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Spreading GIS-Infused Instruction: A Cross-Case Comparison of Two Instructional Approaches

Katherine James, Northwestern University, katie.james@northwestern.edu
Steven McGee, The Learning Partnership, mcgee@lponline.net
David Uttal, Northwestern University, duttal@northwestern.edu
Bob Kolvoord, James Madison University, kolvoora@jmu.edu

Abstract: This work is part of an ongoing partnership that seeks to create a sustainable infrastructure to support GIS-infused instruction in a large urban school district. In this paper, we report an illustrative cross-case comparison of two teachers' approaches to infusing GIS in their courses. The goal of this analysis is to examine how GIS-infused instruction is adapted in different contexts and to consider the affordances of divergent approaches. Findings illustrate the relationships among organizational context, individual and collective context, particularly teacher identity, and instructional practice in the work of spreading GIS-infused instruction. We also discuss key lessons learned in our partnership thus far and implications for district-level partnerships focused on spread and scale.

Issue addressed and potential significance

Spatial reasoning is an important part of the practices of many disciplines from STEM to the social sciences. However, spatial reasoning is rarely explicitly taught in the K-12 classroom (NRC, 2006) and efforts to design curricula that support the development of spatial reasoning skills have been limited. Given that spatial thinking improves with training and experience these efforts could be extremely beneficial for young learners (e.g., Uttal, Miller, & Newcombe, 2013).

Recent research and standards emphasize the value of Geographic Information Systems (GIS) as a tool for enhancing K-12 students' spatial reasoning (e.g., Jant et al., 2020; NGSS, 2013; NRC, 2006). GIS has been suggested as a tool to support spatial reasoning skills because it enables users to create rich data visualizations and reason about spatial patterns and relationships among different types of data (Bednarz et al., 2008; Bodzin, 2011). Prior work suggests GIS is effective as a learning tool in multiple contexts (e.g., Edelson, Smith, & Brown, 2008). For example, GIS-infused instruction led to better understanding of concepts in energy, climate change, and social science compared to typical instruction in those areas (e.g., Edelson et al. 2008; Lee & Bednarz, 2009). Given the potential value of GIS, a critical next step is to develop effective approaches for incorporating GIS into classroom instruction.

The current work is part of an ongoing partnership that builds on the Geospatial Semester (GSS), a year-long high school course focused on developing geospatial problem-solving skills using GIS and applying those skills to local problems chosen by students (Kolvoord, Keranen, & Rittenhouse, 2019). The goal is to understand whether and how the GSS can be adapted to meet the needs of Chicago Public Schools (CPS), a large, urban school district teaching a variety of content areas and to create a sustainable infrastructure to support GIS-infused instruction in CPS. Given the widespread, career-relevant applications of geospatial technologies, we focus in particular on the CPS Career and Technical Education (CTE) program, which serves groups currently underrepresented in STEM careers, with the goal of building career-relevant GIS skills in the pathways students are already pursuing.

Our work is informed by Coburn et al.'s (2013) conceptual framework of spread and scale (see Figure 1). Spread is defined as the process by which tools, ideas, practices, or programs move to a greater number of people or organizations through both top-down and bottom-up means (p. 3). Coburn et al. consider who spreads, what spreads, strategies to foster spread, and the contexts that influence spread. They also discuss the various levels at which contexts influence spread: individual and collective, organizational, environmental, and policy. In this project, we focus primarily on the individual and collective level, which involves teacher identity, knowledge, and skills, and the organizational level, which includes support from administration and colleagues and availability of technology. Within these contexts, capacity building and participation are key spread strategies. Coburn et al. use the term scale to refer to the intended outcome of spread and note that scale can be defined in several distinct ways, including adoption, replication, adaptation, and reinvention. In the current work, we define scale as adaptation. Adaptation privileges modifications that incorporate contextual perspectives and needs over strict fidelity and seeks to engender widespread use (Coburn et al., 2013). Modifications can be either appropriate in that they reflect the key ideas, practices, or principles or inappropriate, often referred to as "lethal mutations" (e.g. Tatar et al., 2008). Design principles provide the means to guide appropriate adaptations (James et al., 2020).

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In this paper, we report a cross-case comparison that illustrates two teachers' approaches to infusing GIS in their courses. The challenge we take up in this paper is to examine how GIS-infused instruction is adapted in different organizational and individual and collective contexts and to understand the affordances of divergent approaches, given contextual differences and local goals for adaptations.

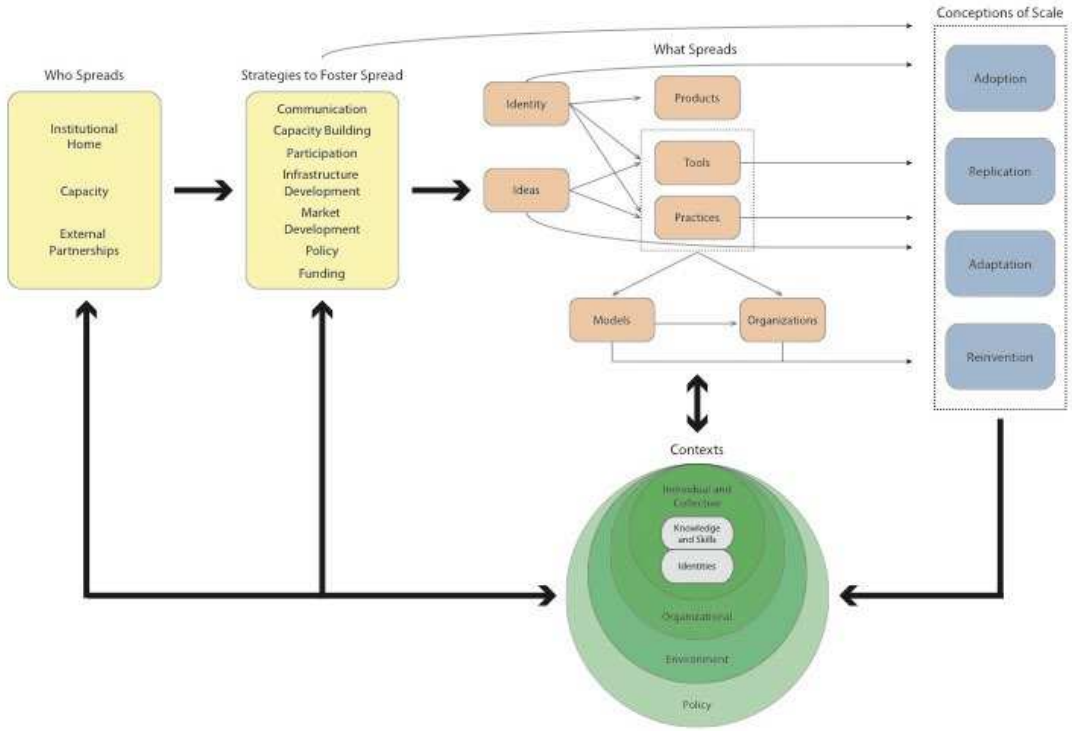


Figure 1. Coburn et al.'s (2013) spread and scale framework.

Methodological approach

Research context

At the outset of the project, we established an ongoing partnership with the CPS CTE office. During Spring 2018, the researchers met with the entire CTE team, including office leadership as well as representatives from the career pathway clusters, such as cluster managers, curriculum specialists, and implementation specialists. We took a top-down approach to recruitment at the organizational level by partnering with the CTE office to identify pathways and courses that could benefit from the infusion of GIS. We initially sought to adapt and implement the original GSS model, which involves an entire year-long GIS course focused on extended student-driven inquiry projects. The partners determined that the CTE capstone course, a year-long, project-based course taken by all seniors in the CTE program, would be a natural fit for this model. Six CTE pathways were initially identified as targets for the year-long GIS course: Pre-Engineering, Entrepreneurship, Agricultural Sciences, Health Science, Construction and Architecture, and Law and Public Safety. Managers of each of these CTE pathways then invited teachers to participate.

In the early stages of the project, it became clear that additional GIS capacity building was needed to help students build the complex GIS and spatial reasoning skills that would be drawn on in the year-long GIS course. To this end, we began incorporating freshman and sophomore content courses outside of CTE that could support GIS capacity building and facilitate multi-year GIS trajectories at schools. In other words, we shifted from spreading the entire GSS model to spreading relevant tools and practices. To facilitate this shift, we began additionally using a bottom-up strategy to recruit individual teachers based on interest. Teachers in the social sciences and computer science chose to join the project.

Professional development and lesson co-design

Teachers participated in a series of professional development workshops, including a five-day summer workshop and one-day mid-year workshop during the 2018-2019 school year (year one) and a four-day summer workshop

during the 2019-2020 school year (year two). During the workshops, GIS technical skills were taught through challenge tasks and skill-building activities. The workshops also incorporated support for lesson planning and implementation, including structured peer feedback routines, small- and large-group discussions of classroom video excerpts (e.g., Sherin & van Es, 2005), and metacognitive reflections on and discussions of teachers' instructional practice. Throughout the workshops, teachers explored how to infuse GIS in ways that align with their context, content, and instructional goals.

Teachers partnered with the researchers and local GIS mentors to develop course maps that lay out a year-long sequence of GIS-infused lessons and pinpoint which units those lessons align with in their course. They then co-designed lesson plans and classroom materials for each of the lessons in their course map and implemented those GIS-infused lessons in their courses.

Case study context

As teachers carried out the work of designing and implementing GIS-infused lessons, we noticed differences in organizational as well as individual and collective contexts, particularly teacher identity relative to GIS-infused instruction. The current study focuses on two different school contexts where contrasting teacher identities emerged: Jackson High School and Addison High School (all names are pseudonyms). Jackson is a high-ranked selective enrollment school located in the center of the city. The racial and ethnic makeup of the school's roughly 1900 students is 40% White, 29% Hispanic, 14% Asian, and 11% Black. At Jackson, there was no organizational-level GIS initiative. Teacher recruitment was done through the social sciences department based on teacher interest. A total of three teachers from Jackson, each of whom taught a different area of social science, initially participated in the project. Thus, each GIS-infused course at Jackson was a standalone course. At Jackson, the teachers viewed themselves primarily as content teachers and, thus, framed GIS as an instructional tool to convey disciplinary content.

Addison High School is a wall-to-wall CTE magnet school located on the periphery of the city. The approximately 820 students are 48% Black, 32% White, and 18% Hispanic. At Addison, there was organizational-level interest in developing multi-year GIS trajectories and infusing GIS into all of the CTE pathways at this school. Indeed, the principal was already aware of GIS and saw the value of integrating GIS school-wide. He mandated that all CTE teachers and several sophomore-level teachers that could support capacity building courses attend the year one professional development workshops, which were also hosted by the school. Initially, seven teachers, including five CTE teachers and two sophomore-level teachers, participated in the project. At Addison, the teachers identified as both GIS technology instructors and content teachers. Thus, they viewed the development of GIS skills and content understandings as equivalent instructional priorities.

To facilitate a cross-case comparison, we selected a course that was common across the two schools: AP Human Geography. We focused on the AP Human Geography teacher from each school with the goal of comparing their approaches to GIS-infused instruction, given noted differences in the organizational and individual and collective contexts. The two teachers, Mr. Bradley and Mr. Mitchell, each co-designed and implemented a different GIS-infused AP Human Geography course. Both teachers implemented their GIS-infused lessons in all sections of their 10th grade AP Human Geography course during years one and two. Mr. Bradley, who is a teacher at Jackson High School (selective school), implemented seven lessons during year one and four lessons during year two. All lessons were a single class period in length. Mr. Mitchell, who teaches at Addison High School (CTE school), implemented five lessons during year one and six lessons during year two. Lessons ranged from three to seven class periods in length.

Data sources

Consistent with design-based research, we used micro-ethnographic methods to observe and document lesson implementation, focusing on teaching and learning processes. Data from the classroom observations include field notes, video, and classroom artifacts, such as lesson materials and student work. At the end of year one, we conducted hour-long, semi-structured interviews with each teacher with the goal of understanding their rationale for and reflections on their design and implementation process. The classroom observation field notes, videos, and artifacts and teacher interview videos constitute the data sources for this paper.

Analytic approach

The classroom observation field notes, videos, artifacts, and interview data were compiled chronologically into case files for each teacher. The researchers engaged in repeated readings and re-readings and thematic summarization of the case files. Analytic memos were written to describe patterns and themes in the data, focusing on each teachers' approach to GIS-infused lesson design and implementation.

To more closely examine differences in teachers' instructional practices, we selected one lesson implemented by each teacher in the middle of year one. These focal lessons were selected because they illustrate the contrasts noted during earlier analysis and are representative of each teachers' instructional approach. The focal lessons were further analyzed through research team debriefing. During the debriefing session, we reviewed an observation summary, which included a description of each lesson and a focal theme, relevant artifacts from the classroom observation data, and a set of guiding questions to structure the discussion around the theme. The research team then analyzed the data with the goal of understanding the affordances of each approach and generating new insights.

Finally, the cases were compared to identify distinctive characteristics of each teachers' approach. The findings presented here are of the two case studies and cross-case comparison.

Findings

The two cases discussed here illustrate variations in the teachers' approaches to GIS-infused content instruction. Table 1 provides an overview of the key differences between the two cases with respect to context, lesson design, learning goals, role of GIS, and timing.

Table 1: Case study teachers

Case	Context	Lesson Design	Learning Goals	Role of GIS	Timing
Mr. Bradley	Selective school, standalone course, content teacher identity	Focused, content-specific lessons	Content-relevant spatial reasoning	Extremely user friendly, minimize interaction with technology	Focus on efficiency, balance with AP content coverage
Mr. Mitchell	CTE school, organizational-level GIS initiative, GIS instructor and content teacher identity	Topical but open-ended lessons, focus on student-driven inquiry	Investigate topics of interest, GIS skill building	GIS as tool for inquiry, productive struggle to figure out GIS skills	Open-ended, space for exploration

Case #1: Mr. Bradley

The focal lesson was the fourth GIS-infused lesson in Mr. Bradley's course. He provided a set of three pre-made maps that contained the information and afforded the content-relevant spatial sense-making he wanted students to engage in. The three maps contained information about 1) world religions, 2) climate, and 3) elevation. To structure students' interaction with the maps, he provided a series of questions that moved from data gathering to analysis and interpretation, particularly noticing and understanding the targeted spatial patterns. In this lesson, students were asked to determine how geographic factors contributed to the spread of a list of religions, focusing on the contrast between universalized religions (e.g., Christianity, Islam) and ethnic religions (e.g., Hinduism, Igbo). Students toggled between the maps to qualitatively analyze the information, focusing on identifying corresponding areas of the maps and understanding relevant spatial patterns. Students worked independently or in pairs to answer the questions based on the information in the maps and then shared their insights and questions with the class. In the excerpt below, the world religions map is projected on the screen and zoomed in on the area surrounding the Himalayas. The teacher poses one of the questions from the activity and the class discusses the spatial relationships between geography and the spread of religion in the region.

Teacher:	Why didn't Buddhism go south and why didn't Hinduism go north? What's blocking the diffusion of the religions here, Charlie?
Student 1:	The Himalayas.
Teacher:	What...are those?
Student 1:	Mountains.
Teacher:	Mountains! The tallest mountain range in the world and they kind of extend this way [gestures east along the Himalayas on the map] That's why these areas have maintained their traditional beliefs because, again, the mountains

and very tropical areas and very difficult to get through so these areas never were really touched by Buddhism. Instead, Buddhists went around using the ocean and thus they reached over here. Why on earth then would these Buddhists be so different than the ones from the north, Maria?

Student 2: There's no interaction between them so they each established different religions.

Teacher: My budding Geographers, you're so close to blossoming. It's beautiful. Right! Look! You have mountains, high elevation...the only way you can reach these areas is through traders going through the ocean, right? So thus, these areas have maintained and then you see a whole different version of Buddhism because there's less interaction.

As the transcript illustrates, this lesson enabled students to make key insights into the spatial patterns and relationships underlying the spread of world religions. Indeed, this GIS-infused activity meaningfully enhanced their understanding of the content while allowing them to build spatial reasoning skills through GIS. As briefly mentioned in the transcript, Mr. Bradley framed GIS as a tool for thinking like geographers, emphasizing that maps are an important source of information in geography and, while they can draw inferences about patterns from this data, there are multiple valid interpretations and a need to corroborate the information with other sources. This rooted the activity in disciplinary practices and connected it to the other work that students were doing in this course.

As reflected in the focal lesson, Mr. Bradley's GIS-infused lessons commonly engaged students in using GIS to analyze content-relevant spatial patterns. These lessons were strongly connected to the content and thoughtfully integrated into units where there were important spatial relationships, such as global patterns, underlying the geography content. In discussing his goal for using GIS in his course, he emphasized building spatial reasoning skills and enhancing students' content understandings through analyzing spatial patterns:

> Teaching human geography, I understand the value of having that spatial awareness and understanding, like, how two things might be related to each other if they're happening in the same spot. I'm trying to get kids, you know...my students, curious about those types of connections to try and figure out why things are the way they are *where* they are. Right? So, we're worried about the location, not just why things are happening.

Importantly, he also indicated that his goal in using GIS in his course was to leverage its affordances for enhancing understanding, rather than building technical skills. This approach to GIS-infused instruction was shaped by the learning goals, content coverage expectations, and time limitations associated with this AP Human Geography course:

> With AP Human Geo there's just not the time to really get kids to kind of work with the software...I just wanted kids to make those connections, it was very basic. I wasn't interested in getting them to learn the software. I was more concerned about learning that spatial awareness skill.

Overall, Mr. Bradley's approach to GIS-infused content instruction focused on efficient, user-friendly lessons. His lessons minimized the time commitment needed and enabled him to balance the GIS work with the content coverage and learning goals of this AP course in a selective enrollment school context. This approach also minimized the GIS technical skills required of both teachers and students, making the lessons usable by GIS novices without extensive training. These lessons reduced the GIS learning curve and successfully avoided "in the moment" technology snafus that can make GIS challenging to use in the classroom. At the same time, these focused, content-driven lessons effectively engaged students in content-relevant spatial reasoning. Indeed, Mr. Bradley's GIS-infused lessons engaged students in reasoning about spatial patterns and relationships in ways that meaningfully enhanced their understanding of the content.

Case #2: Mr. Mitchell

The focal lesson in Mr. Mitchell's AP Human Geography course was the third in the GIS sequence. In this lesson, which took place over four class periods, students independently explored GIS to investigate a historical human migration. The teacher provided a list of possible topics, vetted data sources, and a set of questions to structure

and constrain the task, but students were allowed to choose any human migration that interested them. Students were asked to use GIS to create any three maps and a storymap that told the story of that migration. Storymaps are a GIS tool that allows users to embed maps, videos, photos and other media within a narrative to create a dynamic, interactive presentation that interweaves maps with written analysis. Students had three class periods to explore GIS in small groups and create their storymaps. During this time, the teacher modeled key practices and provided support as needed, but the inquiry was almost entirely student-driven. Indeed, students explored GIS to identify and analyze relevant data and worked together to figure out the technical skills they needed to create their maps and storymaps. On the fourth day, students presented their storymaps orally to the class. The storymaps that students created included maps of key locations and routes involved in the migration and analysis of the factors (e.g., political, geographical, historical) that may have contributed. Many students chose to focus on migrations that were personally relevant, such as their own family's migration.

As illustrated in the focal lesson, Mr. Mitchell's approach to GIS-infused instruction was characterized by exploratory, student-driven inquiry around content-relevant topics. He designed tasks that provided scaffolds, such as vetted topics and data sources, but enabled students to independently explore their interests. In this course, students also commonly used GIS to create their own maps and storymaps, which were presented to the class at the end of each lesson. For example, in their storymap about the dust bowl, one group included a primary source photograph as well as an interactive map with early 20th century county population and agricultural land amounts data for the Great Plains states to illustrate key routes and factors involved in the migration (see Figure 2).

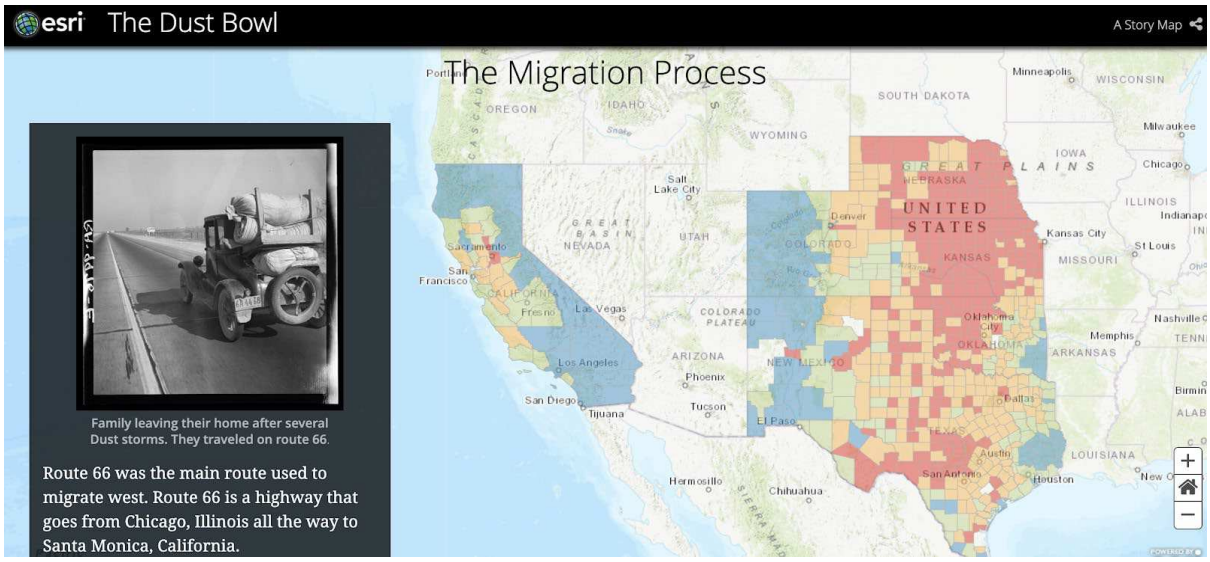


Figure 2. Section of a storymap created by students during the focal lesson.

While creating maps and storymaps introduced additional challenges, it also enriched students' understanding and experience of GIS and enabled them to share and discuss their findings with the community. Indeed, Mr. Mitchell's lessons created space for students to struggle productively and figure out GIS on their own while investigating topics they care about. In discussing his instructional approach, he emphasized the value of exploration and productive struggle for teaching and learning with GIS:

> My teaching style is that they've all got to struggle themselves and they get through that struggle for the most part and they end up doing better. I think it went pretty well, I was really impressed with the stuff they came up with...As we got further and further, I just said ok this is what we're gonna do and then they already had ideas about what layers am I gonna find for that or how am I gonna set this up...it was just them getting the assignment and then them creating and making their own different things.

Indeed, Mr. Mitchell's lesson design motivated and enabled students to do the work of learning GIS. As a result, they developed valuable, real-world GIS-based technical and problem-solving skills:

> What I like about it is after you do [GIS], like we've been doing [GIS] all year, they become little experts...now they actually know more about it than I do...I love seeing that. Giving them something they can actually use in their endeavors forward, regardless of what they actually do.

This exploratory, student-driven approach to GIS-infused instruction, while time-consuming and perhaps challenging to orchestrate, struck an important balance of freedom and structure. Mr. Mitchell's lessons allowed for personalized learning experiences in which students had the space to explore different paths based on their interests and become immersed in that area of the content. As a result, students meaningfully connected with and more deeply understood the content, which also motivated them to develop the GIS technical skills needed to investigate and communicate about their topic of interest. The development of expertise in GIS laid the foundation for application of GIS skills within subsequent CTE pathways.

Conclusions and implications

This cross-case comparison furthered our understanding of the relationships among organizational context, individual and collective context, particularly teacher identity, and instructional practice in the work of spreading GIS-infused instruction. Although they taught the same course, Mr. Bradley and Mr. Mitchell used different approaches to infusing GIS into their instruction. One teacher foregrounded content-relevant spatial reasoning while the other privileged exploratory, student-driven inquiry. Importantly, GIS was also positioned differently in their organizational and individual and collective contexts. Mr. Mitchell's course was part of an organizational-level initiative to develop multi-year GIS trajectories. Specifically, his instructional goal relative to this initiative was to build capacity and prepare students for using GIS in their CTE courses. Thus, he identified as both a GIS instructor and a content teacher and viewed GIS skills and content understandings as equally important in his course. This teacher identity may have shaped his instructional practice, leading to a focus on developing GIS skills through content-relevant, student-driven inquiry projects. In contrast, Mr. Bradley's standalone course was neither supported by earlier GIS capacity building courses nor connected to future courses in which students would apply the GIS skills they had learned. Given this organizational context, he primarily identified as a content teacher. Therefore, only minimal time could be devoted to learning the GIS technology and the focus was instead on building content understandings through the tool. Thus, the organizational and individual and collective contexts in which the GIS-infused instruction occurred may have shaped the specific practices and purposes for using GIS.

This work also underscored the importance of capacity building and adaptation in facilitating spread. With respect to "what spreads", we shifted our focus from the entire GSS model to tools and practices in the early stages of the project. This gave teachers flexibility in the co-design process to tailor their approach to their context and allowed for both of the appropriate adaptations examined in the cross-case comparison. In this way, expanding to incorporate capacity building courses and focusing on adapting tools and practices enabled us to further the spread of GIS-infused instruction in CPS.

In terms of our ongoing district-level partnership, this work also emphasized the value of participation. As is common in large urban districts, department restructuring, teacher turnover, and attrition have occurred. However, in areas where we had a critical mass of team members involved, we have been able to leverage the relationships we had developed and the capacity we had built to continue the partnership in spite of these organizational changes. Indeed, we have found that involving more stakeholders, from individual teachers to department leadership and central office staff, in a partnership leads to greater stickiness and potential for spread. For example, after significant restructuring occurred in the CTE department, we were able to continue our work because the new CTE director was involved in our partnership and planning discussions from the beginning. Additionally, given the success of Mr. Mitchell's and other teachers' capacity building courses at Addison High School, there is ongoing interest from the principal and teachers in expanding the role of GIS at this school.

The next phase of this work will entail revisiting which CTE pathways are the best fit for infusing GIS with the goal of developing both GIS-infused capacity-building and year-long capstone courses for those pathways. We also plan to gradually shift "who spreads" to the teachers and organizational leadership, rather than the researchers. To this end, we will continue to develop our current teachers into teacher-leaders who can train new teachers to implement the courses they've developed with the goal of creating a sustainable infrastructure to support GIS-infused instruction in CPS.

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