son had just matriculated. The technologies demonstrated in the session captured her attention and got her extremely excited. At the same conference, she attended another session about geospatial technologies from a group that offered to bring training sessions to districts. She returned to her district determined to get this training offered locally. She worked very hard to convince administrators to sponsor this free workshop and a year later, the initial workshop was offered.

Teacher #5 reports some disappointment in the outcome of that workshop. While the workshop was of high quality, it was too short and there was absolutely no follow-up. Teacher #5 did not feel sufficiently capable to even ask questions after the workshop as she felt so confused. She describes the initial exposure to geospatial technology as being almost like learning a foreign language. Three days offered too little time to "digest and apply" what she had learned. This was the case for her fellow teachers and most of them donated their workshop materials to Teacher #5 in a clear expression of their unwillingness to incorporate this technology.

Teacher #5 was able to make a few simple interactive maps to illustrate a concept about aquifers. This was an Adopt level activity and she had some success using these with her students. She recognized that the technologies offered much more, but she felt that she didn't understand enough to move forward.

She heard about the Rural STEM workshop in a visit to JMU to see her son and got very excited about participating. She found the summer workshop experience to be intense, reporting that at times it "hurt her brain", however the experience gave her the confidence that she could in fact become facile with the technology. She found the level of detail both challenging and very good as it gave her a sense that she understood what was going on instead of the technology being a black box. In working with Teacher #5, her prior professional development experience did not seem to have expedited her learning of the technology.

Teacher #5 also really enjoyed learning about the use of GPS units and in fact made that a priority for classroom implementation when she returned. She also invested significant time practicing in the interval between the end of the workshop in mid-summer and the start of school.

Upon returning to school, Teacher #5 wrote and won a local grant to obtain more GPS units to use with her students, and in the succeeding school year, she used those GPS units (typically in Adopt or simple Adapt activities) as well as GoogleEarth. She recognized that it was “not quite” GIS, but it served her classroom needs. It also allowed her to promote the technology with fellow teachers. She did do a couple of GIS activities (Tornados and Energy Use) with the help of a visit from the Rural STEM instructor. Interestingly, the superintendent visited her class that day and was very engaged with the activity and this led to some additional support for the teacher. These activities were very much in the Adopt mode.

Teacher #5 returned to JMU for a summer follow-up workshop. She came with much more confidence than in the earlier session, but she realized that she was not yet skilled enough to do her own lesson design and she was determined to increase her skill level. She felt that the follow-up offered her the time and support to solidify her knowledge.

In the succeeding school year, she dramatically increased her use of geospatial technology, bringing in lessons that had been developed for the Rural STEM project, as well as activities from the Mapping Our World book (Malone et al., 2005). She was firmly in the Adopt stage for GIS and moved on to the Adapt stage by harvesting pieces of lessons and combining them in to new activities. She also organized a GIS Day for her school.

In thinking about her students’ work with GIS, Teacher #5 reports that she found that her sixth graders had moved to a much deeper level of thinking about the content that she was teaching. The visualization tools brought them beyond a surface understanding of the concepts to consider the application (she described the example of thinking about the elevation around her school and how it impacted water flow). The students' questions and thinking had changed to such an extent that Teacher #5 felt that her content knowledge in Earth Science was perhaps inadequate to the task and she enrolled in a Master's program in Geosciences to help build her content knowledge (and apply geospatial technology).

She again returned to JMU for a follow-up session in the summer, but reports that she did not get as much out of that session. She thinks that is was primarily due to distractions in her personal life. Teacher #5 ultimately changed jobs and districts the following year, which severely impacted her use of geospatial technologies. In her new high school job, there was much less support for taking students outside to do GPS-based activities and there were no Windows-based computers on which to do the GIS activities. She returned to the use of GoogleEarth on the Macs she has available and she has joined another professional development project (CoastLines) which offers a Mac-based GIS package.

Barry Fishman 8/13/09 9:36 PM
Comment: Too much detail? *We've made the edit.*

Bob Kolvoord 8/10/09 4:23 PM
Deleted: (her family was moving, eventually to the Tidewater area in Virginia).

Teacher #6 (VISM) teaches at a relatively affluent suburban middle school of about 900 students near a medium sized city in Indiana. He earned a Bachelor of Science from a regional university, a Master's of Science from a major research university, and is currently completing a graduate certificate program in administration and technology from Johns Hopkins University. He has taught for thirty years, and for the past eight years he has taught a course that he was pivotal in creating called the Integrated Solutions Block (ISB). In 8 periods a day he team-teaches a total of 950 6th, 7th, and 8th grade students each week. His classroom is a unique computer lab with over 100 computers in a school that emphasizes 21st Century workplace skills. Throughout the school, students work collaboratively on projects and tasks with the guidance and assistance of the teacher. Project based learning has been implemented across the staff and across the curriculum. As part of his job he facilitates multi-teacher interdisciplinary projects with all three grade levels.

Teacher #6 began his use of scientific visualization tools by taking an image processing workshop in the 1990's. He Adopted and Adapted activities from that experience into his classroom such as determining velocities of model roller coasters using digital images. He also attended a prior training for geospatial technology, but gained little competency with using ArcView. Prior to the Project VISM workshop his students completed an interdisciplinary project in which they presented a business plan to their peers for a startup company in a Southeast Asian country.

Teacher #6 began the VISM summer workshop with a rationale for using the tools based on technology's potential to both motivate students and to help them connect with real world problems. By the end of the workshop he added to his rationale the idea that these tools allow students to see abstract ideas at a concrete level and to engage in higher-level thinking. Five years later his rationale was even more developed, including adding the idea that technology can enable students to do inquiry-based investigations. He described his workshop experience very positively and began to Adopt and Adapt geospatial technology activities into his ISB class (required of all students at his middle school). Sixth grade students completed a study of the Earth using the Internet, Excel, and geospatial technology to learn about the earth, its demographics and geography. Seventh grade students downloaded recent earthquake and volcano data from the USGS website, displayed it, and drew conclusions about plate tectonics from the map. Eighth grade students used geospatial technology to research through a U.S. government database to learn more about states and their capitals using census data. Teacher #6 has also Adapted work from other technology projects into his classroom. On a school visit, I observed his 6th grade student's working in cooperative groups to design a Rube Goldberg machine that applied their knowledge of simple machines. About ten engineers from General Motors joined the students for a 90-minute session to assist the students' work, and ten different home room teachers worked together on this with Teacher #6 coming in to their class to support the project.

When asked prior to the workshop about what obstacles he faced in implementing geospatial technology, Teacher #6 cited a lack of teacher knowledge of the tools and a lack of well-designed curriculum materials that use the tools. Following the workshop he added a concern about a lack of space in a crowded curriculum. Five years after the workshop he restated that time is the key obstacle, both to learn the tools and to prepare activities. He stated that there is little time to really prepare technology-enhanced lessons except through various professional development workshops he has attended. He stated that the other obstacles were gone: “The computers are here, curriculum integration is here, connections to Standards are here without being a constraint.”

Five years after the workshop his skills with geospatial technology had improved. Most participants reported a similar gain in skill even though the project had only offered one 3-day follow-up workshop a couple of summers after the original 3-week workshop. Teacher #6 learned more about geospatial technology by using books he purchased to support his learning and explored the ESRI website and its related tutorials to better understand ArcView. He applied for and received several grants from a leading global technology services provider delivering business solutions to its clients and a major electronics retailer to connect ideas with GPS and geospatial technology. He purchased GPS devices and began to integrate data from those into geospatial technology projects showing relationships and developing activities relating data on the GPS device with geospatial software, working at the Innovate level.

Teacher #7 (VISM) teaches at a small suburban high school in a large city in Arizona. He earned his B.S. in geosciences at a technical institute and then added his secondary teaching credentials from a major research university where he later earned his master's degree. He has taught for thirty years, and for the past eight years he has been on the faculty of a small comprehensive high school of about 160 students located in an industrial park that the allows the school to capitalize on business relationships and connects students to possible future careers. Class sizes average 20 students, and the school website states that the "school and staff provide a challenging academic curriculum that emphasizes science, technology, engineering, mathematics, and business with opportunities to apply knowledge in real-world settings." He currently teaches chemistry, forensic science, conceptual physics, and leads a robotics club. He began his use of scientific visualization tools by taking a month long image processing workshop early in the 1990's. He helped develop activities that used image processing in teaching mathematics and science, and eventually left the classroom for five years to be the project director for a non-profit organization that promoted computer-aided visualization as a tool for inquiry-based learning.

He participated in Project VISM as he was returning to the classroom. Prior to the workshop, he was already using geospatial technology at the Innovate level; he had helped develop geospatial technology activities for other teachers as a project director. A year following the workshop he reported that he had further developed his skills at innovating with those tools. He described his use of ArcView in his environmental science class as “from the first week of school to the last week.”

One major project they completed addressed a question that had been in the local news. During the summer a number of illegal immigrants had died not far from his school while attempting to cross into the United States from Mexico. A policy proposal resulting from this event was to place watering stations out in the desert to prevent future tragedies. He and his students examined the question of what the effect of these watering stations might have on the safety and health of the immigrants by creating a map in ArcView. They then used a teacher-created simulation that modeled the flow of immigrants with and without watering stations. Their conclusion was that establishing watering stations would most likely not help the plight of the immigrants based on the proposed locations. This activity took five weeks to develop and two weeks to complete. A second ArcView project was researching and mapping the flow of goods and people at six border crossings between Arizona and Sonora. They eventually published their work as part of an online electronic atlas (eAtlas). His class was invited to participate in this project by one of the sponsoring agencies. Students researched specific economic indicators and created ArcView maps based on their research. The data included things such as the flow of goods and people at six border crossings between Arizona and Sonora. The class’s contribution was part of a larger economic database of information. Using ArcView they created a map with themes that displayed this data.

Teacher #7’s use of geospatial technology tools has continued over subsequent years, and he has shared his geospatial technology expertise with his colleagues in his small school. Elementary teachers were trained in basic map making and use it with their students. He is using geospatial technology in his Forensics class, Adopting an activity about crime in Houston. Next year he plans to have students do a forensic study on the immigrant deaths - from finding a body, measuring the bones to get gender and height, and plotting on a map to find where they came from using real and fictional data. He has become involved in doing Partners in Science projects in the past, and in the next year he plans to work students to determine the best places to start a prescribed burn up in a nearby mountain range. That data will then be used to make another forensic case study of a fire, using maps to trace it back to the origin and determine if it was human caused or lightning started.

There have been a number of supporting factors in Teacher #7's exemplary use of visualization tools. His prior expertise in using these tools on a regular basis in his teaching was critical. The eAtlas project happened in his classroom because of his prior contacts with the local university's office for K-12 partnerships. As a teacher he talked about how he sees the relevance of geospatial technology mapping activities in everyday news items and has a strong interest in drawing that into the classroom to help connect scientific learning with current events. The immigrant studies and forest fire forensics are both examples of this. When asked to describe how he was able to keep his skills sharp in using these tools, he stated, "To learn the tool, I teach students with the tool." His "use it with my students or I'll lose it" attitude tolerates a fair amount of uncertainty in the first use of the tool, critical to its successful use.

The lack of teacher time to prepare quality lessons and the increasingly crowded curriculum were seen as the major obstacles that teachers face in using the tools. For this experienced and successful user of scientific visualization tools, professional development opportunities like Project VISM were a place to develop his teaching craft knowledge as well as learn new tools. Even as an accomplished computer user, Teacher #7 found himself gaining increased confidence with the computers and the tools, and encouragement from the other teachers to use it in the classroom. Participating in Project VISM made him think "Yes, I can do this with my students." When asked his rationale for using the tools with students, he was very clear in his response: they are engaging for students. It involves them and puts them into the problem. These tools allow for activities that can be adapted to current events so easily–in some cases right from this week's headlines.

19.5 Recommendations for practice

1. A key predictor of successful implementation of geospatial technology projects is that prior to the workshop teachers can describe other projects (with or without technology) that they had implemented with their students that accomplish district curriculum goals. Thus the innovation involved in using geospatial technology was as much facilitating project-based learning as it was the employment of advanced scientific visualization tools. We see this both in earlier survey and interview data and in the cases described above. Teacher #1 had a strong project-based focus in his classroom prior to the workshop. Teachers #2, #3 and #5 describe a project-based approach in contrast to typical science and social studies offerings in their state. Teachers #4, #6 and #7 showed clear evidence of project-based learning skills prior to workshop. Because geospatial technology lends itself best to scientific projects more than isolated activities or exercises, prior experience in doing projects that accomplish district curriculum goals is critical to whether teachers can use geospatial technology successfully.

2. Others have recognized that "Investing in long-term professional development goals…means relying on the professionalism and expertise of each teacher, not only in the areas of content and pedagogy, but also in the appropriate use of technology" (Bowe and Pierson, 2008, p. 11). We would state further that effective teacher professional development initiatives should be informed by the idea that teachers construct their own unique program for professional development (Charles & Kolvoord 2003) while acknowledging that this development takes place in a system which is "superficial and fragmented" (Ball & Cohen 1999, p. 5). This program is initiated by the teacher, and is based on the professional's own goals, and the professional's intrinsic motivation to create a better classroom. This is in contrast to staff training models that are often mandated by the organization, whose program is determined by organizational mission and goals, and is based on extrinsic motivation. All seven of the teachers described above have used geospatial technology over an extended period of time to

Thomas R Baker 8/13/09 9:36 PM
Comment: This depends upon how you define "Successful implementation". Using PBL-GIS (or inquiry with GIS) is certainly not the only measure of success as defined by your four stage adoption model. *True…addressed above and in this section*

Barry Fishman 8/13/09 9:36 PM
Comment: So are you saying that teachers need to *arrive* at your PD already understanding inquiry? This isn't something that you teach in the PD? That's a pretty major head-start, at least in the science world. This means you can just focus on the technology integration aspects of GIS. I just want to be sure that this is what your claim is. What I might have expected here is for you to claim that teacher understanding of inquiry is a key to their implementation – and therefore that your workshops need to focus on inquiry to the greatest extent possible. *It isn't inquiry…it is the completion of projects, since GIS lends itself to that…We've edited the section to try to address Barry Fishman's concern*

Thomas R Baker 8/13/09 9:36 PM
Comment: This is an important point. I think this argument would be considerably stronger if another citation, in addition to the authors' own work was used. I think this statement is very broad and could be contested. Perhaps a related field can corroborate this assertion. *Added Bowe and Pierson's quote and Ball & Cohen quote.*

support the goals of their curriculum. Over time we have evolved more effective follow-up support for those teachers. But all seven teachers showed an ability to construct their own programs.

Thomas R Baker 8/13/09 9:36 PM
Comment: What follow-up support should good PD programs provide? What does your follow-up look like? *Addressed in an edit below.*

Teacher #1 experienced sustained follow up support in the GODI project, but he also was involved in two other projects (American Studies and the University of Kansas project) on his own initiative that allowed him to develop his skills. He became an instructor for state-wide professional development in geospatial technology, and eventually was involved in the Geospatial Semester. Teachers #2 and #3 Adopted the Geospatial Semester, but also joined the GRASP PD experience, making up for missed sessions. They were intrinsically motivated to improve their classroom. Teacher #4 resolved some of his confusion about geospatial technology following the first workshop identifying a local community college instructor for support in using the tool, and then attended more follow-up sessions. Teacher #5 first attended a couple of geospatial technology sessions that were not that effective, but eventually found the right PD sessions (Rural STEM with follow-ups) to apply the ideas of geospatial technology to a tool she finds easier to use and more appropriate for her students: GoogleEarth. Teacher #6 was involved in a workshop that provided limited direct follow-up, but he has purchased books, used geospatial technology provider website tutorials, and has been awarded grants from local businesses to better connect GPS and geospatial technology ideas. Teacher #7 also was involved in the same project with limited direct follow-up, but his prior work developing geospatial technology curriculum, his involvement with other projects that use geospatial technology such as the immigrant studies and forest fire forensics, and even his use of the tools with his students have all further developed his skills.

It is possible that only teachers in what Rogers (2003) refers to as Innovators and Early Adopters are more likely to construct their own program for professional development, while teachers in Rogers Early and/or Late Majority category need more of a staff training approach. The survey and interview data we have received are more likely to have captured the work of Innovators and Early Adopters of geospatial technology. But that is not true of all of the cases described. Three of our seven cases (Teachers #2, #3, and #5)

Thomas R Baker 8/13/09 9:36 PM
Comment: If Rogers, then based on the only national and state survey data we have, it's not possoble that we're training "Late Majority" (50^{th} - 84^{th} percentiles) and even unlikley there are many in "Early Majority". *We added a reference and edit the paragraph to clarify.*

Thomas R Baker 8/13/09 9:36 PM
Comment: If these terms are in reference to Rogers, then your use of "Early Adopters" may not be what you intend. Innovators? See our reply to the comment above.

are from teachers whose technology skills are not as advanced compared to the other cases, but whose students use the tools very well due to their strong pedagogy. They are very familiar with project-based learning tied to district standards. They may be more typical of teachers in the Early Majority of teachers using geospatial technology, and they too have constructed their own unique program for professional development

3. Employing geospatial technology often involves curricular innovation, even for those who do project-based or inquiry-based science. Such innovation can be severely constrained by the current system. We have seen this from the larger sample of survey and interview data as surprising obstacles to the use of geospatial technology have appeared such as a lack of access to computers. This question of access is a bit of a moving target. One year a teacher has access to the computers, programs, and lab time needed; the next year those same computers might be used exclusively for state mandated assessments of remedial programs. There are some cases where the curricular innovation is adopted more smoothly. Teachers #4 and #6 both reported that geospatial technology "fit like a glove" for themselves and their colleagues. Teacher #7 reports that his use of geospatial technology has varied by which subjects he is asked to teach each year. Designers of professional development should both take advantage of the growing array of published curricular materials as well as design new materials that help scaffold teachers as they move from Adopt to Adapt/Innovate stages in their use of the tools.

Thomas R Baker 8/13/09 9:36 PM
Comment: What is the recommendation for PD designers from this item? *Added sentence to the end of this section.*

Thomas R Baker 8/13/09 9:36 PM
Comment: It would be excellent to expand on this. *In our section on Prior Assessment Work, we provided details on our surveys and interviews.*

19.6 Recommendations for research

We have compiled sufficient evidence that some teachers are able to use geospatial technology, and that they employ them routinely in their practice because, in their professional judgment, these tools help their students learn. Teacher's professional judgment is one acceptable form of evidence. But there is a clear need for research that shows evidence of improved student learning based on the thoughtful use of these tools. Such research would describe the complex interaction of content knowledge with technological and pedagogical knowledge, or TPACK (Borthwick et al 2008; Koehler & Mishra, 2008), that is involved in any successful integration of

Thomas R Baker 8/13/09 9:36 PM
Comment: The recommendations for research on student learning seem to be secondary to the content of this chapter. Are there additional specific recommendations for research, based upon the work outlined in this manuscript? *We've edited this section to clarify.*

Thomas R Baker 8/13/09 9:36 PM
Comment: Citation for the evidence? *The case studies above are the evidence – we're not sure what Tom is looking for here?*

technology. Teachers' spatial thinking knowledge and concepts inform much of what they do in the classroom with these technologies and that may need to be assessed in a different way than content knowledge or technological/pedagogical content knowledge. Clearly with geospatial technology, the issue of students' spatial thinking skills and conceptual understanding is also a critical underpinning to assessing the impact of the technology on their learning. Another ongoing challenge is to develop assessment activities that incorporate the affordances of geospatial technologies in evaluating students' conceptual and process understanding.

Thomas R Baker 8/13/09 9:36 PM
Comment: A citation would be great for this. *Note to Eds. – perhaps we could cite one of the other chapters in the book for this. We don't have a cite handy for this….*

Strong administrative support is essential for any technology to be successfully adopted and integrated into P-12 settings. Under the pressure of academic accountability born of No Child Left Behind, there is little incentive for teachers to utilize technology if they receive neither the support nor the credit for their technology integration efforts. The recently refreshed National Educational Technology Standards for Administrators (NETS-A) call for educational leaders to "promote an environment of professional learning and innovation that empowers educators to enhance student learning through the infusion of contemporary technologies and digital resources" (ISTE, 2009, ¶ 3). Future research should examine strategies for garnering and sustaining strong administrative support both in the school building and at the district level to deploy geospatial technologies in ways that lead to meaningful student learning.

Additional research is needed to find out what geospatial technology adoption looks like for the larger group of teachers (e.g., Early and Late Majority) as well as Innovators and Early Adopters. Our participants reported that they believed their attendance and involvement in our teacher professional development efforts improved their knowledge and skills and helped them become better teachers. But what does this look like as teachers' competence and confidence advance over time? What kinds of questions do teachers ask? What kinds of learning activities do they devise? How do they make good instruction even better? As our chapter has tried to highlight, it is important to observe the change that happens over longer periods of time to fully understand the impact of professional development.

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Project Websites

The projects described in paper have websites that feature more detail about each project and offer access to curricular materials developed for each project.

Great Outdoors, Digital Indoors (GODI)
http://www.isat.jmu.edu/common/projects/godi/
Rural STEM
http://www.isat.jmu.edu/stem
Visualization in Science and Mathematics (VISM)
http://www.isat.jmu.edu/common/projects/vism/