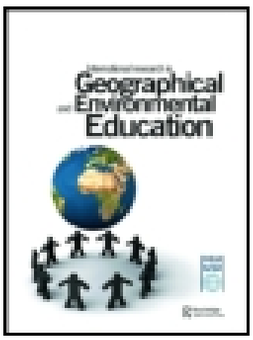

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Teacher training in GIS: what is needed for long-term success?

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ABSTRACT

This article explores teacher training in geographic information system (GIS) and hopes to uncover the necessary elements required for long-term and sustained use of GIS in the K-12 classroom. A variety of models have been proposed for successful GIS professional development including long-term teacher training lasting up to a year in length. Our study takes an additional step by following up with teachers over a full year after they have completed training to determine if they are continuing to teach with GIS and if so, how. We find there remains a disconnect between providing GIS teacher professional development and actually seeing long-term classroom implementation. We offer three recommendations for transformation in teacher practice: pre-service teacher geography and GIS intervention, continuous follow-up and coaching, and including GIS in Academic Standards.

KEYWORDS

Geographic information systems; teacher training; professional development

Introduction

Despite

This one word preposition litters much written on geographic information system (GIS) use in K-12 education. To wit:

> *Despite* a decade of effort, the increasingly important role of GIS envisioned in *Geography for Life* has failed to materialize (Bednarz & Audet, 1999, 65).

> The national survey confirmed that *despite* the presumed utility of GIS tools, a wide gulf remains between the capability of the tools and the implementation of the tools (Kerski, 2001, 83).

> *Despite* manifold endeavors during the last fifteen years, we can still call the usage of geographic information systems (GIS) in the geography classroom marginal… (Höhnle, Fögele, Mehren, & Schubert, 2016, 12).

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These three references are just a few of many that recognize how little K-12 GIS classroom use exists compared to the resources devoted. *Despite* easier to use software. *Despite* more plentiful base maps and easier to access data. *Despite* lower cost hardware options. *Despite* teacher professional development of all types (in-person, online, hybrid) and duration (length of time). Audet and Paris (1997, p. 300) confidently asserted two decades ago that GIS advocates "imagine an inevitable time in the not-too-distant-future, when all schools have GIS available, most students know about GIS, and many apply GIS to drive projects throughout their educational experience." This all-too-sunny prediction has failed to materialize.

This article explores one aspect of the problem – teacher training in GIS – and hopes to uncover the necessary elements required for long-term and sustained use of GIS in the K-12 classroom. Research in this area has been called for previously (Baker, Kerski, Huynh, Viehrig, & Bednarz, 2012). Simply, what is needed from teacher professional development in GIS to eliminate the word *despite* and replace it with *success*?

Obstacles, or why "despite" stays with us

A well-trod list of obstacles to K-12 GIS implementation is amply had elsewhere, though a short review here is useful to move toward those specific to teacher professional development. Kerski (2001) supplied one of the most useful and concise lists; the list includes software complexity, the inaccessibility of computers, a lack of time by teachers to develop lessons, a lack of data, and so forth. Similar findings come from the work of Baker, Palmer, and Kerski (2009), Gatrell (2001), Kerski (2003), and Meyer, Butterick, Olkin, and Zack (1999). Some of these barriers, in particular hardware and software costs and access, have been eased via internet-based GIS (Baker 2005), however a more recent constraint analysis with a focus on German teachers indicates that many of these issues continue as a problem (Höhnle, Schubert, & Uphues, 2011; Höhnle, Schubert, & Uphues, 2013).

Audet and Paris (1997) recognized five areas needing attention during GIS implementation: software, hardware, data, professional development, and the educational context. What is known about the fourth item, professional development, for teachers in using GIS? There are two groups of concern, here: pre-service and in-service teachers. For the former, there is very little GIS exposure in teacher training programs (Bednarz & Audet, 1999; Gatrell, 2001; 2004; Mitchell, Roy, Fritch, & Wood, 2018); Walshe (2017) is a notable exception. It is unfortunate that there is not more GIS exposure in pre-service training programs as geography educators are missing a group of educators potentially more receptive to the technology than in-service educators (Strachan & Mitchell, 2014; for a contrary view, see Höhnle et al., 2013). The vast majority of training, then, has focused on in-service educators. Teacher surveys of those *already* using GIS have indicated that this training – specifically more of it (Kerski, 2001, 2003) – is necessary to enhance GIS use. Teachers coming in at the low end, where GIS is completely unfamiliar, will logically require even greater and lengthier intervention to achieve impact (sustained classroom use). One basic and fundamental obstacle to overcome before a teacher can appreciate the role of GIS to

enhance learning is to understand the discipline of geography first (Bednarz & Ludwig, 1997; Bednarz & van der Schee, 2006) beyond a view held by many pre- and in-service teachers that is typically narrow and information-oriented (Bourke & Lidstone, 2015). Also vital to adopting GIS in the classroom and attendance at GIS training is the teacher's perceived usefulness of the technology (Lay, Chi, Hsieh, & Chen, 2013). Fostering this positive mindset and broadening possibilities for use needs consideration in professional development planning as well.

Model professional development in GIS

A variety of structures have been proposed for successful GIS professional development. One of the more comprehensive was proffered by Höhnle et al. (2016). Their indicators of effectiveness include structural features, didactical features, and activities. *Structural features* include long-term support for teachers instead of one-time events, establishing learning communities, support from administration, and incorporating diverse expertise representing content and every-day classroom experience. These findings comport with those of Alibrandi and Palmer-Moloney-Moloney (2001) who suggest that sustained GIS instruction in schools (at least 3 years) required teacher collaboration with a community partner, interdisciplinary collaboration between teachers, room for the development of electives and/or experimental courses, and an institutional commitment to technology integration. Sufficient time for training also has been broached by Millsaps and Harrington (2017). *Didactical features* include making a connection to the curriculum, consideration of research findings on good teaching, and making opportunities for teachers to co-create the training activity. Similar observations have been made by Hong (2014), Hong and Stonier (2015), and Hong and Melville (2018). *Activities* refer to teacher reflection on practice after input from others (expert, learning community) and testing the new method/material in one's own classroom; the opportunity to experience one's own classroom efficacy; and having access to feedback and coaching. The work of Henry and Semple (2012) echoes this framework and they add that the software should not appear intimidating, that the data should be preprocessed, and that learning to use the GIS should not get in the way of using it for instructional purposes (see teaching *with* as opposed to *about* GIS in Sui, 1995). There also is room within this framework to think about structuring the professional development around the three knowledge domains of technology, pedagogy, and content (TPACK) (Mishra & Koehler, 2006; Figure 1).

If we accept that this model of GIS professional development for teachers is the ideal, then an important research question becomes evident:

> What longer-term evidence exists that these indicators of effectiveness produce competent and enthusiastic teachers who have added GIS as a substantive part of their curriculum?

In the space that follows we describe a GIS training intervention modeled on the Höhnle et al. (2016) indicators of effectiveness and we explore feedback from the teacher participants from a series of surveys and interviews.

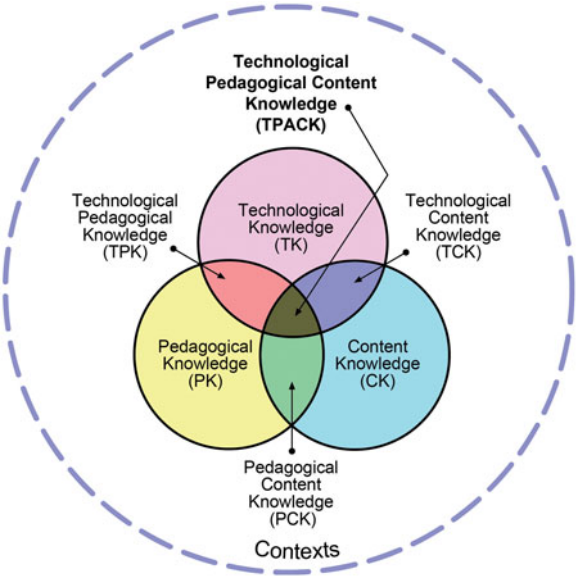

Figure 1. Technological pedagogical content knowledge. Reproduced by permission of the publisher, © 2012 by tpack.org.

Project overview

The experience and results described within this paper stem from a project conducted from the summer of 2015 through the summer of 2016 (a full calendar year) that included 18 teachers from two rural school districts (Blinded for Review, 2018). Their teaching experience ranged from three to 31 years and only one had taken more than one geography course in college. The professional development activities were led by five university faculty from a geography department (3) and a college of education (2). In the first year, the teachers learned about geography across different curricular areas and the role now played by geospatial technology. This first component was crucial given the group's composition; collectively they taught English, social studies, mathematics, physical science, and library/media literacy. This one week experience then focused on taking an existing, standards-aligned lesson of their choice and re-making it with ArcGIS Online, a simplified web-based GIS that still offered analytical tools. Much of the summer week was spent learning the software, gathering data, reflecting on how student learning could improve with a "geo-enhanced" lesson, and fully completing the new lesson. One completed lesson included mapping the Silk Road (Figure 2); another had students calculate area (basic geometry) using landscape features on aerial imagery (e.g. football field, rectangle; traffic circle, circle; Table 1).

In an effort to maintain the community of practice built around this geospatial experience, the faculty team met with the teachers on a periodic basis during the fall of the new school year. Some of these sessions were open discussions to answer technology questions while others were spent with the teachers in their classroom as they delivered new lessons. Feedback was then offered to make the lesson more successful. To build the teachers as leaders and to offer continued professional development, each teacher also was invited to present their lesson at either a state-level social

studies or mathematics conference that fall. Sixteen took advantage of the opportunity. Noteworthy here is that none had ever presented in a conference session previously, and the majority had yet to even attend a professional conference.

Feedback sessions continued into the next spring year, and two other geography-specific workshops were attended by six of the teachers. A second summer week-long institute focused on reporting out as a group the successes and challenges of using GIS in their classes, refining the first or beginning a second lesson plan, and learning about newly created GIS lesson interventions, such as the GeoInquiries developed by Esri (2017).

Considerable teacher attrition took place across the two summers, and this reality structures the order we present our results. Of the original 18, only eight completed

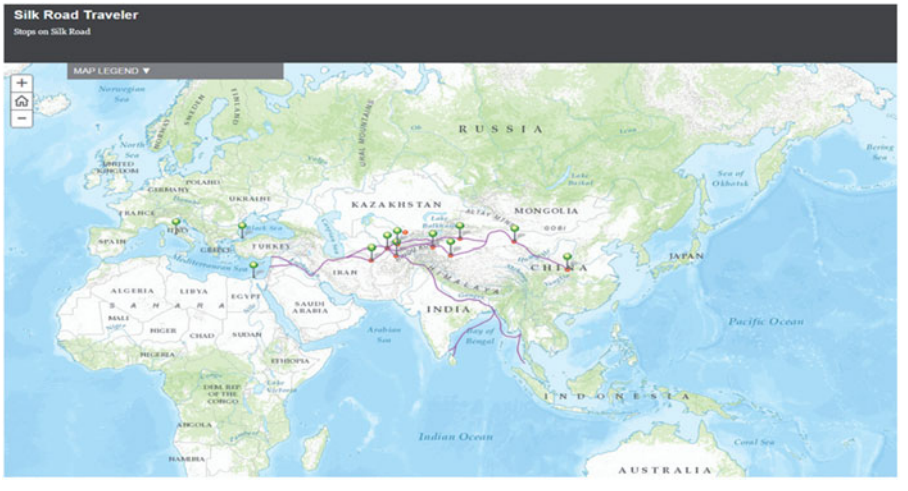

Figure 2. Web Map illustrating the Silk Road in a middle level social studies course. Travel routes indicated by lines with "pushpins" indicating points of interest with pop-up dialogue boxes.

Table 1. Select lesson topics.

Grade Level	Title	Synopsis
4	The Land Bridge Theory	Students explore the Bering Strait and the early presence of humans in the Americas.
5	Westward Expansion	Students investigate physical land features that affected travel and settlement of the American West.
6	Silk Road Traveler	Students use a Story Map to gather information about the people and places located along the Silk Road.
8	Earthquakes, Volcanoes, and Plate Boundaries	Students identify patterns in the location of earthquakes and volcanoes to understand plate tectonic boundaries.
9	Hazardous Waste Sites and Highways	Students identify the location of hazardous waste sites across the United States and make associations with transportation routes.
9–12	Mapping Churches	Students gather church location data to investigate the spread of religion and the relative popularity of different Christian denominations over time.

Table 2. Attitudinal survey results.

Survey Question	Pre-Survey % Yes*	Pre-Survey % Yes#	Post-Survey % Yes#
I enjoy looking at maps and globes.	100	100	100
I like to read about different people and places.	94	86	72
I prefer to use maps when inquiring about places.	83	86	100
I tend to see patterns among things, for example, an arrangement of tables in a restaurant or cars in a parking lot.	72	72	86
I am curious about patterns in information or data, that is, where things are and why they are where they are.	89	86	86
I use spatial terms, such as scale, distribution, pattern, and arrangement.	61	72	72
Using spatial terms enables me to describe certain things more efficiently and effectively.	89	100	86
I have difficulty in describing patterns using spatial terms, such as patterns in bus routes or in the weather.	17	14	29
I tend to use spatial terms, such as location, pattern, or diffusion to describe phenomena.	78	86	43
When I am thinking about a complex idea, I use diagrams, maps, and/or graphics to help me understand.	100	100	100
It is difficult for me to construct diagrams or maps to communicate or analyze a problem.	17	14	14
I find that graphs, charts, or maps help me learn new concepts.	100	100	100
I like to study data or information with the help of graphics, such as charts or diagrams.	94	86	100
When trying to solve some types of problems, I tend to consider location and other spatial factors.	78	72	86
When reading a newspaper or watching news on television, I often consider spatial concepts, such as location of the places featured in the news story.	78	72	72
I am comfortable teaching with maps.	83	72	100
I am comfortable using technology.	83	72	100
I am comfortable teaching with technology.	78	72	86
I know what spatial thinking is.	67	86	100
I believe that spatial thinking is transferable across disciplines, such as math, science, and engineering.	100	100	100

*Pre-survey responses by all original 18 participants that began the professional development.
#Pre- and post-survey responses by the 8 participant subset completing the entire two years of professional development.

the full sequence of activities. Two moved to other states, two simply quit, five became involved in other professional activities, and one had a family issue.

Method and results

To assess the effectiveness of this professional development intervention, our research method includes an examination of four participant data sources: (1) a pre- and post-

attitudinal survey; (2) daily feedback provided by the teacher participants; (3) a teacher-generated strengths, weaknesses, opportunities, and threats (SWOT) assessment; and (4) a series of interviews conducted one full year after the completion of the second summer activities.

Attitudinal survey

On the first day of the professional development institute, the original eighteen participants completed a 20-question survey modeled from Walker's work on geography-related attitudes (2006). An unaltered version of the survey was completed again 1 year later by the eight teachers who completed the entire professional development program. "Yes/No" responses were required. The results are shown in Table 2.

Regarding the initial survey, the responses were mostly positive which may be indicative of some self-selection bias as these teachers volunteered for the professional development knowing that it included geography, maps, and technology instruction. In general, the participants indicated that they were interested in geographic topics, interested in maps, and had a preference for spatial awareness and thinking. Importantly, all participants reported enjoying looking at maps and globes; using diagrams, maps, and/or graphics to help understand complex ideas; using graphs, charts, or maps to learn new concepts; and believing that spatial thinking is transferable across disciplines, such as math, science, and engineering.

Seven of the questions resulted in less than 80% agreement (not including two questions written in the negative). Five of these questions related to thinking geographically and using geographic terminology:

- I tend to see patterns among things, for example, an arrangement of tables in a restaurant or cars in a parking lot.
- I use spatial terms, such as scale, distribution, pattern, and arrangement.
- I tend to use spatial terms, such as location, pattern, or diffusion to describe phenomena.
- When trying to solve some types of problems, I tend to consider location and other spatial factors.
- When reading a newspaper or watching news on television, I often consider spatial concepts, such as location of the places featured in the news story.

This is not particularly surprising given the paucity of geography coursework taken by the participants. Lower agreement also was had for feeling comfortable teaching with technology and knowing what spatial thinking is. Importantly, all participants found that using maps helped with understanding complex ideas and learning new concepts, and that spatial thinking was transferable across disciplines. For the eight participant subset, improvement from the pre-survey to the post-survey was seen for four of those seven questions; two remained even and one declined. Of the twenty questions overall, eight showed increased agreement, eight remained the same, and four showed increased disagreement. Important changes include greater reported

comfort teaching with maps, using technology, teaching with technology, and knowing about spatial thinking.

Daily assessment

For each day of the workshop in both years the participants completed an anonymous daily assessment form. There they ranked four statements on workshop satisfaction and their confidence in teaching the material presented on that day. The response choices were "strongly agree," "agree," "disagree," or "strongly disagree." The results were consistent for each day: all participants either agreed or strongly agreed that the workshop would help them carry out their teaching role more effectively, enhance their ability to support and sustain quality education, and that this professional development was overall a valuable opportunity. The fourth statement asked the participants to evaluate whether their confidence level in teaching that day's material (their own potential efficacy) was higher than before the workshop. All of the participants either agreed or strongly agreed that their confidence was higher with one exception: one participant disagreed in three instances during the first year. While efforts were made to make the learning process less intimidating (see Henry & Semple, 2012), this lack of confidence may be due to the novelty of the technology and the apprehension of learning how to use it in the classroom. Overall, these results suggest that the professional development was not only valuable to the participants, but helped increase their confidence level in teaching with geospatial technologies.

The daily evaluation forms also had a free-response section where participants were asked about the aspects of the daily workshop they most enjoyed. They also were encouraged to offer suggestions to improve the workshop. Aspects most enjoyed during the first summer included the novelty of the new technologies being presented, appropriate pacing of new material, and hands-on exploration of the new technologies. Most participants appreciated not being overloaded with large amounts of new information on the first day and valued ample time to explore the technologies and the freedom to ask questions. On the third day of the workshop, participants reported enjoying the opportunity to begin creating their lessons and were excited to see progress and success. One participant valued "being able to explore and figure things out with the assistance of the GIS team if we needed them" while another reported, "I enjoyed being able to create what I will do in my classroom." Similar reports continued through the remainder of the week with specific praise for receiving the time to finish their first lessons and share them with other participants. As one participant reflected, "I feel more confident about all of this now that we've planned lessons and had the chance to share them with one another and receive feedback."

Suggestions for improvement were very limited but included multiple requests for printed instructions on how to navigate ArcGIS Online, examples for classroom connections specifically for mathematics and elementary-level classes, and less technical information. Participants offered the most suggestions for improvement on day two of the workshop. ArcGIS Online was introduced on this day and several respondents expressed being overwhelmed with too much technical information. Suggestions for

improvement were made on just the first 3 days of year one; only positive comments were submitted for each of the following daily evaluations in both summers.

In the second summer of the workshop, the eight participants who completed the entire professional development reflected most about appreciating the time to explore, collaborate, and develop new lessons to integrate into their classrooms. Opportunities to explore Esri's Geo-Inquiries materials and discuss use in the classroom with other teachers also were highly valued. One participant pointed out that collaborating with other teachers "allows for discussions/adjustments to be made to my lesson by getting other ideas/strategies – always great to collaborate." Another wrote about the importance of "hearing/seeing what other teachers are doing allows me to reflect on my own teaching. This helps me develop new ideas and see what great things my colleagues are doing." Others noted that they most enjoyed simply feeling more comfortable with the technology.

SWOT assessment

Each of the participants was provided the opportunity to present a synopsis of their lesson at a state education conference for mathematics or social studies. As part of the presentation each presenter created a teacher-generated strengths, weaknesses, opportunities, and threats (SWOT) assessment of the lesson implementation with their students. The most frequently noted *strength* described that the technology captivated student attention and kept students engaged. Other notable strengths included fostering student independence, requiring analytical and spatial thinking, data visualization, and interdisciplinary and authentic learning. Participants also noticed improved recall, "looks of wonder and fascination," and "rich conversations" from their students.

The most common *weaknesses* denoted by the participants ranged from too time consuming to create lessons and difficulty in using the technology to slow internet connections and difficulty in creating useful lessons in certain content or grade-level areas, such as mathematics and for kindergarten-aged students. Other weaknesses included student devices not being charged, students not staying on task, lack of technology access at home for students, and steep learning curves. One participant reported that data can be difficult to locate and therefore must be created by the teacher. Perhaps one of the most interesting weaknesses reported was that students do not have a well-developed world view, therefore they experience difficulty in using geospatial tools.

Participants most frequently cited *opportunities* that referenced creative ideas for new lessons to utilize in the future. Several noted the opportunity to utilize these interactive maps as the "hook" for introducing new content, linking each unit in the future to interactive maps, and having great additions to already created lessons which possibly indicates that some teachers still see use of these geospatial tools as add-ons to the curriculum rather than fully changing their practice. Opportunity was also perceived in offering training for students to create their own maps and engage in map analysis. One participant expressed that the lesson "allows students to dig deeper."

The most frequently cited *threat* was simply the lack of time to both create and implement the lessons with students. Another mutually expressed threat was the lack of necessary technology access including smart boards, one-to-one devices, and computer lab accessibility. Also cited was the lack of expertise and comfort among teachers to troubleshoot possible technology issues that students may face, uncertainty about presenting the data in a way that makes this technology useful in certain content areas, and a lack of internet connectivity slowing down the adoption of these classroom tools.

Interviews

How to best conduct teacher training in GIS has been an active research topic over the last two decades. Multiple studies have focused on the necessary elements required for long-term and sustained use of GIS in the K-12 classroom. Like ours, several studies have conducted long-term teacher training lasting up to a year in length. Uniquely, however, our study takes an additional step by following up with teachers over a full year after they have completed training to determine if they are continuing to teach with GIS and if so, how.

In January of 2018, a year and a half after the project ended, phone interviews were conducted with five of the eight participants who completed the project in order to assess long-term implementation of GIS use in the classroom. While one of the eight participants simply did not respond to the interview request, it is worth noting the responses of the other two participants who declined the interview believed that we would be disappointed in their responses because they are no longer or minimally using the technology in their classrooms. One participant stated that he did not believe he had any useful comments for us while the other participant responded, "No thank you, however I still use the program as much as I can. I need to go back to it as I have been slack the last two months."

The phone interviews were conducted individually and consisted of 15 open–ended questions (adapted from Audet & Paris, 1997; Table 3). Questions were organized under the following categories: teacher practices and attitudes, educational technology, professional development, and educational context for GIS.

The questions asked under the *teacher practices and attitudes* category were important in ascertaining whether or not the teacher possessed a teaching philosophy more open to innovative ideas in the classroom. Responses these questions were consistent among all the participants: answers were positive when asked if open-ended questions should drive a curriculum, if they often create their own curriculum materials, make use of alternative assessments, and like collaborative groups. One teacher reasoned that teachers collaborate so therefore they should encourage their students to do the same. Another teacher elaborated that although she did like collaborative work groups, "it is difficult for students to collaborate in a manner that we would want them to; they've never been taught how to do it – we just expect it of them." Teachers had mixed opinions about whether a textbook could be optional in their classrooms. Three teachers were adamantly supportive of textbooks being optional due to the vast array of supplemental resources available especially online. Two

Table 3. Interview questions.

Question Category	Question
Teacher Practices and Attitudes	Explain your opinion on the following: I think that open-ended questions should drive a curriculum The principal role of a teacher is to serve as a facilitator of learning For me, a textbook could be optional I often create my own curriculum materials I like collaborative work groups I frequently make use of alternative assessments
Educational Technology	How would you describe your own computer literacy? How would you describe your administration's support for educational applications of technology? How would you describe your and your students' access to the right technology to do what you would like to accomplish in your classroom?
Professional Development	Describe the professional development provided by your school and district. Describe its usefulness. Describe the GIS professional development provided by us. Describe its usefulness. What makes for ideal professional development that leads to long-term change in your teaching practice?
Educational Context for GIS	Explain how often you used maps before versus after our professional development. In what ways do you use GIS to enhance your curriculum? If you are using it, what are you doing? How often? Any measurable student change in outcomes? If you are **not** using GIS, explain why not. What are the issues limiting your use of GIS in class?

teachers said having a textbook or not was subject dependent arguing that mathematics and Advanced Placement classes indeed needed a textbook. Teachers also provided mixed answers about the role of teachers serving as facilitators. Three teachers agreed that their principal role is to serve as a facilitator of learning while one said both yes and no, and yet another replied, "No. A teacher's job is to teach."

The questions asked under the *educational technology* category helped assess whether or not teachers not only felt confident enough in their own ability, but also believed they had the support and technological tools to successfully implement GIS in the classroom. All five teachers described their administration as extremely supportive of educational applications of technology and stated that their (and their students') access to the right technology to do what they would like to accomplish in their classroom was good. Two teachers, both at the elementary level, reported that it will be even better when the elementary schools implement one-to-one computing devices for students. The middle and high schools already have this technology in place.

When asked to describe their own computer literacy, all five teachers responded with "pretty literate" or "fairly competent." Several teachers elaborated on their answers with responses, such as, "When computer technology first became available I was definitely on the high end, but now I'm probably just in the middle – there is just so much to learn" and "It's very easy for me to learn new technology and use it in my classroom. If I don't know something I just 'Google' it or 'You-tube' it."

The questions asked under the *professional development* category were important in providing an idea of usefulness in past and future professional development. Teachers were asked to describe the professional development provided by their

school and district in addition to describing its usefulness. Responses ranged from the professional development being described as "not super useful due to the focus on literacy training" to "it's not always applicable to my subject-area" to "it is very useful and we have lots of opportunities." However, when asked to describe the professional development provided by our team for this project as well as its usefulness, all teachers responded with descriptions, such as "really good," "very useful," and "incredible." Teachers appreciated receiving abundant amounts of instruction on using the new technology but not feeling overwhelmed due to the pacing and individual support that was available from our team. Having work time to develop lessons and practice new skills coupled with the chance to put it into practice in classrooms was also highly valued. "We had something tangible in hand when we finished that we could take with us, implement, expand, and use over and over again in our classrooms." Although they found the training useful and enjoyed being a part of it, two teachers (one elementary and one secondary mathematics) found difficulty in applying the geospatial technologies to either their subject or age group of students. One teacher remarked that he had trouble creating applicable lessons to Algebra, but stressed that the new knowledge he gained was very mind-opening. Another teacher who teaches elementary age students concluded that she did not even consider using GIS with the younger students because it seemed so difficult a topic and did not know how to make the connections; however, she attributed participating in this project to changing the way she was thinking about teaching.

When asked what would make the ideal professional development that would lead to long-term change in their teaching practice, teachers agreed that follow-up was important. The "one and done" professional development workshops where teachers only participate once may bring awareness to the information being taught, but it does not typically bring about change in the classroom. "The follow-up makes you aware and incorporate it into the classroom. Then it becomes habit." Respondents also claimed that the act of "doing" something rather than just listening in a professional development workshop increases the likelihood of the new material actually being used in the classroom. One teacher emphasized that providing time to work with the new technology while being able to ask questions and receive support by the trainers helps gain the confidence to utilize it in the classroom. Providing time for teachers to not only explore the new information/technology and ask for assistance during the professional development but to have time to create a lesson plan for their classroom was considered to be highly necessary to bring about change in the classroom. "I am much more likely to implement it if there is something I walk away with rather than making the time to develop a new lesson on my own after the workshop is over." Having multiple meetings about the professional development topic that progresses through time and ends with a teacher-created final product was reported to be the type of professional development that would lead to long-term change in the classroom. One teacher suggested that if teachers from around the district or state could connect and collaborate with one another periodically, then useful lessons using GIS could be created and shared that are applicable to their specific age group and subject matter.

The questions asked under the *educational context for GIS* category provided information on whether or not teachers have continued to use GIS in the classroom and what student outcomes have developed from this curriculum. Our GIS training intervention met the suggestions that this set of teachers proposed would be the type of professional development that would lead to long-term change in their classroom. However, when asked in what ways they use GIS to enhance their curriculum today (more than a year after completing the workshop), only two of the five teachers have continued to use the GIS lessons they created during the workshop and none of the teachers have created new GIS lessons for their classrooms. One of the teachers who still use the lessons she created from the workshop noted that it is too time consuming and difficult to apply to the younger elementary school students as the reason why she has not created more GIS lessons. However she reported that her students are much more engaged when she uses digital maps and now incorporates maps much more frequently in her classroom. The second teacher who has continued to use the lessons she created from the workshop has not created additional GIS lessons, but has created two more inquiry lessons for her mathematics students using paper maps. When asked if there was any measurable student change in outcomes, she explained that before attending our institutes she "would stand in front of the class giving notes to students who would then memorize the information. I have flipped that method to letting students dig in and make discoveries on their own about main ideas by using the lesson first and then teaching the content. My students have become much more interested and engaged. They know the information longer now." She conveyed that she never used maps in mathematics before, but the workshop opened her eyes and she now looks at her existing lessons and thinks about how she can incorporate maps.

The other three teachers used their lessons once in their classroom, but are no longer using them and did not create new lessons. One teacher explained that he simply did not use them due to time constraints in their creation and that they did not really apply to mathematics standards. He confesses that he sees "the usefulness of it and would be more open to use if he had more time and could see the more application in the standards." Another teacher reported using the technology much more to reference places and zoom into them to see more detail, but is not engaging in GIS. Perhaps most interesting to note is that the sole geography teacher in the group reported that although he found the GIS lessons very valuable and used them in his classroom, he no longer uses the lessons due to time restraints (both in finding time in the curriculum to teach the lessons and also in finding time to create new lessons using GIS). He stated that he does not use maps more frequently than before the workshop, but he does use the technology more (ArcGIS Online) to reference interactive maps rather than static, paper maps.

Discussion and conclusions

Despite

Despite the fact that our interviewed teachers valued the curriculum and maintained positive mindsets about its use in education, there remains a disconnect between

providing GIS teacher professional development and actually seeing long-term classroom implementation. Why? What do we do next when everything was done "right"?

According to Höhnle et al. (2016), the indicators of effectiveness include structural features, didactical features, and activities. Our study implemented the structural features including long-term support for teachers instead of one-time events, establishing learning communities, support from administration, and incorporating diverse expertise representing content and every-day classroom experience. Additionally, we implemented the didactical features of making a connection to the curriculum, consideration of research findings on good teaching, and making opportunities for teachers to co-create the training activity. Finally, we implemented activities, such as teacher reflection on practice after input from others, testing the new method/material in one's own classroom, and having access to feedback and coaching. Furthermore, participation in our study included additional incentives, such as educational conference registration, presentation experience at an educational conference, financial remuneration, and a laptop computer for the eight teachers who completed the entire year-long training. *Despite* following the suggested components from this and other models for effective teacher training in GIS and providing multiple incentives, only two teachers out of the original 18 participants continued longer-term GIS use in their classroom. We note here, too, that this use can only minimally be called using GIS as none were using any of the analytical properties of the software.

One method for judging learning process effectiveness is suggested by Kirkpatrick and Kirkpatrick (2006). The method includes four steps:

- Step 1: Reaction – How well did the learners like the learning process?
- Step 2: Learning – What did they learn?
- Step 3: Behavior – What changes in performance resulted from the learning process?
- Step 4: Results – What are the tangible results of the learning process in terms of reduced cost, improved quality, etc.?

Returning to the data sources described in this paper (pre- and post- attitudinal survey; daily feedback; a SWOT assessment; interviews), the teachers clearly enjoyed the professional development and reported improved attitudes toward geography and using GIS technology (Steps 1 and 2). It is for Steps 3 and 4 where this work falls short. Behavioral changes – a true change in teacher classroom practice – were at the lower end. The teachers appreciated map use in other disciplines and reported using maps more in instruction, undoubtedly improving the quality of geography instruction even if true GIS use was not part of the curriculum. That is by itself an important step forward, but awareness was not the original goal. We do not believe this result to be a failure of the model or the quality of the intervention. Rather, we see the need to place the model and its parts squarely within an earlier time period of teacher development.

Recommendations for future action

Although the ultimate goal of sustained classroom GIS implementation was not realized through this project, we believe that success may be attained by refocusing efforts around audience, training duration and follow-up, and policy. Our three recommendations are:

Pre-service teacher geography *and* GIS *intervention*

We believe that if pre-service teachers are exposed to GIS during their training years (see Walshe, 2017) rather than as an add-on after they have become an established teacher that GIS will be used more seamlessly and sustainably in instruction. Previously we shared the views of Bednarz and Ludwig (1997) and Bednarz and van der Schee (2006) who argue that before a teacher can appreciate the role of GIS to enhance learning one must understand the discipline of geography first. To this end we recommend a concerted effort to improve pre-service geography education, a long-standing call (see Boehm, Brierley, & Sharma, 1994), that we believe should also be extended to GIS. One possible course model was recently shared by Mitchell (2018). As pre-service teacher education is unlikely to have more than one or two courses focused on geography, efforts must be made to include GIS in geography education courses beyond mere awareness of the technology (Mitchell et al., 2018). Additionally, efforts must also be made to include GIS in education technology coursework that currently focuses on more generic word processing and presentation software (e.g. Prezi, PowerPoint) used in the K-12 classroom.

Continuous follow-up and coaching

Although this project provided much one-on-one training, classroom observations, and opportunities for further training, our work shows that what we provided was still insufficient to create longer-term sustained use. Given the large number of GIS-related courses expected from an undergraduate student *majoring* in geography, we should not be surprised that teachers tasked with a host of other responsibilities would need much more time to learn GIS before even contemplating substituting the technology for teaching strategies that they already deem effective. Simply developing one or two lessons to utilize in instruction is not enough to sustain the long-term use of GIS in the classroom. Due to the technical nature of GIS, teachers need continuous follow-up and coaching in both GIS use and pedagogic strategies in order to develop the confidence necessary before achieving competency. That said, this follow-up may be less-needed if GIS became more present in pre-service teacher training.

Including GIS in academic standards

Much contemporary teaching is driven by academic standards, an agreed upon set of learning objectives (both skills and content) determined at a variety of scales (local to national). If GIS is specifically named, its use will increase. This study showed that time constraint was the biggest challenge of implementing GIS in classrooms. If GIS

is mandated in academic standards, then it is required to be taught and thus "time" is no longer a valid excuse for its absence. In an American context, this inclusion in the standards will need to occur at the state or school district level. Success has been had elsewhere at the national level (e.g. for Finland, see Riihelä & Mäki, 2015; for South Africa, see Breetzke, Eksteen, & Pretorius, 2011). It is imperative that geographers and GIS proponents engage as reviewers and writers of these standards.

As noted earlier: "Imagine an inevitable time in the not-too-distant-future, when all schools have GIS available, most students know about GIS, and many apply GIS to drive projects throughout their educational experience" (Audet & Paris, 1997, p. 300). That time is not now and is unlikely to be so in the not-too-distant-future. We will continue to create pockets of GIS excellence in some schools, have success with stimulating projects in some grade levels, and create general awareness and excitement about GIS's potential. But without aggressive and sustained action on the recommendations we make here, that future will remain elusive for some time.

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