A Design Partnership to Support Teachers' Adoption of Technology-Integrated Curriculum

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Abstract

We present a design partnership with in-service science and social studies teachers to support the development and implementation of technology-integrated science curriculum over a two-year period in an urban high school.

Proceedings Abstract

We have developed a design partnership with urban ninth grade teachers to design, develop, and implement a series of novel Socio-Environmental Science Investigations (SESI) and projects that integrate mobile learning and geospatial technologies into the classroom science and social studies curricula. In our design partnership, education professors/researchers with background in curriculum design and development with geospatial technologies, content experts in the natural sciences and social sciences, and geospatial experts collaborate with classroom teachers to design and develop the SESI learning activities, along with consultation from school administrators and technology staff. Our partnership model focuses on collaborative design and implementation of curriculum in keeping with models of school-based reform. Over the course of two years, six SESI investigations and three projects were developed and implemented with all students in the ninth grade. Each SESI investigation focuses on a driving investigative question that is relevant to the students' community. Each investigation was also designed to develop students' geospatial process skills. These skills include accessing different geospatial applications (Collector app on iPad and Web GIS maps on laptop computers), utilizing data collection procedures, displaying and navigating maps, annotating maps, analyzing data using different tools for pattern recognition and examining outliers, and constructing new data displays and visualizations. The design partnership was successful for promoting technological pedagogical content knowledge with in-service science teachers. This paper describes how the design partnership operated in practice, discusses successful strategies that were effective for promoting technological PCK with in-service science teachers, factors that make design partnerships successful such as the importance of relationship building with in-service science teachers, and the professional benefits that scientists and social scientists received by collaboratively working with in-service science teachers in urban classrooms implementing technology-integrated curriculum for extensive periods of time.

Effectively teaching science with technology-integrated curriculum requires specific technological pedagogical content knowledge [PCK] (Mishra & Koehler, 2006) and implementation supports to effectively incorporate learning technologies into the classroom. Science teachers with technological PCK have a more complete understanding of the complex interplay between science pedagogical content knowledge and technology pedagogical content knowledge and can teach science using appropriate pedagogical methods and technologies. For example, when teachers implement an inquiry-based science curriculum that involves data collection with mobile technologies coupled with data analysis with a Web-based mapping application, understanding how to model geospatial data exploration and analysis techniques and how to effectively scaffold students' geospatial thinking and analysis skills are examples of technological PCK that are needed for successful implementation of such a curriculum.

Unfortunately, many teachers have not had professional development experiences that foster sufficient technological PCK to implement technology-integrated science curriculum that use geospatial technologies to promote both science learning and the development of geospatial thinking skills. In many U.S. school districts, the available time within a school year to provide in-service science teachers with quality professional development to adopt new science education technology-integrated curriculum is limited. To address this common reality, we have developed a design partnership with urban ninth grade teachers to design, develop, and implement a series of novel socio-environmental science investigations (SESI) and projects that integrate mobile learning and geospatial technologies into the classroom science curriculum.

The Design Partnership

In our design partnership, education professors/researchers with backgrounds in curriculum design and development with geospatial technologies, content experts in the natural sciences and social sciences, and geospatial experts collaborate with classroom teachers to design and develop the SESI learning activities, along with consultation from school administrators and technology staff. Our partnership model focuses on collaborative design and implementation of curriculum in keeping with models of school-based reform (Shear, Bell, & Linn, 2004), and is a mechanism designed to leverage the diverse expertise of each contributor. This collaboration also promotes the learning of each partner in a process of co-developing the curriculum and instructional practices that will be implemented in the classroom (McLaughlin & Mitra, 2001). Lastly, this level of collaboration and coordination is necessary to manage multiple and overlapping issues of technical implementation, school management, and curriculum design and development.

Our design partnership began with a shared vision of curriculum reform between education researchers who are also science and social studies teacher educators and classroom teachers in an urban school interested in revising their curriculum to be more aligned to the crosscutting concepts, scientific practices, and disciplinary core ideas in the Next Generation Science Standards [NGSS] (NGSS Lead States, 2013). The teachers were also very interested in promoting important workforce readiness skills that involve technology use in STEM-related careers. The U.S. Department of Labor has identified geospatial technology as a sector "projected to add substantial numbers of new jobs to the economy or are being transformed by technology and innovation requiring new sets of skills for workers" (National Geospatial Advisory Committee, 2012). Geospatial thinking and reasoning skills are essential for occupations in which geospatial analysis skills for solving problems is either critical to the job or enhances occupational competence where there is a heavy reliance on cognitive thinking skills that include knowledge about geospatial relations and geospatial reasoning skills (Goodchild &

Janelle, 2010; NRC, 2006). Geospatial thinking and reasoning skills also involve important scientific practices highlighted in the NGSS and include data manipulation and analysis that invoke and require critical thinking and problem solving that is connected to data referenced to Earth's surface or to the Earth's representation through map and globe visualizations (Huynh & Sharpe, 2013). Thus, we decided on GIS as an important technology to integrate into the students' curriculum to promote important skills found in STEM-related workforce sectors.

We conceptualized Socio-Environmental Science Investigations (SESI) and projects that focus on social issues related to environmental science. The pedagogy was conceived to be inquiry-driven, with students engaging in hands-on work with data to answer open-ended questions. The issues would be multi-disciplinary, involving decision-making based on the analysis of geospatial data, examination of relevant social science content, and consideration of social equity implications. SESI are based on the pedagogical frameworks of place-based education and socio-scientific issues-based instruction. Place-based education focuses on local or regional investigations, is designed around engaging students in examining local problems (Sobel, 2004), and utilizes fieldwork to gather evidence in that local setting (Semken, 2005; Semken et al., 2017). Place-based education connects learners to their immediate environment and can provide opportunities to empower students to address important socio-scientific issues in their community. Socio-scientific issues are controversial, socially relevant, real-world problems that are informed by science and often include an ethical component (Sadler et al., 2007). They are sometimes controversial in nature but have the added element of requiring a degree of moral reasoning or the evaluation of ethical concerns in the process of arriving at decisions regarding possible issue resolution (Zeidler & Nichols, 2009). These issues require the use of evidence-based reasoning, and provide a context for understanding scientific information using an active approach to learning, placing science content within a social context in a way that fosters both motivation for, and the ownership of, learning by the student (Sadler et al., 2006; Zeidler & Nichols, 2009).

Our team created investigations designed for students to gather georeferenced data with GPS enabled mobile devices (iPads) that are essential to each investigation. Content emphasis is placed on social issues related to environmental science. The topics are multidisciplinary and focus on environmental management and social justice. The investigations require students to gather information relevant to urban planning decisions in their own communities. Students are then asked to take on the role of a decision-maker, and inform their thinking and reasoning about decisions based on their analysis of the data they gather, its connection to relevant social and environmental science content, and consideration of the implications for social equity, political opportunity, and environmental sustainability. We incorporate instructional strategies such as scaffolding to support students with their data analysis interpretations. The scope of the investigations has been developed in such a way that by the end of the school year, an authentic communication component can be incorporated: Students will share their findings about the health of their surrounding environment with the local community in a public forum, in order to start conversations that may empower the public to advocate for further research and political action (Connors, Lei, & Kelly 2012; Kolok, Schoenfuss, Propper, & Vail, 2011).

Over the course of two years, six SESI investigations and three projects were developed and implemented with all students in the ninth grade. Each SESI investigation focuses on a driving investigative question that is relevant to the students' community. Each investigation is also designed to develop students' geospatial process skills. These skills include accessing different geospatial applications (Collector app on iPad and Web GIS maps on laptop computers), utilizing data collection procedures, displaying and navigating maps, annotating maps, analyzing data using different tools for pattern recognition and examining outliers, and constructing new data displays and visualizations. The SESI investigations are freely available online at: https://eli.lehigh.edu/sesi.

The initial stages of our project were focused on managing the information technology infrastructure of the school. SESI activities required new iPads to be bound to the school district's network, while still allowing flexible updating and app management from members of our project team. The project also requires an organizational account for the school to use Esri's ArcGIS.com Web GIS infrastructure. The access is free upon request to K-12 schools as a continued part of Esri's participation in the Obama-era ConnectED initiative (Fitzpatrick, 2014). With an institution-level account, one can obtain a single URL for all work in the Web-based GIS environment to gain significant organizational advantages that include central control of shared resources such as datasets and maps that aids team management and the ability to manage both individual student accounts and class-level groupings. A final piece of infrastructure was developing websites for hosting instructional materials and the mentor orientation and training materials.

As the technical and logistical details were being worked out, we began charting our development cycle for the SESI activities. The first step was to gather information about the existing curriculum in both the environmental science and the social studies classes. In this area, the teachers were the experts, unpacking their content, objectives, and assessment practices for the design and development team. The next step was a collaborative brainstorming process, identifying topics for the SESI investigations, locating datasets, and outlining ideas for data collection, visualization, and analysis. Following this brainstorming, we selected and organized the content, focusing on those topics that appeared to be the best fit for teachers' existing curriculum and had strong potential for engaging the students.

From these topic selections, the development team began sketching out the SESI investigations, addressing the following questions in a collaborative planning document:

- What are the enduring understandings?
- What are the learning objectives?
- What background content knowledge for both teachers and students would be required?
- What outside data collection opportunities would be incorporated?
- What pre-existing datasets would we incorporate into students' visualization and analysis?
- What would be the instructional sequence for the learning activities?
- How would we scaffold students' work?
- What would be the role of the mentors?
- What would be the culminating artifact produced by the students?
- Where might time restrictions or complexity of analysis limit students' ability to complete instructional activities?

Simultaneously, we identified the tools we would need to support students' completion of the SESI activities. In addition to the GIS, we selected Esri's Collector app for data collection, additional software such as Google Earth for supplementary visualization, and supplementary data collection tools such as air and infrared thermometers, and tape measures. The end product from this stage was a complete package of materials for each SESI activity that included background content material to give the teachers a foundation in the content, an instructional sheet and videos to guide students' use of the geospatial tools, and a set of tasks for students to complete when examining the data visualizations, conducting analysis, and making initial explanations and claims.

Throughout the materials development process, we elicited iterative feedback from the teachers by reviewing the materials with them and conducting walk-throughs of data collection and visualization. As we completed the initial development of materials for each SESI activity, we requested an initial prototype implementation with a teacher-selected group of 10^{th} graders to provide us with usability feedback on the data collection interfaces and a student perspective on the learning activity's tasks and support materials. After initial prototype testing, we were ready to implement a complete prototype activity with the full class of 9^{th} grade science or social studies students.

The classroom prototype implementations followed a gradual release model. In this approach, the design and development team act as the primary instructor in the classroom until the regular teacher (either environmental science or social studies) feels ready to take on the task of guiding students through the day's activity. For example, over the course of a day, a member of the design and development team might teach the class during period 1, with the teacher providing instructional support. During period 2, the teacher would take over part of the lesson, with the design and development team member playing a backup role as needed. By the last period of the day, the teacher leads the entire lesson.

Following each prototype implementation, the teachers and the design and development team engage in a group reflection on the day's material, discussing what worked well and what parts of the learning materials need refinements for the next iteration. We had rich discussions about student engagement, ensuring that the content was meaningful and relevant to the students' lives, and developing curriculum materials that would be usable for English learners and students with disabilities. After a SESI investigation or project was concluded and student submissions were analyzed, all members of the partnership would meet to discuss refinements for the next time the learning activity would be implemented.

Teacher Professional Development Approach

An essential feature of this project is our hybrid, curriculum-linked professional development process. This process incorporates both face-to-face and online learning and follows a design partnership model (see Bodzin & Cirucci, 2009). By integrating the teachers' professional development into the curriculum design and development activities, we are able to advance teachers' geospatial pedagogical content knowledge (Bodzin et al., 2012) in the authentic context of their curricular practice. This integrated approach is effective in supporting teachers as they adopt new curriculum and new spatial technologies (Bodzin et al., 2012; Fishman et al., 2013; McAuliffe & Lockwood, 2014). Our starting assumption is that our collaborating teachers are the pedagogical experts who will adapt curriculum materials as needed to meet the needs of their students (Penuel, Fishman, Yamaguchi, & Gallagher, 2007). We do support teachers in this adaptation process, but our primary focus is on the content and technology needed for the curriculum: how to use the GIS, for example, or the background understandings that underlie topics such as urban heat islands. We advance teachers' content and technology skills through active learning experiences with GIS, both in exploring background content and when working through sample materials for classroom instruction. We then provide opportunities for integration across teachers' understandings of the content, pedagogy, and technology through collaborative peer discussions and the opportunity to reflect on their own teaching practice (Garet, Porter, Desimone, Birman, & Yoon, 2001; Penuel et al., 2007). By allowing teachers to provide reciprocal expertise, we support the high level of trust and engagement required to build and enact geospatial curriculum.

In the classroom: Instructional modeling and gradual release

An important professional development tactic was the gradual release model of classroom prototype implementation described above. Allowing teachers to adopt elements of the instruction at their own pace enabled them to be comfortable with the process; whenever they took over a new instructional step, they had support in the form of one or more design and development team members. In this process, we have observed one teacher adapt the prototype SESI investigation much more quickly than the rest. This teacher has more experience with geospatial tools and greater familiarity with the content; this background created confidence to quickly take the central role in leading the SESI activities in his classroom. By the second prototype activity, he initiated and directed all stages of the instruction, only turning to the design and development team in the event of a technical glitch. The gradual release model allowed another teacher, with less prior experience with the technologies and topics of the SESI activities, to take a slower process as she advanced her skills and comfort level.

In addition to these face-to-face activities, teachers completed several online professional development tasks. We provided selected readings in geospatial education and geospatially-enabled curriculum, focusing on examples of classroom use of geospatial technology to study social studies and science topics. These readings helped convey the importance of teaching and learning with geospatial technologies, illustrations of classroom enactment, and some of the background content for the inquiry activities. In addition to these readings, teachers reviewed previously-built geospatial curriculum learning activities drawn from the design and development group's past projects.

Evidence of Effectiveness

To examine teachers' growth in their geospatial science pedagogical content knowledge, we administered the Geospatial Science-Technological Pedagogical Content Knowledge [GS-TPACK] instrument (Bodzin, Peffer, & Kulo, 2012) to all participating teachers at the beginning and end of the first year of the project. The GS-TPACK instrument was designed to measure teachers' perceived knowledge of how geospatial technology interacts with their pedagogical content knowledge in ways that produce effective science teaching and student learning opportunities. The instrument includes 23 Likert-type items that are scored with a six-point scale of 1 (Strongly Disagree) to 6 (Strongly Agree). The reliability (Cronbach alpha) of the GS-TPACK instrument is .961.

Findings from the GS-TPACK instrument revealed growth in teachers' geospatial technology use [Pretest mean = 42.25, SD=7.63; Posttest mean = 53.50, SD=3.42], geospatial technology content knowledge [Pretest mean = 46.50, SD=5.20; Posttest mean = 47.25, SD=2.50], and geospatial technology pedagogical content knowledge [Pretest mean = 35.75, SD=2.63; Posttest mean = 37.00, SD=1.83]. For the entire GS-TPACK instrument, the total mean increased significantly [Pretest mean = 124.50, SD=10.66; Posttest mean = 137.75, SD=7.41] with a large effect size (Cohen's d = 1.44).

Benefits for Scientists and Social Scientists

Members of our development team included scientists and social scientists. The development team members received many professional benefits by collaboratively working with in-service science and social studies teachers in urban classrooms implementing technology-integrated curriculum for extensive periods of time. The benefits scientists and social scientists received included enhancing their knowledge about curriculum design and pedagogical models, understanding learner characteristics, exposure to interdisciplinary and multidisciplinary approaches to teaching and learning, have experiences with teaching and learning with GIS and learning about new spatial databases and software, understanding how to use visualizations as a pedagogical tool, and being provided with communication opportunities to present scientific concepts to be understood by non-specialists. Some of these benefits readily translated for use in the scientists and social scientists' own university teaching.

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