So What Happens When the Funding Runs Out? Professional Development for Sustainable Geospatial Technology Integration Initiatives

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Abstract: To date, geospatial educators have focused on classroom-level implementation. Accordingly, professional development efforts regarding teachers' integration of geospatial tools into classroom instruction has focused on individual teacher learning and behavior. In contrast, workforce educators have emphasized the need for institutional learning, rather than just teacher learning. Our experience implementing a geospatial technology integration initiative in an urban high school with high teacher and administrator turnover points out the need to address broader, institution-level goals: geospatial competence throughout the building and not just in selected classrooms. This paper highlights design and professional development strategies that have allowed the project to succeed despite the high rate of turnover and to move toward sustainability past the grant's funding period. Implications for teacher education and other geospatial initiatives are discussed.

Introduction

Ever since the Sputnik crisis, education funding agencies have gone through cycles of investment in improving the nature and quality of teachers' technology integration into their classroom instruction (Saettler, 1990). As an example, the National Science Foundation (NSF)—founded in 1950—had an operating budget of just under $7.5 billion for fiscal year 2017 (NSF, 2017). This funding goes toward a wide variety of initiatives aimed at innovation and improvement in many STEM areas, often with a heavy emphasis on technology integration in high-need areas such as geospatial technologies. For example, as of 2017, the NSF had awarded more than $140 million in grants to develop geographic information systems (GIS) skills among the nation's students and workers (NSF, n.d.).

To date, funded research has focused on teacher professional development, recognizing that teachers function as the "curricular-instructional gatekeepers" of the classroom (Thornton, 1991). This formulation is particularly true for geospatial technologies such as GIS, which carry a steep learning curve. Before one can teach *with* GIS, one first must learn *about* GIS (Sui, 1995)—its file structure, data definition, its indexing of maps and data layers, map projections, and so forth. Borrowing Mishra and Koehler's framework of Technological Pedagogical Content Knowledge (Koehler & Mishra, 2008), GIS requires significant technological knowledge that must be mastered (at least to a minimum threshold) before it can be integrated with teachers' pedagogical knowledge and content knowledge (Hammond et al., 2018). Consequently, significant research and funding has gone towards understanding teacher learning about GIS its effective integration into classroom instruction. For example, in 2014, leading GIS educators and education researchers laid out a research agenda in geospatial technologies and learning:

> Is there an optimal sequence of content, skills, or technology tools to learn geospatial technologies?
> a. What are the appropriate skills to be considered?
> b. How does the optimal sequence vary with different learners, contexts, or geospatial technologies themselves?

c. Are there specific instructional models, sequences, or scaffolding support associated with optimal learning sequences? (Baker et al., 2014, p. 6)

Workforce preparation groups such as The National Geospatial Technology Center of Excellence (GeotechCenter.org) have a similar interest in classroom integration of technology but aim for a far higher level of institutional integration. Consider, for example, their Geospatial Technology Competence Model (Figure 1), in which individuals' academic and workplace skills form the beginning stages (the bottom layers) and lead toward industry-wide and management skills and understandings. This model, in contrast to the teacher education-focused model, aims for geospatial competence and integration not just at the classroom level but at entire systems.

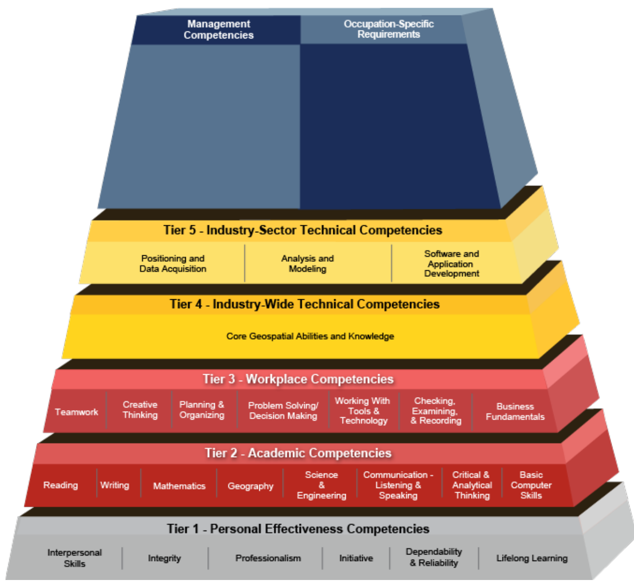

Figure 1: Geospatial Technology Competence Model (U.S. Department of Labor, 2010).

The disparity between teacher educators' smaller, classroom-level focus and the larger, institutional focus of agencies such as GeotechCenter became apparent to us in the course of implementing a current, NSF-funded project on geospatial technology integration in an urban high school. Throughout the course of the grant, we have worked with the entire 9th grade of the high school (approximately 150 students in all), developing and implementing a sequence of geospatially-integrated science and social studies investigations and projects (Hammond et al., in press). These students all have a single science teacher and a single social studies teacher for the entire year, and the grant is now in its third and final year of funding. While these single points of contact—the common science teacher and the common social studies teacher—reduce the number of teachers requiring training in GIS and its effective integration into classroom instruction, we did not account for the level of teacher turnover that we may face over the course of the grant. To date—26 months into the grant—we have had a different social studies teacher every year, turnover in the science classroom to a first-year teacher, two different school principals, and even turnover in the district's technology administration office and superintendent. Given the high level of personnel change, how can a geospatial technology integration initiative thrive? Taking the question a step further, to the institutional level, how can it be sustained past the end of the grant funding?

Purpose

This paper will share the multiple strategies we have used to develop, implement, and sustain a robust geospatial technology integration initiative in a high-needs urban school. The specifics of this initiative are described elsewhere (Hammond et al., in press; Kangas, Hammond, & Bodzin, 2018), and all instructional materials and datasets are available via the project website (https://eli.lehigh.edu/sesi). In brief, we constructed a series of seven inquiry activities and two performance tasks, all of which were embedded in the 9th grade science and social studies curriculum. Each inquiry activity focuses on a driving investigative question and specific content for implementation in a science classroom (trees and ecological services, urban heat islands, carbon sequestration), a social studies classroom (urban zoning, land use change over time), or both (healthy natural and built environments). Concurrently with this content learning, each investigation is 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 performance tasks required students to apply their accumulated content knowledge, spatial thinking skills, and geospatial tools prowess to complete an urban planning challenge.

Our project design drew upon previous literature: emphasizing localized inquiry (McClurg & Buss, 2007), aligning professional development with the curriculum (Kubitskey, Johnson, Mawyer, Fishman, & Edelson, 2014), using educative curriculum materials (Davis & Krajcik, 2005), and chunking the instruction (Alibrandi, 2003). Other choices were shaped by developments in the geospatial industry, particularly Esri's enhancements of ArcGIS Online (arcgis.com) and their decision to make it freely available to all K-12 learners (Esri, 2014). The key design elements, however, emerged from the hard-earned wisdom of earlier geospatially-integration curriculum projects (for example, Bodzin, Anastasio, Sahagian & Henry, 2016). Based on these prior experiences in developing and implementing novel curricular applications of GIS, we incorporated the following strategic decisions into our project design.

1. The implementation team owns the technology

From our initial meetings to organize the grant proposal and solicit institutional partners, we discussed which technology choices would allow for continuation past the end of funding. For example, the decision to use ArcGIS Online was driven by sustainability—a browser-based GIS is far, far easier to implement and maintain than a client-side alternative such as ArcMap or QGIS. Once we committed to using ArcGIS Online, we next needed to determine the who would administer the students' and teachers' ArcGIS Online accounts. We decided that this duty would be carried by the research team for the first two years but then passed over to the local school administration—in the form of the lead teacher on the project—in the final year. By shifting the administration role during the project rather than afterwards, we built up capacity for the school to maintain the project after the research effort concludes; the implementation team could "own" the technology by becoming the chief administrator of the institutional account.

Furthermore, we made all required technology purchases through the school district and in conformity with their specifications. To allow for student data collection, for example, we needed a class set of iPads to run the Collector app and push field data up to ArcGIS Online. We purchased the devices and peripherals—cases and a locking charging cart—and then handed them over to the district for imaging and binding to their wireless network. As a result, the devices are owned by the district and are intended to stay with the teachers past the culmination of the project.

2. Administration and support staff are part of the project team

As education researchers, our primary focus is on the teachers and students in the 9th grade classrooms. However, as curriculum developers and project managers, we recognize that we need to work with a much broader range of school community. Accordingly, our very first meetings involved the school principal, explaining the possibilities and the requirements of the project. We next invited in the support staff, the ESL teachers and special education teachers working with the 9th grade. By including these teachers in our project meetings, we both strengthened the instructional design of our learning materials and built up supports for our intervention group teachers. For those students who worked with the ESL and special education teachers, they would receive improved services and additional productive time working on their geospatial assignments. Finally, we also made a point of connecting with the building-level information technology (IT) technician and the network administrator in the district's central office. Multiple times over the course of the grant, we reached out to one or both of these individuals to resolve problems with students' computers or iPads.

This experience—working with administrators, support teachers, and technical staff—has been a reminder that curriculum innovation does not happen only at the classroom level but also at the building level. When the whole building understands a project, can contribute to its success, and support the teachers and students in the intervention classrooms, the project has a far better chance of continuing past the research phase.

3. Over-sample during teachers' professional development

Any use of geospatial tools requires a robust teacher professional development component (Bodzin, Anastasio, Sahagian & Henry, 2016). Given the high probability of teacher rotation—whether from leaving the school, leaving the profession, or being re-assigned to a different course load—we decided that our professional development efforts should include not only the classroom implementation teachers but also the department heads. (For a more detailed discussion of the professional development procedures, see Hammond et al., in press.) By including the department heads, we both broadened the in-building community of geospatial tool use and strengthened the institutional commitment to the project. We also observed that these department heads, as non-implementation teachers, independently introduced geospatial technologies into their own teaching (Hammond et al., 2018).

At the end of the second year, we invited all science and social studies teachers in the building to participate in our professional development sessions. The payoff was an even broader footprint of geospatial competence – for example, other social studies teachers not affiliated with the study have begun learning about and incorporating ArcGIS Online through their own initiative. The over-sampling and saturation of geospatial professional development reinforces our conclusion that curriculum innovation requires not a just a classroom-level but a building-level familiarity with GIS and commitment to using geospatial tools.

4. Scaffold teachers' instructional implementation

Given the shifts in which teacher is assigned to our intervention classrooms, we have evolved two techniques for rapid on-boarding, including scaffolding the teachers' initial in-class instruction with geospatial tools. The first technique is a soft scaffold (per Brush & Saye, 2002), in which the research team provides person-to-person support for the teacher. We adapted the medical training strategy of "see one, try one, teach one" (Mason & Strike, 2003) into a gradual release model of teacher training: the university team would lead the classroom instruction and allow the implementation teacher to observe and act as an instructional support. After this first iteration, the teacher and the university team adopt a blended model in which the teacher adopts the parts of the geospatially-integrated instruction with which he or she feels most comfortable. Finally, the university team steps back into a limited support role and the teacher becomes the point of focus during whole-class instruction.

The second technique is a hard scaffold (again, see Brush & Saye, 2002), embedding the geospatial instruction within a Story Map. A Story Map is a companion product to ArcGIS Online, allowing users to blend together maps, data, text, and images into a single presentation (Esri, 2013). The result, from a teacher's perspective, is a shift from "sandbox mode" to a more "guided mode." In sandbox mode, the teacher is responsible for directing students' attention and thinking through a sequence of GIS actions (turning on/off data layers, zooming/panning, activating the legend, calling up data for objects or layers, and so forth) and content understandings (identifying main trends, sorting a table to note outliers, contrasting outliers to the trend, etc.). Working in sandbox mode allows a teacher to be completely open-ended, adjusting to any comment or question from a student and changing the flow of instruction on the fly. However, this level of flexibility comes with a price tag: the teacher must be very, very comfortable with the technology, the topic of instruction, and the in-the-moment metacognition required to re-think instructional decisions on the fly. Some of our teachers were not up to this challenge—they were new to the technology, new to the content, and even new to the teaching profession. Accordingly, we began to re-build the more challenging activities as Story Maps, thus shifting teachers out of sandbox mode and into guided mode. In guided mode, the teacher has the major technical and conceptual moves already laid out: the Story Map packages up the changes in GIS interface within a single mouse click, and key content is laid out in accompanying text and images. Figure 2 (below) illustrates the difference between an activity as it existed as an open-ended map in sandbox mode (on the top) and once it had been rebuilt as a Story Map in guide mode (on the bottom).

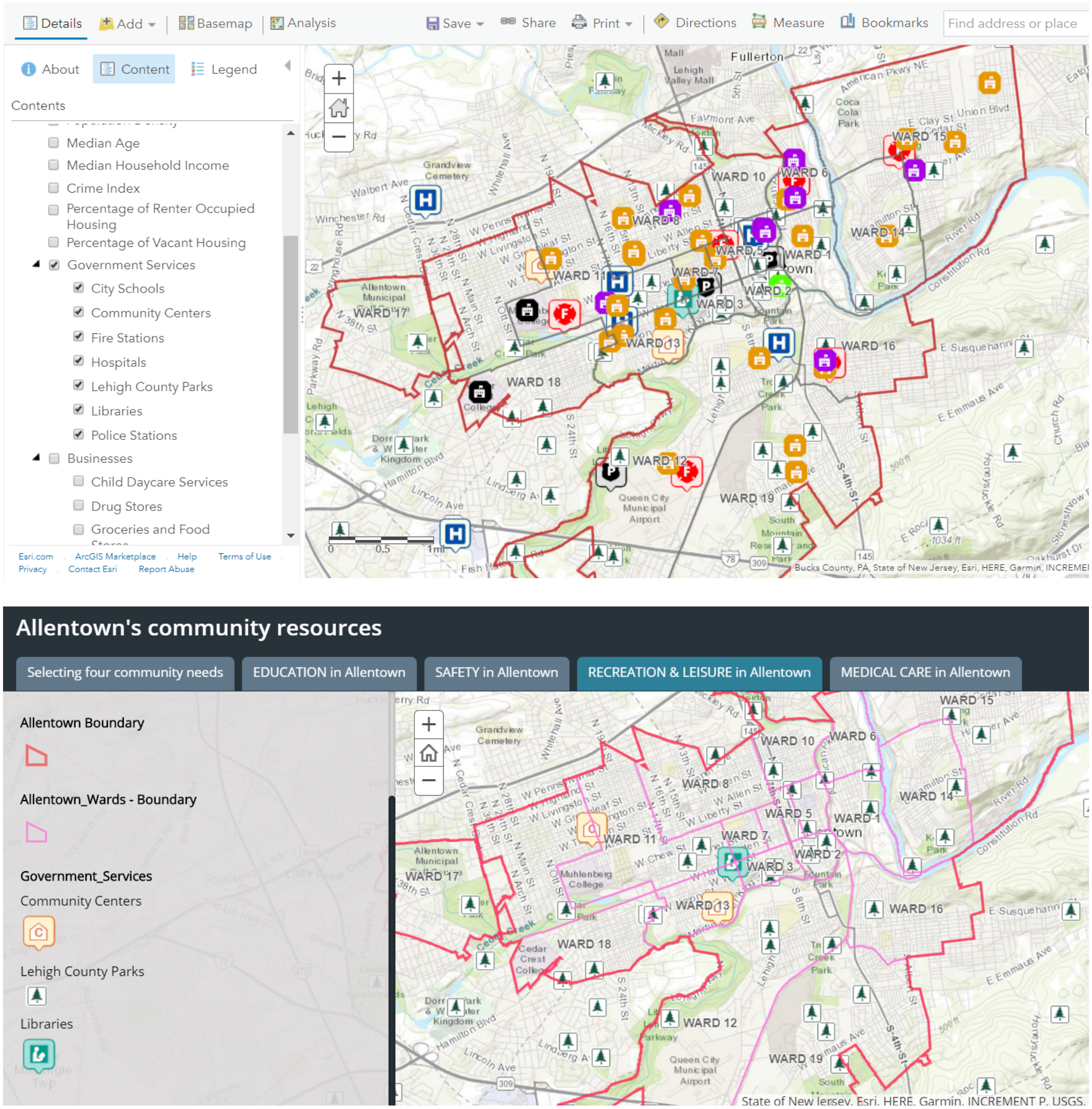

Figure 2: Images showing difference between open-ended web map (top) and Story Map (bottom). In the top image, note the many data layers, each requiring activation by the teacher or student. In the bottom image, the Story Map has chunked data layers by topic (Recreation & Leisure) and displays only the relevant layers.

Combined, the soft and hard scaffolding strategies allow a new teacher to be involved in a decisive role and experience success from the very first day of the project, even if he or she is new to using GIS. Furthermore, both strategies are flexible and can adjust to teachers' growing geospatial TPACK. For example, when or if a teacher decided to deviate from guided mode to sandbox, he or she could move out of the Story Map and instead bring up the open-ended maps used to build the Story Map. By building up teachers' capacity, we allow for future transitions, as one teacher hands off this curriculum to a newly hired or newly re-assigned colleague.

5. Allow teacher adaptation within the implementation

Finally, we permitted and even encouraged teachers to make productive modifications to the instructional sequences to better meet the needs of their students. For example, all instructional materials were provided digitally, either as Word documents or shared Google docs. Teachers would then take these digital versions and edit them for their individual classes. In one instance, a science teacher wished to reinforce her earlier instruction about the scientific method, so she added a "hypothesis-making step" to our Trees and Ecological Services activity to better align the learning to their school-based science competencies. In other cases, the teachers moved our challenge questions (for students who finished early or had strong analytical skills) into the required assignment.

Our decision to allow for teacher adaptation emerged from previous experiences with geospatial curriculum innovation projects and reflects the complexity of geospatial TPACK. Teacher adherence to the geospatial curriculum approach is important for the students to gain important geospatial thinking and reasoning skills. That said, the designed instructional implementation for a learning activity may not be the best possible fit for a specific classroom and a specific teacher. An expert teacher can make the thoughtful adaptations to curriculum materials to allow students to more quickly see the connections to content or smooth over complex steps in using the GIS. Our evaluation of a teacher's fidelity of implementation to the key components of our geospatial curriculum approach encourages these adaptations —what did the teacher change? Why? What insights—about students, the technology, the content, or pedagogy—drove this decision? Indeed, we feel that a geospatial curriculum project that demanded rigid adherence to a prescribed teaching model would not be highly effective and, at best, would be doomed to fail in the long run as teachers either abandoned the project or began to make their own non-productive changes that diverge away from important content learning goals.

Significance

As teacher educators prepare pre- or in-service teachers to integrate geospatial technologies such as GIS into classroom instruction, we should aim not for "islands of excellence"—individual teachers making effective adaptations and implementations in their lone classrooms. Instead, we should seek to build institutional capacity, so that the technical and pedagogical competence that a teacher has with geospatial tools does not leave the classroom when he or she is re-assigned or leaves the profession. By prioritizing these same strategies in teacher education, plus emphasizing the dual goal of personal and institutional competence, we will progress on both the teacher development goals identified by Baker et al. (2014) and the broader, social goals of workforce development agencies such as GeotechCenter.

The five strategies presented here are not exhaustive, and we welcome others' contributions as we continue to identify ways of making our curricular innovations more robust and sustainable. Furthermore, we feel that every project is unique; other curriculum developers and researchers should feel free to pick and choose those strategies that best fit their context and disregard the rest. All decisions, however, should be guided with the end in mind: a sustained, internally-driven program in which teachers, administrators, and support staff all see the value in a challenging curriculum and have the skills to keep it going beyond the life of the grant.

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