Adapting to Online Professional Development and Curriculum Development to Promote Geospatial Inquiry

Kate Popejoy[1], Alec Bodzin[2], Thomas Hammond[2], and Douglas Leeson[2]

PopejoySTEM, LLC[1] and *Lehigh University*[2]

Paper presented at the 2022 Association for Science Teacher Education (ASTE) Annual Meeting in Greenville, SC.

Abstract: Our research team received approval from the National Science Foundation for a multi-site collaborative research project. As envisioned at the time of the grant proposal, the core procedures were to be conducted in traditional, face-to-face formats: in-person teacher professional development, in-person curriculum development meetings, whole-class instruction by teachers and support instructors, and small group data collection by students using school-provided mobile devices. The onset of the COVID-19 pandemic forced us to re-visit intended models of curriculum design and development, professional development, and students' use of technology for online learning environments. After revising and enacting our plans, we discovered that our teacher training adhered closely to our intended process, but curriculum development and instructional support took on a far more rapid pace and were in some cases entirely driven by our participating teachers. This paper reports on our original model, our revisions to accommodate 100% online professional development and learning, and our outcomes to date with five participating teachers across two high schools.

Introduction

Despite accelerating industry growth and congruence across STEM fields, few school-based programs integrate geospatial technology within their curricula. Industries related to geospatial technology impact the economy in many ways; they are "projected to add substantial numbers of new jobs to the economy or affect the growth of other industries or are being transformed by technology and innovation requiring new sets of skills for workers" (National Geospatial Advisory Committee, 2012, n.p.). Geographic information systems (GIS) are extensively used in agriculture, urban and regional planning, environmental resource management, surveying and cartography, conservation, national resource management, public health, transportation, and wildlife ecology, among other areas. Geospatial thinking and reasoning skills are essential for occupations in which there is a heavy reliance on cognitive thinking skills that include knowledge about geospatially referenced data and their relationships (Goodchild & Janelle, 2010; NRC, 2006). These skills involve important scientific practices highlighted in the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013), and include data manipulation, analysis, data mining, computational thinking, and modeling that provoke and require critical thinking and problem solving that are connected to data referenced to Earth's surface or to the Earth's representation through map and globe visualizations (Huynh & Sharpe, 2013). GIS is now the standard for spatially referenced data management, but STEM curricula often contain learning experiences that do not match the analytic practices that are critical for success in STEM-based occupations (Aikenhead, 2005; Chin, Munby, Hutchinson, Taylor, & Clark, 2004). Science and social studies curricula that engage students to collect and analyze data and solve problems provide important skills that help prepare students for career opportunities and lifelong learning (National Research Council, 2011; National Science Board, 2015).

In February, 2020, our research team received approval from the National Science Foundation for a multi-year, multi-site collaborative research project (Awards #1949400, 1949393, and 1949388) to work with teachers in designing, developing, implementing, refining, and disseminating curriculum-aligned geospatial activities in high school science and social studies classrooms. This project was to be a scale-up from a previous grant, in which a single university, Lehigh University, worked with a single local high school to conduct a three-year process of teacher training and curriculum development to integrate geospatial technologies into high school science and social studies classrooms. The newly funded project expands the scope of activity to three universities (Lehigh University, Texas Christian University, and Washington State University Tri-Cities) and six high schools across four states: Pennsylvania, Delaware, Texas, and Washington. In this paper, we focus on one university, Lehigh, and its work with five teachers across two participating urban high schools in Pennsylvania and Delaware.

Obviously, our plans were immediately disrupted by the advent of the COVID-19 global pandemic. As envisioned at the time of the grant proposal, all procedures were to be conducted in traditional, face-to-face formats: in-person teacher professional development, in-person curriculum development meetings, whole-class instruction by teachers and support instructors, and small group data collection by students using school-provided mobile devices. (For details on these procedures, see Carrigan et al., 2019; Hammond et al., 2018 & 2019). However, as has been true for many other education research projects (McCurdy-Kirlis, 2020), we were forced to adapt to the onset of the COVID-19 pandemic: how to conduct online professional development and curriculum development, how to design instruction, and even whether we should still include student-centered data collection. This paper reports on our revision processes, the results of our online enacted model imposed by the pandemic, several changes that emerged from the intersection of teacher practice, and the outcomes of our professional development for our five participating teachers.

Theoretical Framework and Design

Our project draws upon frameworks in three areas: curriculum design, teacher professional development, and university-school relationships. First, the geospatial curriculum activities that we developed follow the socio-environmental science investigations (SESI) design principles:

1. Focus on socioscientific issues: socially relevant, real-world problems that are informed by science (Zeidler & Nichols, 2009).
2. Engage in place-based education (Gruenewald & Smith, 2014; Sobel, 2004), grounding all curricular concepts in students' local environment.
3. Focus on inquiry-driven learning in which students seek to answer driving investigative questions about their local environment.
4. Incorporate authentic data collection by students within their local environment to answer these questions.
5. Use geospatial technologies to promote geospatial thinking and reasoning skills for data collection and analysis to make inferences about the geospatial patterns and relationships in the collected data.
6. Require decision-making by students—including both data interpretation and policy determination (Engle, 1960; Sadler, 2009)—about the local community.

These curriculum design principles aim to produce engaging, relevant geospatial instruction, making complex curriculum topics visible and compelling to students (for example, see Carrigan et al., 2019; Hammond et al., 2019). The SESI instructional model was tested and refined through a successful three-year iterative process of working with local teachers to design, develop, and implement a year-long coherent sequence of curriculum-embedded SESI activities (see eli.lehigh.edu/sesi). The goal of the current project is to adapt the geospatial curriculum approach to more schools and content areas.

Second, our teacher professional development model followed an integrated professional development and curriculum development model. This process began during a summer institute which integrated technical skills development—such as learning how to use geographic information systems (GIS) software and mobile geo-referenced data collection—with collaborative curriculum development following a design partnership model (see Hammond et al., 2019; Kelly et al, 2019). The combination of technology training and curriculum development both engaged teachers' technological pedagogical content knowledge (TPACK—see Mishra & Koehler, 2006; Thompson & Mishra, 2007-08), particularly their geospatial TPACK (see Bodzin et al., 2012; MaKinster & Trautmann, 2014), and acknowledged the teachers' roles as curricular-instructional gatekeepers (Thornton, 1991). Second, during the academic year, teachers received instructional support and coaching during curriculum enactment. This support could take place through a variety of tactics: collaborative materials development, instructional walk-throughs, co-teaching, peer modeling, and gradual release of responsibility (see Hammond et al., 2018).

Finally, we frame our collaborative design relationship with our participating teachers as a Research-Practice Partnership (RPP) (Coburn & Penuel, 2016). A functioning RPP combines the skill sets and knowledge of university and school personnel to produce innovative, sustainable improvements in school practices (e.g., Cobb et al., 2013). In this case, university personnel and researchers with expertise in STEM and social studies content, geospatial tools, teaching and learning with geospatial technology, curriculum design, and research collaborated with five teachers, each with their own content-area and pedagogical expertise, working within two distinct urban school contexts. Two teachers worked at an environmental science magnet high school, and the remaining three worked in a traditional high school with academic achievement tracks. The RPP framing allowed us to acknowledge the complementary roles played by the university and school personnel while pursuing our corresponding but distinct goals of innovative research and teaching.

Research Process

With the arrival of the pandemic, we needed to re-evaluate each component of our instructional model and each strategy for professional development, curriculum development, and instructional support. We examined our design-driven processes with the circumstances brought upon by the pandemic that included shifting from a face-to-face professional development model to a fully online model to meet the needs of our collaborating teachers. While this process placed the project under great strain, it also presented a research opportunity. The following research questions framed our self-study:

1. What *planned adaptations* to the instructional design principles, professional development, curriculum development strategies, and instructional supports were useful to our collaborating teachers?

2. What *emergent adaptations* to instructional design principles, professional development, curriculum development strategies, and instructional supports were useful to our collaborating teachers?

Our inquiry process combined self-study of teacher education (see Kitchen et al., 2020) and participatory research (Cornwall & Jewkes, 1995), which was appropriate for our project tasks and typical of research on RPPs. Our data sources included the documents and teacher surveys from the summer institute's professional development and curriculum development sessions, plus the instructional materials, classroom observation logs, and researcher memos collected during the academic year's classroom support of the curriculum implementation. In total, we had documents from 40 hours of formal professional development and curriculum development over the summer, 21 implemented geospatial lessons, and observation notes from 57 classroom sessions, in addition to *in situ* researcher memos. A final data source were message threads from the Slack community used extensively by the researchers and teachers, in which we deployed channels for curriculum development, technical support for GIS use, and classroom implementation support and coaching. The researchers organized and reduced these unexpectedly rich materials, identifying patterns and establishing themes. Our findings were member checked by our collaborating teachers.

Results

Planned adaptations: Forced choices, easy choices, needs-driven choices

Our notification of funding arrived in February of 2020, with funding to begin in June. Accordingly, we were in planning mode when the first local impacts of the pandemic arrived in March. Through the intervening months of April and May, therefore, we had time to make some purposeful choices about how we might continue with the project despite the challenges posed by the pandemic. Because our teachers were themselves grappling with the difficulties of moving their teaching online and keeping their students engaged, this initial planning process was entirely self-contained within the university research team.

Our first planned adaptation was to move all our work online: all teacher professional development, all curriculum development, and all curriculum implementation and classroom support would take place online rather than face-to-face. This shift to online was a forced choice; our university administration mandated that all in-person research stop, and our participating high schools closed their doors to visitors and went to online-only instruction. For all five of our teachers, working online was the only option for continuing the project. We were fortunate in that the technology that we were using for geospatial instruction—Esri's ArcGIS Online and its associated suite of tools such as StoryMaps and data collectors—are fully online and accessible via an Internet browser or mobile app. Accordingly, our project would be impacted by limitations and inequities in students' home environments, such as access to computers, internet bandwidth, and dedicated time and space for schoolwork; however, these challenges would be endemic to all students rather than unique to our project. We were also fortunate that our primary tools for online communication and collaboration—Zoom, Google Drive, and Slack—were flexible and reliable enough to support the intensive interaction required for our professional development, curriculum development, and instructional support work. Like many teachers and teacher educators, we had used these tools in the past for professional activities, but not as intensively. As we prepared for the pandemic summer, we knew that we would need to maximize the capabilities of these tools to engage and support our teachers.

Our second decision in adapting our work was to restructure our use of the summer institute time. Prior to the pandemic, we met with teachers face-to-face for 40 hours across one or two weeks of the summer. As we contemplated spending days at a time on Zoom, however, we decided to break up the work, spreading out our meeting times into smaller chunks across two months, July and August. This elongation of our summer professional development time was an easy choice for two reasons. First, by the time of our summer professional development, we were all intimately familiar with the phenomenon of "Zoom fatigue" (Wiederhold, 2020); eight straight hours of professional development using Zoom was not appealing and unlikely to be effective. Second, the topic of teaching and learning with GIS lends itself to learning over a longer time frame. As a technology to be learned, GIS mirrors the open-ended nature of the disciplines that it supports; learning GIS is an open-ended process with many possible digressions and divergences, just as with any investigation in environmental science or geography. Spreading out this exploration of GIS over a longer time frame would better support this open-ended process, particularly when limited to meeting via Zoom rather than face-to-face. We therefore modified our planned professional development learning sequence to intersperse whole-group training in GIS skills and follow-up virtual "lab time" for open-ended exploration of maps and datasets. These cycles of direct instruction and lab time were followed with group sharing of what our collaborating teachers did during their individual work and what questions they encountered. For example, after one session on importing data into ArcGIS, one teacher explored importing student data onto a map: using students' home addresses, she wished to see who lived in neighborhoods with low access to broadband internet, in hopes of advocating for more distribution of Internet hotspots and other hardware from her school to the incoming ninth graders she would be teaching. Because she was working with student data, she needed to learn how to de-identify the dataset and mask individual students' identities, triggering an exploration of View layers (in which some data is hidden) and advanced data displays, such as a color ramp in which a ratio is calculated between two variables (see Figure 1, below). This particular learning pathway was something that could more easily evolve from the lengthened and less intensive approach to the summer institute for teachers. Accordingly, spreading out the 40 hours of summer professional development work over eight weeks was an easy choice and was useful for our collaborating teachers.

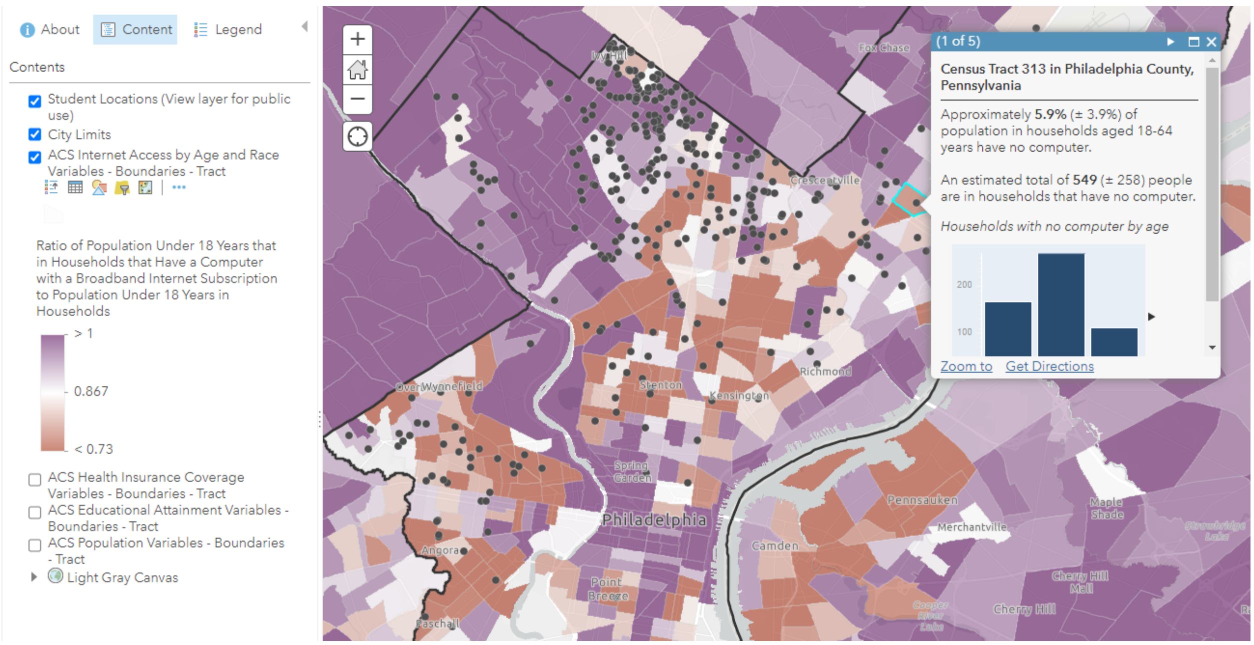

Figure 1: Teacher-created View layer of student with masked student information and neighborhood broadband access.

Our third planned adaptation was to re-prioritize our instructional approach to create a more flexible model for SESI instruction. In our previous work, every activity included every element of our curriculum design principles: data collection, analysis, decision-making, and so forth. Under the stresses of the pandemic, we decided that not every SESI activity needed to include all six design elements. Of the six, we decided that three were essential: addressing socio-environmental science issues, employing inquiry-oriented instructional approaches, and use of geospatial tools. The other three elements—localization, data collection, and decision-making, could be present or absent depending on the teacher's instructional choices. In addition to re-considering our design elements, we added two new priorities as a response to the pandemic: student engagement and teacher support. We could observe student engagement via classroom observation notes, teacher report, and reviews of student activity in ArcGIS Online, such as data collection records or map creation. Teacher support was more loosely defined, meaning meeting whatever need a teacher presented. Accordingly, we created materials for teachers, co-taught lessons, and even graded student work upon request. This adaptation was needs-driven: our teachers needed to be able to utilize the time and skills of the university team throughout the year, while also learning about how to embed the GIS suite of tools in their everyday instruction.

Emergent adaptations – speed, intensity, and innovative approaches to communication and instruction

After the planned adaptations were introduced during the summer PD institute, emergent adaptations began to surface immediately. Unlike the planned adaptations selected when preparing the summer work, these emergent adaptations came from the interactions of teachers and university personnel. We could only observe them in hindsight, once we had noticed that we had adopted a new pattern of behavior.

The first emergent adaptation involved the number and pacing of SESI activities: two teachers elected to begin using GIS on their very first day with students and a third teacher used it within the first week. This pacing was far in advance of what the research team had anticipated and sometimes left us scrambling to catch up with teachers' administrative needs for their implementation. This included setting up student GIS accounts, managing classroom groupings, and sharing data layers across classes. This pace of teachers' GIS use changed through the year, but the net effect was to create faster and more intensive use of GIS in the classroom than we had planned. In our precursor grant, students would experience six SESI activities spread throughout the academic year; this time, our collaborating teachers were doing far more. One teacher implemented eight SESI activities during the year and another implemented four within a single nine-week period. Two other teachers maintained a similar pace of six or more GIS-based activities during the year. By the end of our year of pandemic-restricted implementation, our collaborating teachers had implemented a total of 21 SESI lessons. Of these 21 lessons, 14 were completely novel – they had not existed in any form at the start of the summer institute. The remaining seven were either adaptations from previous SESI lessons, refinements of earlier lessons, or adoptions from external sources. This rate of innovation and implementation far exceeded the pace of activity on the previous geospatial projects, in which collaborating teachers generated seven SESI activities over the course of two years. Despite the challenges of the pandemic, therefore, the students in our collaborating teachers' classes were receiving as much or more exposure to curriculum-aligned GIS as the students in our pre-pandemic project.

A second emergent adaptation was innovation in patterns of communication and instruction. The change in communication came in the form of a Slack community, proposed by our project's graduate assistant. None of the faculty or teachers had previous experience with the messaging tool, but we quickly adopted it—one early message discussed migrating internal grant communications out of email and "to default to slack" (Direct message, 19 August 2020). Between the beginning and end of the first academic year, Slack hosted more than 5000 messages across dozens of channels for curriculum development, classroom support, GIS skills and administration, and research tasks. This volume of communication and collaboration would not be possible if we had persisted in using only email and Google Drive, as we had done during the summer. This change in communication made possible the changes in instruction—as we began working with teachers in generating new SESI instruction, we adopted the habit of creating Slack channels for each instructional topic: cancer, cellular energetics, renewable energy, and so forth. The channels allowed for targeted collaboration across self-organizing groups of teachers and university personnel as they incubated new instructional materials. Given these capabilities of communication and collaboration, the teachers produced not only a large volume of SESI instructional materials, as noted above, but also highly novel uses of geospatial tools. As an example, one teacher introduced the topic of a forensic investigation as an opportunity for creating a SESI lesson. The team created a Slack channel to work on this idea and over the course of a week worked through several iterations of the lesson before hitting upon cellphone towers as focus for geospatial investigation. The resulting instruction—starting from the premise introduced by the teacher—brought the SESI instruction into a new area, using the Analysis tools of ArcGIS, as students interpolated points from cellular connection data to narrow down the possible locations of a criminal suspect (See Figure 2, below). By the end of the year, the use of Slack channels to host curriculum development discussions from initial suggestion through exploration to prototype and then to classroom-ready materials became the standard practice, with all three of the new activities generated in the last marking period being incubated in Slack.

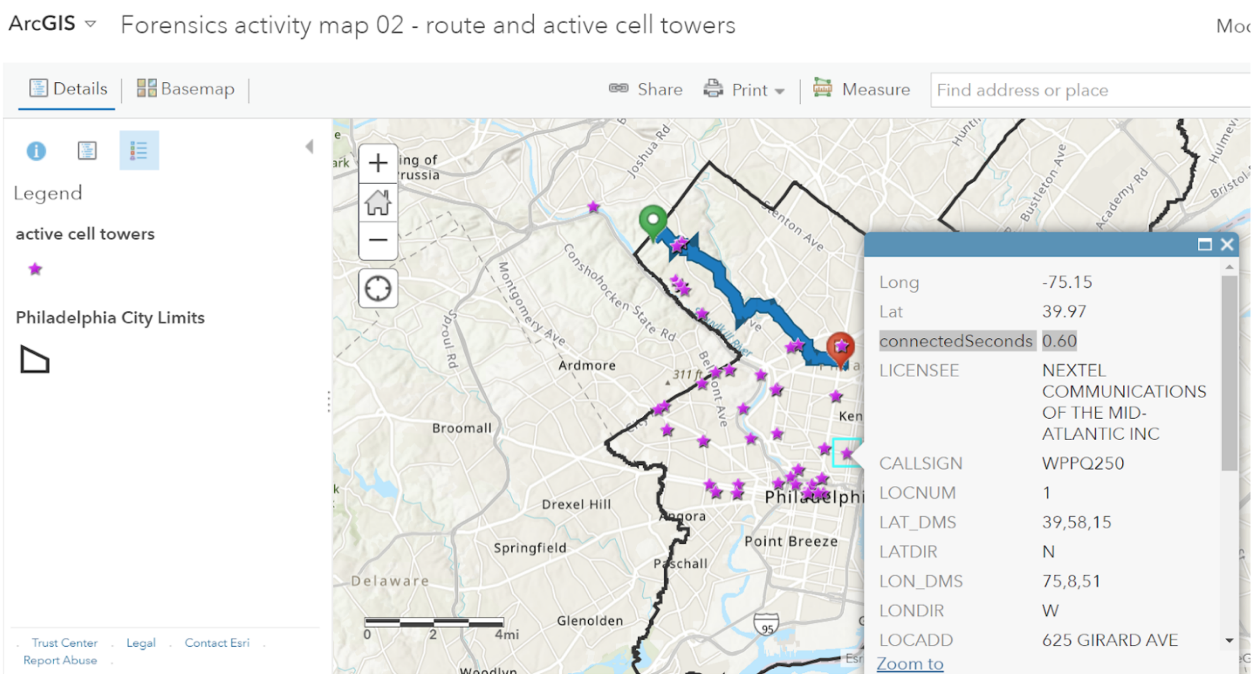

Figure 2: Starting dataset for student analysis in the Forensic Investigation SESI activity.

Discussion

After receiving funding to execute what we had perceived to be a field-tested, trusted model for teacher professional development, curriculum development, and instructional support, we had to re-examine and re-build our plan to adapt to the exigencies of the pandemic. We discovered that while some of the adaptations we could plan for and design for our new reality of online-only learning environments; other adaptations were imposed upon us by the flow of events and the needs of our teachers during this unusual time.

In our short span of work on this project, we have had to significantly alter our plans to meet the constraints of the pandemic and the needs of our participating teachers. We had planned a fast, intense process of professional development followed by a slow, linear, highly unified process of curriculum development and implementation. Instead, we experienced the inverse: a slow, unified professional development process followed by a fast, intense, and diffused process of online curriculum development and implementation. The resulting process has been quite different than we planned, but it has also been richly rewarding both for us as researchers and for our participating teachers. We have found new ways to support teachers and engage students online with geospatial tools, even with the restricted conditions imposed by COVID-19. More importantly, our participating teachers have begun to innovate in ways that we did not expect, finding new applications of geospatial technologies and branching off into their own, independent development cycles.

While we are still less than halfway through a four-year project, we are confident that many, if not all, of the changes we are observing will persist beyond the end of the pandemic and the re-introduction of face-to-face teaching. The social uses of geospatial tools are a wonderful way to introduce students to the technology – as one member of the team observed, "It's the geo-data equivalent of a selfie!" Furthermore, we can now see that—in at least some circumstances—we can step back and observe as our participating teachers initiate their own, independent cycles of curriculum development and implementation. Additionally, we have already observed similar patterns of teacher-initiated curriculum innovation and adaptation at our other partner schools. We anticipate that the pandemic has opened the door to new levels of teacher agency and independent problem-solving. The teachers that are working as our grant partners were already exploring these spaces. Between the necessities imposed by the pandemic and the opportunities presented through the tools and models of geospatial teaching, they have initiated unanticipated, but highly productive, patterns of curriculum development and implementation. We see no reason to expect that this trend will slow down, much less stop, once we are on the other side of the current crisis.

This study adds to the much-needed literature on educators' professional development with geospatial technologies (Baker et al., 2015). The adaptations identified through this reflection and self-study broaden the scope of practice in geospatial professional development, curriculum development, and instructional support. Finally, the described work by our collaborating teachers provides a portrait of resilience and compassion by teachers during the trying period of the COVID-19 pandemic. Rather than executing a retreat to online instruction, our collaborating teachers found ways to innovate and advance their teaching practice. Even as our school and university communities begin to return to normal, we will maintain many of the practices, both planned and emergent, that our RPP developed in the first 12 months of our work.

References

Aikenhead, G. S. (2005), Science-based occupations and the science curriculum: Concepts of evidence. Science Education, 89, 242–275. https://doi.org/10.1002/sce.20046

Carrigan, J., Bodzin, A., Hammond, T., Rutzmoser, S., & Farina, W. (2019, April/May). Investigating urban trees. The Science Teacher, 27-35.

Chin, P., Munby, H., Hutchinson, N. L., Taylor, J., & Clark, F. (2004). Where's the science? Understanding the form and function of workplace science. In E. Scanlon, P. Murphy, J. Thomas, & E. Whitelegg (Eds.), *Reconsidering science learning* (pp. 118– 134). London: Routledge Falmer.

Engle, S.H. (1960). Decision making: The heart of social studies instruction. *Social Education*, *24*, 301-306.

Fitzpatrick, C. (2014, October). Esri makes mapping technology available to us students through President Obama's ConnectED initiative. *ArcWatch*. http://www.esri.com/esri-news/arcwatch/1014/esri-makes-mapping-technology-available-to-us-students-through-president-obamas

Goodchild, M.F., & Janelle, D. G. (2010). Toward critical spatial thinking in the social sciences and humanities. *GeoJournal*, *75*(1), 3–13. doi: 10.1007/s10708-010-9340-3

Gruenewald, D.A., & Smith, G.A., Eds. (2014). *Place-based education in the global age: Local diversity* (3rd ed.). New York: Psychology Press.

Hammond, T.C., Bodzin, A., Anastasio, D., Holland, B., Popejoy, K., & Sahagian, D. (2018). "You know you can do this, right?": Developing geospatial technological pedagogical content knowledge (GS-TPACK) and enhancing teachers' cartographic behaviors with Socio-Environmental Science Investigations (SESI). *Cartography and Geographic Information Science*, *45*, 305-318.

Hammond, T.C., Bodzin, A., Anastasio, D., Holland, B., Popejoy, K., & Sahagian, D. (2019). Shoulder-to-shoulder: Teacher professional development and curriculum design and development for geospatial technology integration with science and social studies teachers. Contemporary Issues in Technology and Teacher Education, 19(2), 279-301.

Huynh, N. T., & Sharpe, B. (2013). An assessment instrument to measure geospatial thinking expertise. *Journal of Geography*, *112*(1), 3-17. https://doi.org/10.1080/00221341.2012.682227

McCurdy-Kirlis, C. (2020, October 20). Back to School - ITEST Project Adaptations: Tips from the Field. STEM Learning and Research Center (STELAR). Retrieved from http://stelar.edc.org/blogs/clara-mccurdy-kirlis/back-school-itest-project-adaptations-tips-field

National Geospatial Advisory Committee (2012). *Geospatial Workforce Development*. Reston, VA: Federal Geographic Data Committee. Retrieved from https://www.fgdc.gov/ngac/ngac-geospatial-workforce-development-paper-final.pdf

National Research Council (2011). *Expanding underrepresented minority participation: America's science and technology talent at the crossroads*. Washington, DC: National Academies Press.

National Science Board (2015). *Revisiting the STEM workforce*. Arlington, VA: National Science Foundation.

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. Washington, DC: The National Academies Press.

Sobel, D. (2004). *Place-based education*. Great Barrington, MA: The Orion Society.

Zeidler, D. L. & Nichols, B. H. (2009). Socioscientific issues: Theory and practice. *Journal of Elementary Science Education*, *21*(2), 49-58.