Design, Implementation, and Assessment of a Geospatial Science-Technological Pedagogical Content Knowledge Professional Development Model

Tamara Peffer, Alec M. Bodzin, and Violet Kulo Lehigh University

Paper presented at the 2010 National Association for Research in Science Teaching (NARST)
Annual Meeting in Philadelphia, PA.

ABSTRACT: This session describes the design, implementation and assessment of the Geospatial Science-Technological Pedagogical Content Knowledge Professional Development (GS-TPACK) Model. The model was applied to a professional development (PD) sequence aligned for a new technology-embedded Energy curriculum. The PD was designed to support teachers in the development of GIT technology skills and pedagogical content knowledge about environmental issues model related to energy. To gauge the efficacy of our 3-day Energy PD summer institute, we utilized a variety of data collection methods including the pre- and post-administration of the newly designed GS-TPACK instrument, ongoing observation and discussions during the PD sessions, and issues lists generated by the teachers after each session. Teachers demonstrated not only increased levels of GSPACK but developed positive attitudes about using GIT to investigate complex environmental issues. Our initial findings appear to demonstrate the efficacy of the PD model.

Environmental issues, including energy use and land use change, are at the forefront of public awareness today. Teaching and learning about such topics require that science teachers possess environmental content knowledge and understand effective science pedagogical approaches. The use of geospatial information technologies (GIT), such as Google Earth or GIS, to spatially explore environmental issues during classroom investigations has proven to be an effective agent in the development of accurate scientific understandings about complex environmental concepts (Bednarz, 2004; Carrara & Fausto, 1995; Heit, Shortreid, & Parker, 1991; NRC, 2006). Unfortunately, many teachers have not had inservice or professional development (PD) experiences that fostered sufficient prerequisite content or technology expertise to implement such novel classroom practices. Few science teacher preparation programs integrate EE within their programs, and even fewer integrate EE and technology simultaneously (Heimlich, Braus, Olivolo, McKeown-Ice, & Barringer-Smith, 2004; Peffer & Bodzin, 2010).

Current science education reform efforts are attempting to change the direction of teacher preparation and PD by supporting interdisciplinary inquiry-based approaches that utilize learning technologies to support student investigations of complex science and environmental issues (AAAS, 1993; NRC, 1996). Position statements from organizations such as Association for Science Teacher Educators (ASTE, 2008, 2009) and National Science Teachers Association (NSTA, 2003) also demonstrate a commitment to such reform by encouraging professional development efforts that concentrate on specific issues of science content, pedagogy, skill development, and technology use that are based on current research practices. Ideally, such PD has the potential to generate teachers capable of emulating the nature of science to their students through unbiased scientific explorations that model discipline specific data collection, analysis, and critical-thinking skills while utilizing modern instrumentation and technologies (Lederman, 1992; Lederman, Gess-Newsome, & Latz, 1994).

While the course to reform is being mapped and implemented at the preservice level, science teacher educators must also provide PD support to inservice teachers so they may also develop the skills to integrate GIT and EE methodologies in their instruction (McClurg & Buss, 2007). Further, PD efforts that focus on environmental sciences require interdisciplinary approaches to inquiry-based learning that address environmental issues. In many school settings, inservice educators may not have sufficient professional development opportunities to acquire the pedagogical content knowledge (PCK), curricular knowledge, content knowledge, or technology capabilities necessary to implement interdisciplinary technology-infused instruction that emulates the nature of science while addressing the multifaceted dimensions of science, technology and society (AAAS, 1993; Brickhouse, 1990; Shulman, 1986; Stapp, et al., 1969; Yager, 2007). Such PD needs to encapsulate specific environmental education knowledge and awareness about the environmental issues being examined. PD sessions should also provide teachers a window into student understandings and potential misunderstandings about scientific concepts and the heuristic tools necessary for teachers to detect and remediate them early in the inquiry process. Through immersion into active learning about an environmental issue, the PD should also reveal pedagogical reasoning for methodology, management techniques and technology integration choices (Kimble, Yager, & Yager, 2006). By enhancing the pedagogical content knowledge of inservice science teachers they acquire the requisite skills needed to effectively guide their students' investigation of complex environmental issues (MaKinster & Trautmann, in press). Science teachers who have not mastered the skills, content knowledge, or developed the interdisciplinary perspectives required for environmental science education may not be able to effectively identify students' misconceptions or differentiate instruction for diverse learning needs and as a result may revert to more didactic instruction (Fishman, Marx, Best, & Tal, 2003).

To address reform initiatives in science and technology, a wide range of environmental science curricula that promote the integration of technology to enhance student investigations of environmental issues have become more freely and commercially available in recent years (Bodzin, Anastasio, & Kulo, in press; Bodzin & Cirucci, 2009; GLOBE, 2009; Linn, Clark, & Slotta, 2003). Designers of such curricula often recommend the use of specific technology tools such as GIT to help teachers and students understand the intricacies of scientific processes in the context of learning abstract concepts (Heit, et al., 1991; Kubicek, 2005; Seung, Bryan, & Butler, 2009). Many schools find themselves investing time in such programs in an attempt to meet reform recommendations and state testing requirements. While many of these curricula appear to be complete and well researched, the range and complexity of content knowledge and skills required to utilize such materials is often underestimated or misunderstood by both teachers and administrators. Potential adopters must recognize that not all curricula provide embedded PD for teachers to acquire requisite content knowledge, awareness of student misconceptions and knowledge deficits, and proficiency in science- and EE-specific instructional skills. Nor do they address emotional discord teachers often experience when changes in classroom structure and behaviors are required (Goleman, 1998; Loucks-Horsley, Hewson, Love, & Stiles, 1998). Adoption of GIT curricula without dedicating sufficient time and resources for PD and technology support may result in classroom implementation that may look different in practice to what the developers had in mind.

While no PD effort should be considered simple, the complex matrix of skills necessary to incorporate inquiry-based, GIT-enhanced, science instruction compounds the financial, political, and time constraints so often experienced by PD providers (Johnson & Marx, 2009). Since many teachers are unfamiliar with EE or GIT and its use requires unfamiliar instructional methods, new technology skills, and adaptive classroom management techniques, many teachers may find the intricacies of implementing such curricula frustrating. Research has shown teachers may avoid teaching curricula that integrates EE methodologies or geospatial technologies if they lack confidence in their own understanding of subject content knowledge, contextual knowledge, pedagogy, technology skills, and student characteristics and needs (Baker, Palmer, & Kerski, 2009; Meyer, Butternick, Olin, & Zack, 1999; Moseley & Utley, 2008; Powers, 2004).

Key to successful adoption of GIT-integrated curriculum is administrative support within the school system that includes invested PD support. However, the reality of time constraints within the classroom limits the extent to which financially strapped school districts can sustain the needed PD. Without ongoing support, many teachers become so overwhelmed that successful implementation of GIT-integrated curriculum may be compromised (McClurg & Buss, 2007; Russell & Bradley, 1997; Speck & Knipe, 2001).

PD that integrates GIT and educative curriculum materials (Davis & Krajcik, 2005) has been found to effectively cultivate inservice science teachers' requisite technology skills, content knowledge, and spatial understandings needed to effectively teach complex environmental issues such as energy use (Kubitskey, Fishman, Johnson, Mawyer, & Edelson, in press; MaKinster, Boone, & Trautman, 2010; MaKinster & Trautmann, in press; Schneider & Krajcick, 2002). Such PD should include personal learning experiences and reflective practices within similar contexts to those that their students might experience (Kimble, et al., 2006; Loucks-Horsley, et al., 1998; Rhoton & Bowers, 2001). In addition, it should enable science teachers to identify their own misconceptions and increase their awareness of potential misconceptions of their own classroom learners (Halim & Meerah, 2002). Addressing teacher and student misconceptions is an important step toward developing PCK (Shulman, 1987). Furthermore, understanding how technology interfaces with PCK, a term now referred to as Technological Pedagogical Content Knowledge (TPACK) (Hammond & Manfra, 2009; Koehler & Mishra, 2009; Mishra & Koehler, 2006) is also quite important for science teachers who use GIT to promote the teaching and learning of complex environmental issues (Bodzin et al., in press; MaKinster & Trautmann, in press).

Some curriculum designers have developed PD networks through partnership with school districts (Kali, Linn, & Roseman, 2009). Keeping time constraints and the need for ongoing practice of new skills in mind, these projects have developed educative curriculum materials, a form of PD designed to promote teacher learning in addition to student learning through immediate and extended applications (Davis & Krajcik, 2005). Curriculum designers, who align PD to the requirements of the curriculum, promote teachers' understanding of connections between curricular components and pedagogical tools and enable teachers to help students discover connections between lessons in the curriculum (Krajcik, Blumenfeld, Marx, & Soloway, 1994; Lin & Fishman, 2006). Curriculum-aligned PD helps teachers to understand the theoretical framework of the curriculum and provides supports for teachers to make informed adaptations in the classroom while maintaining the pedagogical integrity of a GIT-embedded curriculum (Kubitskey & Fishman, 2006).

The Geospatial Science-Technological Pedagogical Content Knowledge (GS-TPACK) Professional Development Model

In an effort to encourage successful adoption of a GIT-embedded science curriculum, our Environmental Literacy and Inquiry (ELI) group developed a PD model designed to increase Geospatial Science-Technological Pedagogical and Content Knowledge (GS-TPACK) while addressing the many constraints faced by educators in urban school settings. GS-TPACK is an adaptation of Technological Pedagogical and Content Knowledge (TPACK) models (Hammond & Manfra, 2009; Koehler & Mishra, 2009; Mishra & Koehler, 2006), specific to development of skills and pedagogical practice within a science curriculum that integrates GIT. It includes three domain areas of expertise:

1. *Geospatial Technology Use* (GTU) - Teacher's knowledge about and proficiency with GIT tools such as Google Earth or GIS applications.

2. *Geospatial Science Content Knowledge* (GSCK) – Teachers understanding to how GIT can be used in science education.
3. *Geospatial Science Pedagogical Content Knowledge* (GSPACK) – Ability to adapt teaching strategies, pair GIT to content, and design and implement science curriculum materials that enhance and assess student learning.

Since technology use, particularly GIT, is an integral component of the Environmental Literacy and Inquiry (ELI) curriculum, the GS-TPACK PD model (see Fig. 1) is designed to support teachers in the development of GIT technology skills and pedagogical content knowledge about environmental issues (Loucks-Horsley, et al., 1998). The keystone structure of the GS-TPACK PD model is a combination of the collaborative partnership that was integral to the development of the ELI curriculum and sustained implementation support. We contend that the fostering of this partnership both during and after PD sessions affects the belief system and self-efficacy level of the participating teachers. To help sustain our PD efforts, we have encouraged school-based teacher support communities lead by teachers who participated during the prototype and pilot testing of the ELI curriculum's Energy and Land Use Change units (Loucks-Horsley, et al., 1998). We believe that our partnership efforts later help lead science teachers address novice teachers' beliefs and biases about energy and GIT curriculum integration (Fishman et al., 2003).

Building on the designs of effective PD for learning with technology, we blended Technological Pedagogical and Content Knowledge (TPACK) PD models with methodologies specific to science instruction and developed a PD model that includes personal learning experiences and reflective practices within similar contexts to those that their students might experience (Fishman, et al., 2003; Hammond & Manfra, 2009; Koehler & Mishra, 2009; Loucks-

Horsley, et al., 1998; Mishra & Koehler, 2006). During the PD sessions participating teachers are immersed in all three phases of a learning cycle that they will emulate later for their students (Marek & Cavallo, 1997).

- ☐ Exploration: assimilation/ awareness of the science concepts and gathering scientific data through direct experience. Presents discord between belief and evidence presented, causing teachers or students to confront misconceptions and reframe their understanding.
- ☐ Explanation: exploration and collective interpretation of data and experiences. Accommodation of new concepts into current experience.
- ☐ Organization: Expansion and application of newly acquired understandings and skills into novel situations.

These facets are quite important to our overall PD model since many preservice and inservice teachers share many of the same science misconceptions or alternative conceptions and knowledge deficits that students hold with regards to environmental issues that include energy (Gomez-Zwiep, 2008; Marek & Cavallo, 1997; Marek, Jaier, & McCann, 2008; Moseley & Utley, 2008; Schoon & Boone, 1998; Valhov & Treagust, 1988). Such misunderstandings may affect teachers' beliefs and influence their self-efficacy in teaching about environmental issues using GIT. The GS-TPACK PD model enables science teachers to identify their own misconceptions and increase their awareness of potential misconceptions of their own classroom learners (Halim & Meerah, 2002).

Context

Preliminary use of the GS-TPACK PD model guided the design of our ELI PD sessions to introduce middle school science teachers to the ELI *Energy* curriculum unit. The initial prototype PD design included a 3-day, 12-hour summer institute, PD sessions held during the academic year during school district inservice days, and classroom and Web-based support. Three 8th grade science teachers participated in our first PD summer institute. These teachers had 5-12 years of teaching experience. One of the teachers had actively collaborated with our ELI development group on the design of both ELI curriculum units and the PD institute.

We presented a second 1-day, 7-hour PD session for two teachers who were unable to attend the summer institute. All participating teachers work in two middle schools with diverse student populations. Approximately 34% of the students in the district are categorized as economically disadvantaged (over 80% at one of the school that is classified as an urban school).

Method

To explore the efficacy of the application of our prototype GS-TPACK PD model we evaluated all teachers who participated in the 3-day *Energy* PD summer institute and our abbreviated one-day PD session. We utilized a variety of data collection methods: the pre- and post-administration of the GS-TPACK instrument (see Appendix A), ongoing observation and discussions during the PD sessions, and issues lists generated by the teachers after each session.

The GS-TPACK instrument is a modified version of MaKinster, Boone, and Trautman's perceived TPACK Instrument (MaKinster, Boone, & Trautman, 2010). The GS-TPACK instrument was designed to measure teacher's perceived self-efficacy, knowledge, and skills pertaining to teaching science topics while utilizing GIT applications. This instrument was administered at the beginning and end of the summer institute for the three attending teachers and at the 1-day academic-year PD session for the two attending teachers. The instrument consists of 25 Likert-type statements using a scale of 1 to 6 divided into three subscales, GTU (9 items), GSCK (7 items), and GSPACK (9 items) [note descriptions above]. The instrument's total score measures teachers' GS-TPACK. The total possible score on the GS-TPACK instrument is 150.

Additional data was gathered through documentation of discussions and issues during and after each PD session. The PD team compiled notes during the PD sessions, documenting teachers' questions, issues, and concerns. Following each session, teachers were asked to list three things they liked or learned during the session and three concerns, questions, or suggestions. These observations and lists were reviewed and discussed each day by the PD team.

Analysis and Findings

Quantitative data collected during pre and post workshop administration of the GS-TPACK instrument during this prototype study indicated that the GS-TPACK PD model supported the development of GIT technological, pedagogical, and content knowledge for each participant. Figures 2, 3, and 4 show the pre- and post-test results for the GTU, GSCK, and GSPACK subscales for each participant. Figure 5 displays the pre- and post GS-TPACK total scores. Teachers 1, 2, and 3 attended the three-day summer institute. Teachers 4 and 5 attended the one-day PD session. Results from the three-day institute showed that each teacher score improved from pre- to post-test for each subscale and that total GS-TPACK scores, although widely variable in the pre-test, were all within one point on the post-test, indicating that this PD experience brought all participants to a near equal level of perceived GS-TPACK. While teachers 4 and 5 had improvements in overall score results following the one-day PD session, there was a substantial difference of 34 points in the post-test GS-TPACK scores. It is important to note that Teacher 3, who had high initial GS-TPACK scores, had been part of the ELI development group and was involved in the design of the PD sessions. This teacher had also implemented the prototype ELI curriculum units in her classroom. While it appears that the experiences during the PD summer institute better supported the development of GIT technological pedagogical and content knowledge for all participants, the alternative 1-day academic year session also resulted in increased GS-TPACK scores.

Qualitative data analysis gathered through documentation of discussions and issues during and after each PD session revealed reduced teacher anxiety about potential classroom concerns with regards to teaching with a GIT-embedded curriculum. Data analysis revealed that the PD experiences reduced many concerns the participating teachers initially had about their abilities to implement a GIT-embedded curriculum. The teachers also expressed excitement about the upcoming opportunities to apply and adapt their new GIT skills and pedagogical content knowledge into their diverse classroom settings.

Initially teachers expressed concerns about their inability to address technical issues, lack of familiarity with new geospatial software, district support, and curriculum assessment requirements. Many of their issues were addressed during subsequent PD sessions that included peer-sharing activities. Some issues required further collaboration with administrators such as district level science curriculum supervisors and school principals. These issues were resolved during the last day of the PD sessions in a joint session that included the PD designers, participating teachers and school administrators. By the conclusion of both the PD summer institute and the one-day PD session, the majority of concerns about pedagogical content knowledge, classroom management, and technology support were eliminated.

Conclusions

Our initial findings appear to demonstrate the efficacy of a PD model that addresses the components of GS-TPACK that includes a collaborative effort among science educators, teachers, and school administrators. Teachers demonstrated increased levels of GSPACK and developed positive attitudes about using GIT for student learning that focuses on the investigation of complex environmental issues.

The GS-TPACK PD model blends both science pedagogy and technology use in a supportive professional learning environment. Use of GIT in the PD encouraged teachers to learn in the same manner as their potential students. The ELI educative curriculum materials, an integral component of the GS-TPACK model, also provided instructional and pedagogical supports for both teacher and students to develop GIT skills and spatial understandings of the environmental phenomenon under investigation. We contend that the GS-TPACK PD model holds much promise as a successful PD model not only for resource-limited urban schools but also for any school or district seeking to reform their PD efforts in science instruction with geospatial learning technologies.

References

American Association for Advancement of Science (1993). *Benchmarks for Science Literacy: Project 2061*. New York: Oxford University Press.

Association for Science Teacher Education (2008). ASTE Position Statement on Technology in Science Teacher Education.

Association for Science Teacher Education (2009). ASTE Position Statement on Environmental Education.

Baker, T. R., Palmer, A. M., & Kerski, J. J. (2009). A national survey to examine teacher professional development and implementation of desktop GIS. *Journal of Geography, 108*(4/5), 174-185.

Bednarz, S. (2004). Geographic Information Systems: A tool to support geography and environmental education? *GeoJournal, 60*(2), 191-199.

Bodzin, A. M., Anastasio, D., & Kulo, V. (in press). Designing Google Earth activities for learning earth and environmental science. In J. G. MaKinster & N. M. Trautmann (Eds.), *Teaching Science and Investigating Environmental Issues with Geospatial Technology: Designing Effective Professional Development for Teachers*. Dordrecht: Springer.

Bodzin, A., & Cirucci, L. (2009). Integrating geospatial technologies to examine urban land use change: A design partnership. *Journal of Geography*, *108*(4-5), 186-197.

Brickhouse, N. W. (1990). Teachers' beliefs aout the nature of science and their relationship to classroom practice. *Journal of Teacher Education, 41*(3), 53-62.

Carrara, A., & Fausto, G. (Eds.). (1995). *Geographical information systems in assessing natural hazards*. Boston: Kluwer Academic Publishers.

Davis, E. A., & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational Researcher, 34*(3), 3-14.

Fishman, B. J., Marx, R. W., Best, S., & Tal, R. T. (2003). Linking teacher and student learning to imporve professional development in sustemic reform. *Teaching and Teacher Education, 19*(6), 843-858.

GLOBE (2009). GLOBE: Global Learning and Observations to Benefit the Environment Retrieved November 11, 2009, from http://www.globe.gov/

Goleman, D. (1998). *Working with Emotinal Intelligence*. New York: Bantam.

Gomez-Zwiep, S. (2008). Elementary teachers' understanding of students' science misconceptions: implications for practice and teacher education. [research]. *Journal of Science Teacher Education, 19*(5), 427-454.

Halim, L., & Meerah, S. M. (2002). Science trainee teachers' pedagogical content knowledge and its influence on physics teaching. *Research in Science & Technological Education, 20*(2), 215-225.

Hammond, T. C., & Manfra, M. M. (2009). Giving, prompting, making: Aligning technology and pedagogy within TPACK for social studies instruction. *Contemporary Issues in Technology and Teacher Education, 9*(2).

Heimlich, J. E., Braus, J., Olivolo, B., McKeown-Ice, R., & Barringer-Smith, L. (2004). Environmental education and preservice teacher preparation: A national study. *Journal of Environmental Education, 35*(2), 17.

Heit, M., Shortreid, A., & Parker, H. D. (Eds.). (1991). *GIS Applications in Naural Resources*. Fort Collins, CO: GIS World.

Johnson, C., & Marx, S. (2009). Transformative professional development: A model for urban science education reform. *Journal of Science Teacher Education, 20*(2), 113-134.

Kali, Y., Linn, M. C., & Roseman, J. (2009). *Designing coherent science education: Implications for curriculum, instruction, and policy*. New York: Teachers College Press.

Kimble, L., Yager, R., & Yager, S. (2006). Success of a Professional-Development Model in Assisting Teachers to Change Their Teaching to Match the More Emphasis Conditions Urged in the National Science Education Standards. *Journal of Science Teacher Education, 17*(3), 309-322.

Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? *Contemporary Issues in Techology and Teacher Education, 9*(1), 60-70.

Krajcik, J. S., Blumenfeld, P. C., Marx, R. W., & Soloway, E. (1994). A collaborative model for helping middle grade science teachers learn project-based instruction. *Elementary School journal, 94*, 483-497.

Kubicek, J. P. (2005). Inquiry-based learning, the nature of science, and computer technology. *Canadian Journal of Learning and Technology, 31*(1), N/A.

Kubitskey, B., & Fishman, B. (2006). *Professional development design for systemic curricular change*. Paper presented at the Annual Meeting of the American Educational Reserach Association.

Kubitskey, B., Fishman, B., Johnson, H., Mawyer, K., & Edelson, D. (in press). Curriculum aligned professional development for geospatial education. In J. MaKinster, N. Trautman & G. M. Barnett (Eds.), *Teaching Science and Investigating Environmental Issues with Geospatial Technology: Designing Effective Professional Development for Teachers*. Dordrecht, Netherlands: Springer.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*(4), 331-359.

Lederman, N. G., Gess-Newsome, J., & Latz, M. S. (1994). The nature and development of preservice science teachers' conceptions of subject matter and pedagogy. *Journal of Research in Science Teaching, 31*(2), 129-146.

Lin, H.-T., & Fishman, B. J. (2006, April). *Exploring the relationship between teachers' experience with curriculum and their understanding of implicit unit structures.* Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco, CA.

Linn, M. C., Clark, D., & Slotta, J. D. (2003). WISE design for knowledge integration. *Science Education, 87*(4), 517-538.

Loucks-Horsley, S., Hewson, P., Love, N., & Stiles, K. E. (1998). *Designing professional development for teachers of sciene and mathematics*. Thousand Oaks, CA: Corwin Press.

MaKinster, J. G., Boone, W., & Trautman, N. (2010). *Development of an instrument to assess teachers' perceived technological pedadological content knowledge*. Paper presented at the National Association for Research in Science Teaching Annual International Conference.

MaKinster, J. G., & Trautmann, N. M. (in press). Understanding the conceptual and pedagogical opportunities to teach science created by geospatial technologies: A case study of TPACK in action. In J. G. MaKinster, N. M. Trautmann & G. M. Barnett (Eds.), *Teaching Science and Investigating Environmental Issues with Geospatial Technology: Designing Effective Professional Development for Teachers*. Dordrecht: Springer.

Marek, E. A., & Cavallo, A. M. L. (1997). *The learning cycle: Elementary school science and beyond*. Portsmouth, NH: Heinemann.

Marek, E. A., Jaier, S. J., & McCann, F. (2008). Assessing understandign of the learning cycle: The ULC. *Journal of Science Teacher Education, 19*(4), 375-389.

McClurg, P., & Buss, A. (2007). Professional development: Teachers use of GIS to enhance student learning. *Journal of Geography, 106*(2), 79-87.

Meyer, J., Butternick, J., Olin, M., & Zack, G. (1999). GIS in the K-12 curriculum: A cautionary note. *Professional Geographer, 51*(4), 571-578.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A new framework for teacher knoweldge. *Teachers College Record, 108*(6), 1017-1054.

Moseley, C., & Utley, J. (2008). An exploratory study of preservice teacher's beliefs about the environment. *Journal of Environmental Education, 39*(4).

National Research Council (1996). *The National Science Education Standards*. Washington, DC: National Academy Press.

National Research Council (2006). *Learning to think spatially: GIS as a support system in K-12 education*. Washington, DC: National Academy Press.

National Science Teacher Association (2003). NSTA Position Statement: Environmental Education

Peffer, T. E., & Bodzin, A. M. (2010). The value of nonformal environmental education-based professional development in preservice science teacher preparation. In A. M. Bodzin, B. S. Klein & S. Weaver (Eds.), *The Inclusion of Environmental Education in Science Teacher Education*. Dordrecht: Springer.

Powers, A. L. (2004). Teacher preparation for environmental education: Faculty perspectives on the infusion of environmental education Into preservice methods courses, *The Journal of Environmental Education*, 35.

Rhoton, J., & Bowers, P. N. P. (2001). *Professional development: Planning and design*. Alexandria, VA: NSTA Press.

Russell, G., & Bradley, G. (1997). Teachers' computer anxiety: implications for professional development. *Education and Information Technologies, 2*(1), 17-30.

Schneider, R., & Krajcick, J. (2002). Supporting science teacher learning: The role of educative curriculum materials. *Journal of Science Teacher Education, 13*(3), 221-245.

Schoon, K. J., & Boone, W. J. (1998). Self-efficacy and alternative conceptions of science of preservice elementary teachers. *Science Education, 82*(5), 553-568.

Seung, E., Bryan, L., & Butler, M. (2009). Improving preservic middle grades science teachers' understanding of the Nature of Science using three instructional approaches. *Journal of Science Teacher Education, 20*(2), 157-177.

Shulman, L. S. (1986). Those who understand teach: Knowledge growth in teaching. *Educational Researcher, 15*(5), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-22.

Speck, M., & Knipe, C. (2001). *Why Can't We Get It Right?: Professional Development in our Schools* (1 ed.). Thousand Oaks, California: Corwin Press, Inc.

Stapp, W. B., et al. (1969). The concept of environmental education. *Journal of Environmental Education, 1*(1), 30-31.

Valhov, S. J., & Treagust, D. F. (1988). Students' knowledge of energy and attitudes to energy conservation. *School Science and Mathematics, 88*(6), 452-458.

Yager, R. E. (2007). STS requires changes in teaching. *Bulletin of Science, Technology & Society, 27*(5), 386-390.

List of Figures

Figure 1. The GS-TPACK PD model. Collaborative and sustained support effects beliefs, knowledge, and leads to increased GS-TPACK

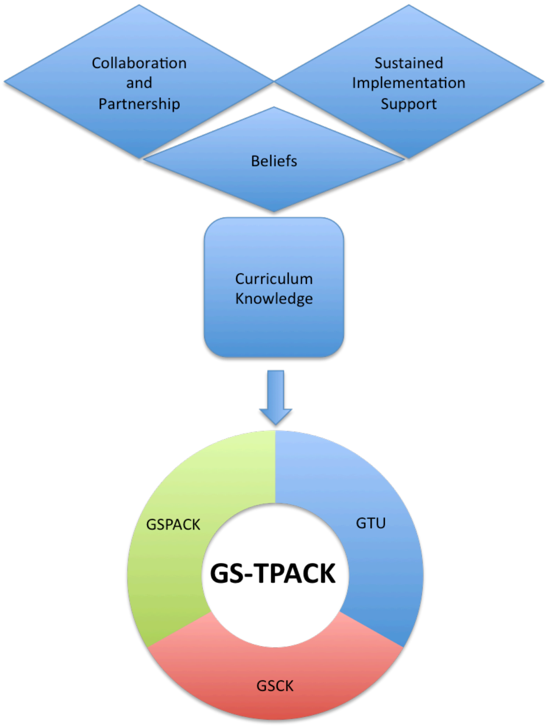


Figure 2. GTU (total possible score = 54)

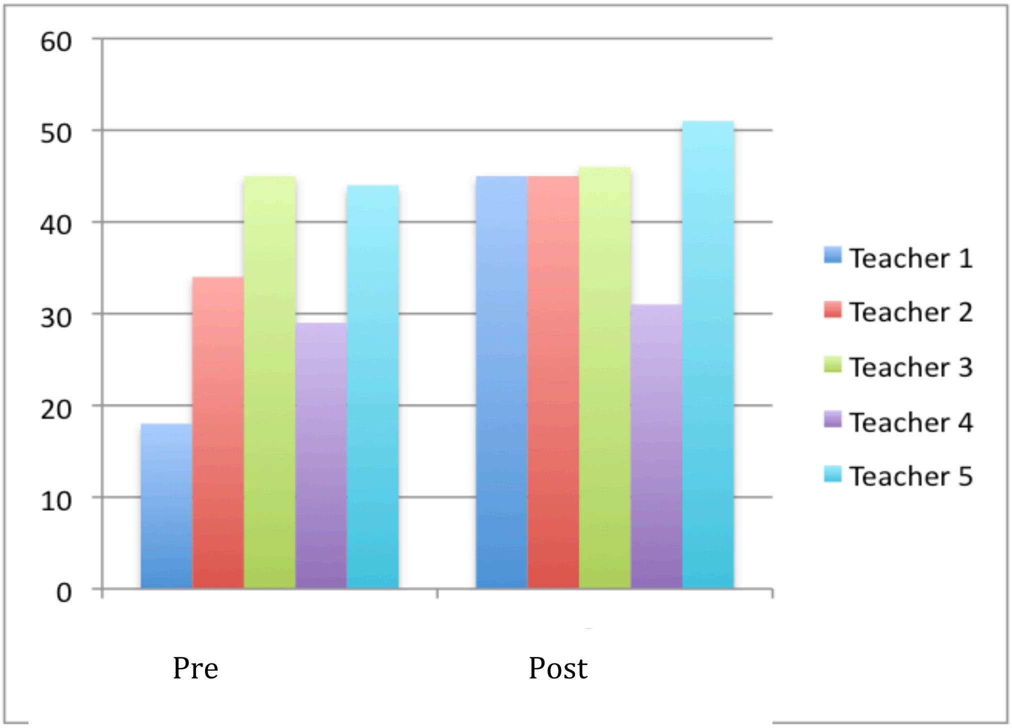


Figure 3. GSCK (total possible score = 42)

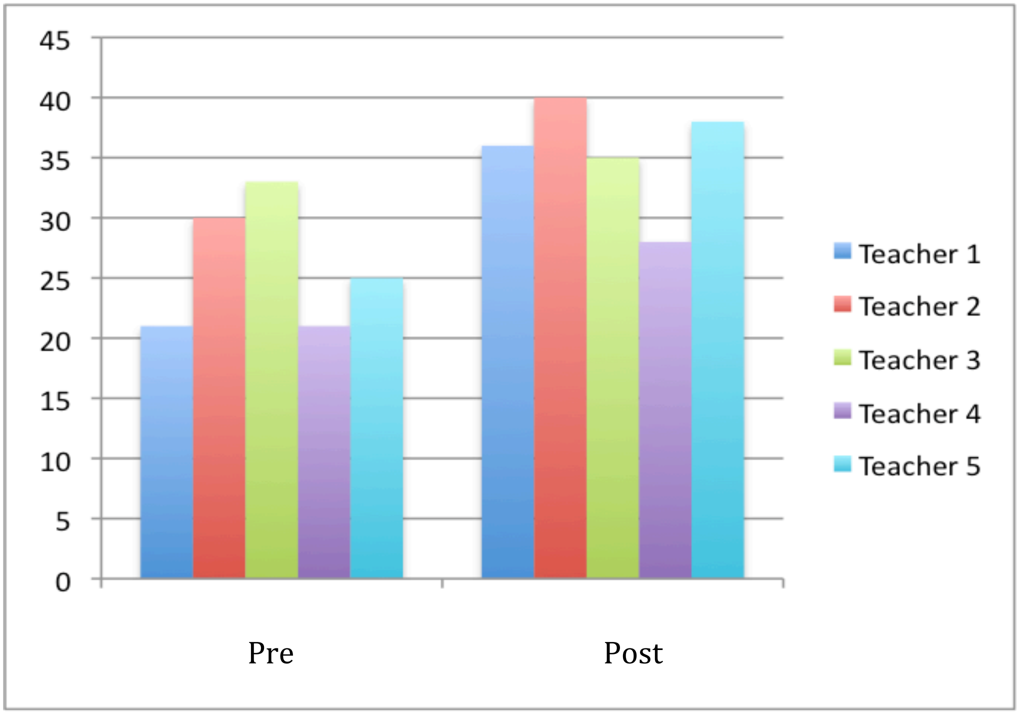


Figure 4 GSPACK (total possible score = 54)

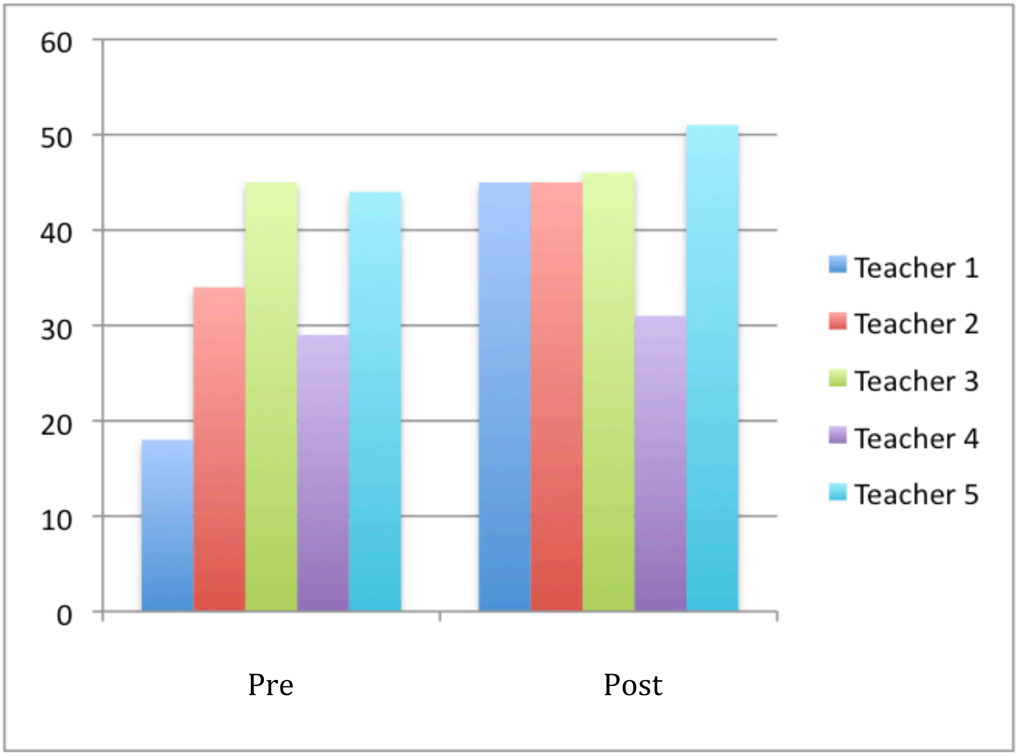
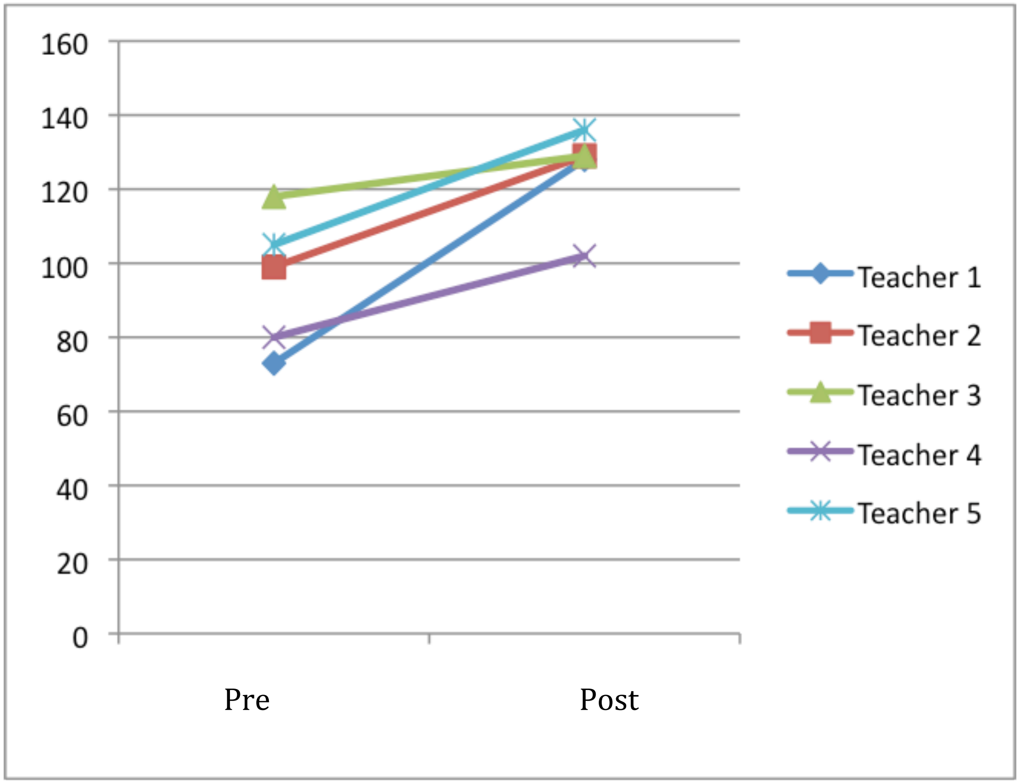


Figure 5. GS-TPACK total (total possible score = 150)



Appendix A. GS-TPACK Instrument

Geospatial Science Technological Pedagogical Content Knowledge (GS-TPACK) is a way of thinking about how teachers integrate their knowledge of geospatial technology and teaching within the science discipline. Below are a series of questions that progress from asking about individual knowledge categories (e.g., Geospatial Technology Use) to knowledge categories that integrate two or more of the domains in GS-TPACK (e.g., Geospatial Science Content Knowledge).

While we realize that you may not have the opportunity to use certain geospatial technologies, we are most interested in your own assessment about your knowledge and abilities. This is your perceived ability, regardless of whether or not you have the opportunity to use that knowledge on a regular basis.

Please feel free to ask questions if there is an item you don't understand.

Geospatial Technology Use

	Strongly Disagree	Disagree	Barely Disagree	Barely Agree	Agree	Stron Agr
1. I can use a variety of geospatial technologies.	○	○	○	○	○	○
2. I can analyze satellite imagery using Google Earth.	○	○	○	○	○	○
3. I can use GIS as an instructional tool.	○	○	○	○	○	○
4. I can use Google Earth as an instructional tool.	○	○	○	○	○	○
5. I can navigate from one location to another in Google Earth.	○	○	○	○	○	○
6. I can use Google Earth for classroom investigations.	○	○	○	○	○	○
7. I can use GIS for classroom investigations.	○	○	○	○	○	○
8. I can create maps using GIS.	○	○	○	○	○	○
9. I can analyze scientific data using GIS.	○	○	○	○	○	○

GSCK (*Geospatial Science Content Knowledge*)

	Strongly Disagree	Disagree	Barely Disagree	Barely Agree	Agree	Stron Agr
1. I am comfortable answering student questions during science investigations that use geospatial technology.	○	○	○	○	○	○
2. I can think of many scientific concepts that students can learn more effectively with geospatial technologies than without these applications.	○	○	○	○	○	○
3. I can think of many science concepts that can be taught effectively using Google Earth.	○	○	○	○	○	○
4. I can think of many science concepts that can be taught effectively using GIS.	○	○	○	○	○	○
5. I can use geospatial technologies to investigate real-world scientific issues.	○	○	○	○	○	○
6. I can plan science lessons that make effective use of Google Earth.	○	○	○	○	○	○
7. I can plan science lessons that make effective use of GIS.	○	○	○	○	○	○

GSPACK (*Geospatial Science Pedagogical Content Knowledge)*

	Strongly Disagree	Disagree	Barely Disagree	Barely Agree	Agree	Stron Agr
1. I can *design* lessons that effectively combine science content, geospatial technologies, and teaching strategies.	○	○	○	○	○	○
2. I can *teach* lessons that effectively combine science content, geospatial technologies, and teaching strategies.	○	○	○	○	○	○
3. I can choose geospatial technologies to use in my classroom that enhance how and what students learn.	○	○	○	○	○	○
4. I can choose geospatial technologies that enhance both the content and teaching strategies of a science lesson.	○	○	○	○	○	○

5. I can use geospatial technology to teach science effectively using a variety of teaching strategies.	○	○	○	○	○	○
6. I can effectively assess student learning in projects that make use of geospatial technologies.	○	○	○	○	○	○
7. I can adapt my use of teaching strategies when using geospatial technology for student learning.	○	○	○	○	○	○
8. I am comfortable managing my classroom when using geospatial technology for student learning.	○	○	○	○	○	○
9. I can help other teachers coordinate their use of science content, geospatial technologies and teaching strategies.	○	○	○	○	○	○