Professional Development: Teachers Use of GIS to Enhance Student Learning

Patricia A. McClurg and Alan Buss

Abstract

This article explains a professional development experience of fifth to twelfth grade teachers in using geographic information systems (GIS) and global positioning systems (GPS) technologies to enhance classroom teaching and learning environments. A key challenge faced by the developers was whether teachers would value the technology tools enough to warrant the time necessary to develop the skills for productive use of the technology. Based on five years' experience, researchers identified seven key components and elaborated on them with examples and related processes.

Key Words: *geographic information systems, professional development, instructional technology, technology integration, technology implementation*

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Introduction

Geographers have advanced four basic reasons for the importance of geographic information systems (GIS) for Kindergarten through twelfth grade (K-12) geography instruction (Keiper 1999; Lemberg and Stoltman 1999). First, local applications of GIS enable students to complete in-depth study of local issues and conditions. Second, GIS is an especially powerful tool for analyzing conditions and changes in the environment and for examining potential solutions. Third, the technologies used and the meaningful nature of the issues and problems that they shed light on enhance student interest in geography. Fourth, students who gain familiarity with technology and its applications in the early grades will be more inclined to learn and use technology in later education and in adult life.

Incorporating new technologies into classroom settings requires that teachers acquire new knowledge and skills. Learning experiences for teachers are often formalized into a series of workshops, institutes, or classes termed professional development experiences (PDE). This investigation demonstrates that professional development experiences, which provide adequate support, relevant content, and opportunity for sustained participation, can be designed and implemented to effectively assist educators in bringing GIS and GPS into the fifth through twelfth grade classroom.

Spatial Data Tools

Geographic information systems (GIS), remote sensing, and the global positioning system (GPS) are tools used extensively by researchers, scientists, and civic planners to assist decision-making about real world problems. Application of this technology to such concerns as the environment, agriculture, land use management, and infrastructure development is occurring on local, regional, and national levels. In particular, GIS is a powerful tool for storing, analyzing, displaying, and processing spatially referenced information.

While these spatial data resources have been used widely in business, industry, and government agencies, educational implementation especially at the K-12 level has been impeded due to prohibitive software costs, data availability, awareness, training opportunities, and hardware limitations such as high student-to-computer ratios, low capacity processors, and insufficient random access memory (RAM) and hard drive memory. Recent advances in hardware capabilities and relative reduction in costs have resulted in the introduction of powerful, affordable, personal computers in schools that can be used to run GIS software and manipulate large spatial data sets. Additionally, software companies such as Environmental Systems Research Institute (ESRI) and Clark Labs have produced software bundles designed for school systems at affordable educational prices.

Now that supportive technologies are more readily available, educators are beginning to use GIS and GPS technology in fifth- through twelfth-grade teaching and learning environments. Examples are varied and range from students researching and creating GIS layers of American Civil War battles (Alibrandi 2001), to mapping community hazards in Detroit (Wilds and Martin 2005), to examining connections between geography, history, and technology in the context of the Underground Railroad (Bloom and Palmer-Moloney 2004). Other students have become involved in mapping and analyzing data relevant to local environmental issues (Bull, Bull, and Mason 1999; Paul and Hamilton 2000; Queen, Easterling, and Connors 1998).

Journal of Geography 106: 79–87

Imagery and data sets from such agencies as the National Aeronautics and Space Administration (NASA), the United States Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA) involved in observing and monitoring earth systems are available to K-12 students via the World Wide Web. Many state and local agencies maintain a growing number of local data sets appropriate for spatial analysis. The available data, which can be coupled with student-collected data, provide rich opportunities for substantive, authentic investigations in earth science, geography, life science, physical science, mathematics, and social studies.

Partnerships are emerging between schools and institutions of higher education to tackle the challenges of identifying and creating accessible data sets, developing exemplary instructional materials, and developing effective professional development experiences for teachers (Baker 2005; Malone, Palmer, and Voigt 2002; McClurg and Lerner 1998; Slater, Beaudrie, and Fixen 1998). Investigations examining the claims that novices can use GIS technologies as problem-solving tools and that these tools can enhance student understanding are informing instructional practices (Audet and Abegg 1996; Audet and Paris 1997; Ramirez 1996). Some schools are instituting curricula that require GIS technologies in at least two different modes: GIS education and GIS *in* education (Baker 2005; Kerski 2003).

Professional Development Experiences

While initial users of GIS were often self-taught, it is not realistic to assume that most teachers, while working full time in demanding jobs, will be able to incorporate strategies using these new tools into their professional repertoires. Ample evidence exists to suggest that, in order to learn new teaching strategies, teachers need information, theory, modeling, coaching, support, and feedback through sustained, intensive experiential learning opportunities (Darling-Hammond 1998; Garet *et al.* 2001; Joyce, Showers, and Fullan 2002; Lester 2003).

Of the barriers to reform teaching, teacher time is a key issue (Fullan and Miles 1992; Kerski 2003). Professional development experiences can facilitate change by providing long-term support and opportunities to learn. Bohlin and Hunt (1995) reported an increase in confidence and positive attitudes and a decrease in computer-anxiety when pre- and in-service teachers were enrolled in courses that met over a longer period of time. Additionally, in a national survey of 1,027 teachers, high quality professional development activities were characterized as spanning longer periods of time and involving a considerable number of contact hours (Garet *et al.* 2001). Sustained experiences provide time for teachers to learn new skills, experiment, practice, reflect, revise, and to integrate new understandings (Loucks-Horsley *et al.* 1998). Along with sufficient time to gain initial understandings, the National Staff Development Council emphasizes the importance of intensive follow-up as a component of high-quality training programs (National Staff Development Council 2001a).

Initiative Objective

The objective of this initiative was to develop and deliver effective and reproducible professional development experiences (PDE) resulting in fifth- through twelfth-grade teachers using GIS and GPS technologies in their classrooms to enhance their classroom teaching and learning environments. One challenge facing the realization of this objective was time. GIS software is more sophisticated than many of the application programs used in schools. How much time is needed for teacher participants to obtain the skills and knowledge necessary for meaningful transfer to the classroom setting? How much time is needed for fifth- through twelfth-graders to obtain the skills and knowledge necessary for productive use of these tools? And, more importantly, would teachers value the tools enough to warrant the time necessary for them and for their students to develop the skills for productive use of the technology? These were not trivial questions, particularly in the context of new demands on teacher and student time resulting from increasing accountability measures tied to state and national standards and annual yearly progress reports required through No Child Left Behind (2002).

Six separate professional development workshops were delivered during the five-year development and refinement of this PDE model, and they provide the basis for this discussion of lessons learned. A total of one hundred and thirty participants completed the workshops, with content expertise in secondary science (sixty-four), social studies (twenty-nine), mathematics (eleven), art (five), vocational education (five), business (four), and English (one), as well as general elementary (six), library science (two), computer lab management (two), and administration (one). Teachers' grade level assignments ranged from fourth to twelfth grades with the majority teaching at the middle school or high school level in a largely rural state. On average twenty teachers attended each PDE. Teams comprised of two to three university faculty members and one to two fifth- through twelfth-grade teachers facilitated each PDE. Each facilitator had received in-depth instruction on the use of GIS software and participated in the PDE planning.

Evaluation Tools

Several methods were employed to measure progress toward meeting the initiative objective. These methods were used in feedback loops to guide the successive development of the resulting professional development experience. Participant self-ratings of confidence and attitude, participant demonstration of specific skills, and participant performance on graded assignments, were used as tools to assess the participants' mastery level

Your ability to take a series of locations (using a GPS unit) and then create a new layer (theme) for your GIS project.

1______2______3______4______5______6______7______8______9______10

Figure 1. Sample item from participant rating scale.

of the GIS and GPS knowledge and skills. Examples of students' work emerging from unit plans implemented in participants' fifth- through twelfth-grade classrooms provided evidence of the degree of transfer into the classroom setting based on the problem complexity and the extent of technology use.

Participant Self-Ratings

Teacher participants entered the workshop with various levels of exposure to GIS and GPS technologies. Given the relatively short instruction time with participants, a real concern emerged that teachers might be overwhelmed, discouraged, or disenchanted with their ability to use the technologies. To assess participants' confidence level and attitude toward GIS and GPS, participants were asked to rate themselves on a 15-item Likert scale at the beginning and the end of the professional development experience. While perception and misrepresentation are limitations of self-reported data, the feedback obtained from such rating scales has great potential for the improvement of instruction (Hopkins 1998).

Surveys were distributed at the beginning of day one and participants were asked to rate themselves by placing a B (beginning) over their personal rank on each item. The surveys were redistributed at the end of the last day and participants were asked to rate themselves by placing an E (end) over their personal rank on each item. Figure 1 is an example of an item asked. Items 1 through 12 dealt with participants' level of confidence regarding their ability to use specific GIS and GPS skills. Items 14 and 15 surveyed participants' attitude toward GIS and GPS as effective tools in their teaching and learning environments. Open-ended responses requesting suggestions for improving the workshop elaborated on the information gained from the self-rating instrument.

Figure 2 summarizes participant self-ratings collected in three professional development workshops after the format had undergone major changes based on feedback from earlier workshop iterations. Participant responses that did not include both a pre- and post-ranking were discarded from consideration. Inspection of these descriptive statistics suggests that participants' confidence in their ability to use GIS and GPS and their attitude toward GIS and GPS as useful tools in the classroom increased substantially. However, closer review of the survey results alerted project staff to areas needing additional attention. For example, participants expressed more confidence in their ability to use GPS units and display and overlay themes than in their ability to query multiple themes. Clearly, more substantive work was needed to increase participants' confidence in their ability to geo-reference images. This information assisted with the next iteration of the professional development experience; this example is one illustration of the use of formative feedback in the quest to meet the initiative objective.

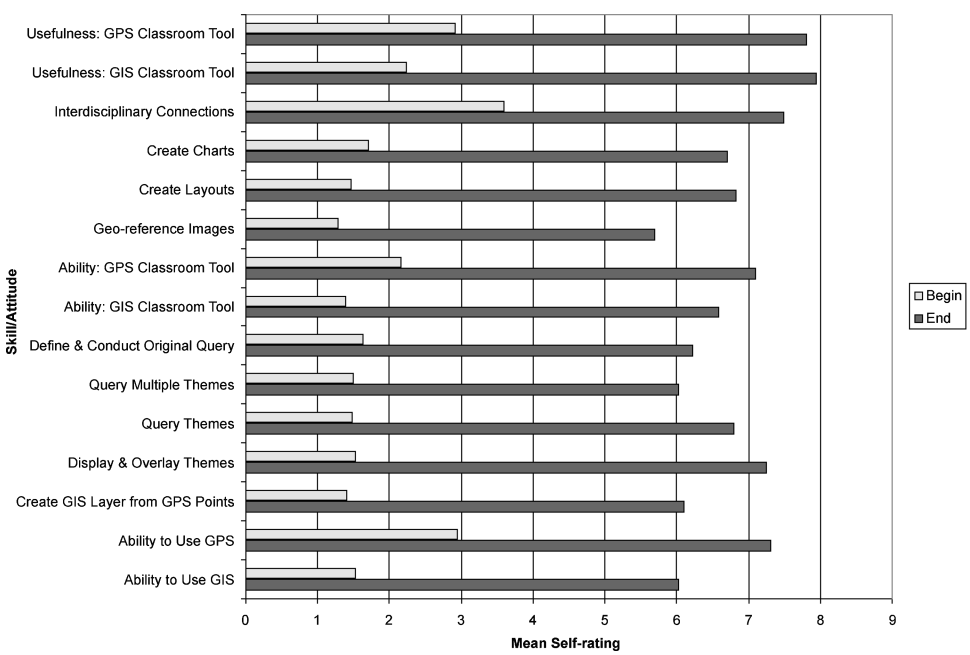

Figure 2. Mean participant self-ratings.

Participant Demonstration and Presentation

Participants also were required to demonstrate their skill in using GIS and GPS through in-class group work and through graded assignments that were completed individually. At critical junctures during the workshop, participants were combined in small groups of three to four and paired with one workshop facilitator. Each member demonstrated how she or he was able to accomplish a targeted skill. For example, after completing an assignment requiring querying multiple themes, each individual in a small group was required to demonstrate the procedure and results of an investigation that required querying multiple themes. Individuals demonstrated their skill to a facilitator, and at the same time, group members were exposed to multiple applications of the skill. Based on these demonstrations, facilitators worked individually with any participants who were experiencing difficulty with a specific skill. Likewise, participants shared the results of their investigations by displaying and discussing charts and map layouts they generated during work sessions.

Key Components

Continuous examination of participant survey results, of participants' demonstrated skill levels in initial and applied settings, of suggestions for improvement received in open-ended forums, of participant performance on homework assigned, and of examples of fifth- through twelfth-grade students' classroom work resulted in the identification of components key to this effective professional development experience. Each of these components is elaborated upon in the following sections.

Pacing

Adjusting the pacing of the workshop was the first and perhaps most important change to the professional development experience. The first workshop design included five consecutive, intensive full-day sessions during the summer followed by on-site support in teachers' classrooms throughout the year. Feedback gathered at the end of the five-day session was extremely positive. However, observations and comments collected during on-site visits revealed that participants had not retained the skills and knowledge obtained in the initial five-day period in enough depth to transfer their skills to the classroom. For instance, some participants did not remember how to install the GIS software, set up data folders on their classroom computers, or conduct basic ArcView queries. Additionally, participants reported that so much new material was covered in the use of the ArcView software and GPS units that they felt overwhelmed.

Pacing of instruction with immediate opportunities to apply the skills is an essential component for most participants to be able to achieve the goal of providing professional development that leads to meaningful integration in the participants' classroom. The intensive weeklong workshop format was modified to a series of three two-day sessions extended over a six-month period in order to provide participants with opportunities to test and refine their skills at home and in the classroom between sessions. The first two-day meeting introduced teachers to concepts of GIS and basic functions of the software, including adding data layers, conducting spatial and tabular queries, changing projections, and creating layouts. Teachers also began the planning process to incorporate the use of GIS in their teaching. The second two-day meeting focused on applications of GIS in the classroom. A key feature was a field trip for data collection, including the use of digital cameras for capturing images to be hotlinked, and GPS units for recording latitude and longitude to create event themes. In this way, the participants learned to build their own data sets. Between the second and third sessions, the participants were required to incorporate the use of GIS in their teaching. As part of the requirements, their lessons needed to address district content standards. The third two-day meeting provided an opportunity for participants to report on how they incorporated GIS in their classrooms, share examples of student work, and describe how it affected student learning. Participants also were introduced to additional processes, such as geo-referencing images and advanced querying, to show additional potential for use in the classroom to enhance learning.

An additional measure introduced to improve integration and retention was requiring participants to complete homework assignments in between workshop sessions. This included using Web-based discussion tools to exchange and refine ideas. Debriefing and sharing strategies for completing the assignments and discussing problems encountered in implementing the learned skills in their classrooms became an integral part of each workshop session.

Relevancy

The power of GIS to display and analyze spatial data intrigues most people. However, to devote the personal and class time necessary to use GIS in the classroom, teachers need to see the relevancy of its power in terms of accomplishing learning goals for their students. In today's standards-based, assessment-driven environment in K through 12 schools, it is imperative that explicit connections are made to these standards throughout the PDE. One key sequence of assignments required participants to:

1. Identify concepts in content standards that could be studied using GIS
2. Plan lessons to address these concepts
3. Assess student learning resulting from implementation of the plan

Instead of using the widely available examples from business and government to illustrate GIS features, workshop leaders used examples explicitly tied to the state and national standards. Since participants included fifth- through twelfth-grade teachers from a range of discipline areas (mathematics, science, social studies, art, general education), we developed a series of illustrations, assignments, and activities that clearly addressed specific content and inquiry standards in a variety of content areas. For example, when introducing the creation of new map layers, we instigated field trips to gather raw data using GPS and spreadsheets. Data collected on variables in multiple disciplines, such as land cover, historical events, and locations of petroglyphs on public lands, were later mapped using GIS.

Relevant Data

A critical component of relevant tasks is the availability of relevant, accessible data sets. The data sets available in most commercial GIS training and tutorials were too limited to provide rich examples that stimulate student learning of state and national standards. On the other hand, participants just beginning to use GIS have not acquired the skills to download rich data sets from Web sites and other sources. To address this challenge, a database specifically designed for use by teachers in a five-state region was prepared. The use of this regional database was a particularly helpful way of introducing connections to participants' classroom settings. Data included in *The Prairie to Mountain Explorer* (McClurg *et al.* 1999; McClurg and Buss 2000) was selected for relevancy to state and national content standards and for the depth needed to conduct meaningful inquiries that could reveal patterns and relationships. Approximately 1.5 gigabytes of thematic data were provided for Idaho, Montana, North and South Dakota, and Wyoming. Examples include bedrock geology, roads, boundaries, cities, general and agriculture demographics, climate, land cover, land ownership, species occurrences or habitats, rivers, watersheds, and elevation. Participants could explore these data layers close up (large scale) or from a regional perspective (small scale). Either way, students could query these data sets to find relationships such as the specific climates most suitable for growing corn, the elevations and vegetation types that certain species prefer, or the areas of most diverse populations. *The Prairie to Mountain Explorer* data sets enabled the participants to begin their investigations in familiar territory.

Since these data included county scale information, participants were introduced to hand-held GPS units in a field experience where they collected information, recorded specific locations, and then added the information as county level event themes. As a result, participants and their students were uniquely equipped to immediately display and analyze relationships among map layers and themes that had personal relevance.

Conceptual Introduction

A participant from the second workshop who taught fifth grade demonstrated an introduction to GIS that she had used to help her students understand the concept of GIS as a tool. Feedback from other participants was extremely positive and, with the permission of the teacher, this lesson was incorporated into the first session of each succeeding PDE. Paper maps displaying different themes of an identified region are distributed to small groups. Each group produces a handmade rendition on an overhead transparency of their assigned theme that includes an identically scaled and projected outline of the area to be examined. The transparencies are collected and used to demonstrate how two or more layers or themes can be displayed simultaneously. Next, a series of questions are posed that require participants to consider which layers should be superimposed to best answer the question. This concrete conceptual introduction helped bridge familiar tools—the transparencies and paper maps with an unfamiliar tool—the GIS software, and resulted in quicker understanding of the elementary features of the tool the participants were exploring.

Support Structures

Providing multiple levels of support increased the effectiveness of the professional development experience. Support provided by the professional development team evolved to include:

1. Maintaining a Web site for participants to share ideas and problem-solve concerns.
2. Providing individual e-mail or phone access to participants who had questions.
3. Making personal on-site visits upon participant request.
4. Distributing support manuals and handouts detailing and generalizing the skills covered in each workshop session.
5. Checking out GPS units to teachers wishing to use them in their classrooms.

In concert with the professional development team assistance, peer support structures were created, including building-level partnering and focus groups. Additionally, participant selection criteria and fee structures were modified to encourage each school to send a team of teachers. Having two or more teachers from the same site provided a locally situated support group.

Hardware and software acquisition and management required district and school-level support. Participant feedback from the first two iterations of the PDE indicated that a major obstacle to implementation in the classroom was being able to access and maintain server space in the school computer lab. Subsequently, each school was strongly encouraged to send the manager of the computer lab as part of the site team. When such participation occurred, the transition in the school setting was much smoother. This result is logical as GIS software and data sets are large and managing the server space consumes considerable time. When the computer lab manager participated, she or he appreciated the value and power of the software and was disposed to managing the software. They also understood the necessity for student projects to be able to reference files in the same location over time and provided teachers and students with appropriate network access.

File Management

In the first workshop, participants met in a computer lab where the software and data sets had been loaded prior to their arrival. While this process allowed the instructors time to test software and hardware and increased the time-efficiency of delivering the workshop activities, it was not a successful strategy for achieving the ultimate goal of the workshop: to transfer newly acquired technology skills to the teacher participants' classroom settings. Requiring each participant to bring a school-owned computer, load the software, decide the names and locations of the files and data sets, complete demonstration activities, and practice on a computer to which they had consistent access improved participant understanding. This requirement complicates the logistics of the workshop and consumes precious workshop time. Nevertheless, if the goal is to achieve transfer to the teachers' instructional setting, it is critical that each participant should be required to bring a familiar computer to which they have full administrative access.

Motivators

Participants in the first workshop iteration were supported through state-level grant funds. Many participants completed all assignments; others did not, particularly the assignments that occurred after the intensive workshop was completed. The resulting differences in skill level, confidence, and transfer were obvious; a stronger incentive was necessary to encourage full participation by all participants. In subsequent workshops all participants were required to register for either university graduate credit or state-department continuing credit. Additionally, a school site fee to send a team of up to three participants was assessed, as well as an extra individual fee for each team member thereafter. While it may seem counterintuitive, both of these requirements acted as participant motivators. Fewer participants dropped out during the workshop timeframe and all participants completed the assignments. In return for paying the registration fees, school site licenses of the GIS software and *The Prairie to Mountain Explorer* were provided. Several participants indicated that having the school administrative support reinforced both the value of the experience as it applied to their teaching and their feeling of self-worth as professionals.

Meaningful Transfer to the Classroom

Along with teacher participation and workshop development, this investigation also considered the level and type of use by the teachers who participated. As might be expected by the spread of grade levels and content areas, the complexity of the lesson plans varied. Generally, the elementary, middle school, and art teachers used GIS to conduct visual investigations without accessing advanced querying capabilities of the software. For instance, a sixth-grade teacher designed a lesson using GIS to introduce her students to the five themes of geography by looking at such things as the characteristics and features of a place. An art teacher asked her students to use GIS to investigate landforms and landmarks and then create their own landmark stamps. The students then used these stamps along with principles of design and printmaking skills to create new maps of the areas under investigation.

The junior high and high school science, geography, and mathematics teachers tended to use more of the software's functionality. Three examples of teachers' work demonstrating a more complex level of use are presented here. An eighth-grade science teacher prepared and tested a lesson about which physical features of an area need to be considered before drilling an oil well. She wrote:

> The purpose is to prepare students for our Oil Rig Simulation by getting them to think about what problems may occur because of natural and human features, and what things could be affected by drilling a well. Students will eventually be asked to write Environmental Impact Statements for Drilling. By looking at actual features around actual wells, we can start discussing the potential problems they may need to address.

A junior high earth science teacher designed a plan in which the students would investigate seismic activity and the associated seismic risks in Yellowstone National Park by posing questions and scenarios. The teacher reported:

> Does the number and location of seismic events remain relatively constant each year in the park? . . . Do significant seismic events occur near areas of sustained human use, so that some assessment of the likely risk of a seismic event occurring can be conducted? The quake events would have to be examined in relationship to the physical environment of the park (mountains, valleys, rivers, geysers) as well as the human features there (roads, campgrounds, visitor stations, etc.). Not only could the students point out the relative likelihood of seismic events in areas of current use in the park, but they could also provide some information on potential high-risk areas that should be avoided.

A high school mathematics teacher used GIS to print maps on graph paper for students to calculate area using Trapezoidal Rule and Simpson's Rule. After testing the lesson he wrote:

> One thing that I forgot about was to have them select an appropriate map projection that displayed with equal areas. This was the cause of some errors in their calculations. I had a thought, though, that this would a good comparison lesson, to have different students map the same regions using different projections. Then they could see how much the projection matters in calculating the correct area.

All of the teachers who completed the workshops prepared lesson plans, but not all were able to implement their plans during the workshop timeframe. Those teachers who successfully tested their plans reported positive learning outcomes by their students and submitted student work to illustrate student mastery of content. Some student investigations continued beyond the workshop time frame. Two examples are presented here.

First, two middle school teachers in Riverton, Wyoming, collaborated with the Wyoming Department of Environmental Quality, the Teton Science School, Wyoming Game and Fish, and Central Wyoming Community College to engage sixth- through twelfth-grade students in data collection and analysis. Students learned how to navigate using compasses and GPS, how to measure and map alpha, beta, and gamma radiation, and how to measure and map water chemistry variables and macro-invertebrate counts. The students engaged in the water quality projects discovered patterns in the detected changes and relationships among environmental variables and the types of organisms capable of living under specific conditions.

Second, a high school teacher in Gillette, Wyoming, used the skills and knowledge gained from the workshops to direct an independent study project for an advanced student in life science. The student used GIS to map out the locations of coal-bed methane wells in the county and to investigate the impact of the wells on sage grouse mating areas, raptor nesting sites, and prairie dog communities. Along with vector data of the wells, power lines, and roads, he used remotely sensed images and ground verification to study the critical issues. Upon completion of the study, the results were incorporated into an environmental impact statement for further coal-bed methane development in the county.

Regional Teachers and Students Sharing

Continuing grant support has allowed teachers and students in the five-state region to share their work in two venues. A Web site was created that allows teachers to post lesson plans that have been successfully implemented. Teachers can access this resource for ideas to use in their classroom and to make connections with other regional teachers and students interested in similar topics. Additionally, selected students and teachers have showcased projects and investigations that have been enhanced through the use of GIS, GPS, and remote sensed images. These opportunities have not only recognized students and teachers for their innovative work but have served to inspire other educators and community members to continue to explore the power of GIS and to expand its use to enhance teaching and learning. For instance, nine teams of students and teachers presented their work at South Dakota's Eighteenth Annual Education Technology Conference (2004).

Discussion

Except for a small percentage of early adopters, in-service teachers need a sustained quality professional development experience to gain the knowledge and skill necessary to use GIS and GPS units to enhance their students' attainment of targeted learning objectives. This five-year development effort resulted in a replicated professional development experience that increased participants' confidence in their ability to use GIS and GPS successfully in their teaching and learning environments. Teachers successfully planned and implemented lessons in their classrooms, reported positive attitudes toward the value of these tools to enhance student learning, and provided assessments documenting their students' learning.

Several identified attributes of this professional development experience reinforce recommendations for quality professional development (National Staff Development Council 2001b):

1. Participants joined a learning community that prioritized a nexus of technology-supported learning and real world experience.
2. Administrators committed resources to support teacher participation by paying for the software, instruction, and release time days.
3. Continuous support was available through the Web site, e-mail, phone and on-site availability of the professional development instructional team.
4. The professional development opportunities were spread out over time allowing time for reflection, practice, and integration.
5. The experience deepened participants' content knowledge and skill and introduced them to powerful tools to support learning in standard-based environments.

Other effective procedures included requiring participants to bring a school-owned computer, providing a rich and relevant local user-friendly spatial database, offering university credit for successful completion, maintaining contact with and among participants between sessions, and requiring participants to integrate these tools into their own teaching or learning environments.

Conclusion

The impetus for this project came from our goal to develop a professional development experience that would provide the training and support necessary for teachers to be able to use GIS and GPS productively in their teaching and learning environments. Formal and informal feedback collected and analyzed during successive professional development implementations informed this process and resulted in the identification of several essential components. These components include:

1. Pacing professional development activities to provide time for practice and application of knowledge and skills, including a conceptual introduction to GIS.
2. Providing relevant, accessible data sets, developing skill in file management, using relevant examples to introduce skills.
3. Implementing an array of support structures and participant motivators.

Providing participants with the opportunity to share their lessons and examples of their students' work also stimulates ideas for enhancing the learning environment and provides indicators of the transfer of tools to the classroom setting. It is our intent that this identification and elaboration of key components will contribute valuable information to others who are considering offering professional development opportunities for teachers interested in exploring the power of GIS and GPS as learning tools.

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