Chapter 8
The Inquiring with GIS (iGIS) Project: Helping Teachers Create and Lead Local GIS-Based Investigations

Cathlyn D. Stylinski and Cassie Doty

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8.1 Introduction

Local environmental investigations can engage students with science content, while helping link prior knowledge to new understanding. Geospatial technologies offer powerful visualization and analysis tools for these community-based activities (e.g., Bodzin, 2008; National Research Council, 2006). Like other information technologies, they can also expand opportunities for student-centered inquiries (e.g., Varma, Husic, & Linn, 2008), illustrate complex scientific phenomena (e.g., Bell & Trundle, 2008; Gordon & Pea, 1995), and improve technological skills and attitudes (e.g., Baker & White, 2003). Furthermore, GIS can dramatically extend the classroom experience, allowing students to make real-world applications and develop crucial information technology skills that are fundamental and expanding components of most occupations.[1]

Despite their value, geospatial explorations, particularly locally based activities, present many challenges for classroom teachers. These challenges include limited skills and time for acquiring and preparing local datasets, limited training opportunities and resources appropriate for the classroom, and limited administrative and technological support (e.g., Kerski, 2003; National Research Council, 2006). Even when they have access to geospatial software, many teachers are not using it or do so in limited ways (Edelson, 2008; Kerski, 2003; National Research Council, 2006;

[1] Bureau of Labor Statistics, http://www.bls.gov/oco/ocos042.htm#outlook, accessed April 10, 2009.

C.D. Stylinski (✉) • C. Doty
Appalachian Laboratory, University of Maryland Center for Environmental Science, Cambridge, MD, USA
e-mail: cstylinski@umces.edu; cdoty@umces.edu

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White, 2008). One of the chapter authors (Stylinski) conducted a survey of 17 leaders in GIS education from university, national and regional organizations, and research institutions. Survey respondents described the status of GIS integration in K-12 schools as "abysmal" and "challenged." They described "small pockets of excellence surrounded by large oceans of ignorance," and categorized usage as "excruciatingly varied….[T]he capability of educators extends from stunningly inadequate to consistently inspiring." These trends parallel overall information technology use in schools, much of which is limited to low-level applications such as word processing, email, and drills (e.g., Bebell, Russell, & O'Dwyer, 2004; Becker, 2000; U.S. Department of Education Office of the Under Secretary, 2003).

The *Inquiring with GIS* (iGIS) teacher professional development project sought to take advantage of the benefits of geospatial technology as a tool for teaching and learning, while addressing educational needs and challenges. With funding from the National Science Foundation's Innovative Technology Experiences for Students and Teachers (ITEST) program, the iGIS project helped teachers incorporate authentic GIS investigations into their classrooms to enhance students' scientific understanding and interest in technology-based careers. Through the professional development experiences, teachers learned to use and apply geospatial technology and the iGIS unit in the examination of human impact on their local watersheds. Teachers and students used GIS to delineate watersheds, calculate percent impervious surface, and estimate stormwater runoff using techniques similar to environmental scientists and resource managers. Dr. Cathlyn Stylinski led the project with staff at the University of Maryland Center for Environmental Science Appalachian Laboratory and partners at the University of Wisconsin, Madison (content support), Northwestern University (curriculum support), and The Learning Partnership (evaluator). This chapter reviews the theoretical framework, design, and outcomes of the iGIS project.

8.2 iGIS Theoretical Framework

The iGIS project built on the theory that local investigations are a valuable and effective approach to learning. In addition to having students engage content relevant to their lives, community-based activities legitimize students' prior knowledge (e.g., familiar places, issues, organisms) and allow them to use this knowledge to enhance their understanding of new concepts (Carlsen, 2001). Lieberman and Hoody (1998) suggest the local environmental context can serve as a "…framework within which students can construct their own learning." These authors further provide evidence of improved academic achievement, reduced disciplinary issues, and increased engagement and enthusiasm. Such investigations also have the potential to expand students' awareness and knowledge of their local environment – a critical first step towards environmental stewardship (Fishman, 2005).

Watersheds provide a particularly useful focus for local real-world investigations (Donahue, Lewis, Price, & Schmidt, 1998). They come in all sizes; can be delineated for any stream flowing near students' schools or homes; combine concepts from multiple disciplines including ecology, chemistry, biology, physics, geology, and social studies; and connect curriculum content to authentic issues outside the classroom walls. Furthermore, both children and adults harbor common misconceptions about watersheds and the water cycle (National Environmental Education and Training Foundation/Roper Starch Worldwide, 1998; Shepardson, Wee, Priddy, & Schellenberger, 2007). With their landscape-level visualization and analysis capabilities, geospatial technologies are particularly well suited to improving students' understanding of watershed concepts (Bodzin, 2008; Donahue et al., 1998) and provide an opportunity to apply geospatially based environmental data in authentic and meaningful ways.

The iGIS design also drew from effective teacher professional development features identified in two seminal research papers – Penuel, Fishman, Ryoko, and Gallaher (2007) and Garet, Porter, Desimone, Birman, and Yoon (2001). First, effective professional development activities should focus on improving and deepening teachers' content knowledge, as teachers confident in content will allow for more student discussion (National Research Council, 2000). For geospatial technology, this includes understanding the intersection between technology, subject matter content, and pedagogy – in other words, technological pedagogical content knowledge (e.g., Bednarz & Bednarz, 2008; Doering, Velestsianos, & Scharber, 2008; MaKinster & Trautmann, this volume). Second, there should be proximity to practice; that is, professional development activities should help teachers prepare for classroom situations. For technology-based professional development, providers should imitate the kind of teaching participants promote, and teachers should use technologies in ways that parallel their own classroom use (Basista, Tomlin, Pennington, & Pugh, 2001; Easton, 2008; Linn, 2003; Vrasidas & Glass, 2005). Proximity to practice can be supported by mentoring or coaching by professional development staff during the school day, which Varma et al. (2008) found particularly effective in their technology-intensive teacher education program. It may include curriculum-linked professional development (e.g., Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003), which can be a powerful way to promote changes in teaching practices (Cohen & Hill, 2001). Third, there should be opportunities for active learning, which occurs when teachers are engaged in meaningful discussions, planning, practice, and reflection. As described by Penuel et al. (2007), teachers are more engaged and better able to understand underlying curricular framework when materials are tailored for their classrooms, when implementation of these materials is planned, when they have the opportunity to observe others teaching these materials and be observed in their own teaching, and when they can review student work. Fourth, there should be good coherence with teacher professional lives, including alignment with professional development, other training activities, and state/district standards and assessments. Teachers' interpretation of this alignment is most relevant, as this affects how they perceive the experience and ultimately apply it in the classroom. Fifth, effective professional development promotes *collective participation* involving teachers from the same school, grade, or subject. As described by Garet et al. (2001), Penuel et al. (2007), and others, discussions and collaborations are likely to be more productive and support sustained changes in teaching practices when teachers have similar goals and challenges. Sixth, many professional activities are too short and provide little or no follow-up support during implementation.

Thus, effective professional development should be of an extended duration, allowing time for active learning, including discussions of students' preconceptions, practicing strategies, and receiving feedback. Finally, Penuel et al suggest that, although it is not directly part of the professional development experience, providers must consider and supply resources necessary to support classroom implementation.

8.3 iGIS Design

8.3.1 Participants

From 2005 to 2009, 69 middle and high school teachers from the Central Appalachian region of Maryland, West Virginia, and Pennsylvania participated in the iGIS project in one of four cohorts (Fig. 8.1). Teachers were recruited throughout this region via the project website; email solicitations; phone calls to science supervisors, school principals, and science teachers; and presentations at local schools, district meetings, and regional conferences. Recruitment also occurred through word of

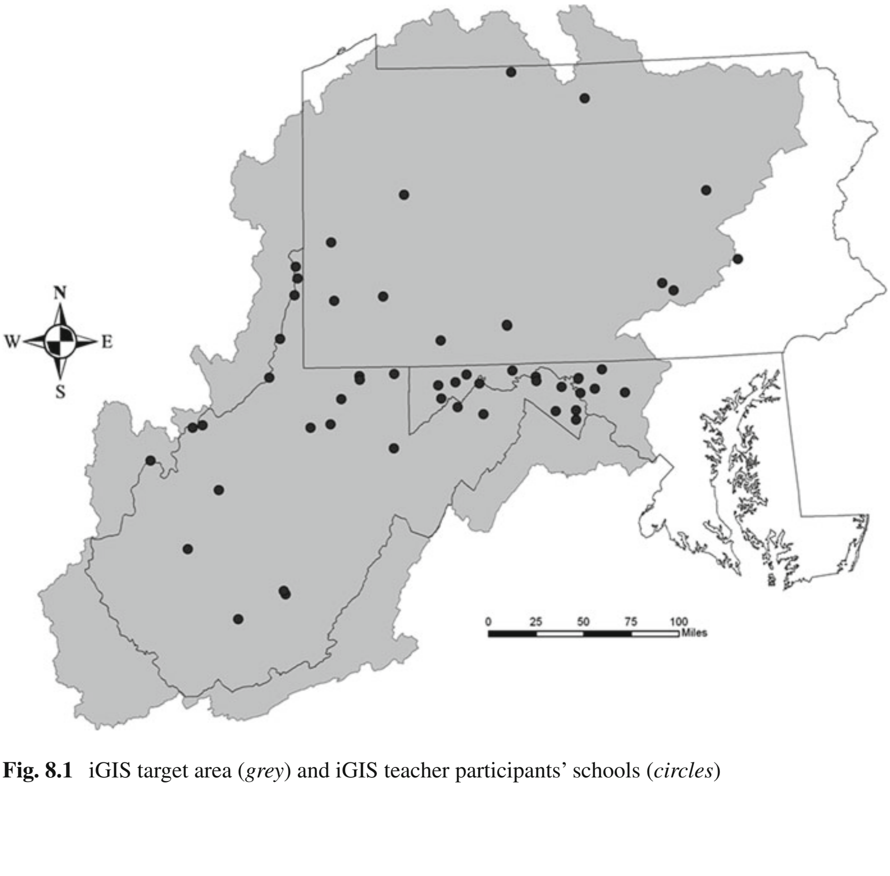

Fig. 8.1 iGIS target area (*grey*) and iGIS teacher participants' schools (*circles*)

mouth, especially from past participants. While the target region was quite extensive, *collection participation* was promoted by limiting participation to those teaching middle or high school science courses that incorporate water cycle and land use concepts (environmental science, earth science, general science, and biology) and encouraging teachers from the same school to apply (through school visits, calls to principals, and asking applicants to promote the project with colleagues). Ultimately, participants included four, three, and five pairs of teachers from the same school in the first three cohorts; the fourth cohort included one pair plus four teachers from the Maryland Department of Juvenile Services. Most iGIS teacher participants were mid-career and certified in their subject areas, had a Masters degree, and taught at schools in small towns and rural areas. Most had little or no prior experience with GIS. Each teacher participant received a stipend ($1,575), iGIS unit and datasets, GIS desktop software program (school-wide license), GPS device, various GIS and watershed video and print resources, access to watershed lending kits, and optional university graduate credit (tuition/fees were not covered). A significant portion of the stipend was withheld until participants completed all project requirements including classroom implementation or until participants could offer a reasonable explanation for their inability to implement. Many participants traveled significant distances to attend workshops in Frostburg, MD, and summer institutes at host schools; they were compensated for all travel expenses. One hundred and fifty-five Central Appalachian teenagers also participated in the project through summer youth institutes. Youth participants received a small stipend, inflatable globes, and professional-looking portfolios with maps created during the institute. Each year two iGIS teachers hosted an institute at their middle or high schools. As hosts, they handled logistics (e.g., catering, computer access, field trip buses), recruited and selected youth participants, and received an additional stipend for their efforts.

8.3.2 Structure

The iGIS project was extended in duration to 120 contact hours, with each cohort of teachers participating from May through June of the following year. The project was nonresidential, although travel expenses were provided for teachers living a significant distance from workshop and institute locations. After project refinements, the professional development activities were as follows:

- Mid-May – One- to two-day introductory workshop. Teachers reviewed the project goals, watershed focus, and requirements, were introduced to the staff and each other, started initial lessons in the iGIS curricular unit, learned basics of the GIS software, and reviewed logistical issues (e.g., loading the software/data on home computers for the online session).
- June, approximately four hours per week – Four-week online session. Each week teachers worked independently through one to two unit lessons, submitted answers to unit reflection questions and posted screengrabs of their GIS work, and shared

asynchronous online comments on the units' strengths and weaknesses with project staff and each other. Answers and comments were due Thursday of each week, with staff feedback provided within a few days.

- Early July – One-week core workshop. Teachers completed the unit; worked through each optional activity in the unit, including collecting biotic, abiotic, and geographic data at a stream site; attended lectures and field trips with environmental scientists and GIS specialists to get a deeper understanding of stream ecology and environmental hydrology; created local datasets necessary for implementation of the iGIS unit; started working on curriculum adaptations; and prepared for upcoming summer youth institutes.
- Mid-July and immediately following the core workshop. One-week youth institutes. From 9 am to 1 pm, teachers led youth through hands-on activities from the iGIS unit, allowing teachers to practice their new skills and knowledge and examine youth work. At each institute, a local GIS professional gave a presentation on his or her own watershed and/or land use change work. Each GIS professional interacted with teachers and youth and helped assess youth work. After the youth departed each day, the teachers spent the afternoon reflecting on the morning's activities, planning for the next day, working on any unit adaptations, and developing classroom implementation plans.
- Mid-September and Mid-March – Two one-day follow-up workshops. Teachers learned about GIS careers and worked through several GIS career activities from the iGIS unit, reviewed key software functions, and shared implementation challenges, strategies, and successes.

Each professional development activity was designed to build directly on the preceding one. The iGIS project used a blended approach, which offered the strength of both face-to-face interactions and online learning (Dede, Ketelhut, Whitehouse, Breit, & McCloskey, 2009). This included giving participants opportunities to work both on their own and with peers and staff, to share opinions in different settings, and to spend less time away from home. Time away is a significant issue in rural areas where participants must drive long distances and often stay overnight to attend in-person events. Because retention problems can occur during web-based instruction, the online session was sandwiched between the in-person introductory and core workshops to reduce attrition, ensure assignments were completed on time, and promote online communication. Specifically, the introductory workshop established relationships among participants and with project staff and ensured confidence with basic GIS skills. The core workshop applied online works to complete and customize the iGIS unit (e.g., finalizing the unit's local stream site using sites proposed during the online session). After the spring and summer professional development activities, the project staff regularly emailed and telephoned participants during the school year to check on progress and help address problems or concerns. The iGIS staff also visited each participant's classroom to observe unit implementation, assist with any technical or pedagogical issues, and provide encouragement. Support continued beyond the yearlong professional development experience, including ongoing staff feedback,

Table 8.1 Teachers' participation in the iGIS professional development (PD) and curriculum implementation in their classroom

Cohort	Completed all iGIS PD activities (%)	Submitted the final report (%)	Implemented all or most of iGIS unit (%)	Implemented only some of iGIS unit (%)	Unknown or did not implement iGIS unit (%)
1 ($n=19$)	100	89	58	32	10
2 ($n=17$)	88	71	76	0	24
3 ($n=19$)	100	100	100	0	0
4 ($n=14$)	100	100	93	7	0

updated versions of the iGIS curriculum and software, and access to watershed lending kits. This extensive follow-up support was instrumental in achieving a high rate of classroom implementation (see Table 8.1).

8.3.3 Curricular Materials

Using the curriculum-linked professional development approach, the iGIS professional development centered on the iGIS unit, which explores human impacts on the water cycle and in watersheds. Students' preconceptions of the water cycle often lack understanding of the movement of water across the landscape as surface runoff and groundwater, and their understanding of a watershed is often quite limited – sometimes literally defining it as a shed that holds water (Shepardson et al., 2007). The iGIS unit addresses these misconceptions and gives students an opportunity to understand water quality issues in their communities. The unit focuses on teaching with the tool, rather than about the tool (also see McAuliffe and Lockwood, this volume), and thus incorporates GIS functions only when necessary for visualization and analysis. Others have promoted this strategy including one GIS education leader who recently responded in a survey that, "Too much time has been focused on the nuts and bolts of the software and data, and too little time on what problems students can solve with these tools or how they can turn information into knowledge" (Stylinski, unpublished).

In the first pilot year, the project staff created an extensive unit (23 lessons) that compared spatial patterns among large watersheds in the Central Appalachian region. Most teachers only implemented a small portion of the unit (see Table 8.1), and many expressed concern about the length and complexity. In addition to the main unit, optional activities were also developed to support more local explorations. Because these units were more difficult to enact, the project staff thought teachers would incorporate them only after becoming skilled with the main unit. Instead, participants were more enthusiastic about the local activities and wanted to use them in place of or before the main regional investigation. As one teacher explained, "Students reacted better when the lesson progressed from the concrete (local stream/watershed) to the abstract (regional ecosystem/watershed)."

With this feedback, the project staff significantly revised the unit – removing the regional-level investigation and centering the unit on a local stream site selected by the teacher. The Understanding by Design framework (Wiggins & McTighe, 2005) was used to ensure that revised activities supported targeted student outcomes. First, following a backward design, project staff identified Maryland, West Virginia, and Pennsylvania education standards. Staff members then developed enduring the following enduring understandings and essential questions for the iGIS unit:

Enduring understandings

- A stream site is affected by environmental conditions in its upstream watershed.
- Human land use choices can impact the water cycle and stream ecosystems.

Essential questions

- Will a new housing development affect a local stream site?
- What should we consider to understand health of a stream at a particular site?
- Are there ways to reduce negative impacts on local streams?

These overarching concepts and questions were "unpacked" into key knowledge, skills, and abilities, such as:

- Water flows from areas of higher elevation to areas of lower elevation.
- A watershed is all the land that drains to a particular site on a stream, lake, bay, or ocean. You can pick any site on a stream and draw its watershed.
- The water cycle includes evaporation, transpiration, condensation, precipitation, stormwater runoff, infiltration, and groundwater movement.

Second, the iGIS staff determined assessment evidence that would allow students to demonstrate the desired results. This consisted of reflection questions on specific concepts and performance tasks. Sample reflection questions include "Is it possible for a stream to flow north? Explain your reasoning" and "Recall how you used GIS software in this lesson. Describe how this would have been difficult to do with a paper map." For the performance task, students take on the role of a GIS specialist to report on how a hypothetical proposed housing development will impact a local stream site. This framework helped the project staff identify the need for additional scaffolding on the water cycle (e.g., using GIS software to explore changes in elevation along a stream) and for more opportunities to identify students' preconceptions about the water cycle, hydrology, and watersheds.

As the final step, the staff created a five-lesson unit that met these desired results and incorporated this assessment evidence. The unit begins with students discussing local development pressures, created when urban residents from nearby metropolitan areas seek cheaper rural housing options. Students use GIS and aerial photos to predict how a proposed housing development will impact their local stream site then take a step back to examine concepts necessary to understand this impact. First, students consider human impacts on the water cycle by (1) creating their own water cycle model, comparing it to a provided model, and explaining how a new housing development would impact each component of the water cycle and (2) by reading about impacts of impervious surfaces on stormwater runoff and proposing ways to reduce runoff in their schoolyard. Next, students use GIS to examine water movement across their landscape. Using only prior knowledge and provided stream and elevation layers, they delineate the area that they think impacts their local stream site (often ignoring elevation data and drawing a circle around the site). They then are guided more closely to examine the provided layers to determine stream flow direction, identify the stream network for their stream site, and predict the flow direction of provided “raindrops” near their stream site. They also read about watersheds. Applying this information, students redraw the area impacting their stream site (i.e., watershed) and compare this to their initial prediction. They then examine an impervious surface layer with the proposed housing development, clip it to their watershed, determine the percentage and distribution of impervious surface in their watershed, and use these results to calculate the volume of stormwater runoff with and without the proposed development. Finally, they return to their original question and use their findings and new understanding to describe how the proposed development will impact their stream site and propose ways to reduce this impact. The unit activities parallel those of professionals conducting a watershed analysis intended to determine stormwater runoff and other impacts on a particular stream site.

In addition to the lessons, the iGIS curricular materials include extensive guidance on implementing each lesson in the classroom, technical support documents, and optional activities (e.g., creating a physical model of a watershed, collecting field data at the local stream, and examining infiltration and runoff for different surfaces in the schoolyard). Curricular materials were provided in Microsoft Word format so that teachers could revise text as needed. Teachers were strongly encouraged to connect the hypothetical housing development to actual development projects in their communities and incorporate schoolyard and stream field trips into their unit. Such trips were supported by the optional activities and were thoroughly reviewed and practiced during the core workshop and youth institute. Sixty-five percent of teachers led students in a stream field trip as part of their iGIS unit, based on a follow-up survey with 50 of the 55 teachers in cohorts, one, two, and three.

8.3.4 Classroom-Friendly Software and Data

The iGIS unit uses a GIS software program developed by Northwestern University specifically for the classroom environment (*My World GIS*, Edelson et al., 2006). This program allows teachers and students to complete sophisticated GIS functions using an intuitive interface with separate sections for accessing data layers, visualizing spatial patterns, analyzing data, and creating new data layers. Instructions are straightforward with minimal jargon. Many complex functions are automated, and common hurdles are addressed (e.g., easy navigation to needed data layers and recommended file names for new data layers).

Teachers have to create their own local data layers before implementing the iGIS unit in their classroom. To minimize this challenge, only a few local data layers are required, and all are given names to match the unit text. These data layers were relatively easy to create using provided iGIS regional baseline datasets and My World GIS software. Teachers created these layers by subsetting provided regional layers (e.g., streams, elevation) or delineating new points or polygons using these provided layers as a guide (stream site, proposed development). They had to acquire only one new layer (local aerial photo), which was done in one simple step using the software. Ultimately, each iGIS teacher received the following CDs:

- Training CD (sample data to work through the unit)
- Regional CD (data of their region used to create the local data layers)
- Classroom CD (all local and regional data needed to complete the unit; this is the only CD that needed to be loaded on school computers)

Teachers created all local layers during the core workshop; they also received written instructions in case they wanted to create additional layers in the future. Initially, the Regional CD was only needed during the core workshop to create the Classroom CD. However, teachers could return to it for additional environmental data layers as they developed expertise and expanded their GIS classroom investigations. All other resources needed to enact the unit and optional activities were provided, including a school-wide My World GIS software license and access to iGIS watershed lending kits. These included materials such as schoolyard rainwater infiltration kits with multiple GPS devices and digital cameras and stream sample kits with PASCO water quality probes.

8.3.5 Delivery

The iGIS professional development highlighted active learning through discussion, practice, reflection, and planning. Before and after working through the iGIS unit, the project staff reviewed and discussed the iGIS Understanding by Design framework so that teachers were aware of targeted learning goals and strategies. Like students, teachers worked through each unit lesson and optional activity, including completing the unit worksheet ("report") and answering unit reflection questions. During the online session and the core workshop, teachers met virtually and face to face to reflect and share challenges, concerns, strategies, and successes for teaching the unit and promoting learning. To gain a better understanding of environmental hydrology concepts, participants also interacted with scientists during lectures and on field trips examining different stream sites, various land cover types, and hydrological gauging stations. On the last day of the core workshop, participants prepared for the youth institute (see below) and began work on their implementation plans for the upcoming school year. In planning, participants described how the iGIS unit complements existing curriculum, considered relevant local or state content/skill standards, weighed any unit adaptations, and formed plans for assessing student work. In afternoons of the youth institute, participants completed these implementation plans and worked on unit adaptations. Based on the follow-up survey with the first three cohorts, many teachers did some customization of the iGIS unit, including deleting lessons or parts of lessons (63 %), adding lessons or parts of lessons from other sources (54 %) or iGIS optional activities (40 %), and switching the order of lessons or activities (42 %).

The weeklong youth institute provided iGIS teachers with an opportunity to plan, practice teaching, observe other teachers, be observed, and review student work. Teachers worked in teams to colead the half-day nonresidential institutes. The institutes had two goals – (1) enhance teachers' skills with GIS and the iGIS unit outside the pressures and constraints of the classroom and (2) promote teenagers' interest in GIS investigations and science/technology careers. Skill development served as the initial goal of the program, which led to participant teachers guiding youth through each lesson in iGIS unit. But this focus created a setting too much like school in what was intended as an informal education experience. Further, the school atmosphere led to poor youth engagement. So, the focus shifted to developing youth interest in GIS. The iGIS staff provided an outline of the overall institute structure using selected hands-on and field-based elements from the unit and optional activities like sampling a local stream site and measuring rainwater infiltration rates at the host school campus. Teachers adapted this structure, modifying activities, adding additional activities (e.g., geocaching with GPS units), and developing a schedule. Teachers were strongly encouraged to use a "paperless" approach for institute activities. That is, they only used their unit binders as a guide and instead orally presented activity goals and key steps with visual supported from a computer and LCD projector as needed; this allowed youth to apply their developing skills with the intuitive software to complete the tasks. This approach was modeled in the workshops and encouraged for classroom implementation (the iGIS unit includes short written summaries of each lesson that can be distributed to classroom students). One teacher captured the pedagogical benefit of this approach, saying, "[Working] without using our [unit] binders made us 'think' about what we were teaching and why." Teachers also helped develop and apply a rubric to assess youth participants' work through an embedded assessment. Individuals or teams prepared and orally presented portfolios of their spatial investigations.

Throughout, the project staff tried to be nimble in the professional development to meet the individual needs of each teacher and cohort. During the workshops and throughout the classroom implementation, the staff gathered verbal feedback on current concerns and questions and then adapted delivery and activities as needed. For example, at times staff expanded discussion and planning time, added an additional field activity, or streamlined the implementation report. Other providers have highlighted the value of this rapid response for project success (Granger, Morbey, Lotherington, Owston, & Wideman, 2002; Varma et al., 2008).

8.4 Outcomes

The impact of the iGIS project on teacher participants was examined using surveys, informal discussions, and teacher artifacts, including project applications and classroom implementation plans and reports; findings from this evaluation are summarized below.

To ensure full participation, a significant portion of teachers' stipends was deferred until completion of the final implementation report, which contributed to low attrition rates. Overall, most teachers participated in all project activities, submitted their implementation reports, and implemented all, most, or portions of the iGIS unit in their classrooms (Table 8.1). The percentage implementing all or most of the unit increased substantially after the first cohort, presumably due to curriculum refinements described earlier. One teacher volunteered in an email that "The new [unit] accomplishes the task of introducing GIS and watersheds without overwhelming the course taught. And although I will miss some of the parts…this one is more realistic and will more likely be integrated into classes." In the follow-up survey conducted with the first three cohorts two or more years after participating, 77 % of respondents reported using the iGIS unit at least once since the yearlong iGIS project, and 78 % reported they plan to use it again. Twenty-two of the 50 respondents reported using GIS beyond the project's minimum requirement of integrating the iGIS unit into one course. This included integrating GIS into other existing courses like mathematics and AP environmental science, creating new GIS-based courses like "GIS and the Environment", using GIS for other environmental science field investigations, and assisting with other GIS-based teacher professional development.

There was evidence of good coherence within the iGIS project with teachers' broader professional development goals and with district standards and assessment (Table 8.2). Penuel et al. (2007) identified teachers' perception of coherence as a key element in their study. Teachers also found communication with other teachers useful. One teacher commented, "I learned a lot of great ideas from the other [teachers] as they shared how they implemented GIS in the classroom and how they extended concepts." Another wrote, "I…liked hearing the stories from the other teachers so that I can see that I'm 'about right' in terms of my teaching new things with other teachers making similar efforts." However, teacher feedback also indicated that they needed more opportunities for this.

Based on pre- and post-project surveys, teachers' self-reported GIS skills, knowledge, and abilities improved dramatically (Table 8.3), especially for our final cohort. One teacher noted, "I felt I was lacking in integrating technology in the classroom and now I feel comfortable using GIS software, GPS units and water quality probes with my students – I'm excited!" By contrast, their overall computer skills and comfort did not change much, possibly because the iGIS unit constituted only a small portion of their yearlong teaching activities. Two or more years after participating in the iGIS project, a majority of participants believed the project had a moderate to high impact on their knowledge of GIS and land use impacts within their watershed (96 % and 83 %, respectively) and their skill integrating this knowledge into the classroom (92 % and 94 %, respectively).

Most teachers gave very positive feedback on the yearlong project, with some improvement after piloting activities and materials with the first cohort (Tables 8.4 and 8.5). Overall, many participants felt that the professional development activities were useful, effective, and appropriate and gave them confidence to integrate the iGIS materials into their classrooms. One teacher highlighted the strong proximity to practice, commenting, "Everything had a purpose to why we were doing it.

Table 8.2 Teachers' rating of the coherence of and communication during the iGIS professional development activities. Data are the average percentage of teachers who gave the two highest ratings on a four-point scale ("agree" and "strongly agree," "satisfied" and "very satisfied," "frequently" and "very frequently," or "useful" and "very useful") for five or six iGIS professional development activities. Data are not available for cohort one

	Cohort 2 (%)	Cohort 3 (%)	Cohort 4 (%)
The workshop built upon what you learned in the previous iGIS workshop(s)	87	97	95
The workshop was consistent with your goals for professional development	89	97	98
The activities in this workshop were well aligned with your state or district standards and curriculum frameworks	91	94	94
The activities in this workshop were well aligned with state and district assessments	92	90	91
How useful was your communication with other participants?	82	86	83
How frequently did you communicate with the other participants?	59	66	68

Table 8.3 Teachers' rating of their GIS and computer skills. Average percentage of teachers who gave the two highest ratings on a four-point scale ("somewhat high" and "very high" or "somewhat comfortable" and "very comfortable") before (pre) and after (post) participating in the iGIS project

	Cohort 1		Cohort 2		Cohort 3		Cohort 4	
	Pre (%)	Post (%)	Pre (%)	Post (%)	Pre (%)	Post (%)	Pre (%)	Post (%)
How would you rate your current skill using GIS software?	6	56	0	83	5	83	0	93
How would you rate your current understanding of what GIS is?	11	81	6	92	5	83	14	100
How would you rate your ability to integrate GIS activities into your curriculum?	33	69	12	92	26	78	7	93
How would you rate your current skills using computers as a tool when teaching students?	78	81	82	92	79	89	46	64
How comfortable or uncomfortable are you using computers as a tool when teaching students?	89	94	82	92	89	94	86	79

Also all of this is directly transferable to the classroom." Teachers also indicated the experience would improve their teaching practices. One teacher wrote, "The experience has real concrete value. I can immediately apply the material to my curriculum and enhance it." Another volunteered:

> I am presenting a poster session at the AGU conference in San Francisco [titled] 'How [the Earth System Science Education Alliance] has changed how I teach.' I hope you don't mind but I've included iGIS in my presentation [as it has played a key] part of tying all the spheres together.

Table 8.4 Teachers' feedback on the iGIS professional development activities. Data are the average percentage of teachers who gave the two highest ratings on a five-point scale ("most of the time" and "always") for five or six iGIS professional development activities

During the workshop how often did you feel	Cohort 1 (%)	Cohort 2 (%)	Cohort 3 (%)	Cohort 4 (%)
What you were doing was not too difficult?	75	76	78	88
Excited about what you were doing?	56	81	80	78
Not bored?	56	80	76	77
Not frustrated or anxious?	58	46	61	74
Eager to learn more about the topic?	65	91	86	80
That what you are learning can be used in your classroom?	71	92	86	77
That you were involved in effective professional development?	80	99	90	89
That the instructors could relate to teachers like you?	89	88	86	83
That your needs as an adult learner were adequately met?	83	96	88	91
That what you are learning will help you be a better teacher?	76	94	88	84

Table 8.5 Impact of the iGIS professional development activities on teachers' satisfaction and confidence. Data are the average percentage of teachers who gave the two highest ratings on a five-point scale ("satisfied" and "very satisfied") or a four-point scale ("confident" and "very confident") for five or six iGIS professional development activities

	Cohort 1 (%)	Cohort 2 (%)	Cohort 3 (%)	Cohort 4 (%)
How satisfied or dissatisfied are you with this workshop?	76	98	91	89
How confident are you that you will be able to integrate what you have learned in this workshop in your classroom?	67	89	87	79

Teachers felt the youth institute was particularly valuable and reported that it enhanced their confidence to work with the unit and software. As one teacher said, "The highest order of learning is teaching. To teach the students, work through their problems and answer their questions [during the institute], was a great experience." Another wrote, "Having real students to 'practice' with makes me much more comfortable as I decide how I will implement GIS this fall." Many were surprised by the teenagers' technological literacy. One teacher noted, "I've seen how students can pick up the iGIS skills very quickly, so it makes me more confident in teaching it." Several highlighted the benefit of learning from other teachers. One wrote, "It was great to get practice with large group instruction and individual assisting. I feel much more confident now in my ability to implement the curriculum" while another said, "We all had things to contribute and we learned things from each other as well as the students. Too often we don't get a chance to be observers in educational settings." One participant even remarked on the value of working with students from another school system saying, "I lost all fear." With the fourth cohort, half of the institute was devoted to an open-ended investigation with teachers and students working as a team. Most teachers were quite pleased with this format, noting it helped them enhanced their skills while "…nurturing a genuine curiosity and interest of the young students." Teachers did identify some problems during the youth institute including the need to be "more student centered with less teacher-talk" and insufficient time to complete the open-ended investigation. However, most teachers felt the institute achieved the dual success for teachers and youth, noting youth "…had the opportunity to learn GIS in a non-threatening, supportive environment that interspersed outside 'games' with hands-on computer learning."

8.5 Recommendations and Conclusions

Findings from the iGIS project support other studies that highlight critical features of effective professional development (e.g., Garet et al., 2001; Penuel et al., 2007). Specifically, the yearlong project included a strong focus on curriculum and content; good coherence; access to essential classroom resources; opportunities to plan, practice, discuss, and reflect; and extensive support to tailor and implement a provided curriculum in the classroom. This approach helped ensure high participant retention and classroom use. All of these elements laid the foundation for classroom implementation, with extensive follow-up support serving as a linchpin to successful implementation. Squire, MaKinster, Barnett, and Luehmann (2003) also found that extensive technical, emotional, and personnel support was critical for technically innovative curricula.

Results here also illustrate that, with the appropriate resources, teachers new to GIS can create local data layers and adapt GIS-based investigations for their communities. For the iGIS project, these resources include a standards-based unit focused on content and using classroom-friendly software and data. Wilder, Brinkerhoff, and Higgins (2003) have shown that professional development focused on generating datasets offers teachers ownership, better understanding of content, and experience with real-world problem solving. Squire et al. (2003) note that adapting curriculum to local needs and contexts can be a very powerful learning experience for teachers.

The iGIS informal youth education experience was a particularly effective component of this K-12 teacher professional development and illustrated that emphasis can be placed on promoting youth interest without compromising opportunities for teachers' classroom skill development. Other ITEST-funded projects have also identified these teacher-youth experiences as critical components of their professional development activities (McAuliffe and Lockwood, this volume; Moore, Haviland, Whitmer, & Brady, this volume; Parker et al., 2010). The summer institute experience was required by the NSF ITEST grant program and aligns with elements of effective teacher professional development regularly cited in the literatures, such as review of student work (e.g., Desimone, Porter, Garet, Yoon, & Birman, 2002; Garet et al., 2001; Penuel et al., 2007). However, neither formal nor informal learning research has specifically examined approaches, challenges, and benefits of integrating K-12 teacher training within out-of-school settings. Results presented here indicate that involving K-12 teachers in informal learning experiences can (1) enhance teachers' confidence and understanding of new content and skills outside the pressure and constraints of the classrooms and (2) increase informal science education opportunities, especially for youth in rural areas with few such offerings. Research is needed to better understand benefits to teacher education and informal learning and to determine best practices.

Teacher feedback suggested that the iGIS project could have benefited from more collaboration and promotion of communities of practice, particularly by having participants communicate and work together beyond the iGIS professional development activities. Promoting communities of practice within and beyond the confines of formal professional development has been shown to be particularly effective at supporting adaptation and implementation of provided curricular materials (Avery & Carlsen, 2001). Such interactions might have helped mitigate significant challenges that iGIS teachers faced during implementation (expressed during informal discussions). These included insufficient time, insufficient technology facilities, delays in software/data installation, and difficulty storing and accessing student data files. Researchers of technology-based teaching and learning have cited similar challenges (e.g., Ertmer, 2005; Hew & Brush, 2007), including a recent review of other teacher education projects funded through the NSF ITEST program (Parker et al., 2010). Technology has changed considerably over the course of the 5-year project. For example, almost all US schools now have classrooms with Internet access (Parsad & Jones, 2005), including many of the rural schools involved in the iGIS project. As a next step, the iGIS project staff is exploring the use of a regionally based online software program (developed by the National Geographic Society) to support local watershed investigations. Of course, new hurdles associated with online geospatial inquiries will need to be considered, including restrictions on student Internet access and data file size (and thus spatial resolution). Additionally, because yearlong efforts like the iGIS project require considerable financial support and may hamper efforts to reach teachers who do not frequent professional development offerings, the project staff is also examining ways to adjust their blended learning approach to increase online training and support while still maintaining critical face-to-face interactions.

Lasting change in teaching practices takes time and often does not occur in the first year of implementation (Basista et al., 2001; Squire et al., 2003). The iGIS project provides evidence of initial changes in teaching practices with a majority of past participants continuing to use the iGIS unit in at least one course and almost half using GIS beyond this course. Teacher surveys and pre-/post-embedded assessment suggest improvement in content knowledge of iGIS teachers' classroom students (data not included here); however, it is difficult to directly link iGIS teacher professional development to changes in student achievement and participants' teaching practices (e.g., Bebell et al., 2004; Blank, de las Alas, & Smith, 2008). To understand this more broadly, the project staff has joined colleagues at Educational Development Center and TERC to examine links between technology-intense teacher education and changes in teaching practices using NSF ITEST projects as a study group.

Overall, research on geospatial technology in K-12 education is still in its adolescence and lacks a clear agenda (Doering et al., 2008). There are many unanswered questions, including the following: What pedagogical models are being used or should be used to support integration of geospatial technologies into the classroom? What knowledge/skills/attitudes should we target in teacher education? How do geospatial tools foster learning transfer from one subject to another? How can geospatial technologies promote student-centered learning? What teacher education strategies are most effective at helping teachers integrate geospatial technologies into their classrooms? Additionally, like many other teacher professional development efforts (Blank et al., 2008; Parker et al., 2010), the iGIS project used customized instruments and depended on teacher self-reporting, which presents validity concerns and limits broad application of the findings (Brinkerhoff, 2006). To convince teachers and administrators of the importance of spatial fluency and the efficacy of geospatial technologies in fostering learning, education researchers and practitioners need to develop and apply a universal, valid, and robust set of evaluation instruments.

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