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Five Steps to Success: Implementing Geospatial Technologies in the Science Classroom

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Abstract

This research article presents the interpretations of three science teacher leaders and twelve participants involved in a professional development program called the 5-Step GT Program. Interviews and a questionnaire were used to construct case studies of implementation. The findings showed that the program was unique in that it was cumulative and flexible, with each step increasing in complexity, taking the participant from learning a base of computer skills and science content, to conducting community-based projects but at the teacher's own pace. A built-in leadership component provided a means of dissemination into the local school districts. Continuous support, geospatial technology community support, amid collaboration with scientists; and direct pedagogical instruction proved to be essential components of the program. Approaching teacher professional development from a personal teacher development perspective supported teacher confidence in using geospatial technologies in the teachers' classrooms.

The ability to use geospatial technologies (GT) to explore and analyze the world is no longer isolated to a few skilled scientists and professionals. Geospatial technologies include the computer hardware and software used to collect, import, manipulate, store, analyze, and display geospatial data. Included are such technologies as: Global Positioning Systems (GPS), Geographic Information Systems (GIS), remote sensing, and other visualization systems. These technologies have become available to nearly everyone through a variety of mobile devices. Over the past decade, consumer demand has skyrocketed for these devices as a way to manipulate and display geospatial information (Folger, 2008). For example, the integration of GPS data with digital maps has led to handheld and dashboard navigation devices used daily by millions of people worldwide. The release of Google Earth in 2005 made it possible for people from all walks of life to manipulate digital maps and geospatial data (Folger). This ability to swiftly and dynamically represent the Earth's geographic, scientific, social, political, economic, as well as a variety of other types of data visually and from different perspectives creates a powerful learning opportunity for teachers and students. Geospatial tools expand the scope of topics that students can explore, promotes interdisciplinary learning, and changes the way students learn to reason about and interpret data (Audet & Abegg, 1996). Anything that can be referenced to a specific geographic location becomes an opportunity for exploration (Ramamurthy, 2006).

Research on the use of GT in schools has shown that teachers and students are able to engage in data visualization and analysis, spatial interpretation, and real-world problem-solving (Alibrandi, 1998; Alibrandi, Thompson, & Hagevik, 2000; Audet &

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Abegg, 1996; Baker, 2002; Hart, 1979; Kerski, 2000; McWillimas & Rooney, 1997). A recent report by the National Research Council, *Learning to Think Spatially* (2006), states that GIS has the ability to meet four educational goals: (a) support the inquiry process; (b) be useful in solving problems in a wide range of real-world contexts; (c) facilitate learning across a range of school subjects; and (d) provide a rich, generative, inviting and challenging problem-solving environment. Additional research has further documented other important benefits for students including increased motivation (McWillimas & Rooney, 1997), self-efficacy, attitudes toward technology (Baker, 2002), acquisition of spatial analysis skills (Audet & Abegg, 1996), increased mathematics ability (Coulter & Polman, 2004) and geographic and scientific content knowledge (Kerski, 2003).

For more than a decade, educators and researchers have developed curricula as well as initiated professional development efforts that have engaged large numbers of teachers and provided compelling examples of the potential of GT to enhance teaching and learning. Teachers and other advocates of geospatial technologies in schools have stated that what makes these technologies different is that students are able to interact with dynamic visual displays of real-world data which provides them with an opportunity to develop fluency in visual representations of data, quantitative data analysis, and experience in database techniques (Edelson, Gordin, & Pea, 1999). Despite this enthusiasm, Kerski (2003) found that in a survey of more than 1500 high school teachers who had purchased GIS software, 45% of them had not used GIS and another 15% had no plans of using it. Of those that had used GIS, only 30% had used it in more than one lesson.

A report by the Geographic Data in Education (GEODE) Initiative at Northwestern University (Edelson & Moeller, 2004) identified the significant challenges facing teachers and students in their use of GT in the school computing environment, such as access to appropriate hardware and software, technical and administrative support, and integration of GT into the curriculum. Overcoming these significant challenges took time and significant effort. Teachers needed time to convince the schools to install the software on school computers or servers, time to find ready-to-use data for their projects, time to identify and possibly modify existing curricular materials, and time to find and learn how to use the many types of GT tools available. This report reiterates the importance of effective teacher preparation with continued support if the tremendous potential of GT in schools is to be realized. This article also addresses a professional development approach implemented in environmental science through the SCI-LINK program called the 5-Step GT Program. The goal of the program was to enable secondary science teachers to design and implement curriculum projects in which students used GT technologies to address relevant environmental issues both locally and globally.

Theoretical Framework

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Characteristics of Effective Professional Development

Subject specific professional development is considered an essential mechanism for deepening teachers' content knowledge and developing effective teaching practices (Desimone, Porter, Garet, Yoon, & Birman, 2002). Garet, Porter, Desimone, Birman, and Yoon (2001) identified in a national study effective characteristics of professional development to be a focus on content knowledge, opportunities for active learning, and coherence with other learning activities. Key structural features included activity, collective participation by teachers from the same school, grade, or subject, and duration of the activity. Other criteria for high quality professional development for teachers were opportunities for sustained professional development, increased content knowledge and understanding of learning, active and collaborative learning, being part of a coherent program, and resulting in increased teacher knowledge, confidence, and skills (Constible, McWilliams, Soldo, Perry, & Lee, 2007; Desimone, 2002; Supovitz & Turner, 2000). The Environmental Sciences for Elementary School Teachers (ESEST) 14-year program indicated a two-fold increase in content knowledge and improved teaching skills by participants (Constible et al., 2007). They argued that partnerships between K-12 and post-secondary institutions were necessary for effective science teacher education. In addition, others have identified a critical need to go beyond content during professional development programs (Loucks-Horsley, Hewson, Love, & Stiles, 1998). Components including teaching self-efficacy beliefs and experiences, asking participants to reflect on their learning, providing emotional support and encouragement, and modeling and learning through contextual experiences were equally critical (Borko & Putnam, 1995; Reys, Reys, Barnes, Beem, & Papik, 1997; Showers, Joyce, & Benett, 1987). In a 2007 writing, Penuel, Fishman, Yamaguchi, and Gallagher analyzed the role of professional development on teachers' abilities to implement the GLOBE program. They found that meaningful, ongoing, and coherent training experiences (which were consistent with their schools' local and district goals) were most valuable. Providing support and equipment, localized implementation, and university-based collaboration were additional pluses.

Professional Development for Teaching with Geospatial Technologies

The purpose of using GT in the teaching of science is not to simply train teachers and students in how to use the software, but rather to enable them to synthesize, analyze, and use complex data sets in new ways (Trautmann & MaKinster, 2010). Professional development for teaching with GT needs to provide not only training in how to use relevant hardware and software, but also give teachers many opportunities to explore ways in how to best use GT to improve the learning of their students (Coulter & Polman, 2004). There have been very few published studies that have evaluated GT professional development. Ongoing support seems to be one critical component and is most likely especially pertinent when integrating new technologies such as GT into the teaching of science. Trautmann and MaKinster pointed out the importance of time, ongoing support, and promotion of a supportive learning community. Similarly, Wilder, Brinkerhoff, and Higgins (2003) reported key features to be long-term, project-based

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professional development that built teachers' self confidence and knowledge regarding GT skills. McClurg and Buss (2007) listed other components such as providing ready-to-use data sets, using paper maps to introduce spatial thinking skills before using GT software, and connecting lessons to relevant state and local science teaching standards.

The study reported here provides further focus on professional development, using the 5-Step GT program developed over the past seven years through a university partnership with funding from both state and national sources. The focus of this professional development was environmental science, specifically land, air, and water. The program was unique in that it offered a built in leadership component and focused on the personal development of teachers as well as content and pedagogical approaches to using GT in the science classroom. In this study we investigated the following two research questions related to the 5-Step GIS program: What facilitated the development of the science teacher leaders, and what were the implications of these findings for GIS professional development of science teachers?

Context: The SCI-LINK Approach to Teacher Professional Development

The SCI-LINK program (Stubbs, 2010) brought together science teachers, environmental scientists, and others so that teachers could learn about current scientific advances. Teachers then translated their knowledge into interesting and effective lessons and activities for their students in environmental science (Howe & Stubbs, 1997). The purposes of the SCI-LINK program were for teachers to (a) increase their knowledge of environmental science, (b) infuse this new knowledge into their own classroom science curriculum materials, (c) become more self confident as professionals, and (d) become a part of a learning community. The program, located at a large state university, has brought together teachers from many other states and countries such as India, Canada, Finland, Monaco, and Brazil for residential workshops in the summers and at other times during the school year. Over the past thirty years, SCI-LINK has expanded to become a constellation of different programs and activities but has maintained its focus on current environmental research.

The building blocks of the SCI-LINK program were (a) the formation of a learning community that included a professional atmosphere between scientists, science educators, and teachers so that productive professional relationships could be formed; (b) recognition of individual differences so that each teacher could follow his or her own path; (c) challenging teachers' images of themselves as effective and competent persons leading toward reassessment and further challenge with guidance; and (d) the fostering of learning opportunities throughout the year for renewal and stimulation. In summary, the SCI-LINK program developed a broad model of professional development that incorporated a social constructivist perspective, with attention to personal and social development, in addition to the more traditional areas of content and pedagogy (Howe & Stubbs, 2003). This professional development program was adapted to incorporate the use of GT in environmental science for teachers. The program for

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leadership development, as the one in the SCI-LINK program, included and elaborated on a model of leadership development by Palus and Drath (1995).

The Palus and Drath model focuses on enhancing the individual's ability to participate in the leadership processes of the community of practice to which he or she belongs. Leadership development is accomplished by providing opportunities for persons to participate in and be changed through five interwoven processes: readiness, experience and disequilibrium, equilibrium and construction, potentiation, and outcomes (Palus & Drath, 1995). The following describes these five processes, which were used in this study to illustrate leadership development in three teacher leaders, who exemplified this growth.

- Readiness refers to factors that play a significant role in determining if one is ready for the development program. These may be personal (internal) such as health-related or external such as a work situation or family responsibilities. This is why flexibility and non-linearity is important in professional development programs for teachers that consider a leadership model (Howe & Stubbs, 2003).

- Experience and disequilibrium recognizes that an experience must be provided that engages the individual in meaning making and stretches their capacity to accept the experience. There should be confusion and may be resistance to accepting the experience as meaningful at first. It is important to recognize that the feeling of losing one's balance is a part of the process. As some teachers have remarked when learning new technologies, "This isn't going to be easy."

- Equilibrium and construction refer to providing an environment in which participants are supported as they explore new understandings. Since individual experiences are different, it is important that the program be able to support teachers at many stages of development as they work towards reaching a state of equilibrium and re-envisioning new possibilities for both themselves and their teaching. As a result, professional development models should include ongoing support for teachers both professionally and technically. In this way equilibrium and the construction of new and different ways of teaching with new technologies can take place for teachers.

- Potentiation refers to future growth and development. There is a back and forth movement between old and new perspectives as an individual grows and new perspectives are attained. As a person goes through the process of disequilibrium followed by attainment, the new equilibrium causes a sensitization to the possibility that other new perspectives and ways of knowing can be found. This allows for future development as individuals become more open to the possibility of future growth.

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- Potential outcomes for individuals may be any or all of the following: (a) development of new competencies that include "facility for engaging the process of development, an experimental, reflective approach to taking action, and a better map of where developmental experiments may lead," (b) acquiring new meaning structures that include "new, revised, and alternative ideas, maps, insights, and perspectives," and (c) moving into a new developmental stage (Palus & Drath, 1995, p. 22). Since each person begins at a different point, the outcome or final stage of the developmental process will not be the same for everyone.

Methodology

Selection of Cases

The 5-Step GT Program was developed over the past seven years as a part of the SCI-LINK program. Teachers in the GT program in small groups evaluated different aspects of the program. The feedback was used to continually change the program, sometimes immediately as the program unfolded. To participants who continued to be involved, SCI-LINK provided support beyond the usual teacher stipends. This included online support, school visits, organization of presentations at conferences, and one-day meetings or seminars usually held on Saturdays. From this emerged the 5-Step GT Program composed of a series of summer and school year professional development opportunities for secondary science teachers. Table 1 below provides a brief description of each step of the program.

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Table 1
Description of five steps in the SCI-LINK geospatial technologies program

Step		Workshop Description	Outcomes
1	ArcGIS Explorer and Google Earth Introduction	Introduction to maps, spatial thinking, and using GT through Internet mapping to learn about the environment. (3 hrs.)	Create map using provided data.
2	Moss Land	Field mapping the microclimates of a site, learn problem-study approach (42 hrs. /yr.) http://www.ncsu.edu/scilink/studysite	Conduct 10 x 10 meter plot study on your school campus.
3	Beginning Land, Air, Water	Utilize statewide environmental data to develop an individual project. (42 hrs. /yr.)	Develop beginning GT project for your classroom.
4	Advanced Land, Air, Water	Relate your school to the community and then to the world. Use more advanced GT applications such CITYgreen GIS and global data sets. (72 hrs. /yr.)	Develop advanced GT project for your classroom.
5	Apprenticeship Community based projects	Conducting community-school projects with cooperating partners as mentors to bridge to leadership. (variable)	Complete your school-based community project and associated curricula.

While the program is described in steps, it was flexible and teachers attended each step as many times as they liked and in any order they felt was best for them. Teachers were awarded certificates upon completion of each step. From this data it was determined that fifty-five teachers had taken steps one through four anywhere from one to five times each. In total, there were approximately one hundred teachers between steps one and three.

Likewise, teachers who had completed a step and used it in their classrooms could apprentice and teach with the professional development staff at that particular step. After completing this process, they became a teacher leader for that step. Some teachers became teacher leaders but others did not, choosing to use the GT applications in their classrooms with their students.

Four teachers in three counties in one southern state completed all five steps and became a teacher leader for each of the steps. Three of these four teacher leaders volunteered to be a part of the study. We used a multiple-case, replication design, as

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described by Yin (1994). In this design multiple cases are considered as multiple experiments. The design is based on the logic of replication, not on the logic of sampling. Each case is a separate study in which evidence was sought with regard to a claim. The subsection below, entitled Data Collection, provides elaboration. The three teacher leaders had different backgrounds and different teaching experiences. We wondered, “How did these teachers become teacher leaders in the use of GT technologies to teach science?”

Data collection

Data were collected from multiple sources in order to corroborate data from one source by data from another source. Data sources included interviews of the teacher leaders, observations of the three teacher leaders conducting GT professional development, and documentation of awards, presentations and other similar records. In addition, twelve teachers at various steps (2-5) were randomly chosen from a stratified sample to be interviewed and completed a 17-item questionnaire to triangulate some of the outcomes of the program.

Interviews of teacher leaders. Individual, in-depth interviews were conducted of the three teachers following methods outlined by Seidman (1998). When the interviews were conducted, we were seeking to understand how these teachers made meaning from their experiences. We asked questions about their teaching experiences, current teaching situations, and experiences in the 5-Step GT program. Then we asked the teachers to reflect on their experiences as teacher leaders and on the meaning of the changes that had occurred as a result. The teachers were asked to explain and elaborate on their comments and on any aspect of their experiences. Each interview was approximately two hours in length. The interviews were recorded and transcribed. After analyzing the interviews and searching for commonalities and patterns, we realized that the teachers were describing the SCI-LINK model for leadership previously described by Howe and Stubbs (2003). We then decided to use and adaptation of the Palus and Drath (1995) model as a framework for interpreting our data. The written analyses of the interviews were member-checked and corrected and revised as needed.

Observations. The three teacher leaders were observed by the authors when conducting GT professional development, making presentations about their GT projects, and helping other teachers incorporate GT into their instruction. The observations were conducted to verify that the three teachers were viewed as leaders by their peers.

Artifacts. We looked at records and collected information about participants' awards, presentations, publications, and grants.

Focus group interview of colleagues. We informally interviewed the twelve teachers who were randomly chosen to complete the questionnaire, described below. The interview occurred as a group discussion before the questionnaire was administered to the group. We asked the teachers for their experiences, observations,

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and comments regarding the leadership of the teacher leaders. Then, we asked them to evaluate and discuss their experiences in the 5-Step GT program and with using GT technologies in their professional lives. Our researchers' observations were recorded in a notebook.

Questionnaire. On a 17-item written questionnaire, participants were asked to rate their use and application of these technologies on a five point scale. A rating of one represented little; five represented a great extent. Participants were also asked to provide demographic information such as age, years of teaching, prior GT experiences, and grade level taught.

Results and Discussion

Case Studies (All Names are Pseudonyms).

Case 1: Sarah. Sarah is a Caucasian woman who has been in the classroom for ten years. She taught science to sixth, seventh, and eighth graders in a modern urban school. She is married and has two school-aged children. She verified that she had been in previous SCI-LINK workshops before becoming involved in the GT professional development. She said that before these workshops, she had never used GIS or any type of geospatial software. In fact, she characterized herself as being able to use only word processing programs and email on the computer.

Readiness. Sarah's enthusiasm for using GT in her classroom was evident. She originally came to the GT summer workshops to learn how to incorporate scientific models into her teaching. She added that her family was not a factor in readiness and that she "was always looking for ways to make her classroom better". The school system was encouraging teachers to use new technologies in their teaching and there was a new technology exam that all eighth graders were required to pass. So she felt that "a combination of technology and a personal goal of being better able to use data to create models with her students" was a win-win situation.

Experience and Disequilibrium. Sarah found it "very challenging and frustrating" when using GT in her classes initially. She began by having students do independent projects. Then as she continued to take additional workshops she began using it slowly in her classes to teach environmental science. She first used an existing curriculum, modifying it for her needs. Eventually, she was able to design her own projects. She said, "It was evident that the students learned much faster than I did. I just had them help me. They were so excited about using the technology. It was different for them than what they normally did. It is so visual. Eventually, I became better and began to be able to solve my own problems. It was then that I could see the potential for my students."

Equilibrium and Construction. Through each of the steps of the GT workshops, teachers developed lesson plans for their own classrooms. The participants

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were provided with data sets of their counties and states to use in their lessons. Sarah explained, “Developing my own lessons that I could discuss with others and then try was a key factor in my success. I felt like I had a ‘whole community’ of teachers and scientists supporting me.” She said, “I could come back over and over again, learning a little more each time, and eventually I felt more comfortable.” Sarah constructed a new understanding of her own potential through the process. She said that, “I went from being frustrated and thinking that I can’t possibly do this to becoming so excited not only for my students but for myself. I was so surprised that I could actually learn how to do this stuff.”

Potentiation. Sarah explained that she has continued to implement GT in her classes and now teaches GT to other teachers. She has become a leader in the state for using GT. She has presented at state and national meetings and has given GT workshops at the state meeting of the National Science Teachers Association (NSTA). Her participation in the workshops has led to her receiving her Master’s degree. She plans to continue to learn more about GT and to share it with others. The experience has “changed my life and I no longer see things the same.”

Implementation of GT (outcomes). Sarah wrote and designed an elective course for her school district with GT as the focus. The course is called Computers, Mapping, and Technology. In this class she has completed two community projects, one with the local zoo and the other with the city in which she lives on land use. Sarah has completed a CITYgreen analysis of her school grounds and does the MOSS unit each year. She is constantly looking for ways to bring real world data to her students. As a result of her involvement in GT, she has had some of her students receive summer internships using these technologies. Sarah said, “There are so many ways students can become involved in real world problems using GT technologies. The connections with other teachers, the support from scientists and other GT professionals has been amazing.”

Case 2. Cheryl. Cheryl is a Caucasian woman with 18 years of teaching experience in a public urban high school. Her content background is in chemistry and she teaches primarily introductory and advanced placement chemistry and physical science. On occasion, she has been asked to teach earth/environmental science which she reports that she “really enjoys.” Cheryl was one of the first teachers in her county to receive advanced technology training through a local university initiative designed specifically for science teachers. It was from this experience that she learned about available training in GT. She classifies her computer skills as better than many of her colleagues but also says she finds it difficult to remain up-to-date.

Readiness. Cheryl attended a session at the state environmental education conference in which a geoscientist explained and demonstrated new computer mapping and data analysis software. Cheryl immediately saw the possibilities of incorporating computer mapping and data analysis into both chemistry and environmental science classes. She was drawn to the possibility of “visualizing data” and felt GT could

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particularly benefit her students with reading difficulties. She immediately registered for the advertised summer workshop with the intention of incorporating GT into an already established problem-based learning strand in chemistry and environmental science. Cheryl was ready for this new experience due to her teaching experience and her overall comfort with technology.

Experience and Disequilibrium. Cheryl found the implementation of her new GT skills "very frustrating with stumbling blocks at every turn." Her media coordinator and district technology director were not at all familiar with GT or its applications to science teaching. Consequently, the software Cheryl received at the first summer workshop was only installed on her desktop computer, which drastically limited incorporation into the curriculum and student use. The second workshop in the GT series introduced Cheryl to a free, less computer-memory demanding, and simplified version of the initial software that was designed specifically for educators. "This is exactly what I needed." The software was loaded on the media center server and Cheryl wrote or modified about 15 separate lessons for her environmental science class. All of her students, regardless of reading or math levels, became engaged in the lessons and remarked how fun and easy it was to learn using them.

Equilibrium and Construction. Cheryl reports that there have continued to be bumps in the road as hardware has been upgraded and technology directors have changed. "I have to fight the same battles over and over but it's worth it. My kids get so much from the lessons and the unintentional geography and math content they learn is amazing." Cheryl developed a close working relationship with the GT professionals at her local city planning office who continue to provide her with current local data and technology assistance. She often refers to this relationship as a partnership and frequently encourages other teachers to seek out similar resources.

Potentiation. Cheryl continues to incorporate GT in her chemistry and environmental science classes. She is known in her district as the "GT lady" and is often called upon to teach short GT workshops for elementary through high school science, math, and social studies teachers. As a result of the 5-Step Program, Cheryl decided to continue her education in a science education doctoral program with a content concentration in GT. She continues to develop GT lessons for her students and has shared them at state and national science teacher and GT conferences. She plans to continue her training in GT and wants to develop more interdisciplinary lessons and projects for high school students. She comments that, "GT is the most powerful tool I have found to really impact my students' learning. Every teacher needs to be using the tool".

Implementation of GT (outcomes). Cheryl has expanded her classroom role to include mentoring seniors who choose to explore GT projects as graduation projects. Students develop a semester long project, collect and analyze data, and then present it to a panel of evaluators from the community. On multiple occasions her classroom students and senior project mentees have had the opportunity to present their own

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original GT work at conferences and competitions. Two students have competed internationally in Beijing, China, and three have received full college scholarships after presenting their projects. Cheryl explains that, "This is why I teach. My students become independent thinkers and problem solvers. They act and react like scientists." Cheryl has also packaged data sets for her students and other teachers to use on GT lessons and projects. Every semester Cheryl's students add local stream water quality data to a GT project database that was initiated 16 years ago. The project has a key role in hydrologic change over time lessons for her environmental science students. As the school grows, she completes a CITYgreen analysis of the site. Her students recently planted 8 trees to help defray cooling costs for a new addition to the front of the school. As part of a biodiversity unit she uses the MOSS program at three permanent sites: a field that includes a driveway, a forested area that includes a stream, and a landscaped area that includes an artificial pond. Cheryl also facilitates GT training and implementation for other teachers at the local and state levels by teaching workshops and classes. She comments, "GT changed the way I teach. Just like the real world, my lessons are no longer static but dynamic."

Case Three. Cara. Cara is a Caucasian woman who has been in the classroom for twenty-seven years. She taught science to fifth, sixth, seventh, and eighth graders for more than eleven years in an urban school in an economically disadvantaged area. Then she became a college instructor in science education. Before becoming involved in the GT professional development she had never used GIS or any type of geospatial software. She characterized herself as being able to use word processing programs and email, and was learning how to create websites.

Readiness. Cara's enthusiasm was not clear from the beginning. She came to the GT summer workshops as a Ph.D. student, not knowing exactly what to expect from the technology. However, it was obvious that she wanted to learn how to include more outdoor science activities and the use of technology in her methods courses; this was her dissertation research topic. Thus, she felt that "a combination of the use of outdoors and the use of technology would fit perfectly for teaching college students to become science teachers." Through Cara's experience as a graduate student, she was ready to gain new ideas to help her with teaching and research.

Experience and Disequilibrium. Cara felt "overwhelmed" when using GT in her classes originally. She first developed lessons for teaching prospective teachers and then tested it in one of her college courses. She began by modeling an outdoor activity with her prospective teachers and then she asked them to create independent outdoor project proposals. As she continued to take additional GT workshops, she started to figure out how to better use GT in her classes. She first used existing curriculum, modifying it for her needs. Eventually, she was able to design her own projects. She said,

> I was embarrassed to realize that the students learned the technology much faster than I was able to learn it. The students were so excited about going

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> outdoors in a methods course and learning alternative ways to use technology. It was very different than what they normally did in a course in the College of Education. We were able to model an entire project. Then the students designed their own proposals to use during their internships. When the students designed their own projects then I could see that they were really ready to use GT in their classes. Eventually we co-developed five activities and these lessons were really awesome.

Equilibrium and Construction. Cara has continued to implement GT in her classes and has developed small projects to teach GT to in-service teachers. She has become a leader in the college for using GT. She has presented at national and international meetings and has taught GT workshops for the State Educational Board. She created a network with other GT educators and is a special issue editor for a national research journal that will be published soon. She plans to continue to learn more about GT and to share it with others. This experience has "completely changed the way I teach my methods course and I will never come back to the way I taught the course before."

Potentiation. Cara wrote a GT course for in-service teachers based on science teaching issues. In this course, participants have to design and present a science project using GT. Two exemplary projects emerged. One was related to a local river that is close to the school site and includes historical and cultural issues. The second one was related to the forest environment and its people. Cara now constantly looks for ways to include real world data and lessons with her student teachers.

Implementation of GT (outcomes). As a result of her involvement in GT, she has had two of her in-service teachers receive international scholarships for a 15-day summer workshop abroad using these technologies. Cara said,

> There are so many ways to include GT in teacher preparation and to make them involved in real world problems using GT technologies. The connections among teachers and the suggestions that arose created an impressive bond and in a supportive environment we were able to reach beyond all of us in ways that I would have never imagined.

Elements of the 5-Step GT Program

There were eight community projects (step five) which included: three on wetlands, one on soils, one on urban forest, one on land use, one on coastal ecosystems, one on wildlife habitat, and one on Dengue Fever. The coastal ecosystem project and the Dengue Fever project (Gioppo & Barra, 2005; Gioppo, da Silva, & Barra, 2006) are international projects by partners in Brazil and can be downloaded from http://www.cinfop.ufpr.br/colecoes.

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The Palus and Drath model (1995) provided a framework to help us understand and describe what happened to these teacher leaders as a result of their participation in the program. This provided us with a means of identifying important elements of the program. Though each of the teacher leaders was different in their backgrounds, experiences, readiness, and purpose, they independently identified common elements of the program that supported their development and growth. The twelve teachers who were informally interviewed and completed the questionnaire verified these elements.

Of the teachers that took the 17 - item questionnaire, ten were female, two were male. All taught science, with half teaching grades 6 – 8 and half teaching high school or grades 9 – 12. The teaching experience ranged from two years to over thirty. The ages of the teachers ranged from 25 to 54 with an average of 38. The mean score of the degree of implementation and leadership roles completed by the twelve teachers was 3.5 or a rating of often (See Table 2).

Table 2

GT Questionnaire

Item	Responding “Great Extent” or “Often”	Mean Score	Rating
Software on computers	100%	4.6	Great Extent
Confidence	100%	4.9	Great Extent
MOSS in class	75%	4.4	Great Extent
Present at conferences	75%	4.6	Great Extent
Teach a lesson using GT	100%	4.7	Great Extent
Present to faculty	75%	3.0	Often
Teach another GT unit	75%	3.0	Often
Teach another teacher GT	58%	3.0	Often
Create own GT project	58%	3.2	Often
Attend other GT workshops	42%	3.2	Often
Teach a GT workshop	33%	3.2	Often
Grants to do GT	75%	3.6	Often
Create a course using GT	17%	1.0	Little
Create GT curriculum	8%	1.0	Little
Use GT as part of an award	25%	1.0	Little
CITYgreen in class	17%	1.1	Little
Attend GT college course	8%	1.3	Little

Note: N=12; 5.0 – 4.0 = great extent, 3.99 – 3.0 = often, 2.99 or lower = little.

Results from the GT questionnaire showed that all the teachers were able to have the software installed on their school computers. All twelve teachers reported that they had confidence using GT while teaching and had taught at least one lesson. Many

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of the teachers had presented their projects to the faculty, taught another related problem solving GT unit, taught another teacher new skills, created their own projects, attended other related workshops, and taught a GT workshop or had written grants to fund their projects. The results showed that the teachers were less likely to create their own GT curriculum or courses and were less confident in using CITYgreen in their classes.

These fifteen teachers brought a wide range of experiences and expertise to the program from using a GPS unit in their cars to taking GT college courses or working in a GT related field for a period of time. The flexibility of the program allowed the teachers to choose from which step to begin depending on their background. The teachers initially remarked that they were anxious and "felt like their students did when they were frustrated learning new concepts and skills". This feeling is common when learning new technologies. This disequilibrium with support can be productive if it leads to new understanding and greater confidence in one's abilities. The fact that this program was neither linear nor unidirectional and allowed individuals to move back and forth between disequilibrium and equilibrium as they gained new perspectives of meaning supported them in these new roles.

All the teachers remarked that the activities presented to them during the environmental science GT program were challenging and sometimes overwhelming. The incorporation of GT into their curriculum was "difficult" and hard to conceptualize. Writing your own lessons using the data sets provided and planning community projects was exciting, but at the same time, a daunting task. Even thinking about how to get the software installed on school computers seemed impossible. Time and continuous support from teachers, scientists, and GT professionals was essential. Community building began immediately from the first step and teachers became a part of a group that worked together to solve problems. This network of teachers as a community of learners is what Palus and Drath (1995) have called a holding environment. SCI-LINK publishes electronic newsletters, offers ongoing professional development, provides access to the resources of the university, publishes teacher – created GT curricula through a website, and acts as a bridge to professional organizations that support the teachers' efforts. Teachers were provided with the books, software, state and local data sets, maps, and equipment needed for their projects. Graduate credit was made available to the teachers.

The opportunity to become a teacher leader proved to be a strong motivator. Teachers who had not previously presented at professional meetings or led workshops were able to plan programs for other teachers. Such activities reinforced newly acquired skills and bolstered confidence.

Conclusions and Implications

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From the above data it was evident that teachers developed new ways of using GT in environmental science as well as new competencies and potential for personal growth. The 5 - Step GT Program was flexible and created a road map for success in which teachers received support for their projects from each other, from scientists, and from GT professionals. Teachers gained new confidences and became leaders. This happened as teachers were provided many opportunities and engaged in stimulating learning at different levels of complexity. As they became more involved in the program, they often moved into new leadership roles in their schools. Many of our teachers reported that they became the “technology experts” in their schools and in some cases in their school districts. The Palus and Drath model of “continuous improvement and change” (1994, p.4) provided a useful framework for this discussion. Teachers needed an opportunity to take on new roles and become leaders in their own context. This agrees with both situated cognition theory which recognizes each teacher’s unique context (Barab & Duffy, 2000), and with Penuel et al. (2007) who found that localized implementation was the most successful.

The “inside-outside” approach was very successful in the GT workshops. Teachers used GT to visualize and analyze the data but the computer work was balanced with work in the out - of - doors. This meant collecting data for themselves outside or going on a field trip to a site that focused on an environmental topic, for example a waste treatment plant or a local stream. We sometimes visited the Department of Safety and Planning in the city and experienced how they used GT to practice hurricane preparedness.

Allowing teachers time to discuss and plan how they incorporated GT into their teaching and having teacher leaders who helped them to visualize how that would happen in their classrooms was important to our success. In addition, we found that discussing and modeling classroom management strategies in the out-of-doors and in the computer laboratory was a component that we added over time. Finally, the five steps evolved with step one getting teachers excited and motivated, step two being something teachers could do on their own school grounds, step three expanding the scale to the state, and steps four and five using national and global data sets. Step two (Hagevik, 1999) was particularly successful because it used the Problem Study Framework with a six-week curriculum unit, lessons, and assessments provided. These materials were teacher developed and designed to model inquiry-based instruction.

Community partners have provided computers, plotters, and local data to teachers. The program has been sustainable over time largely due to these community partnerships through universities and professional organizations as well as businesses. Constible et al. (2007) noted the importance of university partnerships in environmental science teacher professional development. Not only have the participants reported that they “will never look at data and their teaching the same,” but their students benefited through awards such as science competitions, paid summer internships, and college scholarships, some of which were provided through the business partnerships.

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Critical aspects of geospatial professional development according to Trautmann and MaKinster (2010) were the importance of time, ongoing support, flexibility, and the promotion of a supportive learning community. Similarly, Wilder et al. (2003) acknowledged teachers' self confidence as well as knowledge regarding GT skills. The 5-Step GT program went beyond content knowledge and included self-confidence and self-efficacy as recommended by Loucks-Horsley et al. (1998) and Showers et al. (1987). Approaching GT teacher professional development from a personal teacher development perspective empowered teachers who overcame the inherent difficulties of the technology to take on new roles, as they became leaders in their schools.

All 15 teachers reported integrating GT into their science classes and many received grants and taught other teachers about GT. Careful consideration and research into the potential of quality professional development is critical. Reform in science, technology, mathematics, and engineering (STEM) education, now a national priority, demands new and creative approaches to professional development that empowers teachers to develop their own capacities and talents through continued stimulation and support every step of the way.

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