Mapping for Impact: Actionable Spatial Literacy through Counter-Mapping

A Thesis Submitted in Partial Fulfillment

of the Requirements for the Degree of Master of Arts

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Abstract

Counter-mapping is a technique that young people can use to take informed action on community issues through the mapping process. This mixed-methods study examined how ninth-graders in a large urban district in Iowa developed spatial thinking skills while engaging in counter-mapping in their community and the extent to which they used those maps to take informed action. A nine-week learning progression for counter-mapping scaffolded progress variables across three different spatial thinking standards and one inquiry standard. Findings indicated that students improved throughout the learning progression, but some needed teacher support to conduct spatial inquiries. Chances of reaching the upper anchor on a learning goal were positively associated with prior opportunities to grapple with complex spatial reasoning tasks. Students shifted over the learning progression from viewing maps as navigational tools to using them as communication tools. The extent to which students could use counter-maps to take informed action depended on their level of spatial literacy. Student reflections demonstrated that the hypothesized upper anchor of the inquiry standard and the lower anchor of the mental maps standard needed revision. Ninth-graders in the study could not take community-level informed action, but they could take personal action and propose potential solutions to spatial problems. Some significant results showed female students performed better than male students early in the learning progression. Latino students outperformed White students on two tasks. Counter-mapping is a place-based and asset-based pedagogical tool that can build critical spatial thinking skills while affirming students' identities.

This Study by: Rachel Hansen

Entitled: Mapping for Impact: Actionable Spatial Literacy through Counter-Mapping

has been approved as meeting the thesis requirements for the

Degree of Master of Arts

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Dedication

For the love of learning.

Acknowledgements

I first began counter-mapping with students while teaching on an interdisciplinary project-based dream team of some of the finest educators I have had the pleasure to know. Over spirited working lunches and hours of interesting (and sometimes odd) conversations with John Boylan, Sarah Wilson, and the late Cathy Kramer, we brought our first spatial justice project to life. These dream team folks were beyond brilliant. Sarah saw math in everything, John had a special knack for helping students connect with their voices, and Cathy created cutting-edge STEM experiences for students. What began as an authentic way to teach geometry and bioethics concepts through spatial narratives quickly evolved into a much more complex end-of year-project to propose student-generated solutions to spatial issues in the community.

When we were forced overnight into distance learning in March 2020, students got to work mapping WiFi access to provide the school board with timely information about the need for public hotspots, and I quickly found myself at the limits of my technical geospatial skills. I am forever indebted to Anita and Roger Palmer for their guidance and support over pandemic Zooms as we tried to make our maps accurate and useful. They are forever my cheerleaders, and I am grateful for their timely emails of encouragement that trickled in during my time in grad school. Kim Young was also there nearly every step of the way from her porch in Boston, always ready with at least one wild idea and a Pseudo Sue.

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Chapter 1:

Introduction

In 2014, the world's leading GIS software supplier, Esri, committed one billion

dollars to support entirely free access to ArcGIS Online for all kindergarten through 12th-

grade students in the United States (Esri 2014). While the initiative extended President

Obama's plan to strengthen STEM education, it also had potentially far-reaching effects

on geography education. Esri's effort to place cutting-edge geographic information

systems (GIS) software into the hands of school children reflects the widespread growth

of geospatial technologies in private and public spheres over the past three decades.

Online mapping and crowdsourced spatial data lessen economic barriers to accessing

spatial information (Gordon, Elwood, and Mitchell 2016). As a result, these new digital

technologies have contributed to participatory and citizen mapping projects for protest,

city planning, and claims to resources. Such platforms have facilitated research interests

in how youth think about and take informed action on social justice issues (Keiper 1999;

Elwood et al. 2007; Gordon, Elwood, and Mitchell 2016; Dalton and Mason-Deese 2012;

Schlemper et al. 2019; Wilson et al. 2019; Fileborn 2021).

While educational research in geography proposes several frameworks for

developing spatial thinking skills, much less is known about how counter-mapping

experiences shape students' development of spatial thinking skills and their sense of

place. Although Indigenous groups have long used counter-mapping to claim land and

resources (Peluso 1995), only a handful of studies have been conducted on counter-

mapping with adolescents (Taylor and Hall 2013). Youth engagement in participatory

mapping, sketch mapping, citizen mapping, and community mapping has been well-

documented in the literature (Dennis 2006; Lee and Bednarz 2012; Taylor and Hall 2013; Curtis et al. 2014; Gordon, Elwood, and Mitchell 2016; Annamma 2017; Metoyer and Bednarz 2017; Schlemper et al. 2018; Reed 2019; Wilson et al. 2019; Solís, Anderson, and Rajagopalan 2021); however, what students do with the resulting geographic information has yet to be fully understood and articulated. Participatory maps are made but rarely deployed meaningful ways to solve spatial problems in the community.

Research Aims

This study aims to provide educators with a framework for improving students' critical spatial literacy skills through counter-mapping. As a result, youth will better understand equitable access to valuable assets and resources that can improve the quality of life throughout the community. For the purposes of this study, counter-mapping will be defined as a technique young people use to take informed action on community issues through the mapping process. Counter-mapping is a means for young people to build and practice critical spatial thinking skills and take informed action on social justice issues in their communities in ways that produce real change.

Research Questions

The primary research question driving this study focused on the spatial thinking skills that students used while engaging in learning activities related to counter-mapping. In addition, a second supporting research question explored how students used their counter-maps to influence community decisions.

1. How do students learn spatial literacy when counter-mapping?
2. To what extent do students use counter-maps as decision-making and problem-solving tools in their community?

Research Objectives

Guided by the overarching research questions, the following three objectives informed the study design, data collection, analysis, and conclusion. Objectives one and two stem from the primary research question about spatial thinking skills, while the third objective explores the supporting research question about counter-maps as decision-making tools.

1. Identify the spatial thinking skills that students employ while engaging in counter-mapping experiences.

2. Describe the learning progression of spatial thinking skills and capabilities that youth gain through counter-mapping experiences.

3. Evaluate to what extent students use counter-maps as decision-making and problem-solving tools in their communities.

Chapter 2:

Literature Review

Two collections of literature provided a basis for this study: theories of mapping and empirical studies of map use in classrooms. First, this chapter describes how counter-mapping is situated within six theoretical frameworks: 1) critical cartography, 2) spatial thinking abilities, 3) geography instructional standards, 4) learning progressions, 5) cognitive load theory, and 6) critical pedagogies. These frameworks informed the design of the learning progression, proficiency scales, and assessments for counter-mapping. Next, the chapter provides a comprehensive overview of mapping studies conducted with youth, which informed the research methods used for this study. Mapping studies were selected, organized, and analyzed using three themes: 1) focus on spatial thinking skills, 2) access to space and sense of belonging, and 3) youth-led informed action. At the end of the chapter, the researcher presents three considerations for counter-mapping research.

Theoretical Frameworks

Critical Cartography & Counter-Mapping

Cultural studies of mapping provide a critical analysis of the power structures embedded in maps that reflect the cartographer's perspective and mapping methods (Pickles 2004). Mapping is an inherently political act carried out in dynamic social contexts. Choices about how to construct the map reflect the mapmaker's beliefs, interests, ways of knowing, and relationships to dominant power structures (Harley 2001; Pickles 2004; Dalton and Mason-Deese 2012; Vélez and Solórzano 2017; Fileborn 2021). Historically marginalized groups were often erased from this process entirely.

Critical cartographers use counter-maps to challenge traditional positivist approaches in mapping. By acknowledging the mapmaker's positionalities, critical cartographers value local knowledge, evaluating the extent to which maps silence marginalized groups (Kwan 2002; Crampton and Krygier 2005; Vélez and Solórzano 2017). Maps are sources of power and information and can become a tool for activism. When appropriated by historically marginalized groups, they offer an opportunity to restore a power imbalance and enact sustainably just solutions (Peluso 1995).

Peluso (1995) coined the term counter-mapping in her research exploring how local forest dwellers in Indonesia reclaimed territory from state authorities who had drawn them out of official government maps. Counter-mapping enabled locals to appropriate the techniques and manner of representation used by those in power to draw new maps and claim resources. These maps offered a more accurate reflection of how local communities utilized and thought of their resources than the maps produced by state-sponsored cartographers.

Today counter-cartographies are being reimagined as dynamic, responsive ways to map pressing social justice issues. For example, social media sites calling attention to street harassment produce counternarratives to the crime mapping conducted by criminologists, which often neglect the "social and cultural production of space and place" (Fileborn 2021, 1204). Because these sites are interactive, the public actively constructs street harassment crime maps that position the perpetrators as the central focus of the issue, not the victims. Like the counter-mapping in Indonesia, these maps empowered underrepresented groups to reclaim the geographic spaces they occupied.

Critical GIS, a subset of critical cartography, was only an emerging field in the 1990s but has become more widely embraced with the exponential growth in low-cost, open-source mapping services during the 21st century. Participatory GIS (PGIS) incorporates local knowledge into the mapping efforts of urban planners, resource managers, emergency responders, and community activists. PGIS uses an inclusive methodological approach to map community needs and assets by drawing on a participatory action research framework. Visualizations created in partnership with local stakeholders act as practical negotiation tools in communicating with elected officials and decision-makers (Elwood et al. 2007). Centering local voices makes solutions more responsive to community needs.

While GIS is a powerful tool for analyzing and manipulating vast amounts of quantitative data, qualitative GIS is especially effective at mobilizing community action. GIS enables the researcher to situate qualitative data in a spatial context. Sketch maps, ethnographic narratives, images, and videos can provide insights into unique individual experiences that the mapmaker might miss in purely quantitative studies. For example, researchers examining safety in public spaces benefit from incorporating first-hand accounts of lesbian, gay, bisexual, transgender, and queer community members who navigate those spaces in daily life (Boschmann and Cubbon 2014). Descriptive and contextual information is often missing from maps used to negotiate public policy change. As Dennis (2006) explains, because "GIS is the language of planning power," it shapes public debate and government decision-making about important community issues (2043). The everyday experiences of local people get circumvented by the priorities of professional planners, who are often community outsiders (Dennis 2006; Elwood et al.

2007; Taylor and Hall 2013; Wilson et al. 2019). Qualitative GIS conducted in a participatory setting holds great potential to offer more holistic, responsive, and inclusive solutions to local issues.

Spatial Thinking Abilities & Skills in Youth

In the last twenty years, geography researchers have aimed to identify spatial thinking abilities, concepts, and skills and the cognitive processes from which they originate. Table 1 details the progression of this body of research, beginning with the National Research Council's study on spatial thinking in 2006. *Learning to Think Spatially* aimed to explore and explain the intricacies of spatial thinking and then propose a support system for K-12 educators to teach these skills through GIS (National Research Council 2006). This seminal work proposed that spatial thinking amalgamated "concepts of space, tools of representation, and processes of reasoning" used across physical, intellectual, and life spaces (National Research Council 2006, 3).

Three studies after this publication proposed more specific frameworks for spatial reasoning skills. First, Gersmehl and Gersmehl (2007) distilled spatial thinking into eight neurologically independent modes, concluding that spatial thinking develops early in childhood and accumulates over the life course. Second, Golledge, Marsh, and Battersby (2008) proposed a five-level hierarchy of geospatial conceptualization to inform more developmentally appropriate learning progressions. Third, Janelle and Goodchild (2009) argued that eight foundational spatial concepts establish the basis for inquiry on social problems. Using skills, concepts, and abilities identified by these researchers, Lee and Bednarz (2012) generated the Spatial Thinking Ability Test (STAT) to assess spatial thinking in middle school to university students. One limitation of the STAT is that it

only uses the multiple-choice format to assess spatial thinking, which might not account for student abilities demonstrated in other forms of assessment.

Table 1 Progression of Proposed Spatial Thinking Abilities, Concepts, & Skills

Learning to Think Spatially	Gersmehl & Gersmehl	Golledge, Marsh, & Battersby	Janelle & Goodchild	Lee & Bednarz
2006	2007	2008	2009	2012
Identified 3 elements of spatial thinking	*8 independent modes of spatial thinking*	*5-level ontology of geospatial tasks, hierarchically arranged*	*Identified 8 foundational concepts for thinking about social and spatial problems*	*Generated a Spatial Thinking Ability Test (STAT) to assess 8 spatial thinking abilities*
Space	Comparison	I: Identity, location, magnitude, space-time	Location	Orientation and direction
Representation	Aura		Distance	Comparing map to graphic information
Reasoning	Region	II: Distance, order, sequence, distribution, line, shape, direction	Network	
	Hierarchy		Neighborhood and Region	Best location analysis
	Transition		Scale	
	Analogy	III: Slope, pattern, connectivity, adjacency, angle, classification, coordinate/grid pattern, polygon	Spatial Heterogeneity	Slope profile on topographic map
	Pattern		Spatial Dependence	Correlating spatial distribution
	Association			
		IV: Hierarchy, overlay/dissolve, map projection, slope/gradient	Objects and Fields	Visualizing 3-D image from 2-D information
		V: Rotation, translation, transformation, spatial association		Point, line, polygon

Based on the results of the STAT test, Lee and Bednarz (2012) argued that spatial thinking might not be a list of independent skills as previous studies indicated. Instead,

their results suggested that several different skills make up spatial ability, and individuals might be exceptionally skilled in some areas yet weak in others. Despite the STAT's lack of assessment on students' spatial problem-solving techniques, Lee and Bednarz (2012) effectively drew attention to the role of GIS and other geospatial tools in developing spatial thinking skills in young people.

Geography Standards

There are two comprehensive guides to geography instruction for kindergarten through high school students in the United States. The first national standards in geography, *Geography for Life,* were published in 1994 and then updated in 2012. This framework included eighteen geographic knowledge standards across six essential elements. Knowledge and performance statements across three grade bands were added in the 2012 update (Heffron and Downs 2012). In 2015, some states and districts began adopting the College, Career, and Civic Life (C3) Framework for Social Studies State Standards (National Council for the Social Studies 2013). The *Geography for Life* authors (Heffron and Downs 2012) contributed to the development of the C3 framework, paring down the original 18 standards to a more operational set of criteria framed around the Essential Elements. One distinguishing feature of the revised geography standards in the C3 Framework is that they are embedded within an "Inquiry Arc," which serves as a frame for applying geographic concepts to challenges in the world (6). The National Geography Standards and the C3 Framework were critical guides for social studies teachers across the United States in designing and implementing geography curricula in elementary through high school. All 50 states have established state standards for geography, often using *Geography for Life* and the C3 Framework as models. While

states suggest using these standards to guide curriculum planning, more research should focus on how students navigate learning progressions to achieve mastery of geography content and skills (Huynh, Solem, and Bednarz 2015).

Learning Progressions in Geography

Following the 2012 update to *Geography for Life*, the Road Map Geography Education Research Committee (GERC) issued a report with thirteen recommendations to improve research in geography education and support the development of a more geographically literate society (Bednarz, Heffron, and Huynh 2013). One of the key recommendations from the Road Map GERC was to conduct empirical studies to identify learning progressions in geography education. In response to that call for research, the Association of American Geographers produced a GeoProgressions handbook to train geographers and education researchers in methods for conducting and validating learning progressions and assessments related to the three spatial thinking standards within Essential Element 1 of the *Geography for Life: National Geography Standards* (Solem, Huynh, and Boehm 2015). Table 2 provides the standards precisely as they appear in *Geography for Life* (Heffron and Downs 2012).

Table 2 Standards in Essential Element 1: The World in Spatial Terms

Geography Standard 1	How to use maps and other geographic representations, geospatial technologies, and spatial thinking to understand and communicate information.
Geography Standard 2	How to use mental maps to organize information about people, places, and environments in a spatial context.
Geography Standard 3	How to analyze the spatial organization of people, places, and environments on Earth's surface.

Recent research on learning progressions in geography aims to understand how students develop spatial thinking skills while navigating a curriculum. A learning progression documents a student's journey as they gain increasingly sophisticated mastery of a discipline over time (National Research Council 2007). It shows what students know before beginning a learning journey and how their thinking progresses after formal learning opportunities (Larsen and Harrington 2018). Studies on learning progressions have the potential to inform better teaching practices for fostering spatial thinking and might reveal important insights into how students' value systems shape the way they process and organize new information (Solem, Huynh, and Boehm 2015).

Learning progressions contain four essential components: 1) the learning goal, 2) progress variables, 3) assessments, and 4) instructional sequences (Solem, Huynh, and Boehm 2015). These components are clearly defined in Table 3. A learning progression includes an upper and lower anchor, often based on the national standards for the appropriate grade band. Each student might take a different route to an upper anchor, which makes defining the "messy middle" between anchors challenging because students might only demonstrate partially formed or correct understanding (Solem, Huynh, and Boehm 2015). Assessments should match the upper anchor and provide researchers with a way to gauge a student's level of understanding in the learning progression. Most importantly, student responses on assessments can inform the need to refine or modify a progression to maximize student learning (Solem, Huynh, and Boehm 2015; Larsen et al. 2018).

Table 3 Components of Learning Progressions

Learning Goal *Also referred to as "learning targets" and "upper anchors."*	*An educational goal based on student capabilities and knowledge.* Students need these abilities and skills to participate fully in society or to move to the next step in the learning progression. National and state standards can be considered "upper anchors," describing what students can achieve within a grade-level band.
Progress Variables *Also known as "hypothesized developmental progressions of thinking and learning."*	*Hypothetical pathways a student might take while mastering a learning goal and working toward the upper anchor.* They represent the levels of understanding that students demonstrate during an assessment or learning activity.
Assessments	*Learning tasks that allow students to reveal their level of understanding of a learning goal.* Assessments should be validated to ensure they consistently measure student performance.
Instructional Sequence	*Order of learning activities to be carried out by the teacher.* The sequence is designed to provide students with multiple opportunities to learn and grow in their understanding of a learning goal.

Huynh, Solem, and Bednarz (2015) identified three methodological approaches for studying learning progressions. One research model proposes developing a learning progression based solely on literature about student learning. The other two methodologies emphasize developing and revising learning progressions based on student assessment data and performance (Huynh, Solem, and Bednarz 2015). Academic research traditionally looks from the outside in; however, teachers and students are untapped experts in learning progression research. Larsen and colleagues (2018) note the reciprocal benefits for teachers and researchers who engage in learning progression research together. For researchers, classroom observation of student learning and teacher interventions can help them conduct more practical and informed studies of geography education. Teachers also benefit from timely feedback about student learning that can help them develop more individualized and student-centered strategies to support students in subject mastery (Larsen et al. 2018).

Larsen and Harrington (2018) identified three main challenges and solutions for learning progressions in geography. First, because it is challenging to capture how individual students acquire new skills, learning progressions should be responsive and reflective of student identities and experiences in a place (Larsen and Harrington 2018). Culturally responsive teaching practices provide one way to build more student-centered learning progressions (Ladson-Billings 1995; Gay 2010; Paris 2012; Hammond 2014). Second, geography is a complex subject that requires students to build geospatial synthesis skills over time. Reducing the number of subjects in the progression and focusing on crosscutting concepts, like spatial thinking, are ways to reduce the cognitive load on students (Sweller 1988; 2010; Larsen and Harrington 2018). Third, learning progressions are not always developmentally appropriate. Careful consideration should be given to selecting the upper anchor and designing the instructional sequence, assessments, and progress variables that lead students there (Solem, Huynh, and Boehm 2015; Larsen and Harrington 2018; Larsen et al. 2018). Learning progression researchers must engage in iterative conversations with both teachers and students to truly understand how students think about a concept (Huynh, Solem, and Bednarz 2015; Larsen and Harrington 2018; Larsen et al. 2018).

Cognitive Load Theory

Cognitive load theory offers a framework to inform the design of developmentally appropriate learning progressions. Research on problem-solving and instructional design led to the formation of Sweller's cognitive load theory (CLT) in the late 1980s. Sweller's work investigated why some instructional materials were more effective than others at promoting learning. CLT prioritized the impact of instructional design and prior

knowledge on learning rather than motivation or other individual factors (Sweller 1988). Sweller suggested learners face three types of cognitive load: extraneous (due to instructional procedures), intrinsic (related to the complexity of the task), and germane (mental energy expended while learning). Effective instruction balances all three types of cognitive load. By reducing extraneous cognitive load and managing intrinsic cognitive load, teachers can create cognitive space for germane cognitive load (Sweller 2010). Today, CLT is widely recognized as an essential framework for understanding how instructional sequencing and design can be optimized to promote learning.

More recently, Howarth and Sinton (2011) used cognitive load theory to rethink frameworks for implementing problem-based GIS instruction. GIS instructors can use CLT in combination with frameworks of spatial conceptual knowledge to appropriately sequence instruction. Spatial primitives like identity, location, and direction can build toward more complex spatial reasoning concepts like density, pattern, and buffers (Golledge 2002; Golledge, Marsh, and Battersby 2008; Howarth and Sinton 2011). Problem-based GIS tasks are often so cognitively demanding that if students are given minimum guidance or lack prior knowledge, the cognitive load may be too high for them to succeed (Kester, Paas, and Van Merriënboer 2010). Novice students need more structured guidance, while expert students need unguided practice opportunities to build their own internal feedback loops and cognitive representations (Kirschner, Sweller, and Clark 2006; Kester, Paas, and Van Merriënboer 2010; Howarth and Sinton 2011). Ultimately, the design of learning sequences in geography should limit the extraneous cognitive load of the GIS software while maximizing opportunities for students to try out their new knowledge in appropriately scaffolded situations.

Culturally Relevant, Responsive, and Sustaining Pedagogy

One significant challenge in learning progression research is equitable outcomes for various gender and ethnic identities. There are well-documented gaps in academic performance among ethnic and gender groups (Linn and Petersen 1985; Voyer, Voyer, and Bryden 1995; Rittenhouse 1998; McGlone and Aronson 2006; Newcombe 2007; Jencks and Phillips 2011; Milner 2012). Despite a substantial body of literature on opportunity gaps, much is yet to be known about how socioeconomic status, gender, race, or ethnicity might affect spatial thinking. Since the 1980s, researchers generally regarded males as superior to females in spatial reasoning skills; however, more recent research suggests those sex differences are limited and insignificant (Mohan and Mohan 2013). Both males and females perform poorly on spatial tasks and require targeted learning interventions (Terlecki and Newcombe 2005; Mohan and Mohan 2013).

Furthermore, how nonbinary and other gender-diverse students perform on spatial tasks is not understood. A study investigating results of the National Assessment of Educational Progress (NAEP) Geography tests for eighth grade found that large gaps exist for Black and Hispanic students, those on an individualized educational plan (IEP), and English language learners, but gender-based differences were much more minor (Solem 2023). Learning progressions research should address these gaps with more culturally inclusive teaching pedagogies.

Counter-mapping offers a place-based learning intervention to help students build critical spatial thinking skills that affirm gender, racial, and ethnic identities. Learning activities and assessments in this pilot study were informed by Culturally Relevant Pedagogy (Ladson-Billings 1995), Culturally Responsive Teaching (Gay 2010;

Hammond 2014), and Culturally Sustaining Pedagogy (Paris 2012). While these
theoretical frameworks vary, they all support an asset-based approach that affirms diverse
student identities by connecting the curriculum to students' unique cultural stores of
knowledge and prior experiences. Ladson-Billings (1995) recognized the importance of
fostering the kind of critical consciousness in students that enables them to problem solve
and reason, especially about societal inequalities. Paris (2012) extended this pedagogy to
building more equitable access to opportunities for racial and ethnic communities,
arguing that schools are accountable for sustaining the communities they serve. Studies
on stereotype threat reveal that simply reminding students of their membership to certain
social groups can mitigate stigmas that lead to lower performance (Ladson-Billings 2002;
McGlone and Aronson 2006; Borman, Choi, and Hall 2020).

Assessments in counter-mapping draw on students' connection to their
neighborhood, school campus, and the broader community. Mental maps have been
shown to improve student performance and success because they help educators better
understand student values, interests, and cultures (Gillespie 2010). These maps help
teachers develop more culturally responsive instruction to make learning meaningful for
students. Asset mapping is a tool that focuses on the local resources and institutions
already doing transformative, positive work in the community. Asking students to plot
these assets spatially allows them to tap into existing asset networks and deter them from
falling victim to deficit ideology focusing on a community's problems and deficiencies.

Communities that build on their assets rather than focusing on their deficits enact
more sustainable change and gain community-wide support (Kretzmann and McKnight
1993; Mathie and Cunningham 2003; Jakes et al. 2015). Furthermore, local counter-

mapping activities in familiar places affirm student identities and extend new appreciation for the connections between people and landscapes in creating representations of places (Ladson-Billings 1995; Larsen and Harrington Jr. 2018). Using counter-maps to identify, investigate, analyze, and generate solutions to community issues will encourage students to develop their critical consciousness in how they analyze and propose solutions to spatial injustices (Ladson-Billings 1995).

Youth Counter-Mapping Research

Throughout the literature on critical geographies, children's experiences were largely neglected, especially studies of 13- to 18-year-olds (Mohan and Mohan 2013; Curtis et al. 2014). Youth represent an untapped resource in solving community problems. Participatory mapping supports development of critical spatial thinking skills and can empower young people as changemakers in their communities (Taylor and Hall 2013; Gordon, Elwood, and Mitchell 2016; Schlemper et al. 2018; 2019). This section summarizes the recent literature on mapping studies conducted on youth (ages 5 to 18) using three criteria: 1) Did youth gain or enhance spatial literacy skills? 2) Were youth engaged in mapping that increased their access to spaces and sense of belonging in their communities? 3) Did the task lead to youth-led, informed action in the community? Due to the lack of recent literature on counter-mapping with youth, studies of participatory mapping, community mapping, and sketch mapping were considered since they share some inherent qualities with counter-mapping. Table 4 visualizes the review of recent literature on participant mapping studies.

Table 4 Review of Recent Literature on Participant Mapping Studies

Spatial Thinking Skills	Access to Spaces & Sense of Belonging	Youth-led, Informed Action
Gordon, Elwood, & Mitchell (2016)	Curtis et al. (2014)	Schlemper et al. (2018, 2019)
Metoyer & Bednarz (2017)	Dennis (2006)	Solís et al. (2018)
Schlemper et al. (2018, 2019)	Gordon et al. (2016)	Solís, Anderson, & Rajagopalan (2021)
Solís, Anderson, & Rajagopalan (2021)	Reed (2019)	Taylor & Hall (2013)
Taylor & Hall (2013)	Schlemper et al. (2018, 2019)	
	Taylor & Hall (2013)	
	Wilson et al. (2019)	

Note: Studies are listed in alphabetical order by author.

Acquisition of Spatial Thinking Skills

Several studies have been conducted on how young people acquire spatial thinking skills while mapping. According to the participatory mapping study conducted by Gordon, Elwood, and Mitchell (2016), interactive digital mapping enhances critical spatial learning skills that cultivate civic engagement. Based on their study of girls at an independent school in Seattle, interactive mapping fostered critical spatial thinking skills that helped participants unpack the socio-spatial nature of oppressive systems and how to confront them. Many participants could not place their historical topic in a spatial context during the baseline activity but showed marked improvement in spatial reasoning skills throughout the study. Participants learned about the role of space in excluding and marginalizing different groups. The maps helped them visualize inequalities and conceptualize how they were produced. They could also connect historical examples of civic action to the present, including relationships to their personal lives (Gordon,

Elwood, and Mitchell 2016). This participatory mapping project strengthened students'

critical spatial thinking skills and their ability to explain how social and spatial processes

contributed to the social injustices in their world today; however, the participants did not

directly act to rectify these injustices. Additionally, the study had a small sample size

limited to only 29 girls, all attending an independent school.

Other youth-centered participatory mapping projects have noted similar growth in

spatial skills but were also conducted in workshops outside public schools with small

groups of students. In a citizen mapping project with 25 students in grades 7-12,

Schlemper and colleagues (2019) found that students expressed increased confidence in

using geospatial technologies and skills. Throughout the project, students engaged in "a

GPS treasure hunt, drone demonstration, geocaching, fieldwork in the community, and a

variety of geospatial computer games" (26). In another study, Taylor and Hall (2013)

organized a five-week bicycle workshop that engaged six young people in counter-

mapping their city's bike paths. Youth produced hand-drawn maps and Google Maps of

their neighborhoods, and this kind of hands-on work with geospatial tools enhanced

spatial literacy development (Taylor and Hall 2013). Their work supported previous

research on using geospatial technologies to improve young people's spatial thinking

abilities (Keiper 1999; Metoyer and Bednarz 2017). However, small sample sizes and

study settings in summer workshops limit the ability to reproduce these studies in public

school classroom contexts (Goodchild et al. 2021).

One study with 102 students in a tenth-grade honors world geography class in

Texas focused on the development of spatial thinking skills through geospatial

technology (Metoyer and Bednarz 2017). The study found that geospatial technology did

not improve spatial thinking skills; however, students who used geospatial technologies did perform better than students who used paper-and-pencil maps, especially male students. Metoyer and Bednarz (2017) also found that teaching through the use of GIS and other geospatial tools was most beneficial to students who already had high spatial thinking skills. There were no significant differences by gender. The study suggested that novice students require more scaffolded instruction to successfully use geospatial technologies, which is supported by cognitive load research (Kester, Paas, and Van Merriënboer 2010; Plass, Moreno, and Brünken 2010; Howarth and Sinton 2011). However, the small sample size ($n = 102$) makes it difficult to determine to what extent observed trends were due to chance. In addition, the study was limited to honors students, which are unlikely to have more school-wide representative numbers of students on individualized learning plans (IEPs), 504 plans, or English learners (ELs).

Access to Spaces & Sense of Belonging

Participatory mapping effectively assesses how young people access spaces in their communities and construct a sense of belonging. Spatial narratives, a concept proposed by Schlemper and colleagues (2018), are a tool for understanding how young people perceive their neighborhoods. Many of the borders within neighborhoods are socially constructed—invisible on traditional political maps. Only neighborhood residents understand the spatial delineation between belonging and exclusion (Peluso 1995; Curtis et al. 2014; Gordon, Elwood, and Mitchell 2016; Schlemper et al. 2018; Reed 2019). After participating in a summer workshop and conducting fieldwork, sketch maps showed that students expanded their spatial narratives and felt familiar with many of the previously unfamiliar areas where they had conducted fieldwork (Schlemper et al.

2018). Most importantly, students confronted several misconceptions about surrounding neighborhoods through fieldwork, secondary research, and mapping. Although perception mapping activities are suitable for visualizing feelings about an area, results can vary depending on directions given to participants and the types of base maps used for the study (Curtis et al. 2014). Maps of neighborhood perceptions also have limited ability to inform actual policy change (Curtis et al. 2014).

Because of their marginalized position, society often overlooks children as valuable sources of knowledge for informing policy change that could improve their access to community resources. Adults often view youth as social problems, which leads city planners to neglect personal testimonies about their experiences in public spaces. Dennis (2006) argues that qualitative GIS is a means to incorporate the narratives and experiences of young people into the decision-making process at the municipal level. Their insights offer planners important information that should be included in professionally produced maps. For example, city planners often assume abandoned buildings produce negative perceptions of neighborhoods; however, youth do not always think like professional planners. A participatory urban planning study by Dennis (2006) showed that youth often viewed vacant lots as visual reminders of broken promises by city officials to create public green spaces and community gardens. When maps included youth voices from the community, city planners gained an alternative perspective about potential interventions to improve neighborhood perceptions.

Children's perspectives could also improve access to school transportation. The literature suggests that children think differently about adults concerning their perceptions of and experiences in the same environment. Wilson and colleagues (2019)

used participatory action research and qualitative GIS to evaluate how children think about their travel to school. Community stakeholders heard directly from elementary students about their experiences. Ultimately, the study demonstrated the importance of centering children as experts in public policy research. Children assigned perceived meaning to the built environment they experienced on their journeys to school, which illuminated gaps in adult interventions, especially related to their affective landscapes (Wilson et al. 2019). Crossing guards, for example, played a crucial affective role in the school journey beyond safety. Although this study drew on the expertise of children, participants in the study did not gain any practical spatial thinking or mapping skills. In addition, participatory research designs like the one used in this study must be careful not to subvert or manipulate the process toward a predetermined end goal, especially with vulnerable and impressionable young people (Peluso 1995; Pickles 2004; Dennis 2006; Dalton and Mason-Deese 2012).

Youth-Led Informed Action

Despite several studies demonstrating the effectiveness of centering youth voices in policy change (Dennis 2006; Curtis et al. 2014; Gordon et al. 2016; Schlemper et al. 2018; Wilson et al. 2019), only two studies connected youth with local stakeholders. Schlemper and colleagues (2018) partnered youth participants with local stakeholders, and students noted that sharing their findings and making recommendations to local leaders was impactful. Talking with local stakeholders enhanced their sense of connection to the community. Through a five-week bicycle workshop, Taylor and Hall (2013) conducted a social design experiment that taught spatial literacy skills for counter-mapping to six African American teenagers in an urban environment. Youth produced

maps of their neighborhoods, mapped the city by bike, analyzed their personal time geography, and created map layers of their data. In the end, the maps that students produced helped them make meaningful sense of their neighborhood and foster new connections and a sense of belonging. These maps also imagined new ways of accessing the city that differed from the perspectives of local city planners. Urban planners incorporated youth participants in long-range planning efforts; however, the study made it unclear whether or not young people initiated those efforts (Taylor and Hall 2013). Learning progression research should consider the potential of counter-mapping to serve as a means for youth-led informed community action. However, it should do so with more participants in public school settings.

Participatory mapping through crowd-sourced geospatial tools like OpenStreetMaps (OSM) is another meaningful way for students to gain spatial literacy skills while taking informed action beyond their communities. YouthMappers is one global association of high school and college-age youth who use open-source tools to work on humanitarian projects worldwide (Solís, Anderson, and Rajagopalan 2021). Young people build their GIS literacy, gain necessary professional geography workforce skills, better understand local perspectives, and create important data that serves development aid organizations working on the ground to resolve humanitarian crises (Solem, Cheung, and Schlemper 2008; Solís et al. 2018; Solís, Anderson, and Rajagopalan 2021). However, what is known about proficiency in various spatial tools through the YouthMappers program also comes from self-reported and self-rated data. Validated assessments and proficiency scales would offer more reliable results (Anderson 2008; Huynh, Solem, and Bednarz 2015; Solem, Huynh, and Boehm 2015).

Despite the obstacle of distance, students contributed valuable and timely spatial information virtually through OSM that informed local decision-making, especially in under-mapped areas. The need for updated and accurate geospatial data is critical for officials working on development projects related to the United Nation's Sustainable Development Goals (Solís et al. 2018). While online open mapping improves student understanding of global interdependence, the research is still largely inconclusive about the degree to which student-generated data inform local decisions (Solís et al. 2018).

Considerations

Although counter-maps produce crucial insights from local stakeholders' perspectives, their application also has limitations. The power imbued in maps makes them susceptible to increasing state surveillance of marginalized groups. As Peluso (1995) noted, "local people's actual control may be enhanced by exclusion from the map" because their traditional conceptions of territoriality defy conventional political boundaries (388). In some situations, counter-mapping might establish permanent and fixed boundaries that inhibit the spatial rights of local populations. In addition, complex power dynamics marginalize the voices of young people in their advocacy for public policy change. Counter-maps produced by young people that rely heavily on qualitative data might be discredited by city planners accustomed to exercising decisions based on more traditional quantitative-driven GIS analysis (Dennis 2006). However, the absence of marginalized groups on traditional, state-drawn maps outweighs the limitations of counter-maps (Horvath 1971; Bunge 2011).

Using youth development as a conceptual framework, Dennis (2006) argued that participatory mapping in partnership with youth has reciprocal benefits for both

participants and planners. However, government and planning officials can sometimes

manipulate the participatory mapping process to serve their interests (Peluso 1995,

Pickles 2004, Dennis 2006, Dalton and Mason-Deese 2012). Dominant powers

sometimes use community members as a source of free labor in mapping projects

(Dennis 2006). A participatory action research design for spatial justice might alleviate

this power dynamic (Elwood 2009; Taylor and Hall 2013). Nevertheless, it is essential to

ensure that local authorities are not manipulating the process to produce maps that

support their interests.

This research review focused on participatory mapping, sketch mapping, and

counter-mapping with youth; however, it neglected a large body of recent research on

GIS as a tool to develop spatial thinking skills in K-12 students. Future studies on the

potential of counter-mapping with youth should more deeply consider the applications of

open-source mapping platforms and GIS. Exploration of those topics exceeded the scope

and purpose of this review.

Chapter 3:

Methods

This mixed-methods, descriptive research study explored how students employed spatial thinking skills to solve problems while engaged in counter-mapping. Quantitative methods were used first to assess spatial reasoning skills across eight different mapping missions. Then a thematic analysis of open-ended student responses analyzed how students used maps as decision-making tools. The study was guided by an in-situ approach, relying on student data to explore, validate, and revise the proposed learning progression for spatial thinking (Huynh, Solem, and Bednarz 2015). Feedback from the facilitating teacher informed modifications to the study. Ultimately, the researcher evaluated the effectiveness of the proposed progress variables, assessments, and instructional sequence in charting a path toward mastery of spatial literacy skills through counter-mapping.

The Study Setting

Descriptions of the study setting were left intentionally vague to protect the welfare of vulnerable child subjects as stipulated by the University of Northern Iowa Institutional Review Board protocol #23-0001. Citations identifying the location or student population have been obscured and aggregated to the state level. Counter-maps displaying sensitive locational data have obscured base maps that have been altered from the original student-created map.

Community

The study was carried out in a large Iowa school district in an urban setting, but the district includes portions of surrounding rural areas. The high school is situated in an

industrial river town with a population of over 23,000 residents. Most residents identify as White alone, not Hispanic or Latino (73 percent). A thriving, long-standing Latino community that makes up nearly 20 percent of the population. Additionally, recent migrant communities from West Africa are well-represented in local businesses and churches. The 2022 average household income was below state and national levels, and roughly 16 percent of residents were impoverished. This community is growing more racially and ethnically diverse than the state average. Like many other school districts across the United States, students in this district are more ethnically and racially diverse than the communities where they live ("U.S. Census Bureau QuickFacts: Iowa" 2022).

School District

The school district consists of one early childhood learning center (Pre-K), six elementary schools (K-6), one junior high school (7-8), and one high school (9-12). Approximately 4,400 students enroll in the district each year. Students are predominantly White, and there is a substantial Latino population. Students with disabilities (those on an IEP or 504 plan) compose 13.1 percent of the student population, and English learners (EL) make up 5.4 percent of the district body. Nearly half of all students in the district are enrolled in free and reduced lunch, an indicator of low socioeconomic status. Overall, students in the district average below the 50th percentile in English Language Arts and Mathematics achievement. Within the school district, the high school is the lowest-performing building ("Iowa School Performance Profiles" 2022).

High School

The study took place in a large Title I high school in Iowa with an enrollment of roughly 1,500 students in grades 9-12. Title I schools are those "in which children from

low-income families make up at least 40 percent of enrollment" ("Title I, Part A Program" 2018, 1). As a result, this school can use federal funding to support schoolwide programs intended to boost achievement. There are nearly 100 full-time staff, and most are career teachers on a standard license. Approximately 17 percent of teachers are on an initial license in their first two years of teaching. Staff retention falls slightly below the state average. Students in the school are predominantly White (64 percent), with a sizeable Hispanic and Latino population (28 percent). About 10 percent of students are on an individualized education plan (IEP), 6 percent are English learners (EL), and 43 percent are on free and reduced lunch. Compared to the state average, students at this high school are more racially and ethnically diverse and have slightly higher rates of free and reduced lunch ("Iowa School Performance Profiles" 2022).

In Iowa Department of Education rankings, the high school received a Priority rating—the lowest category in the Every Student Succeeds Act (ESSA) rating framework. ESSA categories offer a snapshot of school performance and also identify student groups that are underperforming ("Every Student Succeeds Act (ESSA)" 2022). While all students underperform compared to the state average and national targets, several subgroups of students at this school have been identified by ESSA as below the benchmark. English learners, students on free and reduced lunch, students with disabilities, and Black and Latino students score much lower than the rest of the student body across all measures of achievement. Underachievement was particularly pronounced among these subgroups of ninth-grade students, the population from which this study drew its participants ("Iowa School Performance Profiles" 2022).

Classroom & Study Participants

Students participating in this study were enrolled in a freshman-level, year-long social studies course. Class sizes ranged between 25 to 30 students across six different periods during the school day. The teacher, a White male, had 14 years of teaching experience; however, this was his first time teaching a geography class. All students had personal Chromebook computers provided by the district and free access to Esri's ArcGIS Online software. For most students, this semester was their first time enrolled in a geography class. In the district, students do not have a stand-alone period dedicated to social studies until seventh grade. During that year, students take a global studies class, and in eighth grade, they learn about civics and United States history. As a result, students enter this ninth-grade course with few prior opportunities to gain geographic knowledge or practice spatial thinking skills.

Two groups of students were involved in the curriculum pilots, one in the first nine weeks of the fall semester and the second in the last nine weeks. Tables 5, 6, and 7 provide an overview of student participants by pilot group, gender, and race.

Table 5 Frequency Table: Pilot Group

	Frequency	Percent
Pilot Group 1	30	65.2
Pilot Group 2	16	34.8
Total	46	100.0

Table 6 Frequency Table: Gender

	Frequency	Percent
Female	28	60.9
Male	16	34.8
Nonbinary	2	4.3
Total	46	100.0

Table 7 Frequency Table: Race

	Frequency	Percent
Asian	2	4.3
Black	1	2.2
Latino	11	23.9
White	32	69.6
Total	46	100.0

Instruments for Data Collection

Three instruments were created to assist the researcher in evaluating the proposed learning progression.

1. Learning goals and progress variables were developed to assess students' understanding of three spatial thinking skills.

2. Assessments were developed to reveal the level of understanding of the progress variables at various points during the learning journey. Those assessments were linked to an instructional sequence that served as a helpful guide to the facilitating teacher in implementing the curriculum. In addition to the instructional sequence, the researcher proposed a hypothetical learning pathway through the counter-mapping missions.

3. Two surveys with open-ended reflection questions were created to gather data about the extent to which students viewed maps as decision-making tools.

Learning Goals & Progress Variables

This pilot study charted the pathways high school students took to master the concept, design, and application of counter-mapping using proficiency scales to assess their level of understanding. The nine-week curriculum to support counter-mapping was designed with the aims of 1) building spatial literacy skills, 2) increasing student access to community resources, and 3) assessing how students act on social justice issues in their community. Because no tool for assessing these learning objectives existed, the researcher identified upper anchors and progress variables based on well-researched and field-verified standards in geography, spatial thinking, and civic action (National Research Council 2006; Heffron and Downs 2012; National Council for the Social Studies 2013).

The second edition of *Geography for Life: National Geography Standards* (Heffron and Downs 2012) served as a framework for designing the scaffolded learning goals, the instructional sequence, and the assessments that revealed the level of understanding in the learning progression. The curriculum design was also informed by the spatial knowledge, skills, and capabilities outlined in *Learning to Think Spatially*, which identified three essential characteristics of spatially literate students. First, students develop a "habit of mind of thinking spatially" (National Research Council 2006, 4). Second, students "practice spatial thinking in an informed way," demonstrating their ability to use and reason about spatial representations, tools, and technologies (4). Third, students can "adopt a critical stance to spatial thinking," which means they can use

spatial data as a decision-making tool to solve social problems (4). As a result of these three capabilities, students can describe, analyze, and infer about the appearance, relationship, structure, and function of spatial phenomena. These are essential spatial dispositions students need to produce counter-maps.

The three national geography standards embedded within Essential Element 1: The World in Spatial Terms provide a framework for teaching and learning about the three foundational spatial thinking skills identified in *Learning to Think Spatially* (2006): the nature of space, the use of geographic representations for communication, and how to employ geographic reasoning to solve problems. Because they encompass a variety of spatial thinking skills, several educational reports recognize these standards critical role in informing new research on geography learning progressions (Bednarz, Heffron, and Huynh 2013; Solem, Huynh, and Boehm 2015). In addition, Dimension 4 of the C3 Framework Inquiry Arc was adapted to evaluate how students use counter-maps as a decision-making tool to take informed action in the community.

The research methodology must be replicable to understand better the pathways students take to mastering spatial thinking, (Goodchild et al. 2021). Using *Geography for Life*, *Learning to Think Spatially*, and the C3 Framework provides a familiar set of standards for geographers and educators across the United States, regardless of the school setting (Heffron and Downs 2012; National Research Council 2006; National Council for the Social Studies 2013). These three documents offer the most comprehensive and reliable body of literature on student learning in geography but "require further validation studies with students, in order to test the reliability of students' thinking against the progressions developed" (Huynh, Solem, and Bednarz 2015, 70). This study offers an

excellent opportunity to validate students' spatial literacy against the proposed counter-mapping learning progression.

With the three spatial thinking standards from *Geography for Life* as the upper anchor, the researcher used Webb's Depth of Knowledge model and Hess's cognitive rigor matrix to construct four increasingly sophisticated levels of understanding (Webb 2002; Hess et al. 2009). The *Geography for Life* standards largely adhere to seven verbs of increasing complexity that fit well within Bloom's cognitive taxonomy (Marran 1995); however, many of the verbs appear across several levels, making it challenging to determine complexity (Hess et al. 2009). Webb's Depth of Knowledge (DOK) model deconstructs the conceptual understanding and skill required to achieve a cognitive task from start to finish, making it a good fit for the kind of geographic inquiry required for counter-mapping (Hess et al. 2009). The cognitive rigor matrix proposed by Hess et al. (2009) connects the two frameworks, juxtaposing Bloom's level of cognitive processing for novel tasks with Webb's depth of content understanding. Incorporating Webb's model enables researchers and educators to evaluate complex reasoning skills that require decision-making on the part of the student. For example, level four of Webb's DOK in social studies requires complex reasoning, planning, and investigation over an extended period of time (Webb 2002; Hess et al. 2009). A simple on-demand assessment is unlikely to allow students to demonstrate level four, extended thinking (Webb 2002); however, a more complex and nuanced task like developing a counter-map would certainly encourage students toward that domain.

The four levels in the proficiency scales that follow were informed by Webb's Depth of Knowledge for Social Studies and Hess's cognitive rigor matrix (Webb 2002;

Hess et al. 2009). Level 1 required students to identify specific information based on a map, chart, table, graph, or other visual. Level 2 engaged students in basic reasoning, asking them to describe or interpret "how" or "why." Level 3 required complex reasoning and incorporation of evidence to thoroughly justify "how" or "why" certain geographic phenomena occur. At this level, students can draw conclusions. Level 4 involved extended reasoning over a long period of time to synthesize information from multiple sources, perspectives, and scales across time and place to enact solutions.

Each sub-section below provides a brief overview of the four standards assessed, along with a table outlining the hypothesized developmental progression toward the upper anchor. Each table also shows the pathways the researcher anticipated students might take on their way to mastery of the standard. These proficiency scales became the scoring guidelines for student assessments discussed in the next section. Proficiency scales provided information about students' pathways as they learned about and practiced counter-mapping. Appendix C contains a table with standards aligned to each question of every mapping mission.

Using Maps Overview. The upper anchor of the Using Maps standard required students to communicate a solution to a spatial problem using a counter-map. In the early missions of the instructional sequence—Missions 1, 2, and 3—students were introduced to increasingly complex lessons that taught them about the properties and functions of maps. Missions 4 and 5 exposed students to new forms of geographic representations, collection of geographic data, and problem-solving through spatial analysis. Mission 6 allowed students to explore the real-world application of counter-maps through case

studies, while Missions 7 and 8 provided students with a scaffold for creating their own counter-maps. See Table 8 for reference.

Table 8 Progress Variables: Using Maps

NGS 1: Using Maps & Geographic Representations Students know how to use maps and other geographic representations, geospatial technologies, and spatial thinking to understand and communicate information.		
Level	**Progress Variable**	**Assessment**
4	<u>Communicate</u> a solution to a spatial problem using a counter-map.	Mission 4, 8
3	<u>Analyze</u> a variety of spatial data collected from observations and external sources to ask and answer questions about spatial patterns in the surrounding area.	Missions 4, 5, 7, 8
2	<u>Describe</u> uses for different types of geographic representations.	Missions 2, 3, 4, 5, 6, 7
1	<u>Identify</u> the properties and functions of maps, geographic representations, and geospatial data.	Missions 1, 2, 3, 6
0	No evidence of understanding.	Mission 1

Mental Maps Overview. The learning goal of the Mental Maps standard was for students to create mental maps that helped them make sense of complex spatial relationships in their community. Table 9 shows the increasingly sophisticated progress variables students might demonstrate as they learn to use mental maps. Mission 1 was the only assessment that explicitly asked students to generate mental maps; however, the researcher hypothesized that students might use them to visualize their geo-inquiry question in Mission 7 or their counter-map topic in Mission 8. No students in the study chose to use mental maps without prompting. Unlike the longitudinal analysis of all the other standards, the results chapter presents the student data collected from only Mission 1: Mental Maps for analysis.

Table 9 Progress Variables: Mental Maps

	NGS 2: Using Mental Maps to Understand the Nature of Space Students know how to use mental maps to organize information about people, places, and environments in a spatial context.	
Level	**Progress Variable**	**Assessment**
4	<u>Create</u> an image of your community that integrates the locations, characteristics, patterns, and relationships of features, places, and regions to answer geographic questions.	Missions 7, 8
3	<u>Compare</u> the mental maps of different individuals to identify common factors that influence spatial understanding, perceptions, and preferences.	Missions 1, 6
2	<u>Interpret</u> the geographic information derived from mental maps, such as locations, patterns, and characteristics of physical and human features.	Mission 1
1	<u>Identify</u> and <u>draw</u> from memory landmarks, routes, and boundaries in the school and community setting.	Mission 1
0	No evidence of understanding.	Mission 1

Spatial Analysis Overview. Students achieved the upper anchor of the Spatial Analysis standard when they synthesized various data to describe the consequences of spatial organization. Table 10 shows the progress variables and standards. Early on, when students were learning how to analyze maps, the researcher anticipated they could only describe familiar places using spatial primitives. Mission 1 allowed students to do this with mental maps, and Mission 2 focused on drawing the school campus. Missions 3, 4, and 5 enabled students to create three maps about their community and required them to analyze the patterns and trends. Mission 6 exposed students to complex counter-maps that told stories of human experiences. At the end of the progression, in Missions 7 and 8, students conducted their own spatial inquiry based on a topic of interest. Only in Missions 4, 5, and 8 were there enough data for students to truly synthesize from multiple

sources to make an evaluation. In the final mission, the researcher anticipated most students would reach the upper anchor.

Table 10 Progress Variables: Spatial Analysis

NGS 3: Doing Spatial Reasoning & Analysis Students know how to analyze the spatial organization of people, places, and environments on Earth's surface.		
Level	**Progress Variable**	**Assessment**
4	<u>Synthesize</u> data from multiple sources in order to understand the consequences of the spatial organization of human and/or physical systems in a location.	Missions 4, 5, 8
3	<u>Analyze</u> the processes that influence the distribution and interaction of human and physical processes.	Missions 3, 4, 5, 6, 8
2	<u>Describe</u> patterns and trends in the spatial distributions of people, places, and environments.	Missions 3, 4, 5, 7
1	<u>Describe</u> the spatial organization of a familiar place using the concepts of distance, direction, and location.	Missions 1, 2, 3, 4, 5
0	No evidence of understanding.	Mission 1

Taking Informed Action Overview. Taking informed action base on synthesis of geographic data is the upper anchor of the C3 Inquiry Arc standard. Table 11 shows the progress variables and the assessments that guide students there. Reaching the upper anchor required students to work through the inquiry process, grapple with complex spatial problems, and arrive at a solution. The extended nature of the inquiry process is why the researcher hypothesized that students would not be able to reach Levels 3 and 4 until Mission 8, when they conducted their own geographical investigations. Missions 1 and 2 had students practice new mapping skills in familiar locations. Mission 3 was the first time when students mapped community assets. Missions 4 and 5 required students to critically investigate the distribution of murals and air pollution in their community.

Students were also put in hypothetical situations where they could use the map to propose

a potential action. In Mission 6, students chose a counter-map case study adapted from

This Is Not An Atlas to understand how counter-maps could be used to take informed

action (Kollektiv Orangotango+ 2018; Appendix A). At the end of the instructional

sequence, students were asked to generate their own geo-inquiry question (Mission 7)

and present a solution (Mission 8).

Table 11 Progress Variables: Taking Informed Action

C3 Inquiry Arc, Dimension 4: Communicating Conclusions & Taking Informed Action Students can engage in the inquiry process to apply new knowledge to real problems.		
Level	**Progress Variable**	**Assessment**
4	Take informed action based on the synthesis of the geographic data.	Mission 8
3	Apply geographic knowledge to inform or advocate about a community problem.	Mission 8
2	Describe potential actions or solutions to a community problem.	Missions 3, 4, 5, 6, 7, 8
1	Identify community assets and/or problems.	Missions 3, 4, 5, 7
0	No evidence of understanding.	Missions 1, 2

Assessments & Proposed Instructional Sequence

Learning goals and progress variables informed the development of an

instructional sequence, introducing increasingly complex skills throughout the course

(Golledge 2002; Solem, Huynh, and Boehm 2015). A series of nine mapping missions

were developed, culminating in an opportunity for students to share their counter-maps

with stakeholders. Table 12 provides a description of each mapping mission, the learning

tasks, and the anticipated standards students might use while completing the mission.

Table 12 Proposed Instructional Sequence

Assessments	Tasks	Anticipated Standards
1: Mental Map	Draw, describe, and analyze a mental map of your community from memory. Compare your map with a classmate.	NGS 1, 2, 3 C3 Inquiry
2: Campus Map	Identify the properties of maps and describe their purposes by mapping the school campus. Compare your map with the official school map.	NGS 1, 3 C3 Inquiry
3: Asset Map	Create and analyze an asset map of community resources and institutions. Consider how community organizations might use this map.	NGS 1, 3 C3 Inquiry
4: Mural Map	Collect images and coordinates of murals. Then plot and analyze them in ArcGIS Online using a heat map, buffers, and demographic layers. Use the map to determine the best location for a new mural.	NGS 1, 3 C3 Inquiry
5: Environmental Justice Maps	Analyze the extent to which environmental justice exists in the community using maps, graphs, and interactive GIS web maps.	NGS 1, 3 C3 Inquiry
6: Counter-Map Case Study	Choose a counter-map to study from *This is Not an Atlas*. Describe alternative ways to represent place and the connections between landscapes and people.	NGS 1, 3 C3 Inquiry
7: Geo-Inquiry Questions	Formulate a compelling geographic question to guide and plan an inquiry in the community.	C3 Inquiry
8: Counter-Map Draft	Construct a model, map, or other geographic representation to organize, visualize, analyze, and evaluate data collected on the geo-inquiry question.	NGS 1, 2, 3 C3 Inquiry
9: Counter-Map Final	Present your counter-map to your classmates and local stakeholders. Explain how it should be used to make positive change in the community.	NGS 1, 3 C3 Inquiry

Missions began at an individual-level scale and panned out to the community scale. This sequence allowed students to learn spatial concepts with familiar neighborhood phenomena first and then work toward less familiar, community-wide investigations. Students started the learning progression by making mental maps, maps of their school campus, and community-wide maps. Early in the course, students had opportunities to learn about the properties and functions of maps and the spatial organization of local places. Later, they learned to collect and analyze data to use in counter-maps that communicated answers to spatial problems. The mapping missions help to answer the primary research question, *how do students learn spatial literacy when counter-mapping?* Appendix A contains the entire body of missions created for the study.

These missions allowed students to exercise spatial reasoning skills, which they expressed in their writing. Missions were evaluated using the proficiency scales developed for each of the four standards to determine the level of sophistication ranging from Levels 0 through 4. Before the study, the researcher proposed standards that students might employ at each mission in the progression; however, other standards were assessed if students demonstrated them in open-ended responses. The goal of this study was not to rigidly define the steps students must take to master spatial literacy but rather to use student data to gain knowledge of the various journeys students take toward mastering counter-mapping (Huynh, Solem, and Bednarz 2015). Overall, the study aimed to elaborate upon the upper anchors, lower anchors, and messy middle of the learning progression.

Qualitative Assessments

Open-ended student surveys were used to evaluate the supporting research question, *to what extent do students use counter-maps as decision-making and problem-solving tools?* These responses were administered after each mapping mission, allowing students to 1) reflect on their progress and 2) explain how maps can be utilized in the community. Upon course completion, students were asked what they were doing with their maps to facilitate decision-making in their target community. Paramount in this culminating reflection was the reasoning that students used to arrive at and justify their decisions in constructing the counter-map. Qualitative analysis of these student responses provided an understanding of the extent to which students used their maps to take informed action on an issue in the community. Community action was not inherently embedded in the learning progression design. Table 13 provides a visual of the four questions for qualitative analysis asked after each mission. Table 14 displays the end-of-course survey. These questions provide a student-centered narrative of the learning journey that will inform revisions of the proposed learning progression.

Table 13 Prompts for Qualitative Analysis

1	What was the goal of this mission?
2	How did you go about accomplishing it?
3	What did this mission teach you about geography?
4	How could you use what you learned in this mission in the community?

Table 14 End-of-Course Reflection

1	What problem was your map trying to solve? Or what story was it trying to tell?
2	Based on your map, what is the solution to the problem?
3	How could someone use your map to make decisions or improvements in the school or community?
4	Are you doing anything with your map to take action on an issue in the community? (Yes) (No) (Maybe in the future) (Other…)
5	How are you using your map to take action on an issue?

Note: If students answered Yes, Maybe in the future, or Other… to 4, they were prompted to answer 5.

Research Design Procedures & Guiding Theoretical Frameworks

The study was carried out in four phases: the development of instruments for data collection, the first pilot study, the second pilot study, and data analysis. Work with participants began in late August 2022 and ended in mid-January 2023 at the conclusion of the fall semester. Table 15 details the timeline for developing instruments, collecting student data, and analyzing results.

Table 15 Timeline for Study & Data Analysis

Develop Instruments for Data Collection	Data Collection: Pilot Group 1	Data Collection: Pilot Group 2	Data Analysis & Evaluation
April – August 2022	August – October 2022	November 2022 – January 2023	January – March 2023
Identify low and high anchors and then determine four levels of understanding for each learning goal: NGS 1, NGS 2, NGS 3, and C3 Inquiry.	Launch the learning progression with Pilot Group 1.	Launch the learning progression with Pilot Group 2.	Finish scoring the data and check for inter-rater reliability. Analyze the quantitative data for the level of spatial understanding and spatial reasoning.
Create learning activities, and build the assessments for quantitative and qualitative data collection.	Carry out observations to ensure consistency of implementation. Engage in planning discussions with the facilitating teacher to develop responsive learning interventions and offer feedback on instructional delivery and pacing.	Carry out observations to ensure consistency of implementation. Engage in planning discussions with the facilitating teacher to develop responsive learning interventions and offer feedback on instructional delivery and pacing.	Examine the qualitative reflections for the use of maps as decision-making tools.
Develop an instructional sequence tied to assessments, standards, and progress variables.	Collect quantitative and qualitative assessments after the Quarter 1 grading period.	Collect quantitative and qualitative assessments after the Quarter 2 grading period.	Develop a codebook for thematic analysis of student survey data. Check for inter-coder reliability.
Secure IRB approval for the study.		Begin scoring student missions and assigning scores based on the progress variables for each standard.	Conduct statistical comparisons of the pilot groups to determine whether to disaggregate data or analyze it as a whole.
		Develop a codebook for quantitative analysis.	

Participation in the study was entirely voluntary, and additional measures were taken to protect students since they are considered a vulnerable population by the Institutional Review Board (IRB). Recruitment for the study began on the second full day of class when the researcher provided an in-person overview of the research study using a script, inviting students to ask questions (see Appendix B for the script). The goal of the in-person overview was to mitigate undue influence on students, ensuring they understood that they were free to decide about their participation and that their decision would not impact their grades or treatment in class. All students would perform all class activities, whether they opted into the study or not. Students were sent home with paper copies of the consent form, and an email invitation was sent directly to parents and guardians with the forms attached electronically.

Both student assent and guardian consent were required for students to be included in the study population. Student assessments and reflections were collected on paper, with all identifying student information removed by the classroom teacher. All students enrolled in the study were assigned a Study ID. Demographic information was provided by students in an anonymous survey about their age, grade level, gender identity, and race and ethnicity using their assigned Study ID. This demographic information was used during analysis to investigate if gaps that appear by gender and race in other geography education research also showed up in this study (Solem 2021). All IRB forms can be found in Appendix B.

Planning Discussions & Observations

This study used an in situ approach, using student data and teacher feedback to inform revision of the learning progression (Huynh, Solem, and Bednarz 2015; Larsen et

al. 2018). Resources and instruments were developed by the researcher and implemented by the facilitating teacher. The researcher and facilitating teacher met weekly to discuss lesson plans, how to implement the data collection instruments, and to troubleshoot any problems that arose throughout the study. The researcher spent one or two days in the classroom observing nearly every week. The facilitating teacher made every effort to implement the assessments as designed; however, he made minor adjustments and modifications to be responsive to students' needs and time constraints. Teacher feedback was invaluable to the research process.

As a result of these collaborative discussions, students were only assessed on eight mapping missions rather than the nine planned. Mission 8 and Mission 9 were identical, asking the same questions of students. The goal of assessing students twice on the same skills was to gather information about how students might change their thinking while working on their final counter-mapping projects. Due to time constraints and the need to slow down pacing to meet student needs, data was gathered only once using the Mission 8 form after students completed their final counter-maps. Eliminating Mission 9 from the study did not fundamentally alter the learning progression. This change remained consistent across both pilot groups.

Collaborative conversations between the facilitating teacher and researcher strengthened the instructional methods used to deliver the content and helped the researcher understand ways to improve the data collection tools. Learning interventions were designed to help students work on spatial analysis skills through a series of bell-ringers. The end-of-course survey was modified to ask students how they were using their

maps to take action. Overall, the collaboration allowed for better contextualizing of the research within the classroom environment (Larsen et al. 2018).

Methods for Data Analysis

This mixed methods study combined quantitative and qualitative methods to provide a comprehensive understanding of students' learning pathways to master spatial thinking skills and how they used counter-maps to solve problems. This subsection begins with a justification for combining pilot groups. Median, standard deviation, trendlines, and nonparametric tests for association and signed rank were used to analyze the mapping assessment data. Student reflections were coded and analyzed using thematic analysis. Inter-rater and inter-coder reliability ensured the consistency and validity of the data. Two geography education professors and one graduate student with teaching experience independently assessed a random sample of 25 percent of the data to ensure consistency of findings. Figure 1 depicts a chart of the quantitative methods and procedures, and Figure 2 shows the workflow for qualitative methods.

Figure 1 Quantitative Methods for Data Analysis
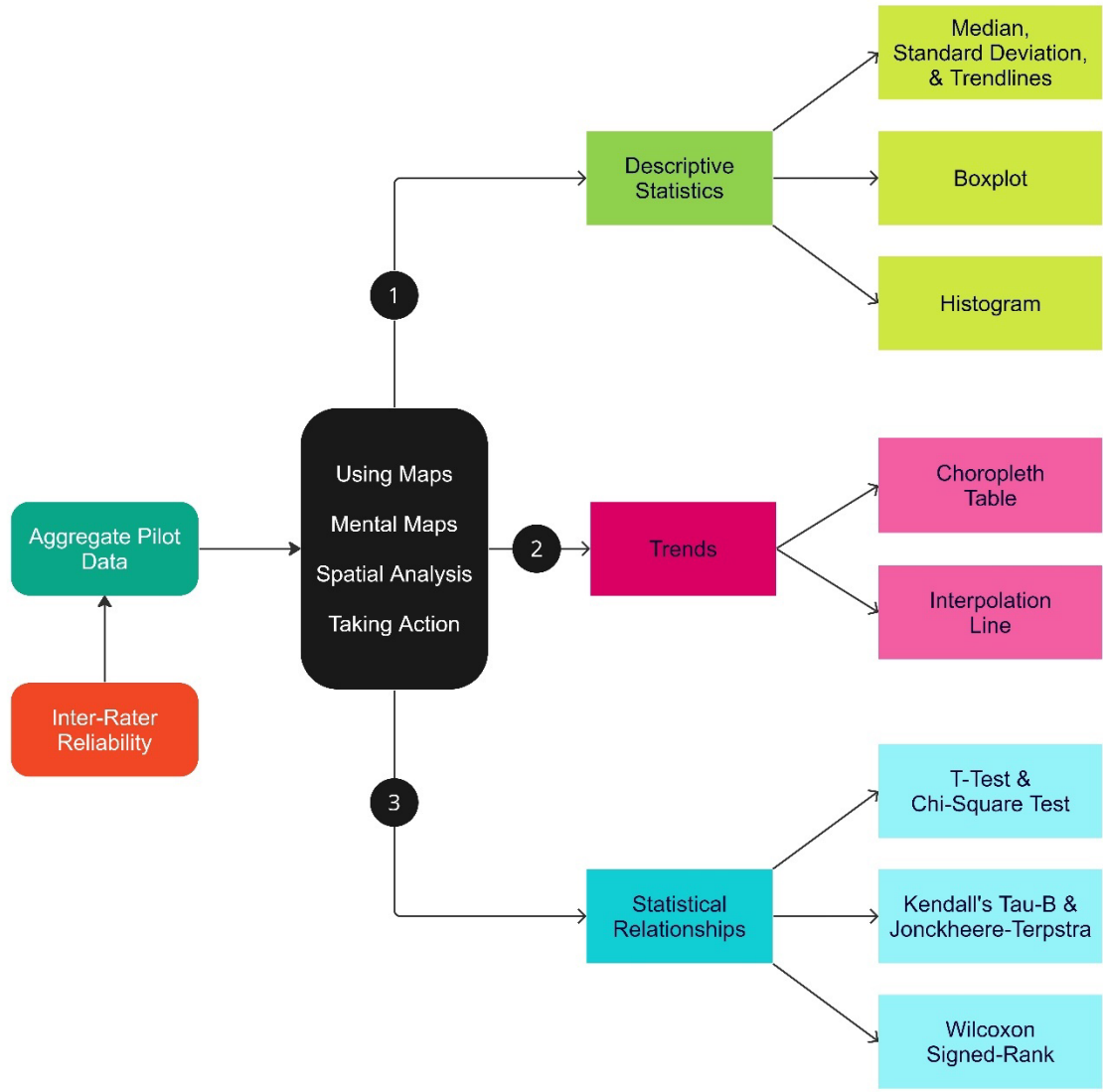
Figure 2 Qualitative Methods for Data Analysis: Thematic Analysis

1	2	3	4	5	6
Familiarize	Initial Codes	Search for Themes	Review Potential Themes	Define & Name Themes	Report Results

Read 1: Scoring

Read 4:
Assigned Codes & Memos

Patterns
Descriptive Statistics &
Code Map

Relationships
Code Relationship Browser
& Code Map

Theme 1:
No Understanding

Read 2: Notes

Theme 2:
Reference Tool

**Answer the Supporting
Research Question:**

*To what extent do students
use counter-maps as
decision-making and
problem-solving tools in
their community?*

20
Community
Codes

9
Process
Codes

7
Community
Themes

7
Process
Themes

4
Community
Themes

Theme 3:
Communication Tool

Read 3: Transcribing

Theme 4:
Decision-Making Tool

Pilot Groups

Before any data analysis was performed, the researcher had to consider whether to examine the results of the two pilot groups separately or as a whole. Differences between the two groups were assessed based on sample size, completion rate, average mission scores, and demographic composition. Results showed Pilot Group 2 had a much smaller sample size ($n = 16$) than Pilot Group 1 ($n = 30$). The significant difference in sample size was a product of the timing of Pilot Group 2, which began mid-semester when access to guardians was more difficult, making it challenging to collect consent forms. Guardians in Pilot Group 1 were contacted during the back-to-school week when families often visit the building, talk with teachers, and complete other consent forms for the school district. Correspondence with guardians in Pilot Group 2 also occurred amidst a disruption in the regular school calendar during parent-teacher conferences.

An independent samples t-test showed no significant differences in completion rate ($P = .813$) or average mission scores ($P = .483$) by the pilot group. Because there were two pilots, the facilitating teacher had more experience and familiarity with the instructional sequence and assessments in the second pilot group. Mission scores did not differ significantly between the two groups, which suggested that teacher familiarity with the learning material was not a factor affecting student outcomes. Students in Pilot Group 2 scored slightly higher ($\bar{x} = 1.62$) on average compared to students in Pilot Group 1 ($\bar{x} = 1.54$), but this difference was not statistically significant ($P = .479$). Looking more closely for differences between pilot groups by individual standard scores produced only one significant difference out of 25 total assessments. An independent samples t-test

revealed that the Using Maps standard on Mission 7 ($P = .046$) showed statistically significant differences by pilot group.

A Chi-square test was used to look for differences in the distribution of genders and racial identities between the two pilot groups. An analysis of the p-values showed no significant difference by gender between groups ($P = .569$); however, there was a significant difference between pilot groups when comparing the distribution of racial and ethnic groups ($P = .047$). Combining pilot groups produced a more demographically representative sample of the high school. Figure 3 presents a visual comparison of demographic data. In Pilot Group 2, White and Asian students were dramatically overrepresented compared to the school population, while Latino students were severely underrepresented. Although combining pilot groups did not produce a perfectly representative sample, it remedied that problem best, used all available data, and had the added benefit of a larger sample size to strengthen statistical power.

Ultimately, no significant differences in student performance suggested a problem with aggregating pilot groups. As a result, pilot groups were combined into one study population of 46 participants to maintain a large enough sample size to conduct significant statistical analysis. Of the 46 cases, only 11 were complete. Some cases had up to 20 percent missing data. For that reason, pairwise comparisons were used to include all data available in each analysis, and statistical significance was only reported for the study if it exceeded the 5 percent level ($P < .050$). Statistical tests were chosen based on their ability to minimize the adverse effects of small sample sizes and missing data.

Figure 3 Study Demographics vs. High School Demographics

	Asian	Black	Latino	White
High School	0.7	4.2	28.1	63.8
Both Pilots	4.35	2.17	23.91	69.57
Pilot 2	12.5	0	6.25	81.25
Pilot 1	0	3.3	33.3	63.3
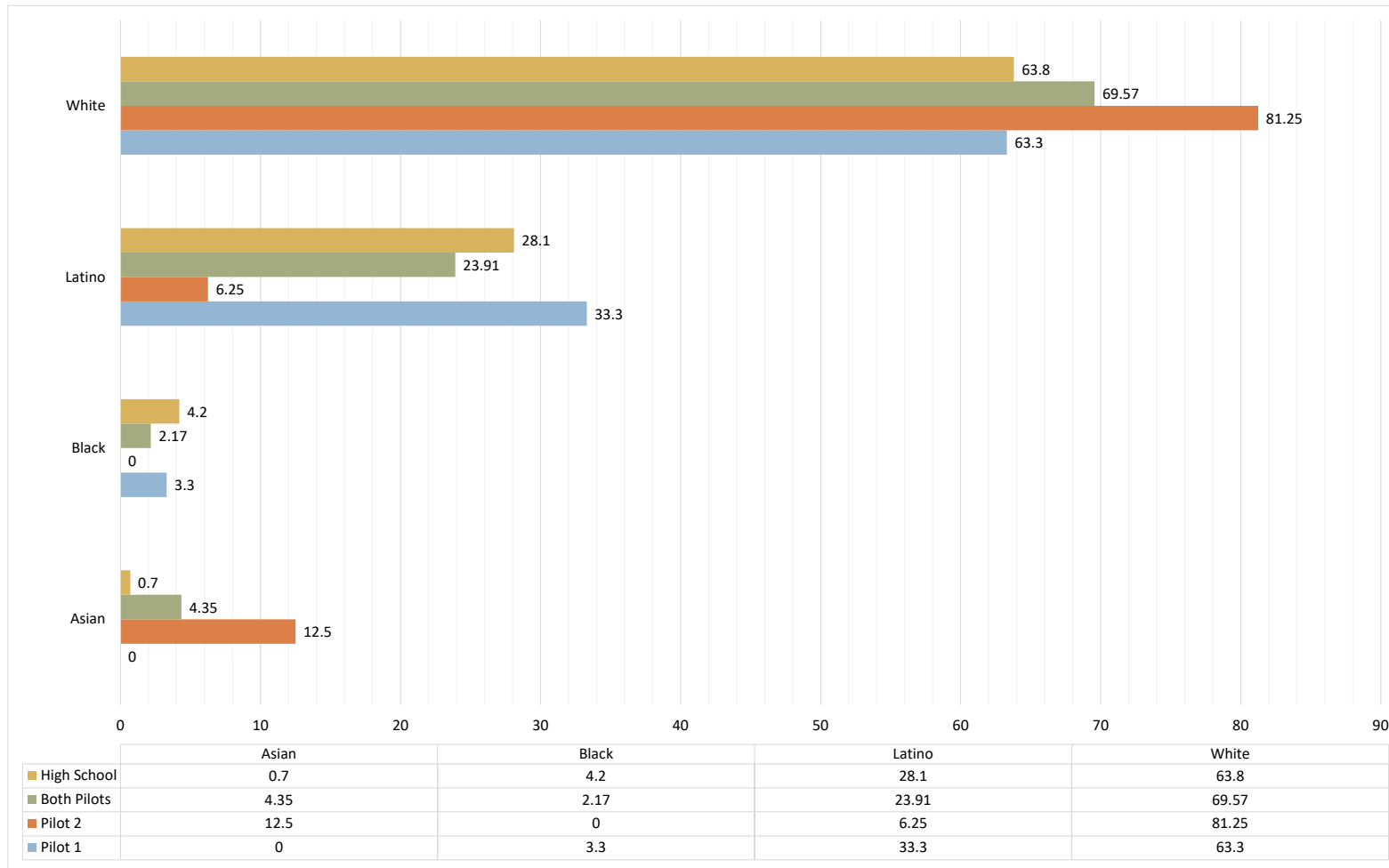
Note. Values are reported as percentages (%).There were no participants in the study who identified as Native American, Multi-Racial, or Hawaiian/Pacific Islander, yet those populations were present in the high school student body.

Quantitative Methods: Spatial Literacy Through Counter-Mapping

Median, standard deviation, trendlines, and nonparametric tests for association and signed rank were used to analyze student data on each mapping mission standard. In total, 25 different scores were reported across eight mapping missions using the proficiency scales. Mission 1 required students to produce, interpret, and compare mental maps, and it was the only mission that captured a snapshot of student learning on all four standards—Standard 1: Using Maps, Standard 2: Mental Maps, Standard 3: Spatial Analysis, and Standard 4: Taking Informed Action. Missions 2 through 8 did not require students to produce mental maps, and no students voluntarily employed mental maps as a strategy in those missions. As a result, Missions 2 through 8 were assessed on only three standards—Standard 1: Using Maps, Standard 3: Spatial Analysis, and Standard 4: Taking Informed Action.

A paper scorecard (see Appendix C) was used to manually capture student scores as the researcher read through student work on each of the eight mapping missions. Student missions were assigned a score from 0 to 4 based on the proficiency scales developed before the study. Those scores were validated using inter-rater reliability and then entered into SPSS, a data analytics software (IBM Corp 2021). Variables were created for each standard assessed within a mission, the average student score on each standard, and the overall completion rate. Appendix C contains all variables by type used to run the analysis in SPSS. The complete codebook for analysis is also in Appendix C.

Sample size, median, standard deviation, minimum, and maximum values were calculated for each standard score by mission and visualized in a descriptive statistics table. Sample size provided pertinent information about missing data. The median

measured central tendency because the values represented ordinal variables tied to five

different progress variables, not continuous numerical data. The median is also more

resistant to outliers, and none of the student scores in any standard were normally

distributed ($P \leq .002$) using the Shapiro-Wilk test of normality (see Appendix C for

outputs of the test). The medians and standard deviations for each score provided a

snapshot of student learning at each milestone in the learning progressions and how much

variability there was in those scores. Boxplots and histograms provided visual

representations of the distribution of the data over time and identified any outliers.

A choropleth table and interpolation line visualized student learning pathways on

each standard. First, the choropleth table assigned shaded values to student results on

progress variables to visualize patterns and trends by mission (see Appendix D). Then, an

interpolation line was created from a scatterplot of student data to visualize how data

changed at each mission.

Two nonparametric tests looked for statistical differences and associations

between scores. First, Kendall's tau-b (τ_b) correlation coefficient checked for the strength

and direction of association between Mission 8 scores within each standard and all the

missions leading up to it. It also examined associations between gender, race and

ethnicity, and assessment scores. This test works particularly well with small sample

sizes ($n < 50$) of ordinal data, so it was chosen over Spearman's rank correlation

coefficient test. Missions within each standard were compared for significance and effect

size, which prompted further analysis of the association's strength, direction, and

magnitude. Table 16 displays the adjectives used to standardize the description of the

association from 0 (no association) to 1 (perfect association) (Botsch 2011). Positive and

negative τ_b values describe positive and negative associations, respectively. Two-tailed

tests determined level of significance since there was no expectation for the direction of

association between variables. Analysis of Kendall's tau-b checked for relationships

between assessments prompting further exploration and investigation of placement in the

learning progression.

Table 16 Strength of Relationship for Kendall's Tau-B

τ_b	Strength of Association
±0.10 or lower	Very weak
± 0.25 to 0.34	Weak
± 0.35 to 0.39	Moderate
± 0.40 or higher	Strong

Next, a Jonckheere-Terpstra post-hoc test for ordered alternatives identified which

gender or racial and ethnic groups differed significantly on assessments. This test was

chosen for its ability to use the ordinal nature of the proficiency scales to identify

statistically significant monotonic trends (Kraska-Miller 2013). Because information

collected on gender contained three categories and race and ethnicity contained four

categories, the Jonckheere-Terpstra test was chosen over the Mann-Whitney U test,

which is more commonly used for comparing variables with two categories. The data met

all six test assumptions, outlined in Table 17. The Bonferroni correction was used to

report adjusted significance values to reduce the likelihood of false positives while

performing multiple hypothesis tests on the dataset (Armstrong 2014).

Table 17 Assumptions for Jonckheere-Terpstra Post-Hoc Test

	Assumptions	Study Data
1	*One continuous or ordinal dependent variable*	Mission assessments measured at the ordinal level with five categories (0, 1, 2, 3, 4).
2	*One ordinal independent variable with 2+ groups*	Gender contained three groups (female, male, nonbinary) and race/ethnicity contained four groups (Asian, Black, Latino, White).
3	*Independence of observations*	No study participants belonged to more than one gender or racial category.
4	*Predict the order of independent variable groups*	It was predicted that the order of gender groups would move from smallest/lowest to largest/highest. (female < nonbinary < male) It was predicted that the order of racial/ethnic groups would move from smallest/lowest to largest/highest. (Black < Latino < Asian < White)
5	*Predict direction of the alternative hypothesis*	Median scores increase for male-identifying students and White students.
6	*Similar distribution of scores for the independent variable*	Histograms show a similar distribution of scores by gender and race/ethnicity.

Finally, a Wilcoxon signed-rank test compared how students performed at the beginning, middle, and end of the learning progression. This test does not assume normally distributed data, and no mission scores were normally distributed in this study (see Appendix C). All variables met the assumption of ordinal data and matched pairs (Sheskin 2020). Cases with complete data were analyzed in a pairwise comparison to test the null hypothesis that there was no difference in median student scores. As a result, the researcher could analyze whether differences in medians were statistically significant. Comparing median scores provided insight into the effects of the instructional sequence on student learning.

Qualitative Methods: Counter-Maps as Decision-Making Tools

Thematic analysis identified patterns or themes within the data to provide context for how students used the counter-maps they made as decision-making or problem-solving tools in the school or community. This process involved collecting open-ended student responses at the end of each mapping mission, and an additional, more detailed reflection one month after the conclusion of the course. Thematic analysis uses a systematic process for familiarizing, coding, and identifying themes among a dataset (Braun and Clarke 2006; 2012). An inductive approach was used for this study, which allowed the content of written reflections to determine the codes and subsequent themes the researcher identified (Braun and Clarke 2012). The researcher's knowledge of spatial reasoning progressions informed coding decisions, but the words and ideas presented in student responses shaped the codes created. The inductive approach allowed new themes and patterns to emerge from the data itself.

First, the researcher became immersed in the data during three full reads of student reflections. This step involved reading, annotating, organizing, and repeatedly interacting with the data. The first read of the data was during the scoring of the missions for the quantitative study. The second read was during a quality check of mission scores, at which time the researcher also made notes about common student phrases and experiences. These were collected in a Google Doc and organized by mission. The third full read of the dataset was to transcribe the hand-written student responses into text. To do this, the researcher dictated student responses into an Excel document. At this point, the researcher had extensive knowledge of the dataset and grouped responses by mission and question. A qualitative software tool, MAXQDA, was used to code and make memos

about student responses (MAXQDA 2022). Memos contained notes about common phrases within each code and which codes might be similar enough to merge during the next step of the process.

In the second phase, the researcher generated initial codes, which required a fourth full read of the dataset. Two sets of codes were generated: one for the questions on the survey about the learning process and a second for the questions asking how students could use what they learned in the community. For the first set of questions about the learning process, nine codes were identified. Twenty codes were created for the question about how students might use maps in the community. Table 18 lists all of the codes generated during this phase.

Third, the researcher used descriptive statistics and a code map to search for a "patterned response or meaning" that would suggest how to merge codes into themes (Braun and Clarke 2006, 82). See Figures 4, 5, and 6 (MAXQDA 2022). The most frequent codes were communicate, solution, draw maps, educate and inform others, navigate, and locate. The code map showed occurrences of codes in the same document, with lines depicting three or more frequencies between codes. From these visualizations, it was clear that some codes were more related than others. The researcher also examined the codes across missions to ensure that initial themes spanned the entirety of the learning progression. Codes were classified into seven emerging themes based on these statistics and visuals. Table 19 shows the process of merging codes into themes.

Table 18 Initial Codes

The Learning Process & Geography	How to Use Maps in the Community
Inquiry	Wrong interpretation
Almost complex reasoning	Investigate
Use of maps	To make a decision
Complex spatial reasoning	Update maps
Perspective	To memorize
Attempts to understand	Maps are not just for pros
Spatial primitives	Making maps as a job
No evidence	To help
Follow directions	How to use and read maps
	Don't know
	Navigate
	Perspective
	Questions
	Newcomers and tourism
	Draw maps
	Educate and inform others
	Self-awareness
	Locate
	Solution
	Communicate
	Lost

Table 19 Emerging Themes: How to Use Maps in the Community

Initial Codes	Emerging Themes
Wrong interpretation, Don't know	No Understanding
How to use and read maps, Draw maps Anyone can make maps not just the pros	How to Use & Draw Maps
Perspective, Update maps	Perspective
Locate, Navigate, Lost, To memorize Newcomers and tourism	Reference Tool
Communicate, Educate and inform Self-awareness, Help	Communication Tool
Solution, To make a decision Making maps as a job	Decision-Making Tool
Investigate	Investigate & Question

Figure 4 Frequency Table: Initial Community Codes
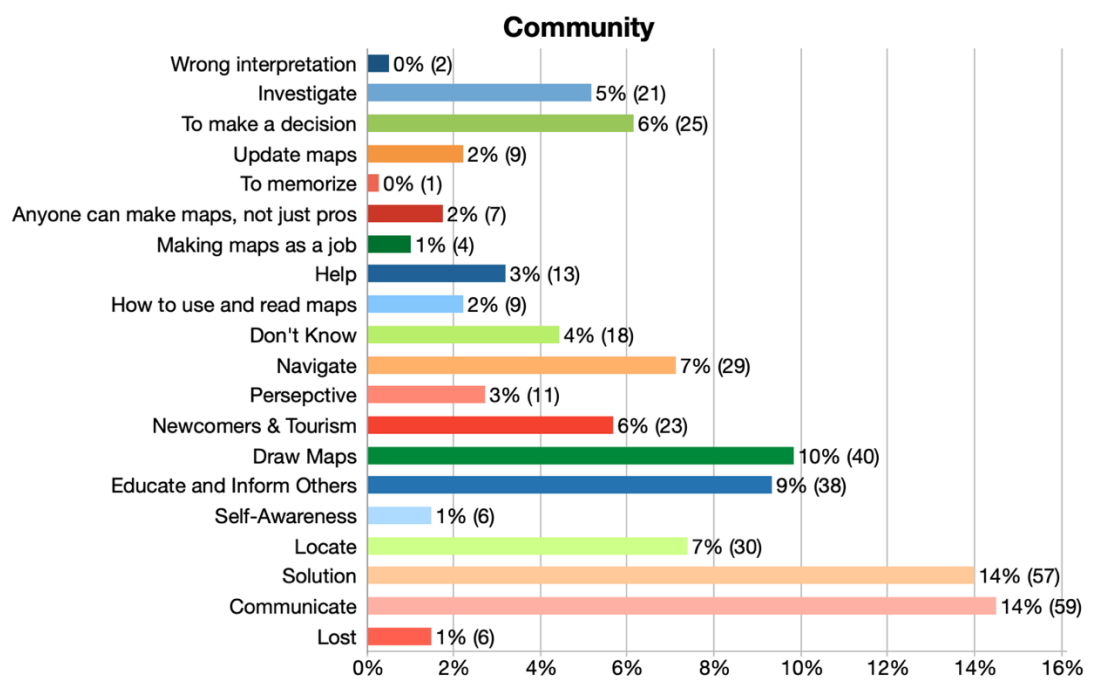
Figure 5 Code Map: Initial Community Codes
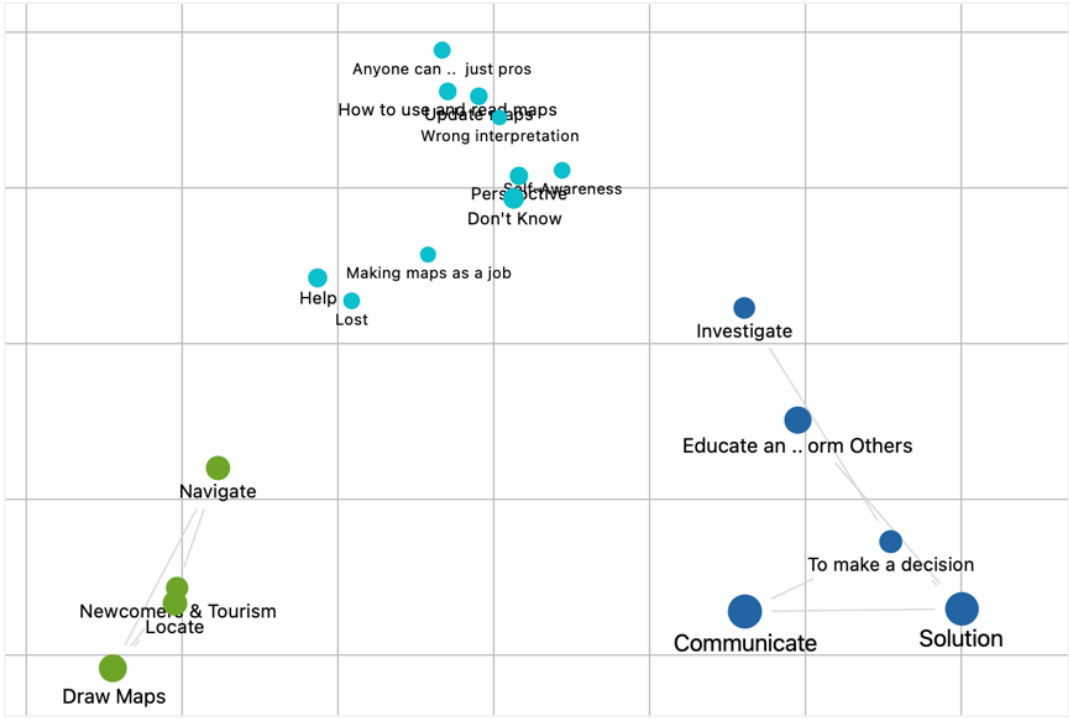
Figure 6 Learning Progression Table: Initial Community Codes

	1	2	3	4	5	6	7	8	9	Total
Community	37	40	39	38	38	34	35	29	39	329
Wrong interpretation									2	2
Investigate						1	9	4	7	21
To make a decision					3	3	8		11	25
Update maps		9								9
To memorize	1									1
Anyone can make maps, not just pr	1	5	1							7
Making maps as a job	1	2					1			4
Help	4	2	2	1		1	1	2		13
How to use and read maps	1	3				4		1		9
Don't Know	1	2		1	2	3	2	1	6	18
Navigate	10	5	10	4						29
Persepctive			1	1		5	2	1	1	11
Questions										
Newcomers & Tourism	6	7	5	2		2			1	23
Draw Maps	16	8	3	1	1	6	1	3	1	40
Educate and Inform Others			2	3	11	2	2	6	12	38
Self-Awareness	2				2	1		1		6
Locate	11	5	6	4	2			1	1	30
Solution			8	8	8	1	5	8	19	57
Communicate	3	1		15	11	7	5	3	14	59
Lost	3	1	2							6

Searching for and identifying emerging themes differed slightly for questions about the learning process. Because these themes described how students learned, the researcher aligned them with well-established progress variables in spatial reasoning (Golledge 2002; Solem, Huynh, and Boehm 2015). The goal was to identify themes that ranged from spatial primitives to complex spatial reasoning skills. These codes provided a secondary layer of analysis to examine the extent to which students used maps as decision-making tools. Figure 7 displays the frequency table for the initial learning process codes, and Figure 8 shows how those themes related to the initial community codes (MAXQDA 2022). Analysis of the relationships between initial codes helped the researcher identify the emerging themes in Table 20. All segments that were part of the "attempts to understand code" were reconsidered and then distributed across several levels of learning.

Figure 7 Frequency Table: Initial Process Codes
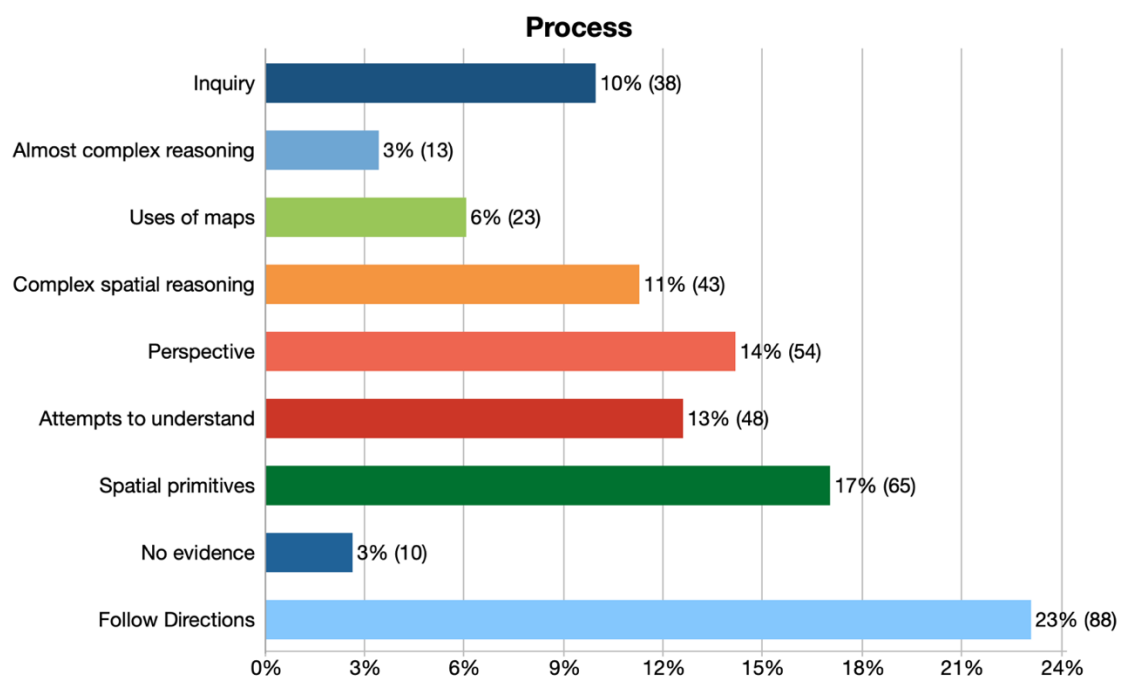
Figure 8 Code Relations Browser: Initial Process & Community Codes

Code System	Uses of maps	Complex spatial reasoning	Perspective	Attempts to understand	Spatial primitives	No evidence	Follow Directions
To make a decision		1	3	1			2
Update maps			6		1		3
To memorize			1	1	3		
Anyone can make maps, not just pr	1	2	2	1	2		2
Making maps as a job			1		2	1	1
Help	3	1	1	3	5		5
How to use and read maps			2	3	4	1	1
Don't Know	2	1	1		1	1	7
Navigate	4	5	9	3	14	1	8
Persepctive	1		8		1		
Newcomers & Tourism	2	3	5	4	8		10
Draw Maps	6	2	9	8	10	1	19
Educate and Inform Others		10	3	4	3		3
Self-Awareness		1				1	3
Locate	4		5	5	13		11
Solution	2	15	1	7	3		5
Communicate	2	8	8	10	5		11
Lost			1	1	2		4

Table 20 Emerging Themes: The Learning Process & Geography

Initial Codes	Emerging Themes
Follow directions, No evidence Attempts to understand	Compliance
Attempts to understand	Types of Maps
Perspective Attempts to understand	Perspective
Spatial primitives Attempts to understand	Spatial Primitives
Almost complex reasoning Attempts to understand	Messy Middle
Complex spatial reasoning	Complex Spatial Reasoning
Inquiry	Inquiry Process

In phase four, themes were revised and cross-referenced with each other and with the research question to generate overarching themes. Irrelevant themes that did not support the research question were eliminated. As a result, the researcher went back through the "How to Use and Draw Maps" and "Perspective" codes to reassign them to broader themes that addressed the supporting research question: *To what extent do students view maps as decision-making and problem-solving tools*? The Code Relations Browser and the Code Map in MAXQDA were used to identify and visualize strong relationships between codes within the same mission reflection (MAXQDA 2022). Code relationships helped the researcher develop four themes: 1) no understanding, 2) reference tool, 3) communication tool, and 4) decision-making tool. A sub-theme emerged within the theme of maps as a decision-making tool—further investigation

In the fifth phase, the researcher defined the essence of each theme, describing their relationships with one another. Table 21 provides a definition and examples of the themes that describe how students used maps. These themes emerged as students reflected on using what they learned in the community. Table 22 describes the kinds of spatial reasoning students were doing when they responded to questions prompting them to describe the mission's goal, how they accomplished it, and what it taught them about geography.

In the final phase of thematic analysis, the researcher synthesized the findings and shared them in the results chapter by theme. This process helped the researcher answer the supporting research question that aimed to understand the extent to which students view maps as decision-making and problem-solving tools. Ultimately, the use of thematic analysis enabled the researcher to explore the personal perspectives of students as they navigated the learning progression while gleaning new insights to inform future research.

Table 21 Description of Themes: Using Maps in the Community

Theme	Description	Examples
No Understanding	Students were not able to articulate how they could use what they learned from the mission in the community.	"I don't know." "I can't." "I don't think I'd use this outside of class."
Reference Tool	Students envisioned using maps to locate, navigate, and understand where things were.	"I could use this to show where certain things are in a location." "To help people who are lost." "To help explain to people where it is."
Communication Tool	Students viewed maps as a tool to provide information about a topic, educate or inform others, and raise awareness. They recognized that maps could be helpful beyond navigation. Within this theme, students could reason about how maps communicated the perspective of the mapmaker and that maps are a snapshot of the past.	"Maybe by mapping areas yearly to see how it changes." "I could use what I learned to teach other people about the history in [the community]. "To tell people where dirty air is in town." "To figure out where certain problems are most prevalent." "I can use what I learned in this mission to spread the message of how hard refugees lives are."
Decision-Making Tool	Students viewed maps as a decision-making or problem-solving tool that could be used to suggest a solution to a spatial problem.	"Most services were held downtown. I would disperse it more like around town, not just in one area." "If you need to make an ad for your business you would want to know where other ads are and where would most people see it." "This map could help business owners on where the most useful place for a coffee shop would be."
Further Investigation (sub-theme)	Students used the map as a tool for further investigation or to prompt more questions. Rather than presenting a solution, the inquiry ended with a call for more research or a revision to the methodology.	"Doing this mission it brought attention to me about this issue. It makes me think is this an issue in [my community]?" "That when asking how much litter there is in [town] I should probably pick a certain area."

The researcher edited student responses to obscure the location of the study using [community] and [town] where appropriate.

Table 22 Description of Themes: The Learning Process

Theme	Description	Examples
Compliance	Students merely followed and restated the directions without thinking through each step. They also focused on getting it "right."	"Doing what I was told to do and trying to do it right." "I followed what the teacher told me and then did what I could." "Just get it done but make it accurate."
Types of Maps	Students described the mission as teaching them about the properties of maps (legends, symbols) or the different types of maps.	"To use symbols." "Learning the difference between a normal map and a counter-map." "I used a digital map."
Perspective	Students discussed how they learned to make maps from their perspective or how maps could represent someone else's point of view.	"It taught me that many people see places differently." "That maps can be different but that doesn't make them less professional." "Tried to understand what the map maker was thinking."
Spatial Primitives	Students mentioned that the mission taught them about locations, direction, or distance.	"How far or close everything is." "It taught me how to find the area where the places/resources are." "The mission taught me how to locate areas, plot points."
Messy Middle	Students mentioned more complex relationships, like pattern or distribution, but could not elaborate on how they used those skills in the mission.	"That places are clustered or dispersed." "I know that air pollution is high." "To analyze the patterns and make connections."
Complex Spatial Reasoning	Student could describe complex spatial relationships they learned about in the mission. Some students could answer "Why?" and "Why care?"	"We thought about how many miles are in certain places and how many people can easily access them." "We looked to see if people with less education lived closer to pollution."
Inquiry Process	Students could describe the steps of the inquiry process, from asking questions to gathering and analyzing data.	"Finding questions that could be mapped." "We asked questions, got data, and made a counter-map showing it." "By creating a survey and mapping the responses."

Chapter 4:

Results

This study aimed to understand how students learned spatial literacy when engaged in the practice of counter-mapping, and the extent to which students used the maps they generated to act on an issue in their community. The chapter begins by presenting results that answer the primary research question about spatial literacy skills. Results in this section are presented by learning goal. The next section of the chapter presents results that answer the secondary research question about the extent to which students use their maps to take informed action. Results in this section are introduced by increasingly complex themes that emerged during the thematic analysis. Limitations of the results are discussed at the end of Chapter 5: Discussion.

How Students Learn Spatial Literacy Through Counter-Mapping

Results in this section are categorized within the four learning goals assessed: Using Maps, Mental Maps, Spatial Analysis, and Taking Action. Each section begins with an overview of student scores for the standard based on the median, standard deviation, minimum, and maximum. Then visualizations of the learning pathways are presented using an interpolation line. Finally, the statistical tests for difference and association are analyzed using Kendall's tau-b correlation coefficient, the Jonckheere-Terpstra test, and a Wilcoxon signed-rank test.

Using Maps

Descriptive Statistics. Student scores on missions for Standard 1: Using Maps are displayed in Table 23. Sample sizes were relatively consistent across missions, except for Mission 7: Geo-Inquiry Question ($n = 35$). The highest median score was achieved in

Mission 8: Counter-Map (*Mdn* = 3), and the lowest median score was in Mission 1:

Mental Maps (*Mdn* = 1). Missions 2 through 6 had a median score of 2, which means that

students could describe uses for different types of maps. Standard deviations were highest

for Mission 7 (*SD* = 1.071) and Mission 8 (*SD* = 1.047), which indicated a greater spread

in student scores from the mean. Student scores were more clustered around the mean for

Mission 1 (*SD* = .612), Mission 2 (*SD* = .595), Mission 3 (*SD* = .615), and Mission 6 (*SD*

= .514). On every mission except Mission 6, there were students who demonstrated no

understanding of the use of maps (*Min* = 0). Students reached the upper anchor (*Max* = 4)

in Mission 4: Mural Map and Mission 8: Counter-Map. Boxplots and histograms

visualizing the shape, central tendency, variability, and outliers are available in Appendix

D (IBM Corp 2021).

Figure 9 displays frequencies and trendlines for each progress variable. Early

missions in the progression contained a large proportion of students in Level 1, but by the

final mission, there were very few students at the lower anchor. Level 2 captured nearly

70 percent of students in Mission 3: Asset Map and Mission 6: Case Study but remained

lower in other missions. Most students achieved Level 3 in Mission 4: Mural Map and

Mission 5: Environmental Justice. Students reached the upper anchor twice during the

learning sequence. Only 7.1 percent reached Level 4 in Mission 4: Mural Map; however,

27.3 percent of students got there in Mission 8: Counter-Map. At the end of the course,

77.3 percent of students demonstrated Level 3 or 4 understanding of the Using Maps

standard.

Overall, students revealed higher levels of understanding about the uses of maps

in Missions 4: Mural Map and Mission 8: Counter-Map. In these missions, they were

engaged in making maps for solving community problems, first under the guidance of a teacher and then on their own. Mission 5: Environmental Justice represented the "messy middle" of the learning journey, where student scores varied between Level 2 and 3 understanding. The lack of student data and the low levels in Mission 7: Geo-Inquiry show that few students understood how to use maps when writing the driving questions for their final counter-mapping projects.

Table 23 Descriptive Statistics: Using Maps

		Mission 1: Mental Map	Mission 2: Campus Map	Mission 3: Asset Map	Mission 4: Mural Map	Mission 5: Env. Justice	Mission 6: Case Study	Mission 7: Geo-Inquiry	Mission 8: Counter-Map
N	Valid	41	42	44	42	46	43	35	44
	Missing	5	4	2	4	0	3	11	2
Median		1	2	2	2	2	2	1	3
Std. Deviation		.612	.595	.615	.975	.882	.514	1.071	1.047
Minimum		0	0	0	0	0	1	0	0
Maximum		2	2	3	4	3	3	3	4

Figure 9 Frequency Table & Trendlines: Proportion of Students by Progress Variable for Using Maps

	Mission 1: Mental Map	Mission 2: Campus Map	Mission 3: Asset Map	Mission 4: Mural Map	Mission 5: Env. Justice	Mission 6: Case Study	Mission 7: Geo-Inquiry	Mission 8: Counter-Map	Trend
4				7.1				27.3	
3			4.5	40.5	32.6	4.7	11.4	50	
2	19.5	54.8	70.5	33.3	37	69.8	31.4	6.87	
1	63.4	40.5	20.5	14.3	26.1	25.6	20	13.6	
0	17.1	4.8	4.5	4.8	4.3		37.1	2.3	

Note. Values represent percentages calucalted from available student data. Sample size varies by mission.

Figure 10 Interpolation Line: Using Maps
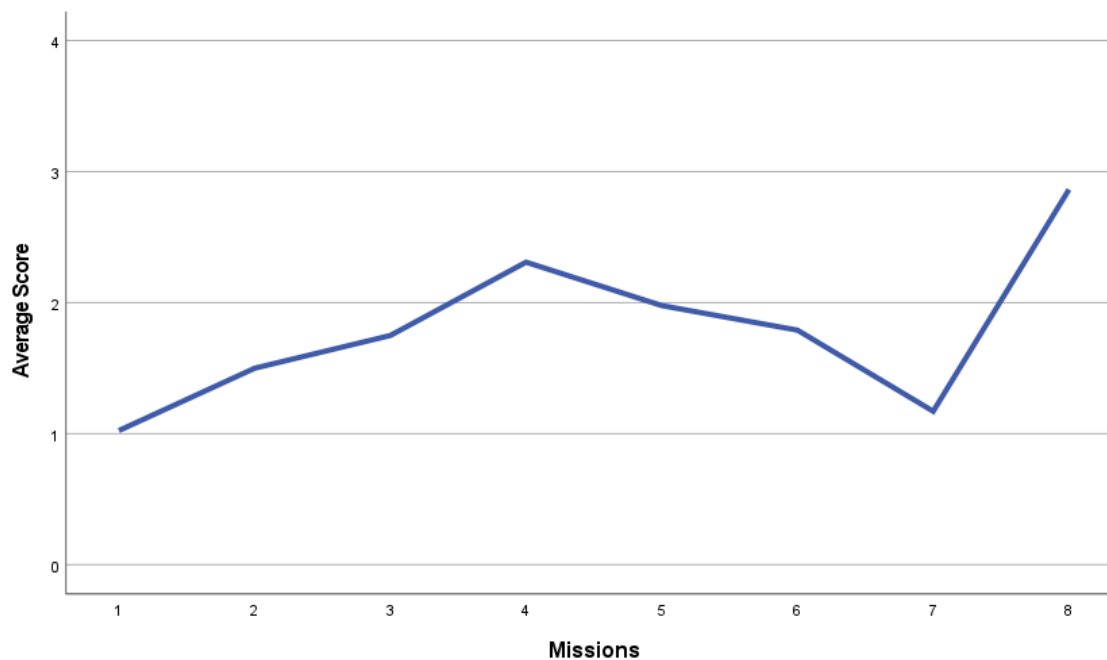
Trends. The interpolation line in Figure 10 shows how the overall student data changed at each mission in the learning sequence (IBM Corp 2021). Student scores increased from about Level 1 on Mission 1: Mental Map to just above Level 2 on Mission 4: Mural Map. After that point, there was a decline in scores through Mission 7: Geo-Inquiry. During Mission 7, students were developing their counter-map inquiries but not using maps of their own. The sharp increase after Mission 7 reflects the high scores achieved in Mission 8 when students created their own counter-maps. Overall, students began at Level 1 on the Using Maps standard and ended up near Level 3. Appendix D contains the individual student data visualized in a choropleth table by mission.

Statistical Relationships. Several positive monotonic associations were found between mission scores (see Table 24). A strong, positive association between Mission 8: Counter-Map and Mission 3: Asset Map was statistically significant at the 0.01 level ($\tau_b =$

.505, $P = <.001$). There was also a strong, positive association between Mission 8:

Counter-Map scores and Mission 5: Environmental Justice ($\tau_b = .420$, $P = .002$). There

were no statistically significant associations between Mission 8 and Mission 1: Mental

Map or Mission 8 and Mission 2: Campus Map.

Table 24 Kendall's Tau-B: Comparing Mission 8 to All Others in Using Maps

	Correlation Coefficient	Sig. (2-tailed)	N	Strength of Association
Mission 8 and 1	.106	.457	40	Very weak
Mission 8 and 2	.019	.898	41	Very weak
Mission 8 and 3	.505**	<.001	43	Strong
Mission 8 and 4	.349*	.011	41	Weak
Mission 8 and 5	.420**	.002	44	Strong
Mission 8 and 6	.388**	.007	41	Moderate
Mission 8 and 7	.341*	.025	33	Weak

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 25 Kendall's Tau-B: Comparing Gender, Race, & Scores

	Correlation Coefficient	Sig. (2-tailed)	N	Strength of Association
Gender and Using Maps 2	−.351*	.019	42	Moderate
Gender and Using Maps 6	−.297*	.045	43	Weak
Race and Using Maps 2	−.563**	<.001	42	Strong

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

There were also three statistically significant correlations between gender, race

and ethnicity, and mission scores (see Table 25). There was a moderate, negative

association between the distribution of scores by gender on Mission 2: Campus Map ($\tau_b = $

$-.351$, $P = .019$) and a weak, negative association on Mission 6: Case Study ($\tau_b = -.297$,

$P = .045$) for the Using Maps standard. A post-hoc test revealed that males performed

significantly worse (*Mdn* = 1) than females (*Mdn* = 2) but not nonbinary students (*Mdn* =

1.5) on Mission 2 (Bonferroni-adjusted $P = .030$); however, there were no significant

differences in the distribution of scores by gender on Mission 6 using the Bonferroni

correction for multiple tests. There was a statistically significant, strong negative

association between race and score on Mission 2: Campus Map for the Using Maps

standard ($\tau_b = -.563$, $P = <.001$). Latino students significantly outperformed White

students on Mission 2 in the Using Maps standard ($P = .002$). Median scores for Latino

students ($Mdn = 2$) were one level higher than for White students ($Mdn = 1$) on Mission

2. Figure 11 shows the distribution of Using Maps scores by gender and race for the

statistically significant results of the Jonckheere-Terpstra test (IBM Corp 2021).

Figure 11 Distribution Using Maps Scores by Gender & Race

Using Maps Scores on Mission 6 by Gender

Using Maps Scores on Mission 2 by Race & Ethnicity
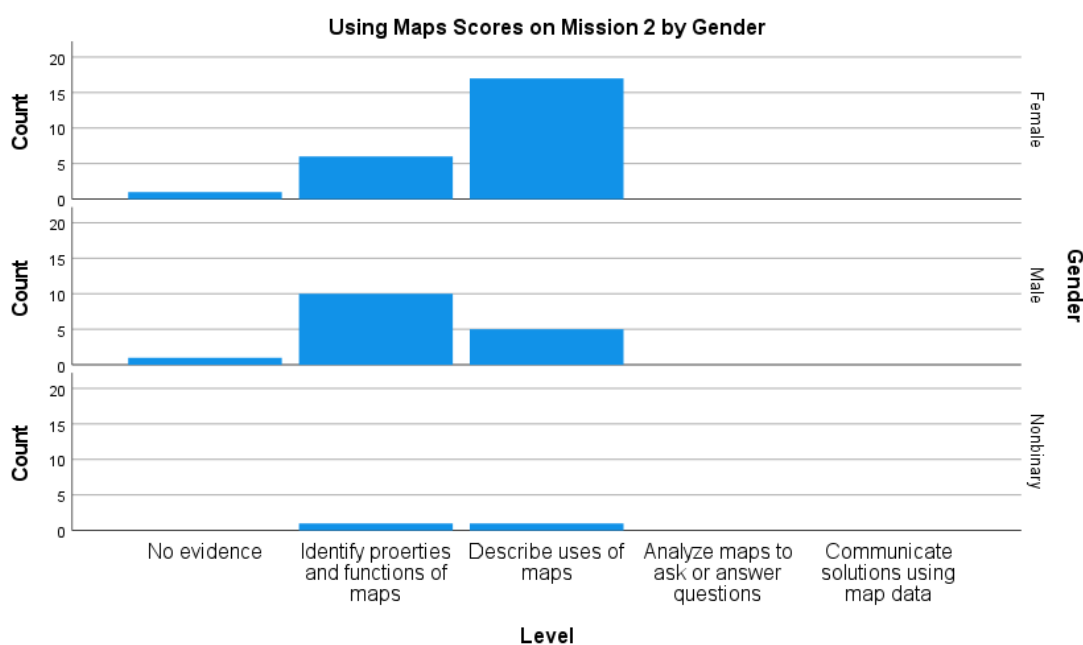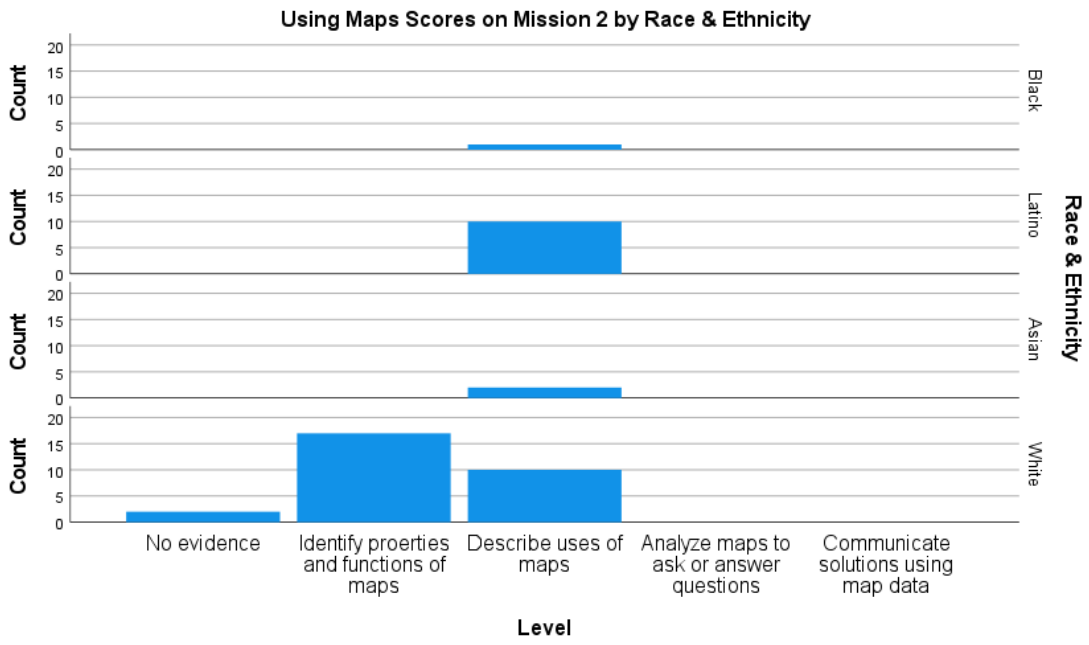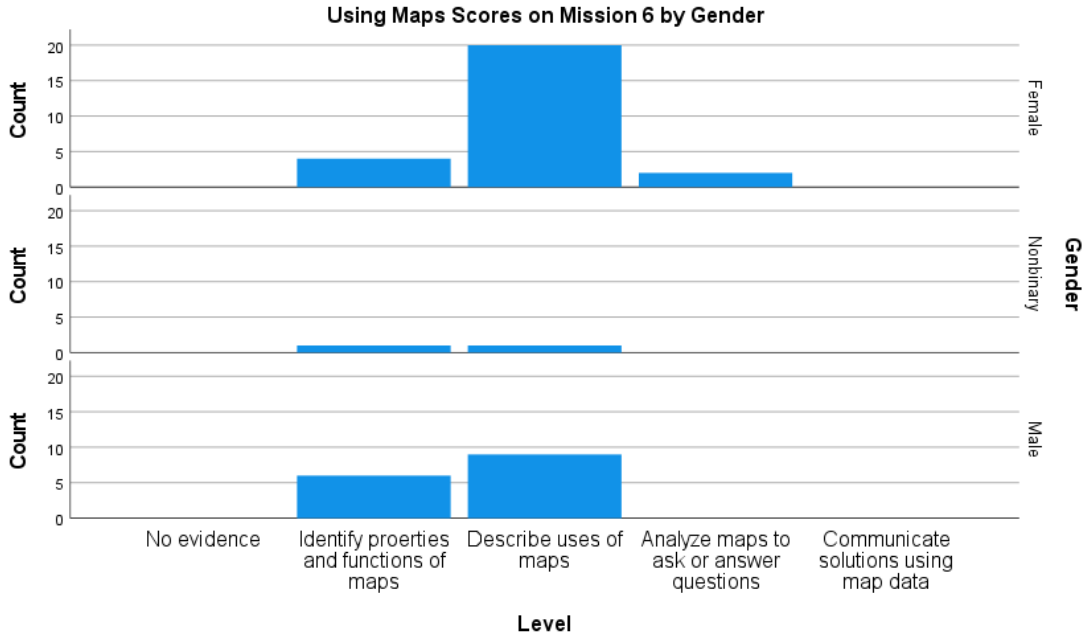
Figure 12 Wilcoxon Test Results: Changes in Using Maps Scores

Changes in Using Maps Scores

■ Mission 1 to 4   ■ Mission 4 to 8   ■ Mission 1 to 8
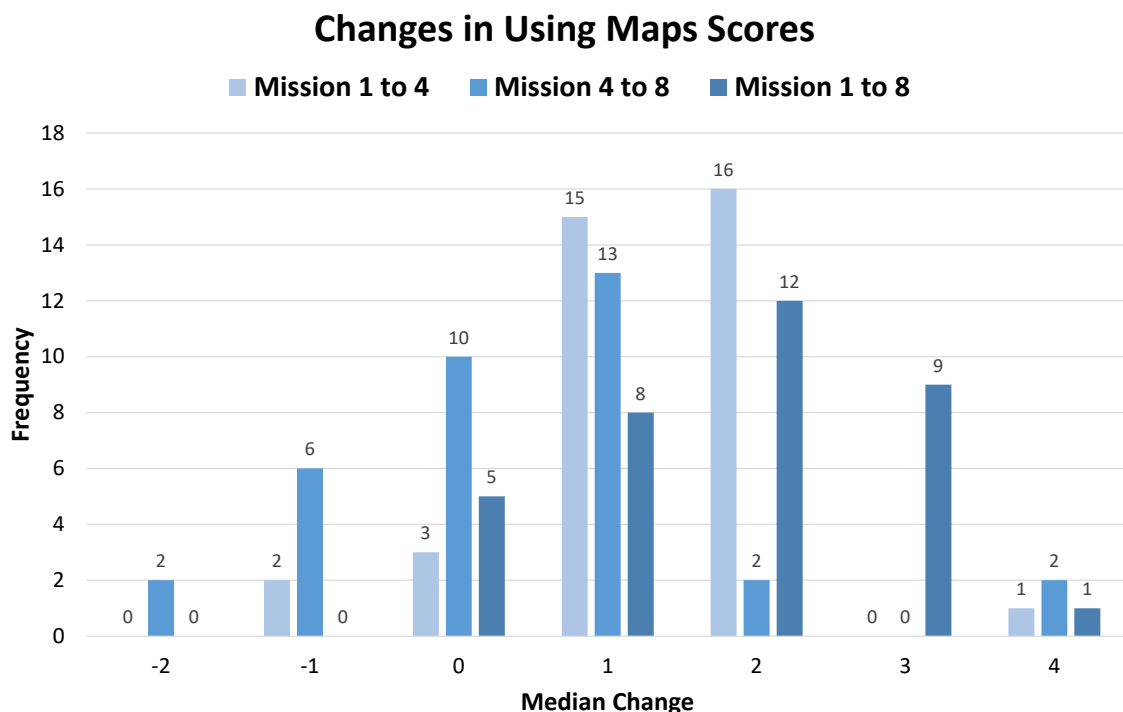
Students showed significant changes in the Using Maps scores from the beginning to the end of the learning progression (see Figure 12). Students grew significantly from Mission 1 to Mission 4 and Mission 1 to Mission 8. There was a statistically significant median increase of one level (from 1 to 2) from Mission 1: Mental Map to Mission 4: Mural Map on the Using Maps standard ($Z = 4.915$, $P < .001$). Students were able to identify the properties and functions of maps at the beginning of the study and describe uses for different types of maps by the middle. There was no statistically significant change from Mission 4: Mural Map to Mission 8: Counter-Map ($Z = 1.691$, $P = .091$). The median value for students in this sample remained at Level 3 across both missions. No students declined from the beginning to the end of the progression. From Mission 1 to Mission 8, there was a statistically significant median increase of two levels (from 1 to 3)

on the Using Maps standard ($Z = 4.845$, $P < .001$). Before any formal learning occurred, students could identify the properties of maps. After learning counter-mapping, students could analyze various spatial data collected from observations and external sources to ask and answer questions about spatial patterns in the surrounding area.

Mental Maps

Descriptive Statistics. Student scores for Mission 1: Mental Maps are displayed in Tables 26 and 27. A standard deviation of $SD = .804$ indicated a moderate spread of the data. Only one student in this mission had no understanding of mental maps ($Min = 0$), and 17 out of 42 students (40.5 percent) reached Level 3 ($Max = 3$), which meant they were able to compare mental maps with other students to identify common factors that influence spatial understanding, perceptions, and preferences. Another 40.5 percent were able to interpret information about a place's location, patterns, and features, and 16.7 percent could draw a familiar space in the community from memory. A boxplot and histogram are available in Appendix D to visualize the shape and distribution of student scores. Because there were no longitudinal data collected across missions for the Mental Maps standard, no further visualizations of learning pathways were possible.

Table 26 Descriptive Statistics: Mental Maps

		Mission 1: Mental Map
N	Valid	42
	Missing	4
Median		2
Std. Deviation		.804
Minimum		0
Maximum		3

Table 27 Frequencies: Mental Maps

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0 – No evidence	1	2.2	2.4	2.4
	1 – Draw a mental map	7	15.2	16.7	19.0
	2 – Interpret mental maps	17	37.0	40.5	59.5
	3 – Compare perceptions	17	37.0	40.5	100.0
	Total	42	91.3	100.0	
Missing	System	4	8.7		
Total		46	100.0		

Table 28 Kendall's Tau-B: Comparing Mental Maps to All Standards & Gender

	Correlation Coefficient	Sig. (2-tailed)	N	Strength of Association
Spatial Analysis 1	.354*	.017	41	Moderate
Using Maps 2	.380*	.012	39	Moderate
Spatial Analysis 2	.462**	.003	38	Strong
Using Maps 3	.342*	.018	41	Weak
Using Maps 5	.285*	.039	42	Weak
Using Maps 6	.471**	.001	40	Strong
Spatial Analysis 6	.349*	.013	40	Weak
Spatial Analysis 7	.358*	.023	32	Moderate
Gender and Mental Maps 1	−.368*	.011	42	Moderate

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Statistical Relationships. There were two strong, positive associations for scores on Mission 1: Mental Map and all other standards in the progression (see Table 28). Increases in Mental Maps scores were positively associated with gains in Using Maps Mission 6: Case Study scores (τ_b = .471, P = <.001). A strong, positive association was also statistically significant between scores on Mental Maps and Spatial Analysis on Mission 2: Campus Map (τ_b = .462, P = .003). A post-hoc test found that the distribution of Mental Maps scores was significantly higher for females (*Mdn* = 3) compared to males (*Mdn* = 2) but not for non-binary students (*Mdn* = 2.5) at a significance value of P = .023.

Figure 13 shows the distribution of scores for Mental Maps Mission 1 (IBM Corp 2021).

Appendix D has the full results.

Figure 13 Distribution of Mental Maps Scores by Gender
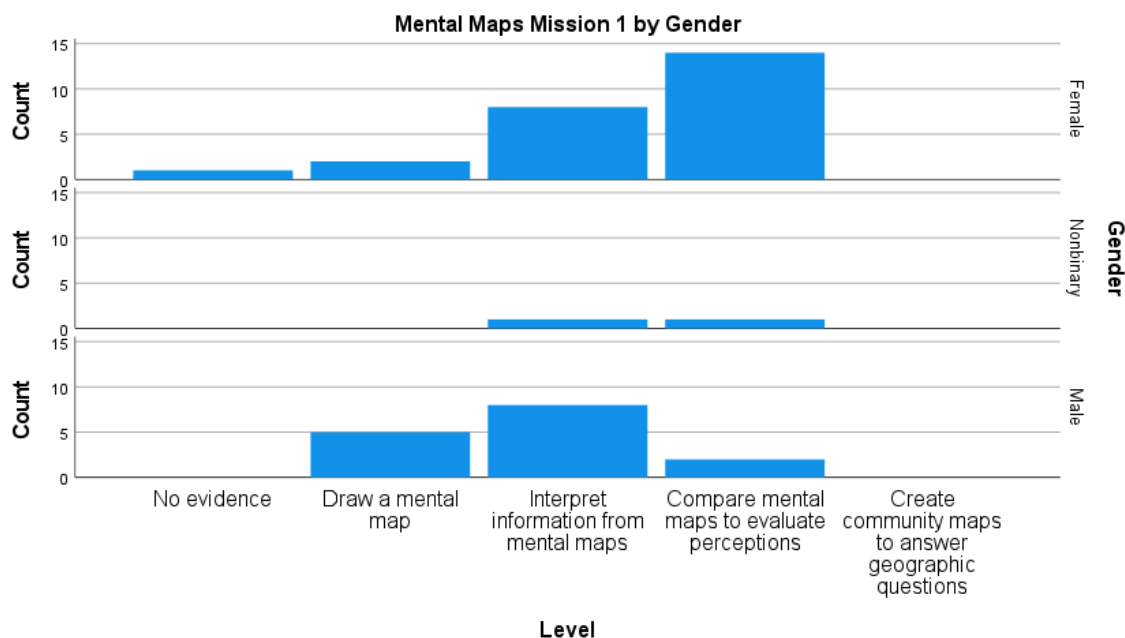
Spatial Analysis

Descriptive Statistics. Table 29 shows student scores on all Standard 3: Spatial

Analysis missions. Sample sizes were relatively consistent across missions, except for

Mission 7: Geo-Inquiry Question. That mission had 12 students with no data ($n = 35$).

The highest median scores ($Mdn = 3$) occurred in the middle of the progression in

Mission 4: Mural Map and, in the end, in Mission 8: Counter-Map. At Level 3, students

could analyze the processes that influence the distribution and interaction of human and

physical processes. Missions 1, 2, 6, and 7 had the lowest median scores in Spatial

Analysis ($Mdn = 1$). Mission 3: Asset Map and Mission 5: Environmental Justice had

median scores of 2, which meant students could describe patterns and trends in the distribution of spatial phenomena.

The standard deviation was highest for Mission 8: Counter-Map ($SD = 1.031$) and lowest for Mission 1: Mental Map and Mission 2: Campus Map ($SD = .273$, $SD = .264$). The standard deviation was about 3.8 times larger from Mission 8 compared to Missions 1 and 2, suggesting a much broader spread of the data. A minimum score of 0 was reported in the early missions and again in Mission 6: Case Study and Mission 7: Geo-Inquiry. Students revealed an understanding of the upper anchor ($Max = 4$) twice in the progression, once at Mission 5: Environmental Justice and again at Mission 8: Counter-Map. In those missions, students could synthesize data from multiple sources to explain the consequences of the spatial organization of features in a location.
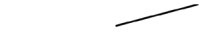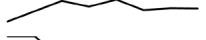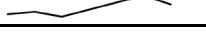
Figure 14 shows that over 90 percent of students scored at Level 1 in Mission 1: Mental Map and Mission 2: Campus Map, showing they understood simple spatial relationships like distance, direction, and location. There were no students at Level 1 in Mission 4: Mural Map or Mission 5: Environmental Justice; however, by Mission 6: Case Study and Mission 7: Geo-Inquiry, 38 percent of students were back at Level 1. Only 11.6 percent of students scored at Level 1 on the final assessment. The "messy middle" appeared in Missions 3, 4, and 5, as students fluctuated between Levels 2 and 3. At this point, students could describe patterns and trends in spatial data in some contexts but not others. They could even analyze the processes that cause those trends in certain situations. For the final three missions, about one-third of the students remained at Level 2. Many students scored at Level 3 in Mission 4 (61 percent), but that percentage dropped in Missions 6 and 7.

Only 4.3 percent of students reached Level 4 during Mission 5: Environmental Justice, but 30.2 percent achieved the upper anchor on Mission 8: Counter-Map. Growth trends in Levels 2 and 3 peaked in the middle of the progression. Notably, 23.8 percent of students showed no evidence of spatial reasoning on Mission 6, which was when they conducted a case study of other model counter-maps. Boxplots and histograms visualizing the shape and distribution of the data are available in Appendix D (IBM Corp 2021).

Table 29 Descriptive Statistics: Spatial Analysis

		Mission 1: Mental Map	Mission 2: Campus Map	Mission 3: Asset Map	Mission 4: Mural Map	Mission 5: Env. Justice	Mission 6: Case Study	Mission 7: Geo-Inquiry	Mission 8: Counter-Map
N	Valid	41	41	45	41	46	42	34	43
	Missing	5	5	1	5	0	4	12	3
Median		1	1	2	3	2	1	1	3
Std. Deviation		.273	.264	.668	.494	.586	.898	.894	1.031
Minimum		0	0	0	2	2	0	0	1
Maximum		2	1	3	3	4	3	3	4

Figure 14 Frequency Table & Trendlines: Proportion of Students by Progress Variable for Spatial Analysis

	Mission 1: Mental Map	Mission 2: Campus Map	Mission 3: Asset Map	Mission 4: Mural Map	Mission 5: Env. Justice	Mission 6: Case Study	Mission 7: Geo-Inquiry	Mission 8: Counter-Map	Trend
4					4.3			30.2	
3			40	61	39.1	7.1	11.8	23.3	
2	2.4		53.3	39	56.5	31	35.3	34.9	
1	92.7	92.7	4.4			38.1	38.2	11.6	
0	4.9	7.3	2.2			23.8	14.7		

Note. Values represent percentages calucalted from available student data. Sample size varies by mission.

Figure 15 Interpolation Line: Spatial Analysis
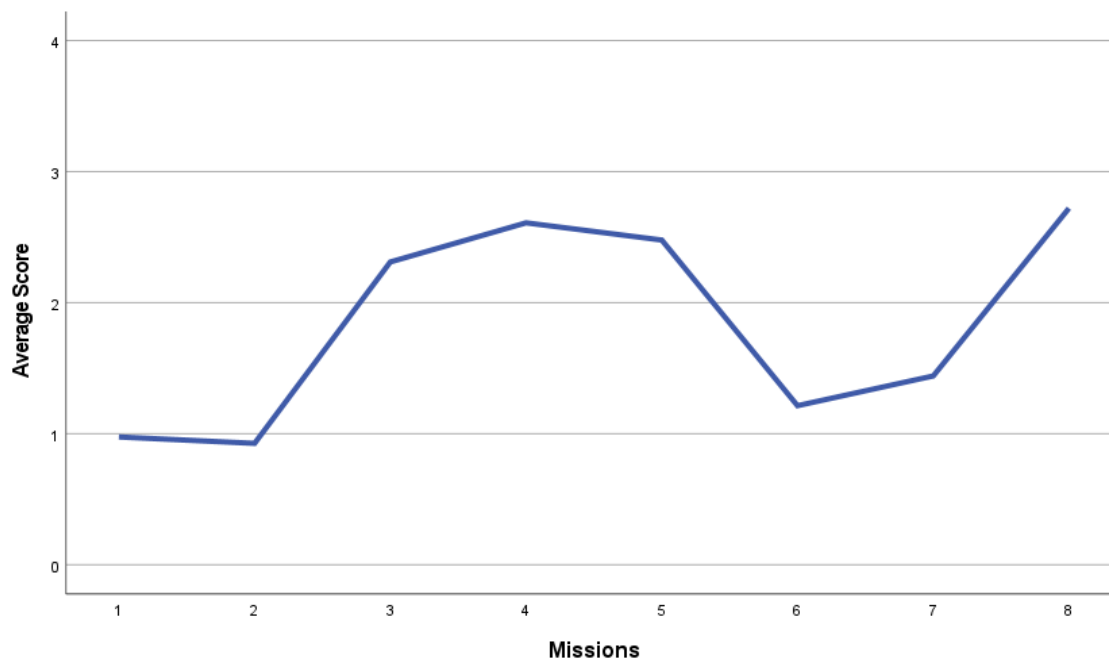
Trends. Figure 15 shows an interpolation line generated using linear regression for all available student data on Spatial Analysis (IBM Corp 2021). On this learning journey students began at Level 1 for the first two missions, and then leaped to Levels 2 and 3 for Mission 3: Asset Map, Mission 4: Mural Map, and Mission 5: Environmental Justice. There was a rapid decline from Mission 5 to Mission 6: Case Study, followed by a gradual, then rapid rise to Level 3 by the end of the progression. More generally, there were two peaks and two valleys in the level of sophistication students showed with their spatial reasoning. Progress fluctuated as students employed simple spatial relationships (distance, direction, adjacency, location) at certain points in the course and more complex spatial relationships (distribution, pattern, dispersion, clustering, density) at others. Progress variables did not build linearly over time.

Statistical Relationships. There were four statistically significant correlations on the Spatial Analysis standard (see Table 30). There was a strong, positive association that was statistically significant at the 0.01 level between Mission 8: Counter-Map and Mission 4: Mural Map (τ_b = .421, P = .005), Mission 5 (τ_b = .431, P = .002), and Mission 7: Geo-Inquiry (τ_b = .436, P = .005). Mission 8: Counter-Map and Mission 6: Case Study also showed a statistically significant and moderately positive association (τ_b = .338 P = .014). Higher scores on the four missions leading up to Mission 8 were associated with higher end-of-course scores on the final assessment. All other assessments showed only weak associations.

Table 30 Kendall's Tau-B: Comparing Mission 8 to All Others in Spatial Analysis

	Correlation Coefficient	Sig. (2-tailed)	N	Strength of Association
Mission 8 and 1	.212	.152	40	Weak
Mission 8 and 2	.186	.215	41	Weak
Mission 8 and 3	.085	.550	43	Very Weak
Mission 8 and 4	.421**	.005	41	Strong
Mission 8 and 5	.431**	.002	44	Strong
Mission 8 and 6	.338*	.014	41	Moderate
Mission 8 and 7	.436**	.005	33	Strong

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 31 Kendall's Tau-B: Comparing Gender, Race, & Spatial Analysis Scores

	Correlation Coefficient	Sig. (2-tailed)	N	Strength of Association
Gender and Spatial Analysis 1	−.297	.053	41	Weak
Gender and Spatial Analysis 2	−.333*	.026	41	Weak
Race and Spatial Analysis 4	−.409**	.008	41	Strong

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

There were two significant correlations between gender, race, and Spatial Analysis scores (Table 31). There was a weak, negative association between gender and

Mission 2: Campus Map on the Spatial Analysis standard ($\tau_b = -.333$, $P = .026$). A

follow-up test revealed that the distribution of scores was significantly higher for females

than males ($P = .049$). However, further analysis revealed that three outliers in the data

for male-identifying students may have skewed the results. In Mission 2, all gender

groups had a median score of two. There was a strong negative association between race

and Spatial Analysis scores on Mission 4: Mural Map ($\tau_b = -.409$, $P = .006$). A post-hoc

test showed no significant differences in the distribution of scores by race when adjusted

by the Bonferroni correction for multiple tests (Figure 16, (IBM Corp 2021). Without the

correction ($P = .013$), scores for White students ($Mdn = 3$) were significantly higher than

for Latino students ($Mdn = 2$) on Mission 4: Mural Map for Spatial Analysis.

Figure 16 Distribution of Spatial Analysis Scores by Gender and Race
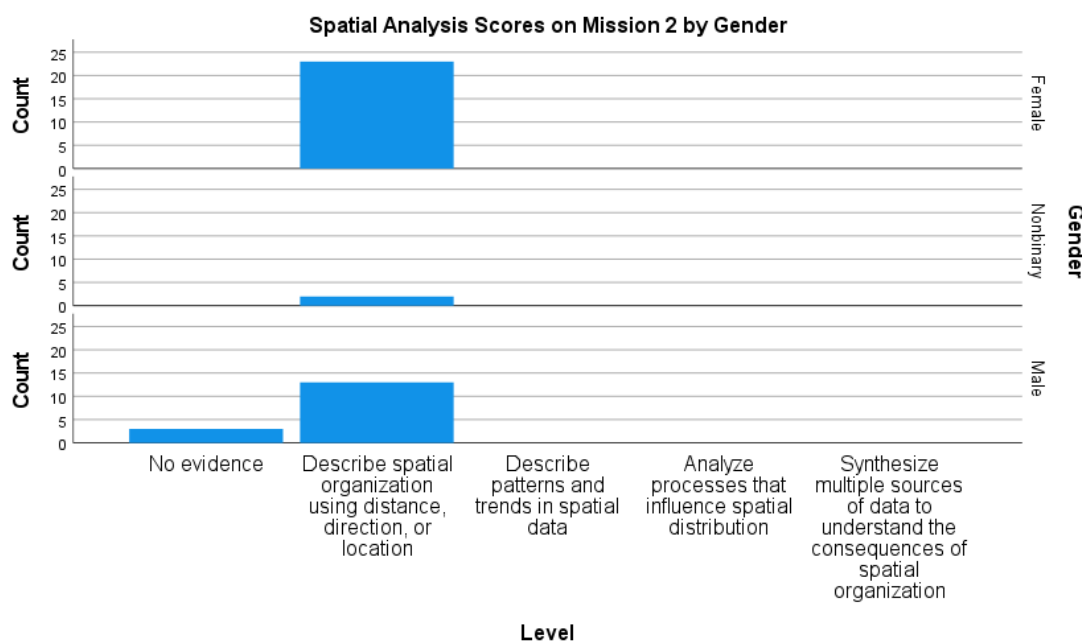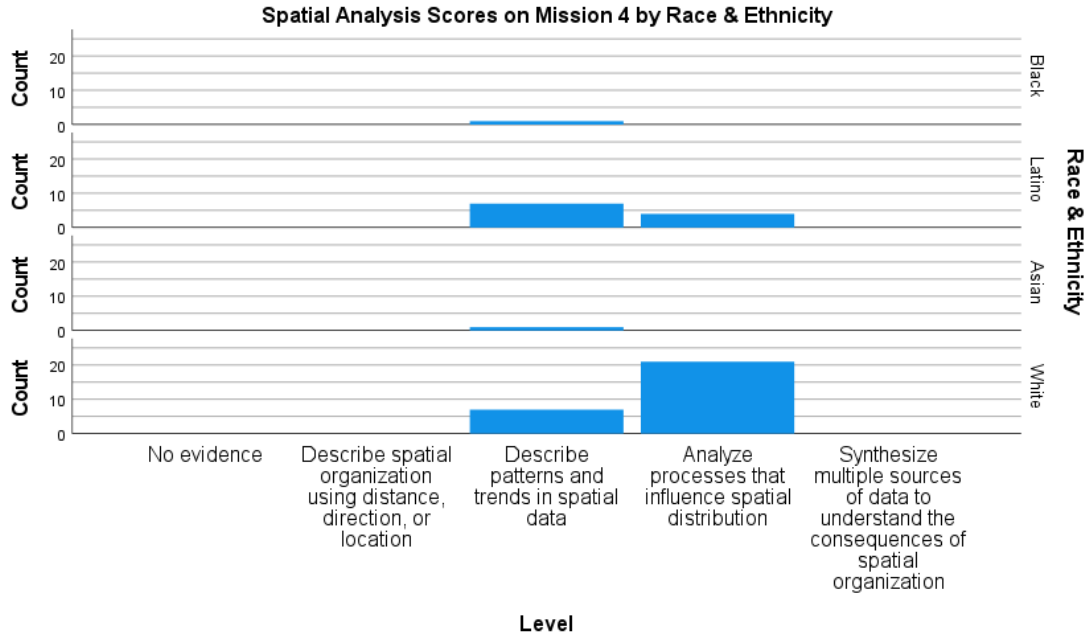
Figure 17 Change in Spatial Analysis Scores
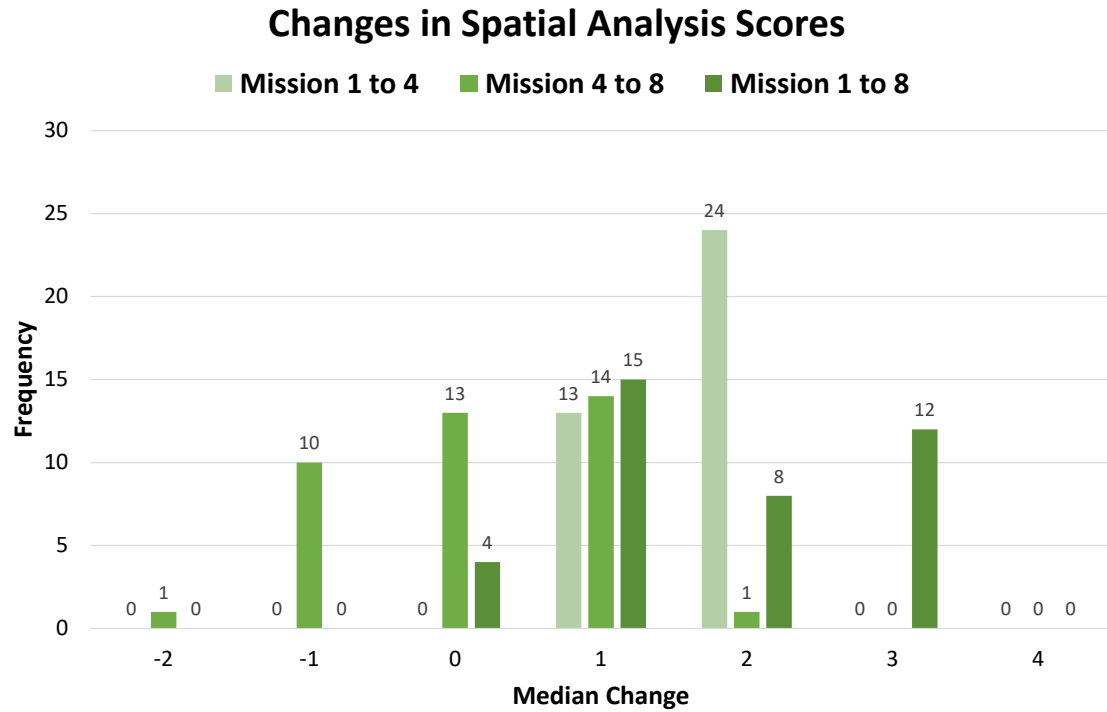
There were significant changes in the Spatial Analysis scores from the beginning to the end of the learning progression (Figure 17). The most considerable changes in the median score were from the beginning to the middle and from the beginning to the end of the course. Of the 37 students analyzed in the test, all 37 showed statistically significant positive growth from Mission 1: Mental Map to Mission 4: Mural Map ($Z = 5.516$, P <.001). Median scores increased from Level 1 (describing spatial primitives) to Level 3 (analyzing spatial processes). Similarly, from the beginning to the end of the study, 89.7 percent of students showed a statistically significant positive difference in medians of two levels, from Level 1 to Level 3 ($Z = 4.845$, P <.001). From the halfway point of the course to the end, students were similarly split among positive differences (15), negative differences (11), and ties (13). There were no statistically significant changes from Mission 4 to Mission 8 on the Spatial Analysis standard ($Z = .704$, $P = .482$). The median value for students in this sample remained at Level 3 from the middle to the end of the learning progression.

Taking Informed Action

Descriptive Statistics. Results of students' scores on the Taking Informed Action standard appear in Table 32. Sample sizes for this standard were smaller than the other three standards assessed, and both Missions 6: Case Study and Mission 7: Geo-Inquiry had between 21 to 22 percent missing data ($n = 36$, $n = 35$). Median scores for the first two missions stayed at a median of 0, then doubled for Mission 3: Asset Map ($Mdn = 2$). The median score would not reach that level again until the final assessment, Mission 8. The highest progress variable achieved ($Mdn = 2$) demonstrates that students could use a map to describe potential actions or solutions to a community issue. Median scores were

at Level 1 for Mission 4: Mural Map, Mission 5: Environmental Justice, and Mission 7: Geo-Inquiry. In those missions, students could identify community assets or problems using maps.

Student scores were most clustered in Mission 1: Mental Map and Mission 2: Campus Map, when performance was low. The most extensive spread in the data was in Missions 3, 4, 7, and 8 (SD = .834, .818, .843, .821). However, the standard deviation was the least variable for Taking Informed Action compared to the other spatial thinking standards. In every mission, at least one student demonstrated no understanding of the use of maps as problem-solving tools (Min = 0). Two students did reach the upper anchor in Mission 8, showing the ability to take informed action based on the synthesis of their counter-map (Max = 4).

Figure 18 shows the frequencies of student scores on the progress variables and the trends across each variable. The highest proportion of scores at Level 0 was in Mission 1: Mental Map (94.9 percent), Mission 2: Campus Map (85 percent), and Mission 6: Case Study (58.3 percent). Most students at those points in the progression struggled to show how maps could be used to solve problems in the community. At best, they could use the map to identify an asset or a problem. In Level 1, the highest proportions were found in Mission 4: Mural Map (34.1 percent), Mission 5: Environmental Justice (39.5 percent), and Mission 6: Case Study (38.9 percent). Mission 3: Asset Map was the first time in the progression that students could use maps to describe potential actions or solutions to community issues. This increase came after two missions where students mostly did not understand maps as problem-solving tools. Only 2 students (4.3 percent) could identify assets or issues using a map at the beginning of the

learning progression. By the end of the learning progression, that number increased to 5 students (10.9 percent).

Students did not reach Level 3 or 4 until the final mission. In that mission, 21.4 percent of students reached Level 3, and 4.8 percent hit the upper anchor. However, individual student outcomes varied in the final mission. There were 23 students (50 percent) who could describe potential solutions using a map and 9 students (19.6 percent) who could apply geographic knowledge to inform or advocate about a community issue. The remaining 7 students assessed (15.2 percent) were able to identify issues. Boxplots, histograms, and complete student datasets are available in Appendix D (IBM Corp 2021).

Table 32 Descriptive Statistics: Taking Informed Action

		Mission 1: Mental Map	Mission 2: Campus Map	Mission 3: Asset Map	Mission 4: Mural Map	Mission 5: Env. Justice	Mission 6: Case Study	Mission 7: Geo-Inquiry	Mission 8: Counter-Map
N	Valid	39	40	44	41	43	36	35	42
	Missing	7	6	2	5	3	10	11	4
Median		0	0	2	1	1	0	1	2
Std. Deviation		.223	.362	.834	.818	.781	.558	.843	.821
Minimum		0	0	0	0	0	0	0	0
Maximum		1	1	2	2	2	2	2	4

Figure 18 Frequency Table & Trendlines: Proportion of Students by Progress Variable for Taking Informed Action
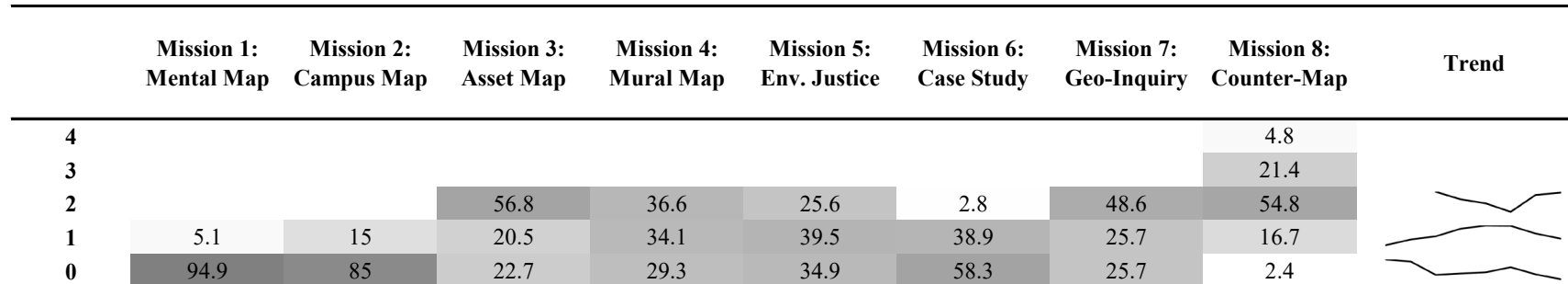
	Mission 1: Mental Map	Mission 2: Campus Map	Mission 3: Asset Map	Mission 4: Mural Map	Mission 5: Env. Justice	Mission 6: Case Study	Mission 7: Geo-Inquiry	Mission 8: Counter-Map	Trend
4								4.8	
3								21.4	
2			56.8	36.6	25.6	2.8	48.6	54.8	
1	5.1	15	20.5	34.1	39.5	38.9	25.7	16.7	
0	94.9	85	22.7	29.3	34.9	58.3	25.7	2.4	

Note. Values represent percentages calucalted from available student data. Sample size varies by mission.

Figure 19 Interpolation Line: Taking Informed Action
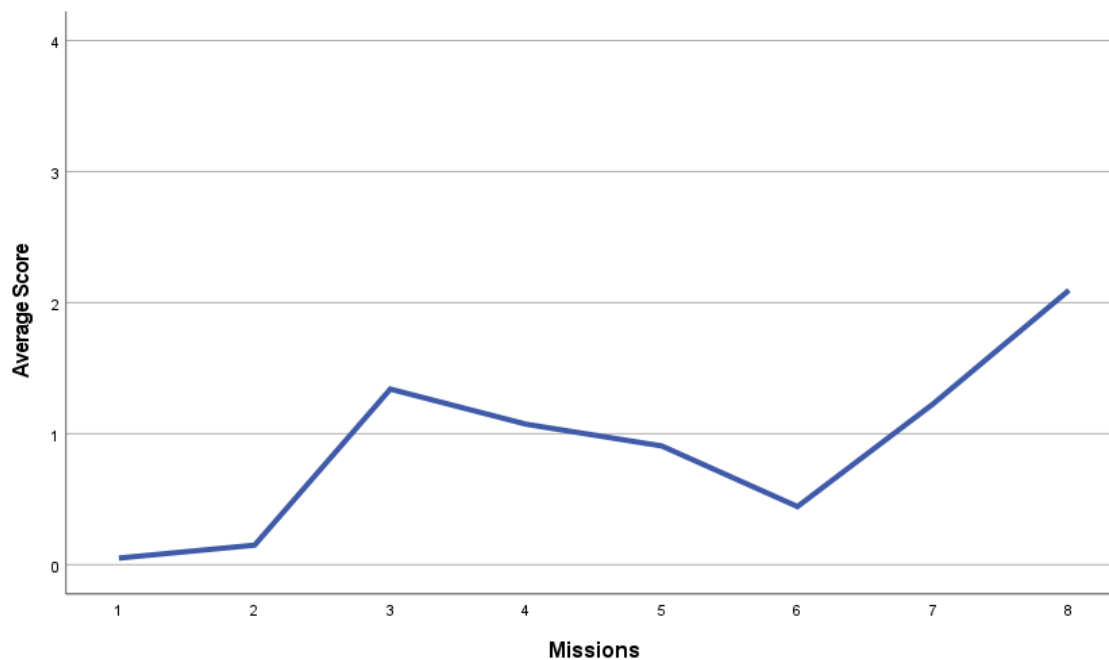
Trends. Before any learning interventions, students showed little to no

understanding of maps as decision-making tools (see Figure 19, (IBM Corp 2021). The

sophistication of reasoning improved from Mission 1: Mental Map to Mission 3: Asset

Map, then gradually declined until Mission 6: Case Study. Students generally reached

Level 1 understanding during this time, demonstrating that they could identify

community assets and issues using a map. The use of maps as a decision-making tool

improved from Mission 6: Case Study to Mission 8: Counter-Map. Students

demonstrated the highest level of understanding at the end of the progression. On

average, students could discuss, think about, and propose possible solutions to a spatial

problem using a counter-map. Overall, students improved their ability to use counter-

maps to communicate conclusions and take informed action; however, this growth was

not linear.

Statistical Relationships. There were very few statistically significant

associations among Taking Informed Action scores (see Table 33). Outcomes on Mission

6: Case Study had a moderately positive association with Mission 4: Mural Map (τ_b =

.353, P = .038) and Mission 5: Environmental Justice (τ_b = .341, P = .036) that was

statistically significant. Mission 5: Environmental Justice and Mission 7: Geo-Inquiry

were also moderately positively associated (τ_b = .352, P = .026). Strong positive

associations occurred between Missions 4: Mural Map and Mission 5: Environmental

Justice (τ_b = .496, P = .<.001) and Mission 3: Asset Map and Mission 4: Mural Map (τ_b =

.405, P = .005). The final assessment in the learning journey, Mission 8, had only one

statistically significant association with Mission 3: Asset Map (τ_b = .352, P = .013).

Table 33 Kendall's Tau-B: Comparing Mission 8 to Others in Taking Informed Action

	Correlation Coefficient	Sig. (2-tailed)	N	Strength of Association
Mission 8 and 1	.182	.251	36	Weak
Mission 8 and 2	.257	.102	37	Weak
Mission 8 and 3	.352*	.013	41	Moderate
Mission 8 and 4	.186	.200	38	Weak
Mission 8 and 5	.137	.335	40	Weak
Mission 8 and 6	.090	.574	34	Very Weak
Mission 8 and 7	--	--	42	Missing Data

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

There were two statistically significant, weak correlations between gender and

Taking Informed Action scores in Mission 2: Campus Map (τ_b = −.348, P = .026) and

Mission 3: Asset Map (τ_b = −.348, P = .015), displayed in Table 34. Post-hoc tests

revealed a moderately higher distribution of scores for females (Figure 20, (IBM Corp

2021) compared to males on Taking Informed Action in Mission 2 (P = .050) and

Mission 3 (P = .022). Female students (*Mdn* =2) had a significantly higher distribution of

scores than males (*Mdn* = 1) on Mission 3. There was a significant weak, negative

correlation between race and Taking Informed Action in Mission 5: Environmental

Justice (τ_b = –.315, *P* = .015); however, a post-hoc test revealed no significant differences

in distribution by race using the Bonferroni correction. Without the correction, Latino

students scored higher than White students on Taking Action in Mission 5 (*P* = .046).

Table 34 Kendall's Tau-B: Comparing Gender & Taking Informed Action Scores

	Correlation Coefficient	Sig. (2-tailed)	N	Strength of Association
Gender and Taking Action 2	–.348*	.026	40	Weak
Gender and Taking Action 3	–.348*	.015	44	Weak
Race and Taking Action 5	–.315*	.015	44	Weak

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Figure 20 Distribution of Taking Informed Action Scores by Gender & Race

Taking Informed Action Scores on Mission 3 by Gender

Taking Informed Action on Mission 5 by Race & Ethnicity
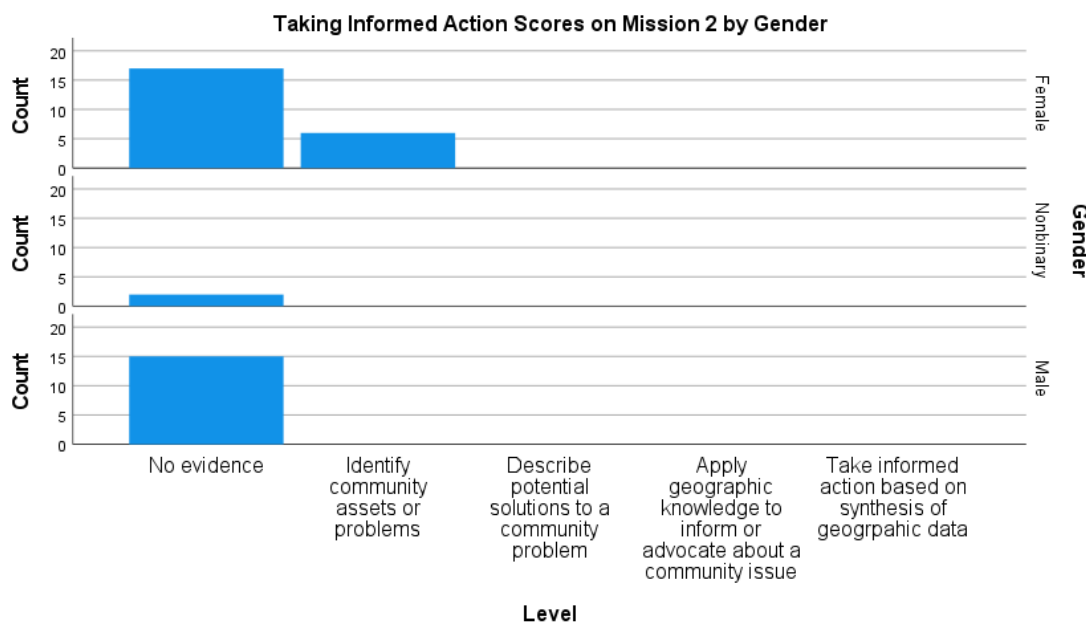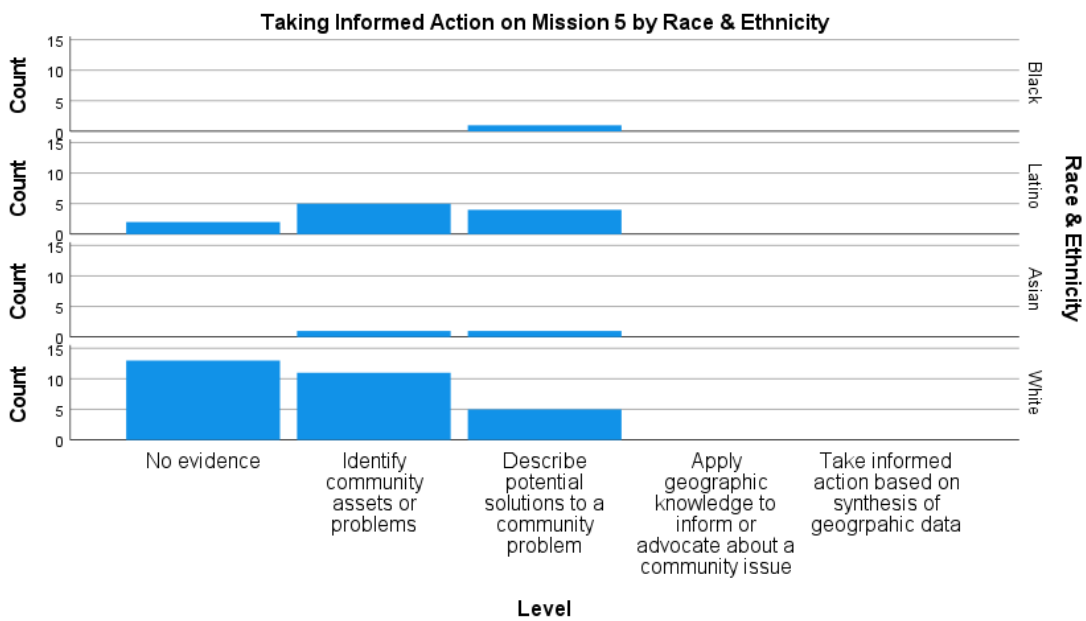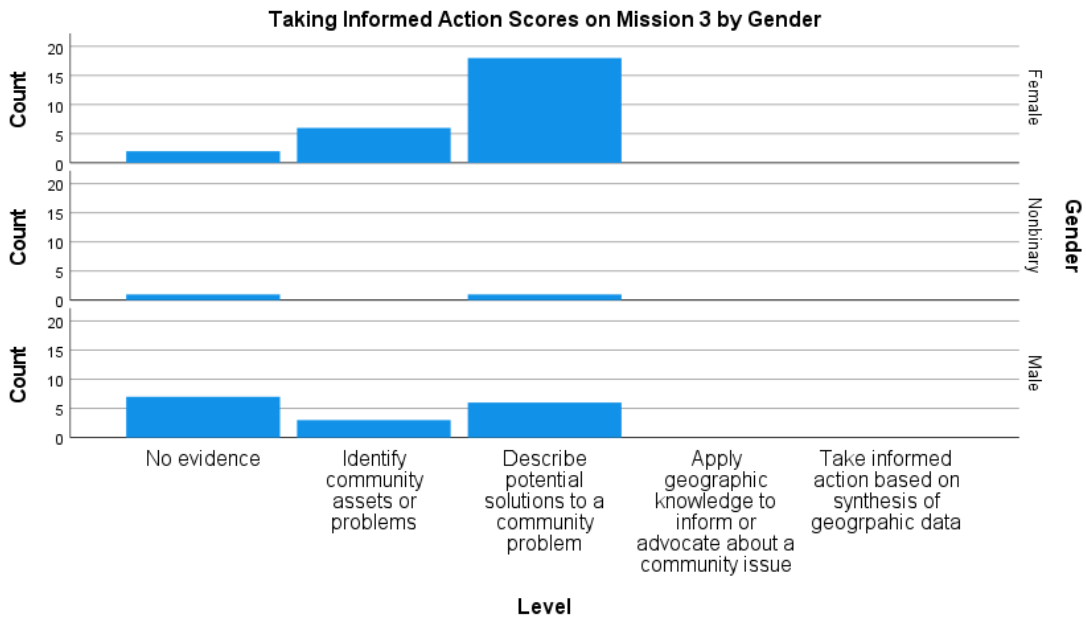
Figure 21 Change in Taking Informed Action Scores
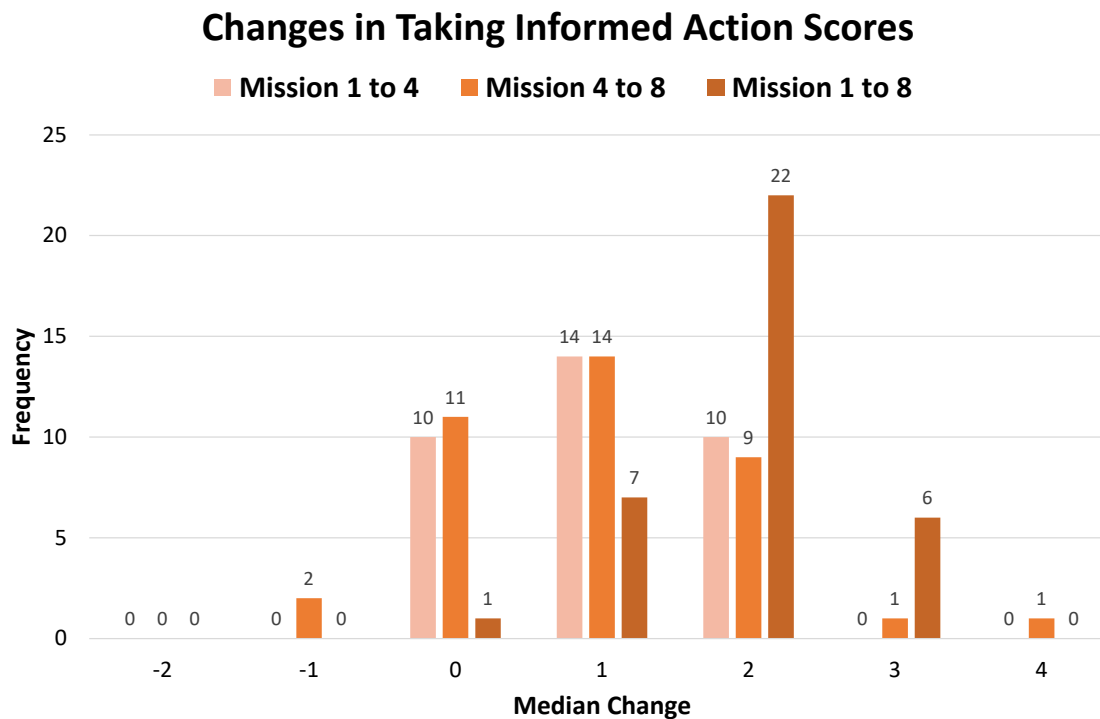
Student scores on the Taking Informed Action standard improved significantly from the beginning to the middle of the learning progression (Figure 21). There was a statistically significant median increase of one level (from 0 to 1) from Mission 1: Mental Map to Mission 4: Mural Map on the Taking Informed Action standard ($Z = 4.428$, $P <.001$). In that paired sample, 24 students (70.6 percent) showed positive growth, and 10 (29.4 percent) did not change. There were no students who had a negative difference.

From the middle to the end of the course, there was a statistically significant change in median scores from Level 1 to Level 2 ($Z = 4.257$, $P = <.001$). The test showed 25 students improved (65.8 percent), 2 students declined (5.3 percent), and 11 students did not change (28.9 percent). The most dramatic difference in median scores came from Mission 1: Mental Map to Mission 8: Counter-Map. There were 35 students who showed growth (97.2 percent), no students declined, and only 1 student (2.8 percent) showed no

change. This change was statistically significant ($Z = 5.328$, $P <.001$), and students showed two levels of growth, from Level 0 to Level 2. That meant students went from having no understanding before formal learning opportunities to producing potential solutions using maps after the learning progression.
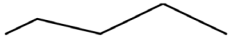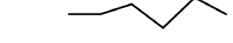
How Students Use Counter-Maps to Take Informed Action

Thematic analysis of 326 student reflections collected after each mission and one month after the conclusion of the course compose this section. Every document was assigned at least one code using the process outlined in the Methods chapter. Four themes emerged and are presented in the subsequent sections of this chapter in order of increasingly sophisticated levels of student reasoning. Figure 22 displays percentages of coded student responses for each theme (MAXQDA 2022). Figures 23 and 24 on the next page visualize frequencies and trendlines for each theme.

Figure 22 Themes in the Code System
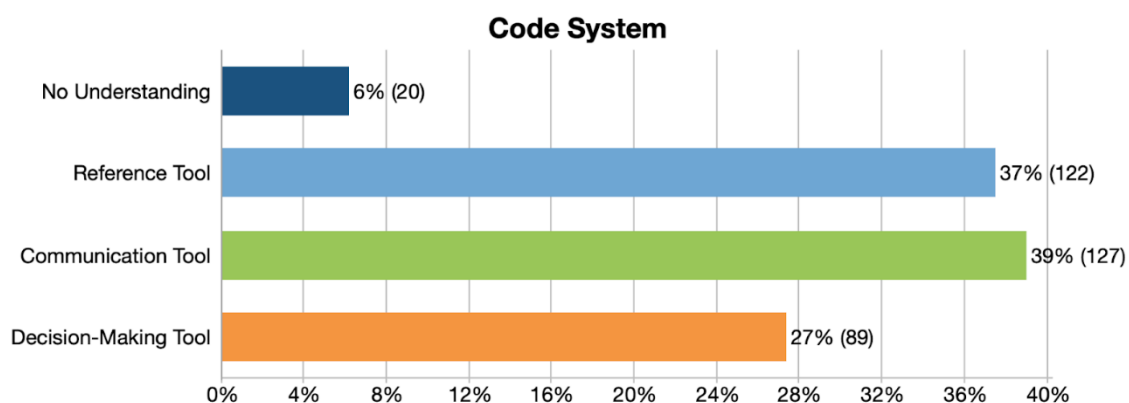
Figure 23 Matrix & Trends: Themes by Mission

	1	2	3	4	5	6	7	8	9	Trend
No Understanding	1	2		1	2	3	2	1	8	
Reference Tool	56	29	27	11	3	12	2	5	3	
Communication Tool	10	13	5	20	23	16	10	12	27	
Decision-Making Tool			8	8	11	4	13	8	30	
*Further Investigation						1	9	4	7	

Note. Columns 1-8 were mission reflections. Column 9 was the end of course reflection. Values represent # of reflections.

*Further Investigation is a sub-theme of Decision-Making Tool.

Figure 24 Matrix: Relationships Among Themes

	No Understanding	Reference	Communication	Decision-Making	Further Investigation
Compliance	8	47	29	7	3
Types of Maps	2	15	7	2	
Perspective	1	27	26	4	1
Spatial Primitives	1	42	20	8	
Messy Middle	1	5	8	6	2
Complex Spatial Reasoning	1	10	19	16	
Inquiry Processes		2	15	13	11

No Understanding

The theme of no understanding represented students who could not articulate or generate ideas about how to use what they learned in the community. Of the 326 documents coded, 20 documents (6 percent) reflected no understanding. Students who were part of this theme responded with some variation of "I don't know" or "I can't." Lack of understanding was highest one month after the completion of the course, when 8 students (2.5 percent) could not explain how they were using what they learned. This theme most frequently co-occurred with compliance (8 documents), followed by types of maps (2 documents).

Maps as Reference Tools

The reference tool theme refers to students who used maps to locate, navigate, and understand where things were in the community. Maps as reference tools was the second-most common theme in the dataset (37 percent). Students most frequently viewed maps as reference tools in Mission 1: Mental Maps (56 documents). Mission 2: Campus Map (29 documents) and Mission 3: Asset Map (27 document) also had elevated levels of students who viewed maps as reference tool, primarily for navigation. This theme commonly co-occurred with compliance (47 documents) and spatial primitives (42 documents).

Maps as Communication Tools

Students who viewed maps as a communication tool used them to share, educate, and inform about various topics and issues. Using maps as communication tools was the most common theme in the dataset, with 127 documents (39 percent). In the learning sequence, students used maps as communication tools across all eight mapping missions.

Mission 8: Counter-Map (27 documents), Mission 5: Environmental Justice (23 documents), and Mission 4: Mural Map (20 documents) had the most significant shares of students who used maps in those missions as communication tools. The trendline shows that students were more likely to think of maps as communication tools in the middle of the progression. Using maps as communication tools most commonly occurred in the same documents as compliance (29 documents), perspective (26 documents), and spatial primitives (20 documents).

Maps as Decision-Making Tools

The theme of decision-making tools reflected students who viewed maps as a way to solve a problem or visualize a solution. Using maps to make decisions was the third most common theme among student reflections (27 percent). Students began to see maps as decision-making tools in Mission 3: Asset Map (8 documents); however, the highest proportion of students in this theme was during the end-of-course reflection (30 documents). Mission 7: Geo-Inquiry (13 documents) and Mission 5: Environmental Justice (11 documents) also had moderate levels of students who used maps to make decisions. In the trendline, this theme peaks in the middle and end of the course, with a large dip between those points. Students who viewed maps as decision-making tools also mentioned themes of complex spatial reasoning (16 documents) and the inquiry processes (13 documents) in their reflections.

A subset of students used maps to prompt further investigation while also using them as decision-making tools. There were 21 documents within the decision-making theme where students used the map as a tool to prompt further investigation or ask more questions. Prompts for further investigation occurred most frequently in Mission 7: Geo-

Inquiry (9 documents) and the end-of-course reflection (7 documents). Students who talked about using the inquiry process in their reflection also frequently viewed maps as a tool for further investigation (11 documents).

The end-of-course reflections were completed by 39 out of the 46 students in the study (84.8 percent). In the reflection, 20 students (51.28 percent) said they were not taking action using their map, 14 students (35.9 percent) said they might take action using their map in the future, and 5 students (12.82 percent) said they were using their map to take action currently. Two students were using the map to take informed action on bullying at the middle school and security at the high school. Two other students said their maps had led them to take personal action by volunteering at shelters, donating old clothes, and picking up trash.

Chapter 5:

Discussion

This study aimed to understand how students learn spatial thinking while counter-mapping and to what extent they use those maps to take informed action in the community. This chapter restates the research problem and briefly reviews the methods used to investigate it. The major sections of this chapter summarize the results and discuss their implications. Limitations of the study are presented at the end of the chapter.

The Research Problem and Methodology

The research was a mixed-methods study of how students learn spatial literacy while doing counter-mapping. The study took place in an urban high school in Iowa with 46 student participants from a ninth-grade social studies class. Students entered the class with few formal opportunities to practice spatial thinking, and the teacher had no experience instructing geography courses. The researcher developed four instruments for the study: learning goals, mapping assessments, an instructional sequence, and qualitative surveys.

Learning goals drew from the National Geography Standards and the C3 Framework Inquiry Arc. Progress variables were developed for four standards: Using Maps, Mental Maps, Spatial Analysis, and Taking Informed Action. Eight mapping assessments were designed by the researcher and placed within a proposed instructional sequence. The facilitating teacher carried out instruction and assessments over nine weeks in two different pilot studies. Student scores were analyzed using median, standard deviation, frequency tables, interpolation lines, and tests for statistical relationships.

Thematic analysis of student reflections further explorde how students think about maps as decision-making tools.

How Students Learn Spatial Literacy Through Counter-Mapping

Students take several interesting and varied pathways as they work to master the skills required to produce actionable counter-maps. First, there were very few differences in achievement by gender and race. Second, the pathways students took to master spatial thinking skills were complex and non-sequential but could be classified by patterns of change over time. Third, chances of reaching the upper anchor on a learning goal were positively associated with prior opportunities to grapple with complex spatial tasks. Fourth, in the "messy middle" of the progress variables, students were adept at describing spatial primitives but struggled to utilize more complex spatial reasoning consistently. Finally, student data suggested that the lower anchor was appropriate for Using Maps and Spatial Analysis but required revision for Mental Maps.

Spatial Literacy by Gender and Race

Although there were some significant differences in the distribution of scores by gender, there were more similarities. Female students significantly outperformed male students on only 5 out 25 progress variables assessed. In the early part of the progression, females surpassed males in analyzing mental maps and creating, analyzing, and using hand-drawn counter-maps of the school campus. However, the few limited correlations were moderate at best. Findings in this study supported previous research suggesting gender differences on spatial tasks are minimal and largely insignificant (Terlecki and Newcombe 2005; Newcombe 2007; Mohan and Mohan 2013; Metoyer and Bednarz 2017; Solem 2023).

On 22 out of 25 assessments, there were no significant differences in scores by race or ethnicity. Defying prior studies on racial opportunity gaps, Latino students outperformed White students on two assessments (Milner 2012; Solem 2023). One significant and strong correlation between race and assessment scores showed that Latino students significantly outscored White students on Mission 2: Campus Map for the Using Maps standard. Although not statistically significant in the post-hoc tests, Latino students performed slightly better on Taking Informed Action in Mission 5: Environmental Justice than White students. There was one strong but inconclusive association supporting previous research that White students outperform Latino students (Solem 2023).

These unexpected results for female and Latino students align with prior research that priming students to think about their intersectional identities might improve their performance on spatial assessments (Ladson-Billings 2002; McGlone and Aronson 2006; Borman, Choi, and Hall 2020). Missions in which female students scored significantly higher than male students required them to draw their neighborhood from their perspective, design a more student-friendly school map, and plot community assets of personal interest on a paper map. Latino students performed significantly better on an assessment that asked them to redraw the campus map from their perspective and to identify the distribution of different racial and ethnic groups in the community prior to analyzing a local environmental justice issue. Throughout the learning progression, students were often asked to center their perspectives and positionalities in the mapping process, which was to their benefit.

This study provides important local contextual evidence that challenges broader patterns in student-level predictors of achievement documented by race and gender

(Alderman 2021; Solem 2021; Solem et al. 2021; Solem 2022; 2023). As Dr. Derek

Alderman noted in his 2021 commentary in the special issue of the *Journal of Geography*

dedicated to NAEP scores, the discipline of geography must be "responsive to social

difference and justice" to address disparities in student outcomes by race, gender,

language, and ability (2021, 244). Recent growth in the AP Human Geography course is

often commended for progress in geography education; however, the course contributes

to ongoing disparities by race, ethnicity, and gender (Solem, Boehm, and Zadrozny

2021). Counter-mapping should be considered a pedagogical tool for decolonizing

geography education more broadly, especially at the ninth-grade level.

Figure 25 Typical Learning Journeys
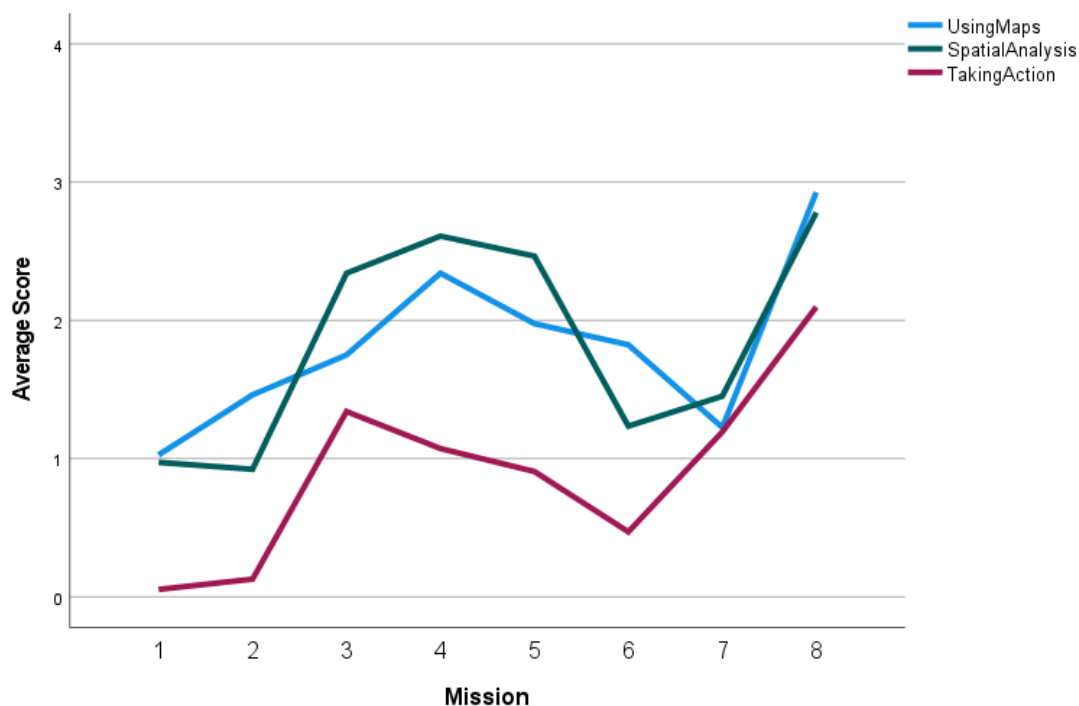
Typology of Learning Pathways

As other research on geography learning progressions have noted, individual student pathways were complex and non-sequential (Bennetts 2008; Solem, Huynh, and Boehm 2015; Huynh, Solem, and Bednarz 2015; Larsen and Harrington 2018; Larsen et al. 2018). Student averages shown in Figure 25 give the illusion of a unified path through the progress variables, yet individual student journeys varied considerably. Even though no two students took the same learning journey, there were common patterns of change from the beginning, middle, and end of the learning progression.

Table 35 Typology of Learning Pathways

Type		Criteria	Percentage of Students by Standard
I	**Succeed Without Support**	Students who maintained or improved their understanding from the *middle* to the *end* of the learning progression.	Using Maps = 77% Spatial Analysis = 72% Taking Informed Action = 95%
II	**Struggle Without Support**	Students who declined from the *middle* to the *end* of the learning progression.	Using Maps = 23% Spatial Analysis = 28% Taking Informed Action = 5%
III	**Stagnate**	Students who showed no significant change from the *beginning* to the *end* of the learning progression.	Using Maps = 14% Spatial Analysis = 10% Taking Informed Action = 30%

Three distinct learning pathways emerged from patterns in student data: 1) students who maintained their skills without support, 2) students who declined without support; and 3) students who stagnated (see Table 35). Mission 4: Mural Map was the middle of the progression. It replicated, with teacher guidance, the counter-mapping processes students would need to perform independently at the end of the progression. Most students fit Type I (72 to 95 percent); they either maintained or built upon the skills

they had learned by the middle of the progression. These Type I students could independently produce sophisticated spatial thinking skills in Mission 8 that they had previously demonstrated with teacher support in Mission 4. Type II was the second most frequent learning pathway (5 to 28 percent). These students performed worse on the final mission than at the midway point of the progression. When asked to conduct their own spatial inquiry to produce a counter-map, they were less successful on their own than when they were guided through an inquiry in the middle of the course. Students needed more support in Using Maps and Spatial Analysis than in Taking Informed Action. Very few students fit Type III, showing no significant change from the beginning to the end of the progression. However, students were more likely to finish the course at the same level where they began on Taking Informed Action (30 percent) compared to Using Maps (14 percent) or Spatial Analysis (10 percent). Figure 26 shows student pathways by type. Lines were created from actual student data.

Figure 26 Sample Student Pathways by Type
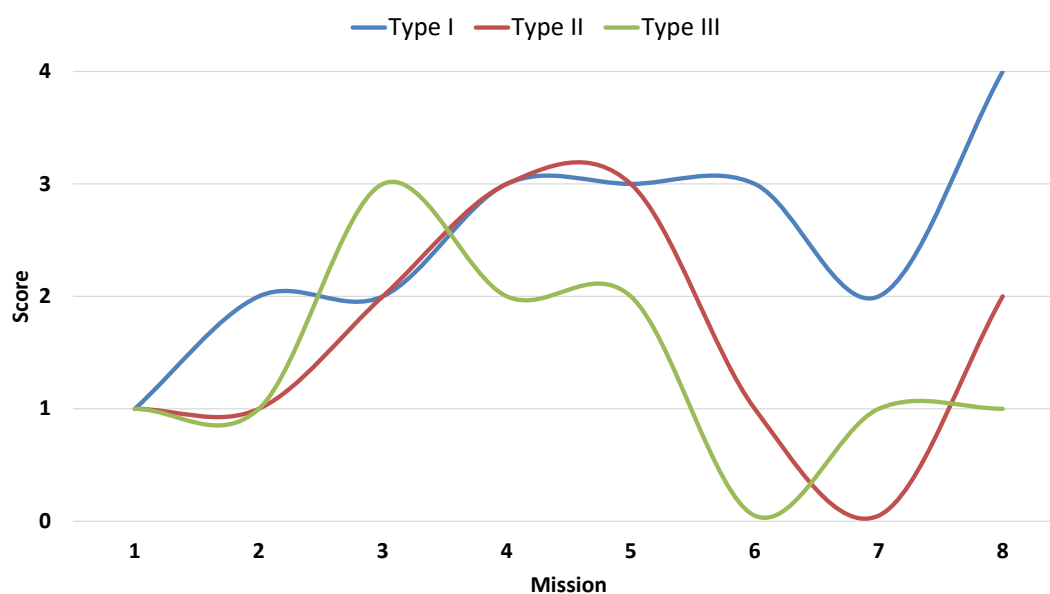
No matter the type of pathway students took, they fluctuated on average one to two levels among progress variables while learning how to do counter-mapping. In standards for Using Maps and Spatial Analysis, students grew from Level 1 to Level 3, and in Taking Informed Action, they went from Level 0 to Level 2. In other words, before any learning interventions occurred, students could identify the properties of maps, draw familiar places from memory, and describe those places using spatial primitives like distance, direction, and location. In addition, almost none of the participants were able to identify community assets or problems using a map at the start of the progression. After completing the learning sequence on counter-mapping, students could analyze spatial data to answer questions about the processes that influence the distribution of human and physical processes. They were also able to describe potential actions or solutions to community problems.

These statistically significant patterns of improvement across all three learning standards suggest that the learning progression had cognitive momentum. However, missions did not always provide the conditions for students to exercise complex reasoning. Mission 6: Case Study and Mission 7: Geo-Inquiry showed a period of low-level reasoning immediately following spikes in complex reasoning in the preceding missions. Students produced some of their lowest scores, regardless of standard, in Mission 6: Case Study. Despite this, nothing was wrong with the progression or the learning activity. We cannot expect students to maintain high levels of cognitive demand for sustained periods (Hess et al. 2009; Kester, Paas, and Van Merriënboer 2010; Plass, Moreno, and Brünken 2010).

Learning progressions do not need to be linear. Students need multiple opportunities to try out new skills and to see applied examples of complex spatial reasoning in the real-world. After three weeks learning to make maps and learning complex relationships like pattern, distribution, overlay, and buffers, students were given an opportunity to see all those skills at work in a series of counter-map case studies in Mission 6. Moreover, high outcomes on Mission 8 often hinged on more sophisticated mastery in the middle of the progression.

Prior Opportunities on Complex Tasks

The design of the learning progression provided students with multiple opportunities to practice and master emerging skills in novel contexts. All three interpolation lines of student learning pathways to master counter-mapping show that students achieved higher levels of sophistication in Missions 3, 4, and 5 in the middle of the learning sequence. Those three missions offered students their first opportunities to try counter-mapping under their teacher's careful and thoughtful guidance. In Mission 3: Asset Map, students worked in small groups to plot community resources on paper maps and then learned how to analyze clustered and dispersed patterns. A student reflection on their asset map in that mission demonstrated Level 2 understanding in Spatial Reasoning (see Figure 27). At this level, students could describe patterns and trends but struggled to analyze the processes behind them.

Figure 27 Student Reflection on Mission 3: Asset Map

> *"We located key resource providers in [town]. Noticed if they were clustered or dispersed. Mine was health and I plotted mostly on Cyprus St/Elm. The mission taught me what clustered and dispersed meant. Clustered was when they were close, dispersed was far apart. Most services were held downtown. I would disperse it more like around town, not just in one are."*

Mission 4: Mural Map provided both guided and unguided opportunities to make maps of community murals using ArcGIS Online. More expert students could play and experiment with geoprocessing tools, and novice students could rely on increased teacher direction. The student sample in Figure 28 shows a student who categorized murals by type, added a heat map to show density, and created buffers around mural locations. This student also created two buffers around their home to evaluate the walking distance to community murals and suggest a new mural location. Mission 4: Mural Map and Mission 5: Environmental Justice were the only times students reached the upper anchor on Using Maps and Spatial Analysis before the final counter-mapping mission. These middle missions enabled students to synthesize multiple sources of spatial data to arrive at conclusions.

Figure 28 Student Mural Map from Mission 4
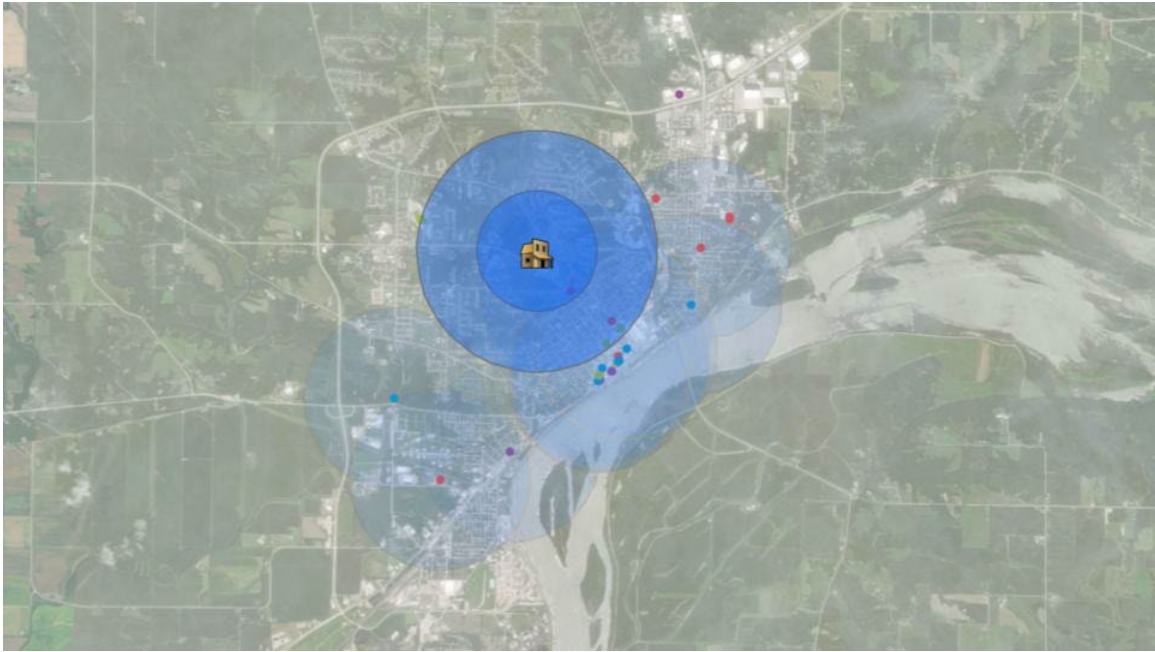
There were strong and significant positive relationships between student scores on the final counter-map project and their prior opportunities to practice. High levels of spatial skill early in the course led to better outcomes later, particularly when using geospatial technologies (Howarth and Sinton 2011; Metoyer and Bednarz 2017). Results of Kendall's tau-b test for association are organized by Mission 3, 4, and 5 in Table 36. Only the statistically significant relationships were included.

Table 36 Statistically Significant Associations Among Missions

Final	Prior Practice					
Mission 8 Standards	Mission	Standard	Correlation Coefficient	Sig. (2-tailed)	N	Strength of Association
Using Maps	3	Using Maps	.505**	<.001	43	Strong
	4	Using Maps	.349*	.011	41	Moderate
	4	Spatial Analysis	.480**	.001	40	Strong
	5	Using Maps	.420**	.002	44	Strong
	5	Spatial Analysis	.328*	.019	44	Weak
Spatial Analysis	3	Using Maps	.395**	.005	42	Strong
	4	Using Maps	.365**	.008	40	Moderate
	4	Spatial Analysis	.421**	.005	39	Strong
	5	Using Maps	.448**	.001	43	Strong
	5	Spatial Analysis	.431**	.002	43	Strong
Taking Action	3	Using Maps	.470**	.001	41	Strong
	3	Spatial Analysis	.286*	.049	41	Weak
	3	Taking Action	.352*	.013	41	Moderate
	4	Spatial Analysis	.399**	.010	38	Strong
	5	Using Maps	.345*	.012	42	Moderate

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

High scores on all three standards on Mission 8 had strong, statistically significant positive associations with Mission 3: Using Maps and Mission 4: Spatial Analysis. Both missions allowed students to organize and plot their own spatial data, first on paper maps in Mission 3 and then on ArcGIS Online in Mission 4. These missions provided critical practice for students before collecting, organizing, and deciding how to visualize their own data during their final inquiry project. Moreover, it enabled them to think about potential actions or solutions based on the patterns they observed in their maps. They discussed people and organizations that might be interested in using their maps of community assets and suggested new locations for a mural based on overlays of heat maps and buffers.

Novice students often need opportunities to try out complex, problem-solving tasks with guidance before engaging in the inquiry process independently (Kirschner,

Sweller, and Clark 2006; Kester, Paas, and Van Merriënboer 2010; Howarth and Sinton 2011). Problem-based learning in this study allowed students to work through real-world problems while acquiring analytical and spatial thinking skills. Research on cognitive load theory (CLT) suggests that guiding students through an entire problem-solving process, where the solution is given prior to having students work on it, can be more helpful than asking novice students to problem-solve independently with little guidance (Sweller 1988; Plass, Moreno, and Brünken 2010; Howarth and Sinton 2011). Showing the entire inquiry process helps students understand how problems are deconstructed and solved.

The student counter-map on crosswalk safety in Figure 29 is an excellent example of a student who benefited from prior opportunities to practice spatial inquiry with guided support. This student achieved the upper anchor on Using Maps and Spatial Literacy and was at Level 3 in Taking Informed Action. Throughout the middle missions (3, 4, 5) this student fluctuated between Level 2 and Level 3. This student also based their data collection methods on the model of an exemplary counter-map they studied earlier in the course. Novice students benefit from solid examples that guide them through the inquiry process (Kirschner, Sweller, and Clark 2006; Kester, Paas, and Van Merriënboer 2010; Howarth and Sinton 2011). This kind of productive intellectual struggle was common for students in the middle of the learning progression. Most students achieved Levels 2 and 3 on missions that scaffolded the spatial inquiry process with teacher support. The messy middle was an essential component for students on their way to mastery of the skills required to create actionable counter-maps.

Figure 29 Student Counter-Map on Crosswalk Safety
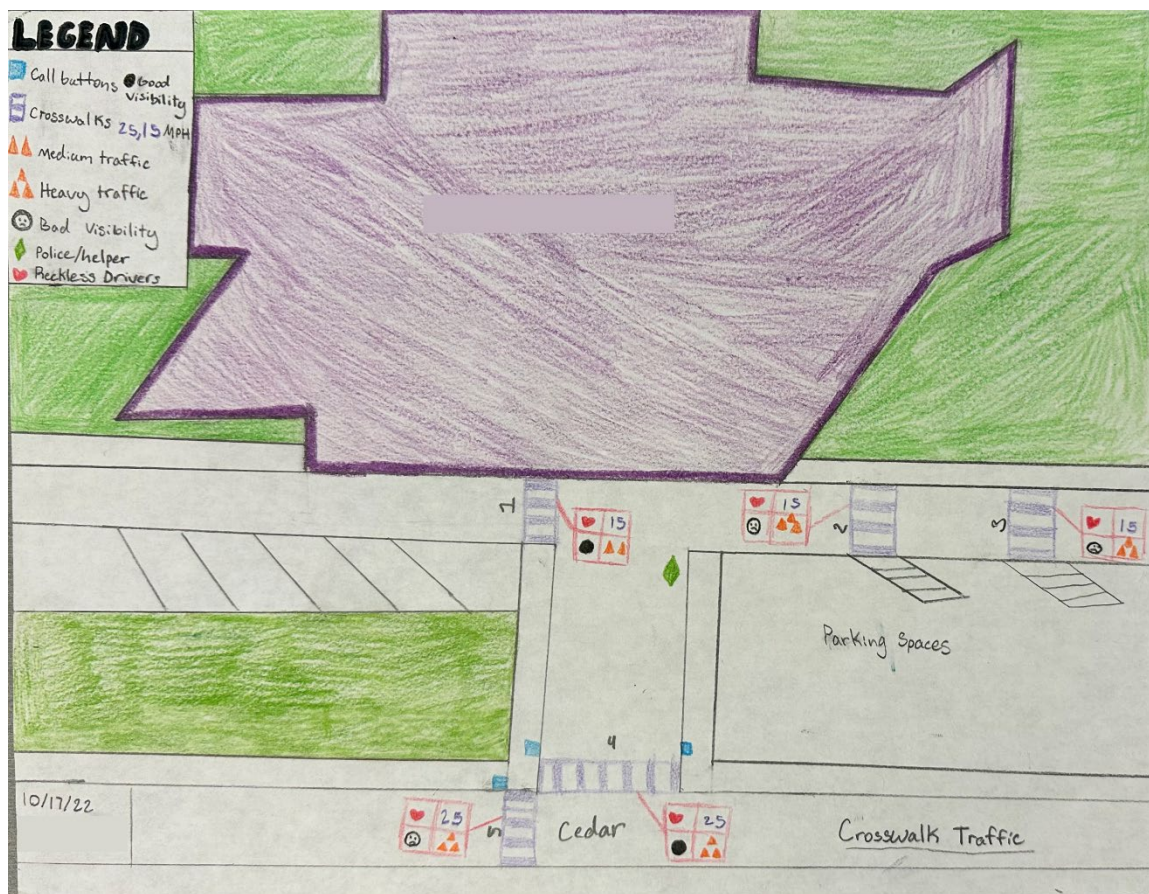
The Messy Middle

Students fluctuated between the middle progress variables of the learning goal.

This variation was most prominent in Mission 4: Mural Map and Mission 5:

Environmental Justice, which exemplify the "messy middle" of the learning progression

(Solem, Huynh, and Boehm 2015; Larsen et al. 2018). The messy middle is where

students have "some, but not all, of the necessary knowledge" for the skill, so their

reasoning might change based on the context or situation in which the progress variable is

being assessed (Solem, Huynh, and Boehm 2015, 6). Students who reached the upper

anchor on Using Maps in the context of Mission 4 with student-generated mural maps did

not necessarily replicate that mastery again in Mission 5 when asked to examine community environmental justice maps. When asked to use the counter-maps they had produced in Mission 4 to suggest a new location for a mural, 32.6 percent of students could use the spatial data from their GIS buffers, heat maps, and layers of demographic information to communicate a solution. However, when asked to evaluate the extent to which environmental justice existed in their community in Mission 5, no students could communicate a solution using the maps provided. The drop in understanding from Mission 4 to 5 suggests that a more abstract concept, like spatial justice, was a more challenging domain than a more visually concrete one, like buffers.

In addition to their inconsistency, students gave partially correct answers in the messy middle (Solem, Huynh, and Boehm 2015). Students were good at answering "Where?" questions but struggled to consistently and accurately answer "Why?" questions. The majority of students on Mission 3: Asset Map (53.3 percent) and Mission 5: Environmental Justice (56.5 percent) could describe the patterns of features using terms like "clustered," "dispersed," and "density." Only 4.5 and 4.7 percent, respectively, could analyze that spatial data in a way that answered questions about the spatial patterns (Using Maps Standard, Level 3). Students began to analyze processes more often in Mission 4: Mural Map but still struggled to do so accurately. For example, when describing what they learned in Mission 4, one student wrote, "it is really important to pay attention to the location and what a mile radius is, which I've never heard of before." They partially explain a buffer, but the student just cannot quite describe *why* it is necessary or *how* it might help them make inferences about spatial patterns on the map.

In addition to planned practice with complex problems, students need timely and targeted learning interventions when working through the messy middle. This study used an in-situ approach, in which the researcher was embedded in the learning environment to assist the teacher in planning for and executing the assessments (Huynh, Solem, and Bednarz 2015). When it became apparent that students were struggling to explain the "why of where," the researcher and teacher developed a series of bell-ringers so students could practice this kind of reasoning in the lessons leading up to Mission 3 and Mission 4. These were missions in which students significantly improved their ability to use maps and conduct more complex spatial analysis. The middle of the learning progression provided invaluable practice for students to work out their thinking and build their skills.

Validity of the Lower Anchors

Table 37 Lower Anchor Frequency Table

	Mission 1			
	Using Maps	**Mental Maps**	**Spatial Analysis**	**Taking Action**
4				
3		37.0%		
2	19.5%	37.0%	2.4%	
1	63.4%	15.2%	92.7%	5.1%
0	17.1%	2.2%	7.3%	94.9%

Student data validated the lower anchors the research proposed for Using Maps and Spatial Analysis; however, the Mental Maps standard requires revision. Mission 1: Mental Map served as a baseline for student's knowledge before learning interventions occurred. Level 1 of each standard was written to capture what the researcher anticipated students would know and be able to do upon entering high school with no formal geography classes. The lower anchor was a particularly good fit for the learning goal on

Spatial Analysis, and a moderately good fit for Using Maps (see Table 37). However, the

lower anchor for Mental Maps set the bar far too low for students in the study. Most

students scored above Level 1 in Mental Maps. Future revisions of the learning

progression should prioritize increasing the difficulty of mental mapping tasks for 14- to

15-year-olds. These students were able to interpret and compare mental maps.

How Students Use Counter-Maps to Take Informed Action

As students learn spatial literacy skills through counter-mapping, they shift from

merely using maps as reference tools to thinking of them as more sophisticated means for

communication and problem-solving. The extent to which students were able to use maps

to take informed action depended on their level of spatial literacy. Student reflections

about the process of creating their own counter-maps demonstrated that communicating

solutions might not be an accurate upper anchor for the culmination of the inquiry

standard. Figure 30 shows the complex relationships and patterns among themes for

taking informed action (MAXQDA 2022).

Figure 30 Thematic Map for Taking Informed Action & Spatial Literacy
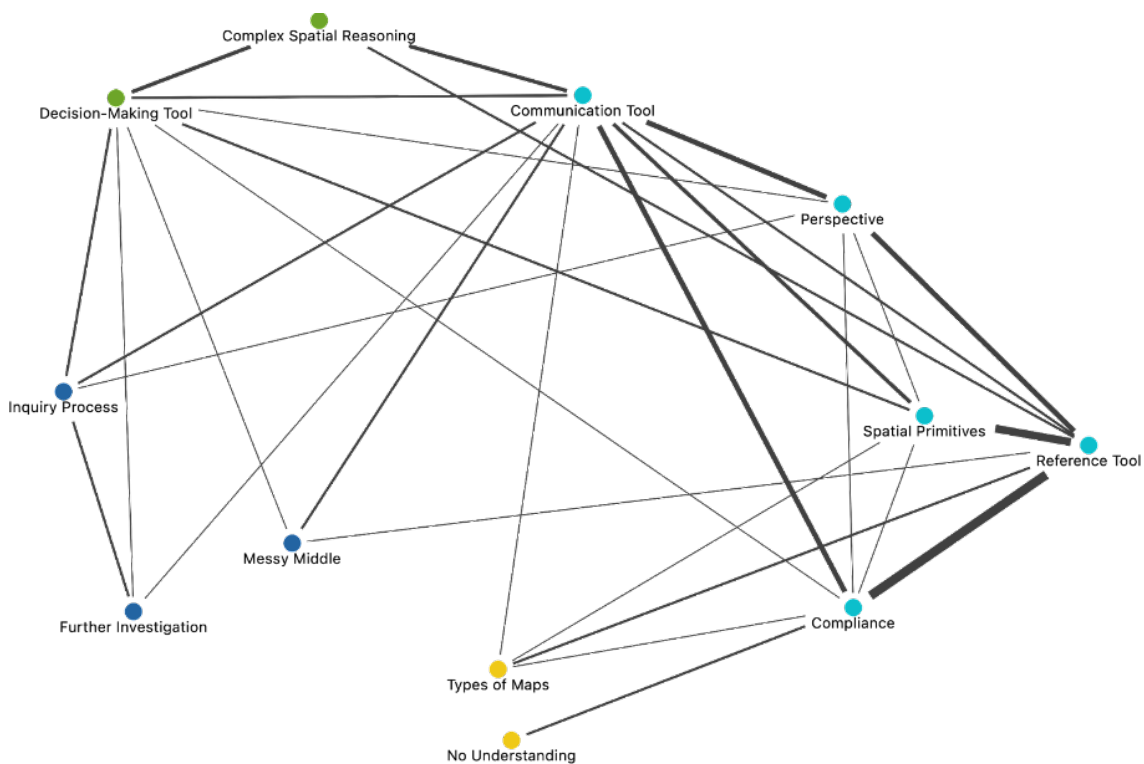
Figure 31 How Students Use Maps Across the Learning Progression
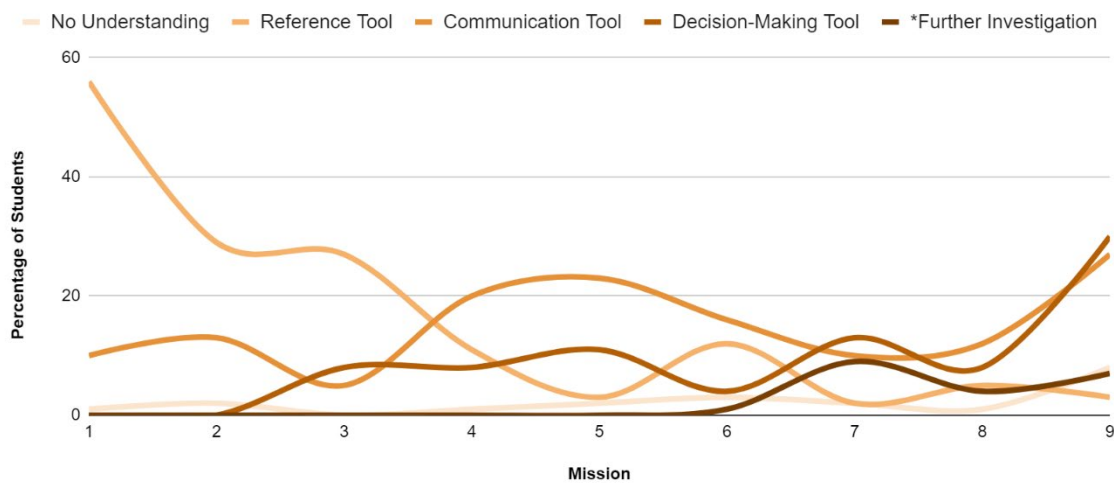
From Navigation to Communication: The Power of Perspective

Early in the proposed learning progression, students viewed maps as reference tools for navigation (see Figure 31). Use of maps as reference tools was especially true in Mission 1: Mental Maps, where most students described maps as a way to show someone how to get around town. By the middle of the course, in Mission 4: Mural Map, students began to see the power of maps as communication tools to share stories about the community. Some students even understood the power of a map to provide supporting evidence for decisions about where to paint a new mural in town, where to place an ad to attract the most attention, and how to improve access to clean air. At the end of the course, once students had designed their own maps in pursuit of the answer to a question, nearly half could articulate how that map could be used to solve a problem or take action.

Incorporating the mapmaker's perspective and experiences into the map design is an essential feature of counter-maps. There was a significant positive association between students' ability to understand the perspective of the mapmaker and their ability to produce a strong counter-map. There were significant correlations between Mission 8 and Mission 6 outcomes. Mission 6: Case Study required students to analyze a counter-map from the anthology, *This Is Not an Atlas*, and explore the ways everyday people map stories about their communities (Kollektiv Orangotango+ 2018). Students who were able to analyze the choices of the mapmaker, the message they conveyed, and how those decisions fit the definition of a counter-map also made more complex and actionable counter-maps of their own in Mission 8.

Moreover, higher scores in Mission 6 were also positively associated with students' ability to discuss the preferences and perceptions in the mental maps of their

classmates in Mission 1. The thematic analysis also revealed common occurrences of perspective and maps as a communication tool in student reflections. When students analyzed mapmakers' perspectives, they also were likely to view maps as tools to describe a location or to communicate a spatial story. All of this suggests that mental maps are an appropriate entry point for building the spatial skills required to produce counter-maps, and ninth-grade students are ready to think about what factors influence how we perceive and make sense of space.

Spatial Literacy Facilitates Decision-Making

Significant positive associations existed between spatial literacy skills and viewing maps as decision-making and problem-solving tools. Thematic analysis revealed important connections between how students used maps and how they reasoned and reflected on the new spatial skills they were learning. Students who simply followed directions or who could only describe simple spatial relationships were also more likely to talk about using maps for navigation and location. They lacked the complex spatial reasoning skills to explain what they were learning in the mission and to think of the map as anything beyond a tool for showing where something is located. Students who demonstrated more complex spatial reasoning in their reflections could also see the benefits of using those skills to make maps work for them. Equipped with the ability to analyze patterns and make meaning of maps, students could use the map to tell a story, educate, inform, or even recommend a particular decision.

There were 11 out of 46 students (23.9 percent) who scored at Level 3 or Level 4 on Taking Informed Action on the final counter-mapping mission. All 11 students also demonstrated complex spatial reasoning skills, scoring no lower than Level 3 on the

spatial literacy skills—Using Maps and Spatial Analysis. High spatial skills were strongly and significantly associated with sophisticated counter-maps that proposed solutions to spatial problems, which was supported in past studies by Metoyer and Bednarz (2017) and Howarth and Sinton (2011). There was no indication that GIS maps produced on ArcGIS Online facilitated higher levels of spatial thinking or decision-making in Mission 8, which counters findings from Metoyer and Bednarz (2017). Only 3 out of 11 students (27.3 percent) who scored highly on Mission 8 created web-based GIS counter-maps. The other 8 out of 11 high-scoring students (72.7 percent) chose to make their counter-maps on paper. Complex spatial reasoning skills were positively correlated with higher outcomes at the end of the learning progression.

Not All Inquiries End in Solutions

Ninth-grade students in this study were largely unable to take informed action using the counter-maps they created. Instead, they were more likely to use their counter-map to describe or advocate for potential actions or solutions for a community problem. Most students could not even reach the lower anchor on Mission 1, and in the end, only 2 out of 46 students achieved the upper anchor for taking informed action. Both of those students focused on school-related issues in their final counter-map. These results suggest a need to revise the Taking Informed Action learning goal for a different kind of rigor.

The upper anchor of the Inquiry Arc from the C3 Framework proposes that communicating solutions and taking informed action is the ultimate outcome of masterful research. However, student inquiries in this counter-mapping study sometimes ended with more questions than answers. For example, a student made a map to improve safety in the community but was puzzled by the result. They found that the police station was

right in the middle of the areas participants in their study had identified as unsafe. In this situation, the inquiry process ended with a new question rather than a solution (Figure 32 and Figure 33).

Figure 32 Student Response: Mission 8

> *"My map that I made would help the community open [their] eyes because the police station is right downtown where the not safe spots is right there! So why do people still not feel safe being around there? What is causing this?*

Figure 33 Student Counter-Map of Community Safety
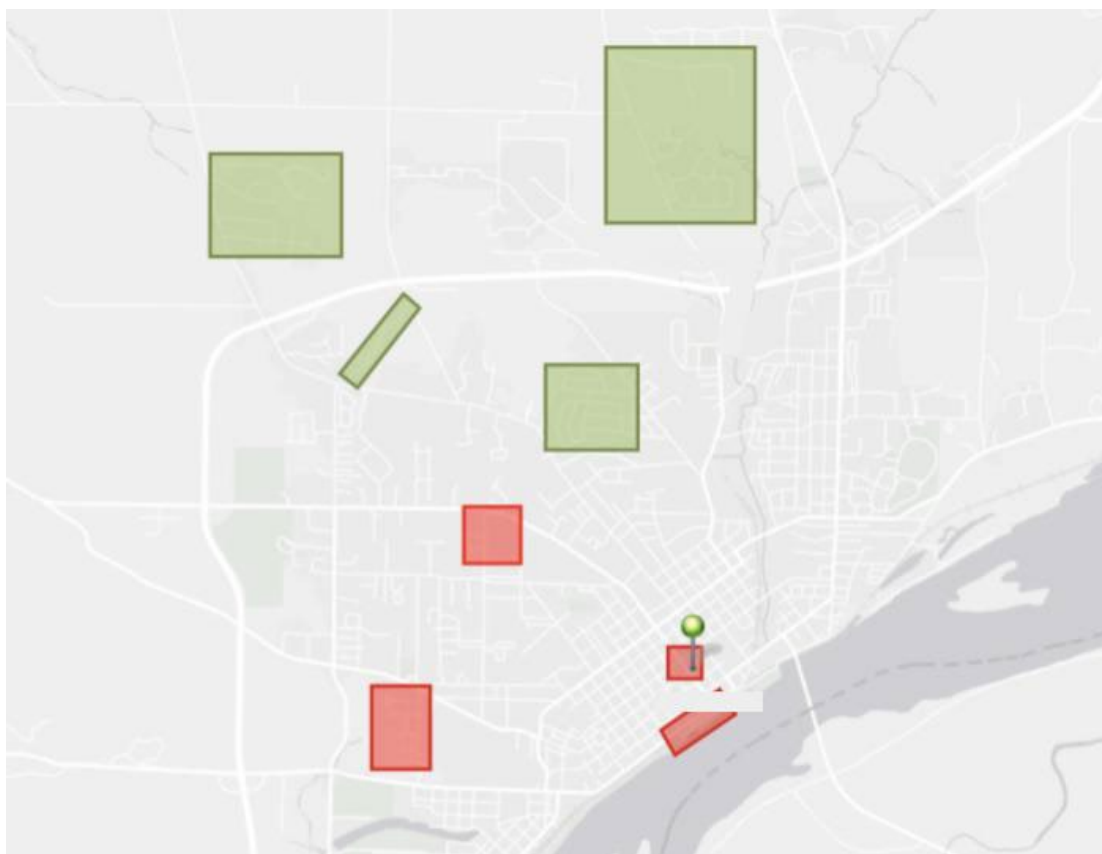
Green: Low Reports of Theft in a High-Income Neighborhood
Red: Low Reports of Theft in a Low-Income Neighborhood
Land Mark: Theft Resource (Police Station)

Sometimes, students realized that the parameters of their inquiry prevented them from producing actionable results. In one example, a student found that the study area was too large to gather meaningful or accurate data. They were researching the issue of litter but said they "should probably pick a certain area" instead of trying to study the entire city. In this case, the inquiry process served as a valuable feedback loop for designing future studies.

Although ninth-grade students were not able to community-level action, they demonstrated an eagerness to make a difference in the future. They were also able to make personal changes in behavior. In the end-of-course reflection, 14 out of 39 students (35.9 percent) said they might consider taking action on their issue in the future. There were also 5 students (12.82 percent) who said they were taking action, which was 3 more students than reached the upper anchor on Taking Informed Action. Student reflections revealed that they considered personal actions and internal behavioral changes as taking informed action, which was not captured in the proficiency scale proposed by the researcher.

Several compounding factors might prevent adolescents from taking action, especially in the ninth-grade year. The transition from middle school to high school is a time of vulnerable change, in which students must often establish new peer groups and bonds with new teachers (Cohen and Smerdon 2009). With few social connections to teachers and other authority figures, ninth-grade students lack access to adults who hold the power to make change. Future learning progression research should consider guided problem-based learning in which the teacher connects students with community stakeholders.

One student who succeeded in taking action in this study tapped into existing networks of teachers, counselors, and building staff at the junior high they attended the previous two years. They investigated bullying at the junior high, drawing on personal experiences and surveys with current eighth-grade students (see Figure 34). At the conclusion of the study, the student was working with junior high counselors to improve hallway monitoring at bullying hotspots. The other student who took action talked with school safety officers to recommend new surveillance camera locations to prevent theft in high-risk zones at the high school (see Figure 35).

The current progress variables for the Taking Informed Action learning goal underestimate the importance of asking new questions in the inquiry process and overestimate the ability of ninth graders to take informed action without teacher support. Student reflections suggested a need to revise the upper anchor of the learning goal to include questions and new inquiries as the result of geospatial investigations. Not all inquiries end in solutions, and action might be personal—not community-wide. Inquiry is an iterative loop of exploration. The standard should give as much credence to exploratory spatial analysis as it does to explanatory conclusions.

Figure 34 Student Counter-Map of Junior High Conflicts

Figure 35 Student Counter-Map on Theft at School
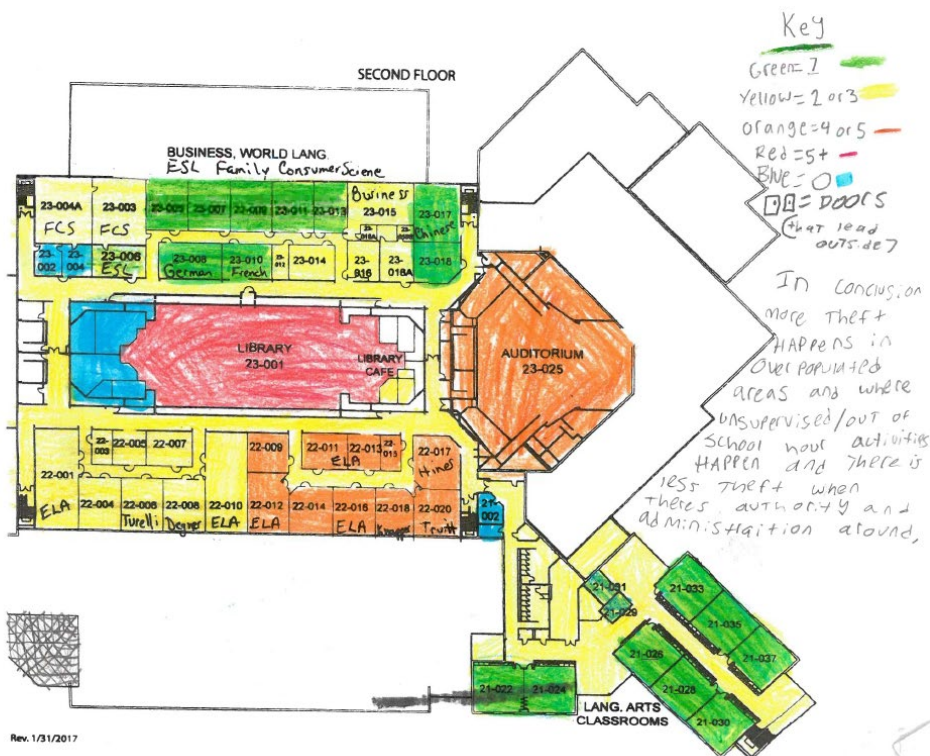
Limitations

The quantitative and qualitative results were calculated using only the data available. The completion rate for the mapping missions was 83.3 percent and 78.7 percent for the written reflections. Missing data lowered the sample size from an already small population of data and disrupted pairwise tests for association and ordered pairs. For example, to run the Wilcoxon signed-rank test, all missing, non-paired data was filtered out, reducing the potential sample size for analysis from $n = 4$ to $n = 11$ depending on the standard and mission assessed. Because the results only used complete datasets, there was a chance that the change in median scores was inflated or overstated.

Future studies with missing data at random might consider using multiple imputation as a technique to produce a complete dataset that minimizes bias and retains statistical power (Allison 2000). Even when results were significant at the 1 percent level ($P < .001$), the lack of a random sample and control group made it impossible to assess for causation.

In addition, sample sizes for gender-diverse individuals were small for this study ($n = 2$) and will most often be small in educational studies. This study provided evidence that the distribution of spatial literacy skills was higher for nonbinary students than male students but lower than for female students; however, none of those results were statistically significant and should be interpreted with caution due to low sample sizes. Future studies should consider multilevel modeling to resolve the issue of small sample sizes of gender-diverse students and to account for the interactions between intersectional social identities that shape educational opportunity and achievement (Evans et al. 2018). Solely using categorical variables like gender, race, ability, and language obscures the

compounding systems of oppression (sexism, transphobia, racism, ableism, xenophobia) that contribute to worse learning outcomes (Milner 2012; Bauer 2014; Evans et al. 2018). A great deal is yet to be known about how nonbinary students gain spatial literacy and take informed action.

Using written reflections on open-ended prompts might have produced a response bias favoring students more likely to write about their experience. Exit interviews or focus groups might capture feedback from students who had meaningful experiences but could not write them. Interviews could benefit English learners and students with IEPs and 504 plans that struggle with writing. Future studies should consider gathering participant data about disability status, English proficiency, and free or reduced-price lunch eligibility. In addition to race and gender, these are standard demographic metrics used on the National Assessment of Educational Progress (NAEP) Geography Assessment and on state standardized test scores reported by each district as a requirement under the Every Student Succeeds Act ("Every Student Succeeds Act (ESSA)" 2022; "Iowa School Performance Profiles" 2022; Solem 2023).

There are several limitations regarding the scope and sequence of this pilot study. Development of learning progressions, data collection and analysis, and subsequent learning progression revision can take years (Marsh, Golledge, and Battersby 2007; Gregg and Sekeres 2006; Yeung 2010). This pilot study accelerated that process over eighteen weeks. Anderson (2008) described conceptual coherence, compatibility with current research, and empirical validation as the three criteria necessary to gather legitimate evidence about learning progressions. The *Geography for Life* standards and the C3 Framework were used to ensure conceptual coherence of the learning progression

and compatibility with current research. However, there was no empirical validation of student learning data by teachers or students (Anderson 2008; Bednarz, Heffron, and Huynh 2013). This study was simply the first step in an attempt to validate the instruments and instructional sequence.

Another limitation of the study is gathering a preponderance of evidence to demonstrate student learning in a standard. A single assessment cannot ascertain the whole level of understanding (Solem, Huynh, and Boehm 2015), and students often need to try out new skills in a variety of contexts over time before they can achieve mastery (Webb 2002; Hess et al. 2009). Certain types of prompts in the learning progression were also designed to elicit higher-order thinking compared to others. Future research might focus on student development using the repetition of a task or a series of tasks or how students integrate their knowledge across the progression (Anderson 2008).

Future research should consider that students might lack the spatial vocabulary to articulate their learning, which can also prevent them from asking the kinds of thought-provoking questions that lead to upper-level reasoning (Gregg and Sekeres 2006; Marsh, Golledge, and Battersby 2007; Yeung 2010; Metoyer and Bednarz 2017). The students entered this study with a minimal working geographic vocabulary. With such a condensed time frame for the study, there were few opportunities for students to practice and gain command of new geographic terms. Lack of geographic vocabulary may have hurt their chances of achieving the upper anchor and completing a spatial inquiry. Emphasis on spatial vocabulary should be considered in future studies.

Although the proposed learning progression was scaffolded to help students produce a counter-map that could be used as a decision-making tool in the community,

that was a demanding standard to meet in a short, nine-week time frame. There were few opportunities to invite community stakeholders to collaborate with students in the classroom. One police officer, a school safety officer, and three instructional coaches provided feedback for some students during the counter-mapping process. Despite the limited opportunities for students to gain access to community stakeholders, students were using their maps to improve hallways at the middle school, enhance crosswalk safety at the high school, and prevent vaping in bathrooms. At the conclusion of the study, the facilitating teacher was working with a local city planner to develop student projects addressing the issues of bike trail expansion in the community.

Figure 36 Student Counter-Map of Vaping at School
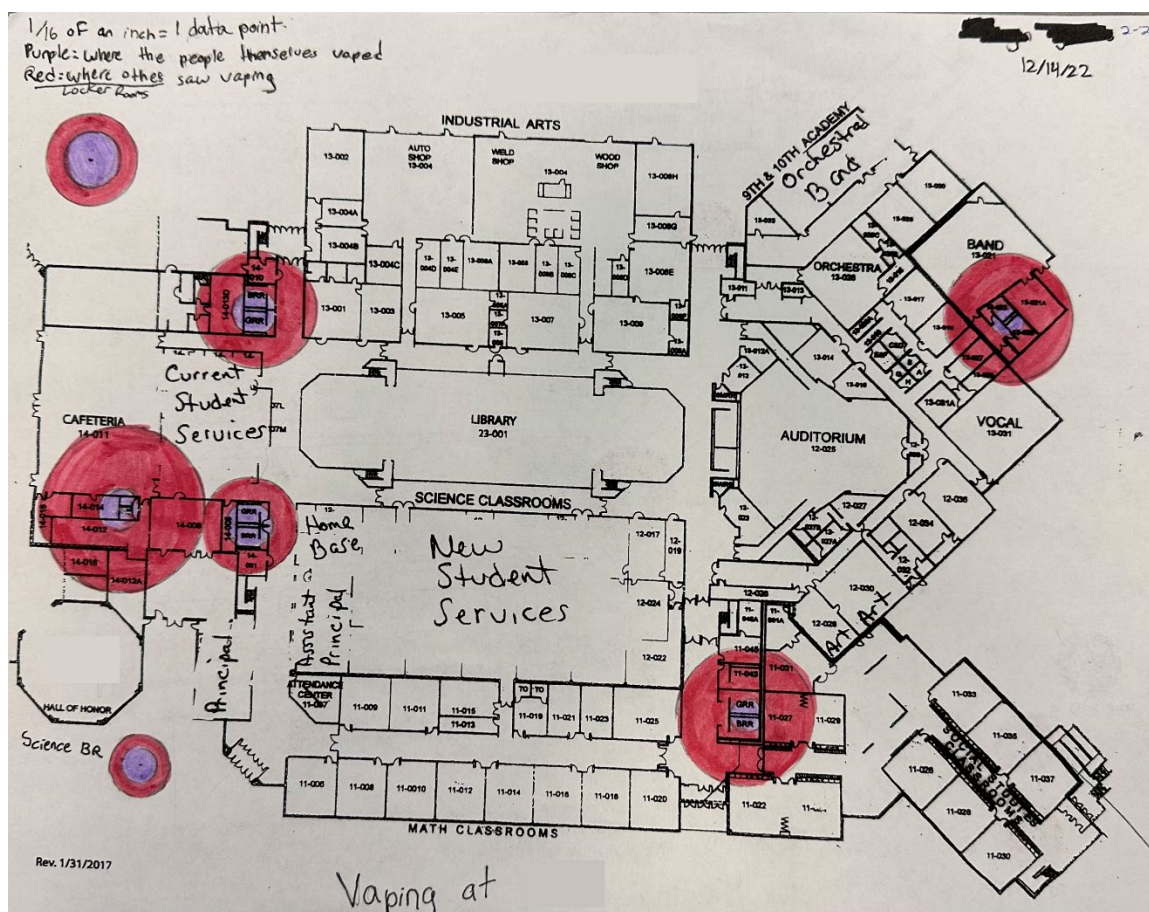
Chapter 6:

Conclusion

Students learn a variety of important spatial thinking skills when engaged in counter-mapping. They learn to use spatial data to ask and answer questions about spatial patterns and develop complex spatial reasoning skills to share those stories. When students are given opportunities to practice solving complex problems, they are more capable of carrying out authentic inquiries of their own.

Students take complex and non-sequential pathways while they learn to build geographic inquiries and design actionable counter-maps. This study found little evidence that students performed differently by race or gender. The possibilities of reaching the upper anchor on a learning goal were positively associated with prior opportunities to engage in complex spatial reasoning. In order to take informed action, students first had to understand how to use maps to communicate information and analyze them in ways that lead to actionable solutions. Without these cornerstone spatial literacy skills, it was challenging for students to envision their maps beyond simple navigational tools.

As a result, future learning progressions should emphasize acquiring spatial literacy in the context of problem-based inquiries. Students should be rewarded for the productive struggle in the messy middle of the progress variable. At this stage, teachers should not focus on whether or not students get the "right" answer; instead, they should emphasize the thinking routines used by geographers to solve complex problems. Over time, with opportunities to practice, students will hone their methods to communicate solutions to spatial problems.

As students progressed to increasingly complex spatial reasoning skills, they also began to see the value of maps beyond a simple navigational tool. More sophisticated spatial thinking transforms a map from a static reference instrument to a dynamic decision-making tool. However, future researchers should reconsider solutions as the apex of the inquiry arc. Inquiry is an iterative loop that generates as many new questions as it answers. Learning progressions should emphasize the capacity to think geographically without so much focus on accuracy. It is possible to think in impressive, complex, and sophisticated ways without arriving at accurate conclusions (Sikorski and Hammer 2010; Solem, Huynh, and Boehm 2015). Learning the process of spatial reasoning and the systematic methods for solving problems is the vehicle to demonstrating mastery of content knowledge across various disciplines. Even when students did not produce completely accurate spatial reasoning, they still benefited from engaging in the process in the long run.

Every map has a story to tell. It invites the viewer into a dialogue with the mapmaker. Inviting young people into the mapmaking process ensures that the map's story reflects their ways of knowing and being in the world. Youth are an untapped resource for improving the quality of life and access to essential resources in their communities. Counter-mapping captures youth perceptions of place, improves their spatial literacy skills, and engages them in meaningful civic action. When implanted alongside an effective progression of spatial literacy skills with guided teacher support, counter-maps have the powerful potential to serve as common ground between policymakers and youth stakeholders looking to better their communities.

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Appendix A: Mapping Missions

Figure 37 Mission 1: Mental Map

Name: _____   Period: _____   Date: _____   Student #: _____

Mission #1: Mental Map

Mental Map Defined
A mental map is a drawing that shows what an area looks like from one particular person's point of view. It shows how a person perceives that place and how they interact with it. Think about your neighborhood. Can you picture it in your head? We use mental maps all the time! You might use one when thinking about how to get from one end of the school to the other before the bell rings. You might even have a mental map in your head when you remember a favorite vacation or field trip!

Task
1. Draw a mental map of your community from memory.

1

Name: _____   Period: _____   Date: _____   Student #: _____

Reflection
2. What landmarks and features did you include in your map? Why?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

3. What kind of symbols did you use to create the map? Why did you make those decisions?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Name: _____   Period: _____   Date: _____   Student #: _____

4. What is the most important part of your map?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

5. What did you leave out that you also think is important?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Name: _____   Period: _____   Date: _____   Student #: _____

Discussion

6. Compare your mental map with a classmate. What similarities and differences exist in your maps?

<table>
<tr><td align="center">Similarities</td><td align="center">Differences</td></tr>
<tr><td>1. _____</td><td>1. _____</td></tr>
<tr><td>2. _____</td><td>2. _____</td></tr>
<tr><td>3. _____</td><td>3. _____</td></tr>
<tr><td>4. _____</td><td>4. _____</td></tr>
<tr><td>5. _____</td><td>5. _____</td></tr>
<tr><td>6. _____</td><td>6. _____</td></tr>
</table>

7. What do these maps say about your experiences here compared to your classmate's? List at least 2 comparisons.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Figure 38 Mission 2: Campus Map

Name: _____   Period: _____   Date: _____   Student #: _____

Mission #2: Campus Map

Ground Truthing

Every map we look at is outdated. Even the satellite images in Google Maps might not include new features in a location. A new road or structure might have been built since the satellite image was taken for the map. Ground truthing is the process of verifying that what is shown on the map accurately reflects what is actually physically present on the ground in that spot.

Task

1. After looking at satellite imagery of the school campus on Google Maps, walk around the campus and jot down notes about what you see. Based on your observations, create a map of campus that might be useful to new students.

Field Notes:

1

Name: _____   Period: _____   Date: _____   Student #: _____

Field Notes:

Name: _____   Period: _____   Date: _____   Student #: _____

Based on your field notes, draw your campus map here.

Name: _____ Period: _____ Date: _____ Student #: _____

Task

2. Consider including the following components in your map. For each component you decide to include in your map, check the box. For *every* component, briefly describe why you <u>did</u> or <u>did not</u> include it in your map.

- Title: _____
  _____

- Legend: _____
  _____

- Compass (direction): _____
  _____

- Scale (distance): _____
  _____

- Symbols: _____
  _____
  _____

- Grid or coordinate system: _____
  _____

- Human features: _____
  _____

- Natural features: _____
  _____

- Built environment: _____
  _____

- Other: _____

Name: _____   Period: _____   Date: _____   Student #: _____

Reflection

3. What landmarks and features did you include in your map? Why?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

4. Which map components are included in the "official" campus map?

- Title: _____
- Legend: _____
- Compass (direction): _____
- Scale (distance): _____
- Symbols: _____
- Grid or coordinate system: _____
- Human features: _____
- Natural features: _____
- Built environment: _____
- Other: _____

Discussion

5. Compare your campus map with the official map used by the school. What similarities and differences exist? Discuss why you think the mapmaker made different design choices in the "official" campus map.

Similarities	**Differences**
1. _____	1. _____
2. _____	2. _____
3. _____	3. _____
4. _____	4. _____
5. _____	5. _____
6. _____	6. _____

7. Which map do you think is more effective—your map or the professionally-drawn map? Explain your reasoning.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Figure 39 Mission 3: Asset Map

Name: _____   Period: _____   Date: _____   Student #: _____

Mission #3: Asset Map

Task

Create a map of resources available to residents of the community.

1. Plot resources from the Student Services brochure on the map.
2. Add any resources you feel are missing.
3. Use the colored stickers to categorize community resources.

Reflection

2. What kinds of local resources are available to residents here? Who are some of the key resource providers?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

1

3. What patterns or trends do you notice in the distribution of these resources? Are they clustered in certain areas or spread out?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

4. What might explain the patterns and trends you observed on the map?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

5. What person or organization might be interested in using this map? Explain your reasoning.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Discussion

6. Compare your asset map with another group. What organizations seem really important to the community? What resources do we need more of in this community?

These organizations are really important…	**We need more…**
1. _____	1. _____
2. _____	2. _____
3. _____	3. _____
4. _____	4. _____
5. _____	5. _____
6. _____	6. _____

Figure 40 Mission 4: Mural Map

Name: _____   Period: _____   Date: _____   Student #: _____

Mission #4: Mural Map

Task #1

Collect images and coordinates of murals in the community.
1. Use Survey123 to take a picture of the mural and record its location.
2. Use ArcGIS Online to create a map of murals in the community.
3. Use color to categorize the murals by location or type.

Task #2

Create a bar graph that tells the story of the murals. You can chart the number of murals by location or type.
1. Label the Y-axis with the number of murals.
2. Label the X-axis with the location or type of mural.
3. Give the graph a title that explains what it is showing.

1

Name: _____   Period: _____   Date: _____   Student #: _____
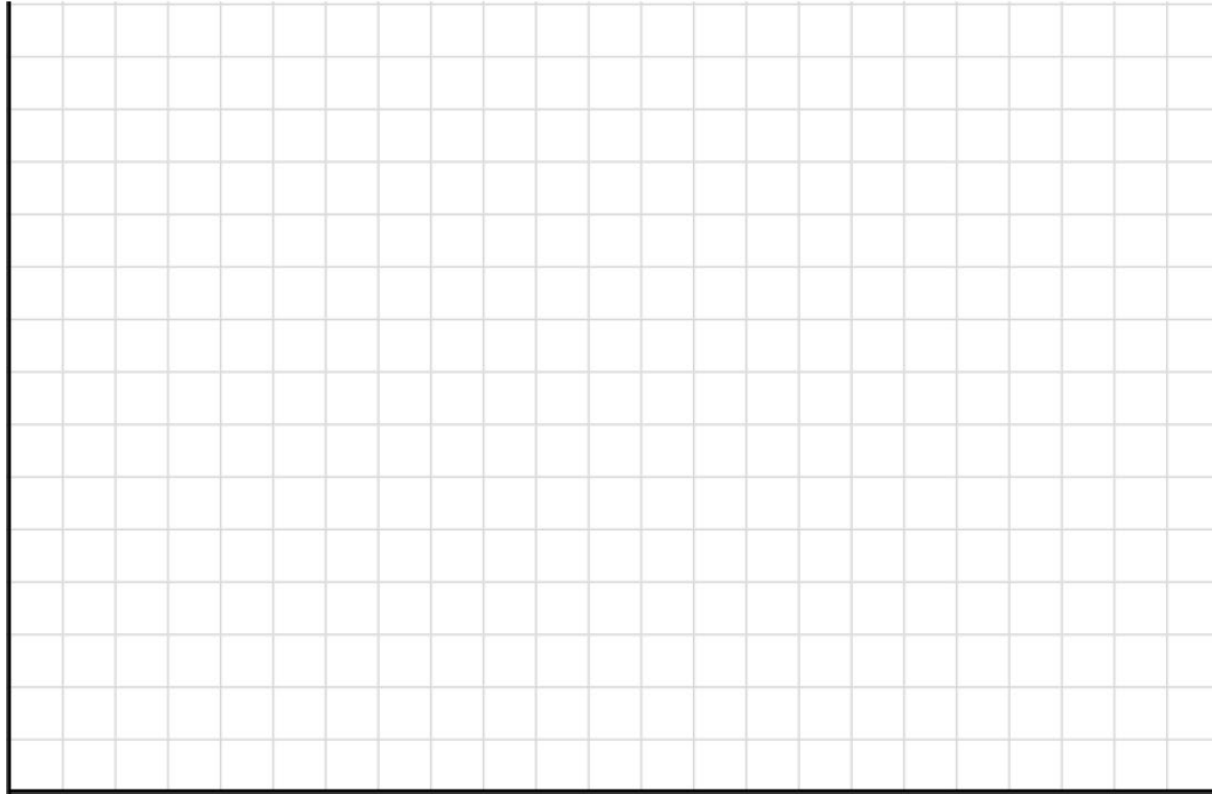
Name: _____   Period: _____   Date: _____   Student #: _____

Reflection

3. What patterns or trends do you notice in the distribution of murals? Are they clustered in certain areas or spread out? Are there certain kinds of murals in particular locations?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

4. What might explain the patterns and trends you observed on the map?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Name: _____ Period: _____ Date: _____ Student #: _____

5. Suggest a location for a new mural based on your analysis of the map and graph. Where should the mural be located? How should the mural be designed?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Discussion

6. Compare your mural map with a classmate. What similarities and differences exist in your maps?

Similarities	**Differences**
1. _____	1. _____
2. _____	2. _____
3. _____	3. _____
4. _____	4. _____
5. _____	5. _____
6. _____	6. _____

Name: _____ Period: _____ Date: _____ Student #: _____

7. Imagine you are visiting our town for the first time. What would be your first impression of our town based on the murals?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

8. How do the murals contribute to your sense of community? Give 2 to 3 examples.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Figure 41 Mission 5: Environmental Justice

Mission #5: Environmental Justice

Environmental Justice Defined

According to the Environmental Protection Agency (EPA), environmental justice "is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies." Fair treatment means that none of those groups of people should bear an unreasonable share of the negative environmental consequences compared to other groups. In order to achieve justice and fairness, all groups of people should have the opportunity to participate in decisions that might affect their environment or health.

The environmental justice movement began in the United States as vulnerable communities struggled against policies that placed toxic waste facilities and other pollutants near their homes. Today, low-income neighborhoods and communities of color still have much higher levels of exposure to the harmful effects of environmental issues like air pollution.

Task

1. Analyze the extent to which environmental justice or injustice exists in our community by using maps, graphs, and GIS.

    Maps
- ➜ Lawsuit Settlement Boundaries
- ➜ Income
- ➜ Education
- ➜ Race/Ethnicity

    Line Graphs
- ➜ Air Quality Index
- ➜ Sulfur Dioxide Level

    GIS (Interactive)
- ➜ Income, Education, Race/Ethnicity
- ➜ Smoke Stack Locations
- ➜ Lawsuit settlement Boundaries

1

Name: _____ Period: _____ Date: _____ Student #: _____

Median Household Income

$35,000 - $37,600
$37,600 - $45,600
$45,600 - $50,900
$50,900 - $60,500
$60,500 - $73,000

0 1 2   4   6   8   10
□■■■■■□■■■■■■■□ Miles

N

Map generated based on sample data from the 2012 American Community Survey
available in the Longitudinal Tract Data Base (LTDB), Brown University.
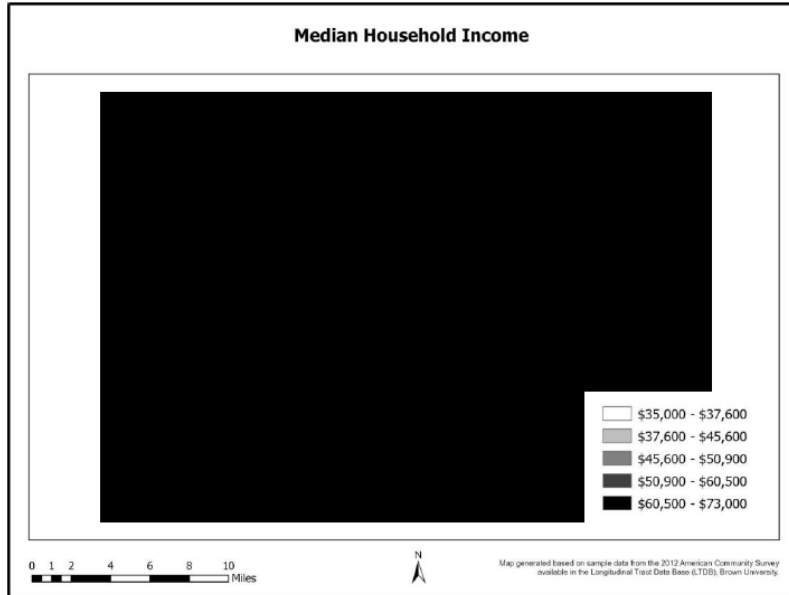
Discussion
2. What patterns or trends do you notice in the distribution of income? Which regions have low, middle, and high incomes? Where are they located?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

3. What do you notice about income in the neighborhoods located near the factory?

_____
_____
_____
_____
_____

Percent with a High School Degree or Less

0-29%
30-39%
40-49%
50-59%
60-69%

0 1 2   4   6   8   10
Miles

N

Map generated based on sample data from the 2012 American Community Survey available in the Longitudinal Tract Data Base (LTDB), Brown University.
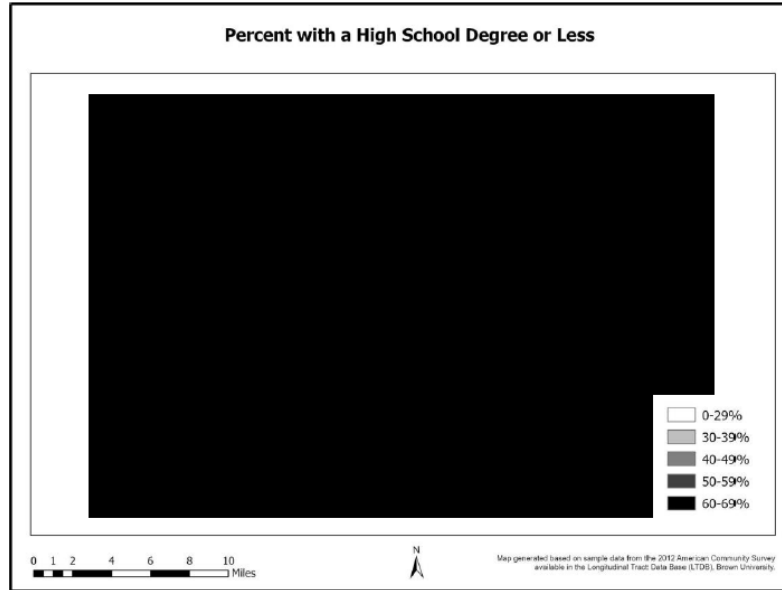
Discussion
4. What patterns or trends do you notice in the distribution of education levels? Which regions have low, middle, and high levels of education? Where are they located?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

5. What do you notice about the level of education in the neighborhoods located near the factory?

_____
_____
_____
_____
_____
_____

Percent White, Non-Hispanic

55-59%
60-69%
70-79%
80-89%
90-95%

0 1 2   4   6   8   10
                            Miles

N

Map generated based on sample data from the 2012 American Community Survey
available in the Longitudinal Tract Data Base (LTDB), Brown University.
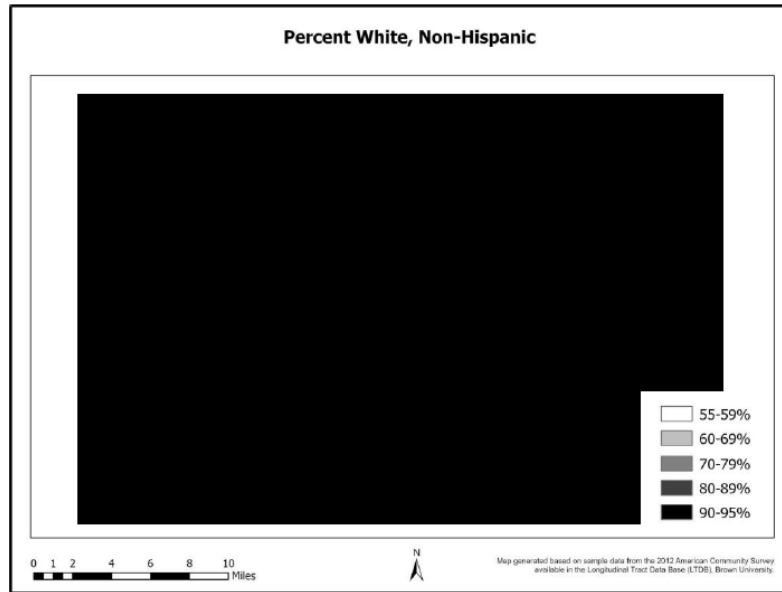
Discussion
6. What patterns or trends do you notice in the distribution of white, non-Hispanic people? Which regions have low and high concentrations of white people?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

7. What do you notice about the number of white people in the neighborhoods located near the factory? Is this similar or different from the number of white people in other parts of the community?

_____
_____
_____
_____

4

Percent Hispanic or Latino

☐	4%
☐	5-12%
☐	13-19%
☐	20-27%
■	28-36%

0 1 2   4   6   8   10
                              Miles

N

Map generated based on sample data from the 2012 American Community Survey
available in the Longitudinal Tract Data Base (LTDB), Brown University.

Discussion

8. What patterns or trends do you notice in the distribution of Hispanic/Latino people? Which regions have low and high concentrations of Hispanic/Latino people?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

9. What do you notice about the number of Hispanic/Latino people in the neighborhoods located near the factory? Is this similar or different from the number of Hispanic/Latino people in other parts of the community?

_____
_____
_____
_____
_____

Name: _____ Period: _____ Date: _____ Student #: _____

Percent Black, Non-Hispanic

0%
0-0.3%
0.3-0.8%
0.9-1.5%
1.6-3.5%

0 1 2   4   6   8   10 Miles

N

Map generated based on sample data from the 2012 American Community Survey available in the Longitudinal Tract Data Base (LTDB), Brown University.

Discussion

10. What patterns or trends do you notice in the distribution of Black, non-Hispanic people? Which regions have low and high concentrations of Black people?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

11. How does this map compare to the other maps of racial and ethnic groups in the community?

_____
_____
_____
_____

6

Name: _____   Period: _____   Date: _____   Student #: _____

Sulfur Dioxide Explained

Sulfur dioxide (SO_2) is a form of air pollution caused from burning coal, oil, or diesel. Small particles can get lodged in the lungs, causing respiratory health problems and making breathing difficult. High concentrations can also harm trees and plants, making it difficult for them to grow.

Discussion

12. Describe the overall trend in sulfur dioxide levels from 2000-2018 in this community.

_____
_____
_____
_____
_____
_____

GIS Exploration

Use the interactive GIS map (geographic information system) to more closely examine all of the data from the community. You can turn layers on/off or zoom in/out on the map to help you answer the next two questions.

Discussion

13. Do you recognize any patterns or trends in the populations that live near sources of air pollution in the community? Consider income, education level, and race/ethnicity in your response.

Income: _____

_____

Education: _____

_____

Race/ethnicity: _____

_____

_____

_____

_____

14. Based on this geographic information, to what extent does environmental justice exist in the community regarding clean air?

_____

_____

_____

_____

_____

_____

_____

_____

Name: _____   Period: _____   Date: _____   Student #: _____

15. Compare your analysis with a classmate. What similarities and differences exist in your analysis of environmental justice?

Similarities

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

Differences

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

Figure 42 Mission 6: Counter-Map Case Study

Name: _____ Period: _____ Date: _____ Student #: _____

Mission #6: Counter-Map Case Study

Counter-Map Defined

A counter-map is a way for people to make their own maps as an alternative to the maps made by professionals. People who live in the community often have a unique way of looking at the joys and struggles of everyday life. As a result, their maps might communicate new and important information that the professionals often miss in the maps they make. A map does not have to be "official" in order to communicate a story. Everyday people can make maps that compel governments to take action on issues that matter to community members.

Task

1. Choose a counter-map to study from *This Is Not an Atlas*. Explore different ways people map stories about their communities.

2. Does the map have these components? If the component is present, check the box and then briefly describe it.

- Title: _____
- Legend: _____
- Compass (direction): _____
- Scale (distance): _____
- Symbols: _____
- Grid or coordinate system: _____
- Points: _____
- Lines: _____
- Polygons (areas): _____
- Regions: _____
- Human features (population, demographics): _____
- Physical features: _____
- Built environment: _____
- Other: _____

1

Name: _____   Period: _____   Date: _____   Student #: _____

Reflection
3. Who made the map?

_____
_____
_____
_____

4. What was the topic of the counter-map?

_____
_____
_____
_____

5. How did the mapmaker design the map? What choices did they make?

_____
_____
_____
_____
_____
_____
_____
_____

6. What makes it a "counter-map"? Look back at the definition on the front page. Apply it to the map you studied.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

7. What story or message do you think the mapmaker was trying to convey? How do you know?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

189

Name: _____ Period: _____ Date: _____ Student #: _____

Discussion

8. Compare your counter-map with a classmate who chose a different one. What similarities and differences exist in these maps?

Similarities

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

Differences

1. _____
2. _____
3. _____
4. _____
5. _____
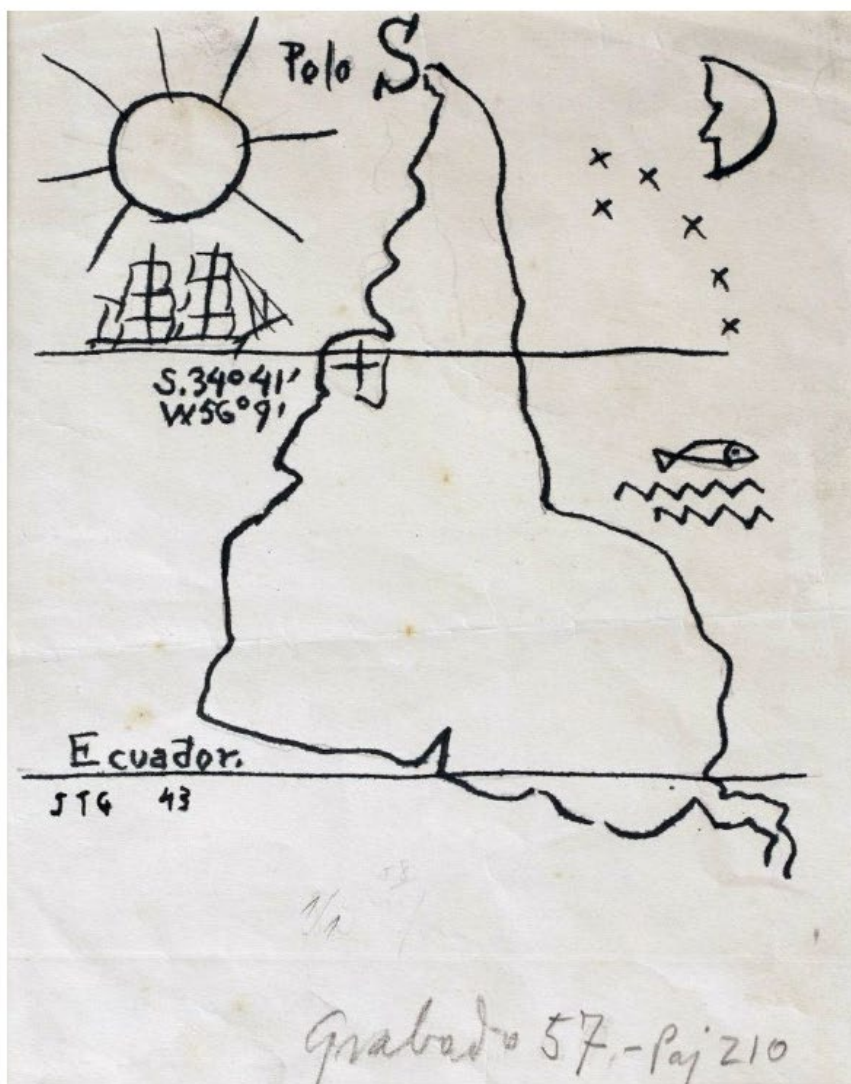6. _____

Joaquín Torres-García, *Inverted America*
by Dr. Maya Jiménez   adapted by Rachel Hansen
August 9, 2015 in *Smarthistory*   September 27, 2022

"*América Invertida (Inverted America)*" by Joaquín Torres-García (1943)

"Our North is the South."

"Our North is the South," Joaquín Torres-García proudly announced in his 1935 book about the future of Uruguayan and Latin American art. Torres-García was born in Montevideo, Uruguay but lived in the United States and Europe for roughly 40 years. In 1934, when he returned back home to Uruguay, he established the *School of the South*, a workshop where he encouraged students to seek inspiration *locally* rather than *globally*. He wanted South American artists to define their art on their own terms, rather than in relation to that of the North (United States and Europe) as it had been in the past. He believed South America should be independent from the artistic power centers of New York City and Paris. Instead, he thought South American people should look to their ancestors for artistic inspiration.

In his counter-map, "*América Invertida (Inverted America)*," Torres-García challenged the old traditional frame of mind that the North dominates the South. Instead, he repositioned the South as the new North, placing it on the top of the map in a position of power.
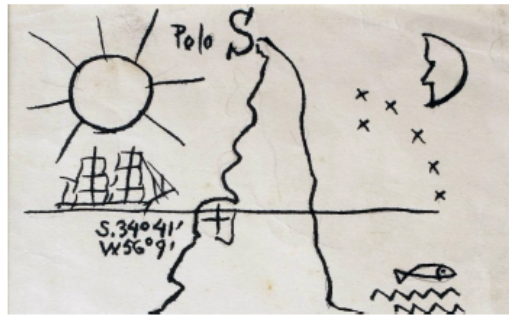
Inverted Map

With the southern cone turned upside down, the viewer is forced to look at the map of South America in an entirely new way. The map communicates important details. Look to see if you can identify these on the map. *Why do you think Torres-García included these in his counter-map?*
- → the cardinal direction of the South
- → the latitude line of Montevideo
- → the Equator

Rather than show the Equator at the center of the hemisphere, as is usually the case, Torres-García instead put Uruguay in a more important, privileged position—on the top! There are also other symbols and drawings on the map. Look to find these and think about what greater meaning they might communicate. *Why do you think Torres-García included these in his counter-map?*
- → sun
- → boat
- → fish
- → moon and stars

Indigenous Latin American Symbols

The sun often appears in Torres-García's other artistic work, and it is a powerful symbol of the original inhabitants of South America. Due to its life-giving force, he included the sun not only in this map, but also in his *Cosmic Monument* (pictured below). In the monument, the sun appears at the center - a place of importance! The boat is usually associated with travel, while the fish represent fruitfulness.

"Cosmic Monument" by Joaquín Torres-García (1938), Montevideo, Uruguay

Torres-García argued that these symbols were indigenous to Latin America and featured in monuments as old as the ones found in Tiwanaku (one of the most prominent civilizations in South America prior to the Inca empire). As a result of their ancient origins and timeless quality, Torres-García believed that these were *universal symbols* - familiar to people everywhere. In the *Gate of the Sun* at Tiwanaku, the Sun God faces out from the top of the gate with rays around his face. Torres-García used ancient Latin American symbols (like the sun) in his artwork to celebrate his cultural identity and suggest a new artistic direction for South American artists today.

Gate of the Sun, Tiwanaku, 500 and 900 C.E., La Paz, Bolivia (photo: thoew, CC BY-NC-ND 2.0)

Mission 6: Counter-Map Case Study
Map Collection

<u>Directions</u>: Choose one of the case studies below to use as you complete Mission 6.

Clicking on the title will take you to a bookmarked link. Just scroll back to the top of this document to get back to the list, or double click on the bottom-right corner of the page.

1. **Mapping the Anti-Eviction Struggle in the San Francisco Bay Area**
   - → Map
   - → Article

2. **Mega-Mining in the Andes Mountains of Argentina**
   - → Map
   - → Article

3. **Participatory Mapping with Homeless People**
   - → Map
   - → Article

4. **Mapping the Worlds of Skaters**
   - → Map
   - → Article

5. **Mapping Life in the Slums of Dhaka, Bangladesh**
   - → Map
   - → Article

6. **Mapping the Experience of a Syrian Refugee**
   - → Map
   - → Article

Mapping the Anti-Eviction Struggle in the San Francisco Bay Area
Written by   Erin McElroy
Adapted by   Rachel Hansen

Local residents add sticky notes to the Oakland Community Power Map.
Click here to zoom in on the map.

Narratives of Displacement and Resistance

The Anti-Eviction Mapping Project (AEMP) is a multimedia storytelling collective documenting the impact of *gentrification* (removing current inhabitants by redoing the area to move wealthier people in) in San Francisco, California. They work with community partners advocating for better housing. These mapmakers incorporate the stories of everyday people affected by displacement into their maps. They study the correlation (relationship) between rental prices, evictions, and demographics. The goal of the AEMP is to recognize the power of maps to create a counter-history to the maps created by real estate speculators and Silicon Valley investors.

People being evicted from their homes throughout the San Francisco area are mostly Black, Latinx, and working-class communities, along with female-headed households, elderly folks, and young people. However, most of the people moving into the area are young white men who work in high-paid technology jobs at places like Facebook, Apple, and Twitter. Evictions today are at an all-time high in San Francisco because rents continue to rise. Rents are growing faster in Oakland, a predominantly Black city outside of San Francisco, than in any other city in the US.

Because of federal government policies from the 1780s to the 1960s, many neighborhoods in the Bay Area remain racially and economically segregated today. AEMP is working to document the power of community resistance in the face of rising rents and eviction rates. Their maps capture neighborhood histories and personal stories of loss, change, and protest. People's words are built into the maps. AEMP publishes their content offline so that it is accessible to everyone. They recently painted a version of their map as a mural, highlighting the stories of 9 local residents. There is also a "call-the-wall" feature so that viewers can call a number (415-319-6865) and hear the featured stories. At the time of the release of the mural, many of the people featured were still in their homes as a result of direct action, and so their stories serve as a powerful example of how to fight displacement.

Oakland Community Power Map

As part of a partnership with the Oakland Creative Neighborhood Coalition, AEMP created a Community Power Map in Oakland's Betti Ono Gallery. This collaborative map was an attempt to reframe conversations about the Bay Area, so people didn't only talk about loss and destruction but also about community assets worth celebrating and fighting for. The base layer for the map was collectively drawn by AEMP and Betti Ono members on two walls, representing Oakland's street geography. Following this, members of the public entered the gallery, adding assets and markers of community power to the wall using sticky notes.

Before taking the map down, AEMP digitized it so that it now lives online. They've also created other Community Power Maps throughout the Bay Area, working with youth groups, anti-eviction coalitions and more. The goal is to work in partnership with local community members to advocate for and also build pride in the local community.

Mega-Mining in the Andes Mountains of Argentina

Written by Julia Risler & Pablo Ares, *Iconoclasistas*
Adapted by Rachel Hansen
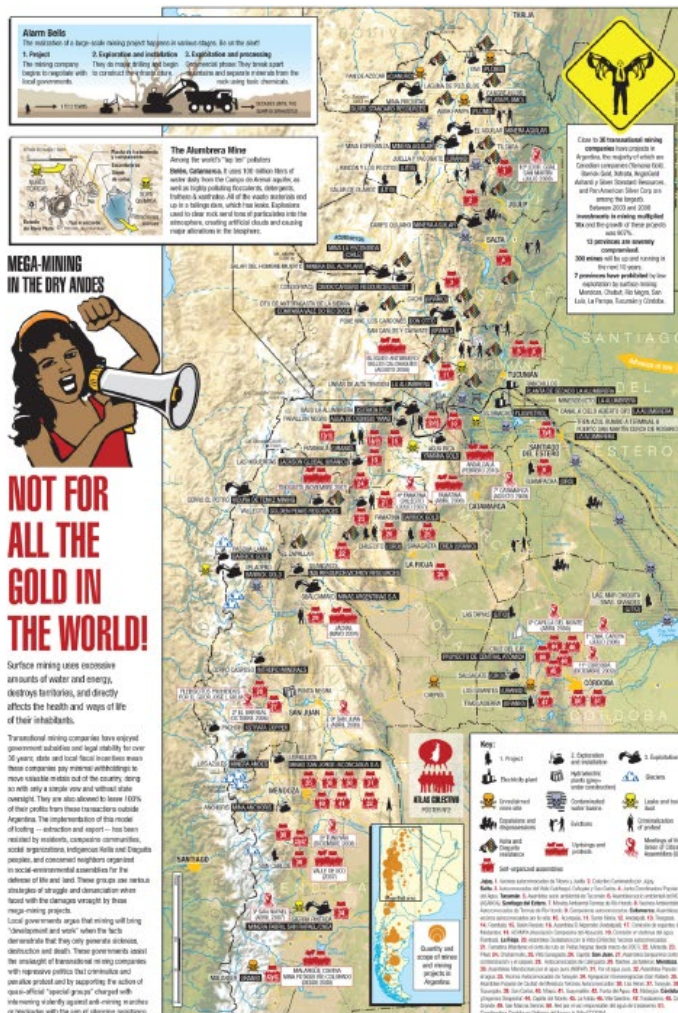
Click here to zoom in and out on the map.
Click here for the original version written in Spanish.

Iconoclasistas

"Iconoclasistas" is a duo that formed in 2006. Julia and Pablo combine graphic art and creative workshops to make resources for local activists that can be used for free. Through their workshops, they try to strengthen communication between activists, set up networks of solidarity, and promote collaborative practices of resistance and protest. They work in Argentina, Latin America, and Europe.

The Mapping Process

Between 2008 and 2010, Julia and Pablo traveled across Argentina, setting up workshops in various cities of different provinces by contacting university students as well as cultural and communicational groups. These sessions and meetings were attended by organizations working for social and environmental change, peasants and native peoples, and neighbors and citizens. During meetings, Julia and Pablo collected stories from local people about the conflicts and resistances taking place within different regions in Argentina. Their goal was to show how local people were resisting big, foreign companies from coming in and taking over their lands.

Open Pit Mega-Mining

After a series of workshops organized near the Andes Mountains, it became clear that local citizens were very concerned about open pit mega-mining for gold, silver, and other precious metals. This map depicts the areas most affected by open pit mega-mining, its effects on people and the environment, and the support networks working throughout the territory to fight back against mining companies. Chinese and Canadian corporations often move into these rural areas without any regulation on their activities from the government. When they mine in the mountains, they use large amounts of water, pollute the air and water, damage landscapes and ecosystems, and harm the rights and health of local inhabitants and communities.

Maps are often used by dominant powers, like the Chinese and Canadian mining companies, to invade and plunder the property of poorer countries like Argentina. Julia and Pablo are working to use maps to show that they are about more than just land and territory. A connection with a particular piece of land is formed through feelings and personal experiences. Maps are more than just land.

Why Work with Maps to Make Change?

Maps allow the mapmaker to share a visual story of the experiences of people in an area. When maps are made using input from locals, they can help communities protect common property, fight against big and powerful corporations, and establish new worlds.

Maps can only capture a snapshot of a particular moment in time. They cannot completely describe the complex, problematic reality of the current moment. Maps should show that territories are always changing and are constantly affected by the perceptions and actions of the people who live there. Maps can be part of a bigger process to foster thinking, boost collective participation, work with strangers, swap experiences, challenge dominant powers, and promote creative solutions to pressing problems.

Participatory Mapping with Homeless People

Written by   Oliver Moss & Adele Irving
Adapted by   Rachel Hansen
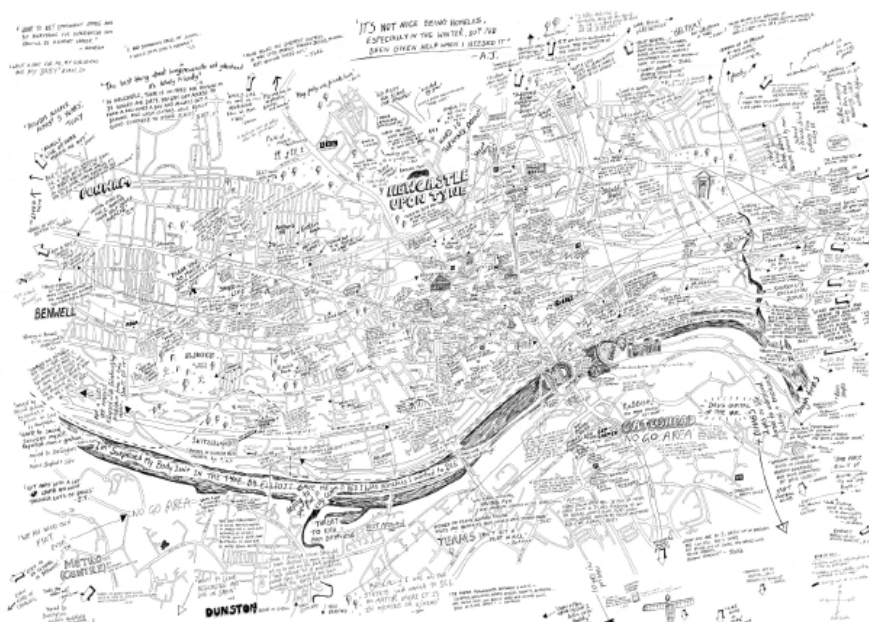
Click here to zoom in and out of the map.

Imaging Homelessness in a City of Care

"Imaging Homelessness in a City of Care" was a participatory mapping project that involved 30 single homeless people in Newcastle-upon-Tyne, United Kingdom. There were three main goals of the project:

1. Try out new, innovative mapping methods.
2. Offer single homeless people an opportunity to comment on local services.
3. Inform and challenge what people think about homelessness.

Levels of homelessness have been on the rise in the United Kingdom, and the increased visibility of homelessnes on the streets produces mixed reactions from people. Gifts and donations to many homelessness charities have increased, but the media has also increasingly questioned and scrutinized the morality of homeless people. Many policies in the UK punish people for being homeless. This is why it is so important to challenge what people think about homelessness.

6

Participatory Mapping

To create the map, 6 workshops were held with 30 homeless people. Participants wrote reflections on maps of the spaces, places, and experiences that were important to them. The maps played a useful role in helping them think about their experiences, attitudes, and values. After all the mapped reflections were collected, a local artist called Lovely JoJo prepared a map.

The map shows complex and often contradictory practices. First, it shows that individuals became homeless in many different ways and anyone can fall victim to homelessnes. Second, the map shows the daily struggles of street homelessness, as well as the many different survival strategies people use to get by. Third, the map is a way to think differently about the way we use city spaces. Doorways, for example, are often thought of by homeless people as spaces to socialize and sleep. Pipes and ducts are shown on the map to provide some warmth and comfort. Finally, the map shows a variety of the city's homessness services. Many of the mapping participants spoke highly of the support they received.

Impact of the Map

The map has captured the imagination of audiences from around the world. When it launched, over 60 policy makers and professionals came to see it. The map emphasizes that there are many different meanings that people assign to different parts of a city. It also helped to humanize discussions about homelessness. One person commented, "I found the maps of the participants and Lovely JoJo deeply affecting. I find myself returning to them and reconsidering the places I thought I knew."

The value of maps like this is in their ability to engage an audience instinctively and emotionally, rather than through traditional rational argument. Creative approaches to mapping are one way everyday people can try to change perceptions of their communities and the people in them.

Mapping the Worlds of Skaters

Written by   Jon Swords & Mike Jeffries
Adapted by   Rachel Hansen
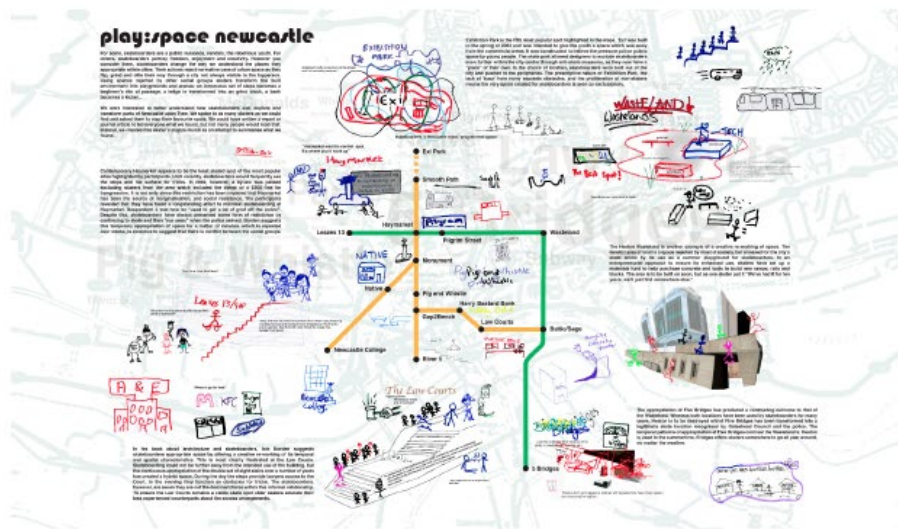
Click here to zoom in and out on the map.

Skaters create drawings and doodles of the places where they like to skate.

8

Making the Skate Map

The map you see here is the result of a project with skateboarders to understand the way they use space in Tyneside, England. Skaters mapped their worlds, making fascinating sketches and doodles full of insight and emotion. Photos and videos produced by the skaters were also featured alongside the maps. In this context, the map became a piece of art, showing the unruly world of skaters that is often hidden from public view. It was a way to criticize the authoritative, official maps of Tyneside, which exclude people such as skateboarders. Most maps of the city center focus on the town's heritage or their shops and stores.

This map created an opportunity for skaters to represent their worlds, giving them permission to be proud. At the map gallery, skaters showed their parents what they had contributed and the spots they went to around the city. This shows that maps can be something to learn from. The map showed popular skate spots, the journeys skaters take between them, and how they are valued within the community. Skaters shared stories and legends of tricks of the past. They told stories of the old lady who felt safe when skaters were around, the deal between skaters and security guards at one skate spot, and the dangers of jumping over certain obstacles. The skateboarders discovered new spots, new friends, and the fact that people value their presence in the city.

Like many other maps, this one shows a historical record of the skate scene. It's like a snapshot in time. The Wasteland, Leap of Faith, and Library Plaza that show up on the map no longer exist. They were knocked down and redeveloped into new properties. This map is the only "official" record of their location. The map was never designed to help people navigate, but it would help someone find spots to skate today. It also helps skaters remember past skate spots that no longer exist.

Map Design

Skate scenes are very visual, and this map has become a helpful tool in Tyneside's skateboard community. The visual style of the map adopts the familiar curve of the river that can be seen in other maps of the area. You can see it lightly in the background, underneath all of the text. The green and yellow lines connecting skate spots on the map reflect the design and color of Tyneside's Metro train system. There are also images, drawings, and words that come from the skaters themselves.

Impact of the Map

The skate map has become a locational tool, a historical record, a work of art, and prompt for new discussions in Tyneside. It has helped to bring a legitimacy to the skate community that makes them proud. Every person that looks at the map brings to it a whole new set of perspectives and meanings.

Mapping Life in the Slums of Dhaka, Bangladesh

Written by   Elisa T. Bertuzzo & Günter Nest
Adapted by   Rachel Hansen

Click here to zoom in and out of the map.

Aerial view of Karail, the largest slum in Bangladesh.

The Wall

It looks so harmless on the map: a thin line that runs east, then takes a sharp 90-degree turn north and again 90-degrees east up to the edge. Yet on the ground, the line is a concrete wall, built to mark the boundary between two worlds, the "legal" and the "illegal." But this boundary is just made up. The "legal" neighborhood, with its rusty huts, old apartment buildings, and children playing barefoot on the roads, doesn't actually differ from what you see on the other "illegal" side. On that side, behind the wall, the same crumbling buildings are just more tightly packed together. When taking a closer look, you realize how the construction of the wall must have cut certain houses in two. The only difference is that the "legal" side of the wall receives city services like running water, electricity, and trash collection, and the other "illegal" side of the wall does not. The people there have no rights to the land they live on.

The Map

The neighborhood behind the wall is one of Dhaka's largest and oldest slums. Bangladesh is a country with one of the lowest sea levels in the world, which makes it prone to floods and land erosion. When people are forced to leave their villages and migrate to Dhaka, the majority end up in *basti*: unplanned, unorganized, overcrowded slums where the poorest people live. *How do they organize themselves there? How do they make sure everyone has access to basic services like water, electricity, and roads?*

The sketches and diagrams placed around and inside the map offer answers to some of these questions. They show statistics from a survey on housing conditions and access to public services. The map is drawn from a Google Earth picture of Dhaka. Today on Google Maps, this neighborhood is portrayed as an empty spot, which does not call attention to the everyday struggles of the 100,000 people living here. Because people do not have the official rights to the land they live on, the government leaves them off of the city maps. As a result, the poorest people get left out of decisions made by city officials.

Impact of the Map

This map worked with residents and local leaders to gain official recognition for the slum. Community members helped to identify shared problems and generate possible solutions. The map mixes personal experiences with geographic location. Many stories emerged from the maps that could be used to take action and advocate for the slum to be officially incorporated into the city, providing it with services.

Mapping as Storytelling

Mapping is a way of storytelling. Stop counting and start talking with the people who live in a place. Stop just digging into the data and go out and listen to what people have to say. What you'll notice is that the place is speaking to you with its own voice.

"And, what about the wall?", you will ask now. The wall is a symbol of how the powerful try to control a space in the fastest growing city in the world, where land prices are constantly rising. It still stands today, but hopefully, people will look at this ridiculously thin line on the map, dismiss their fears and misconceptions, and demand that all inhabitants of Dhaka have access to safe, healthy living spaces.

Mapping the Experience of a Syrian Refugee

Written by	Mustafa Hadj Rasheed, Sarah Bachellerie, Sophie Clair, and Datum Bericht
Adapted by	Rachel Hansen
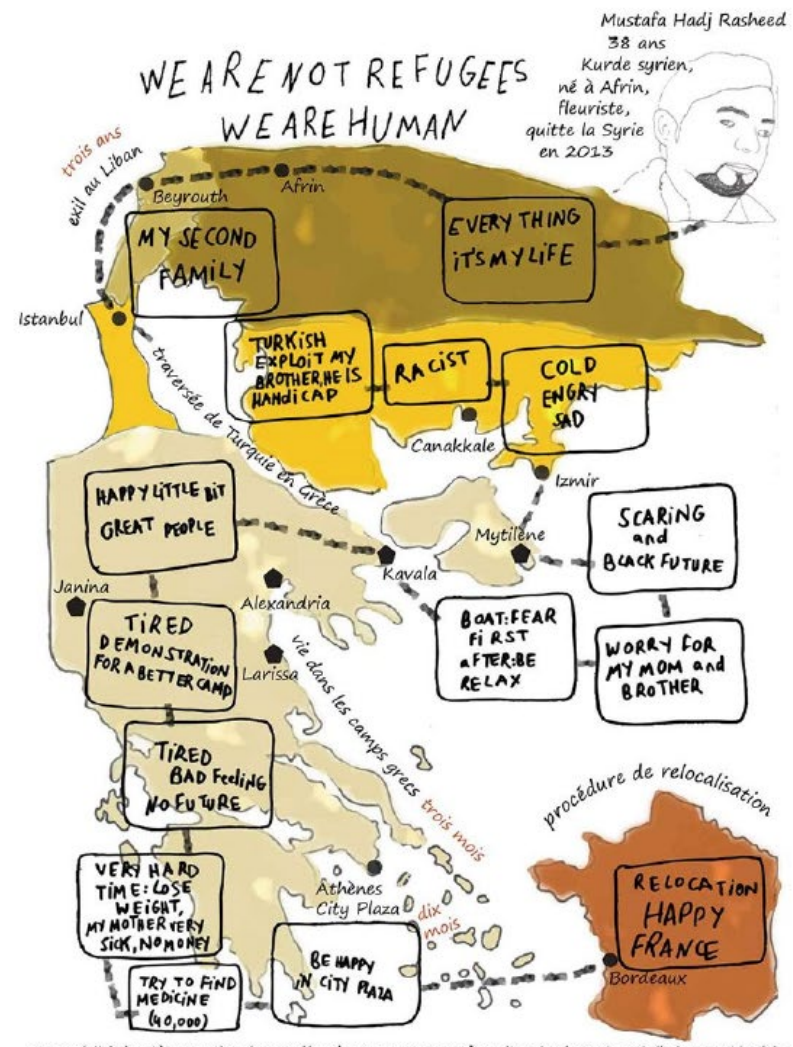
Carte réalisée à Athènes au City Plaza en décembre 2016 par Mustafa Hadj Rasheed, Sarah Bachellerie et Sophie Clair.

Click here for a larger view of the map.

Background and Context

Civil war began in Syria in 2011 forcing many people to flee from their homes for safety. Even today, Syria produces more refugees than any other country in the world. This map shares the story of Mustafa Hadj Rasheed, a 38 year-old florist from Afrin who was forced to flee Syria in 2013. Mustafa traveled through Lebanon, Turkey, and Greece on his way to France. He spent three years in exile in Lebanon, a country that borders Syria to the west. He crossed Lebanon into Turkey by boat, and then from Turkey to Greece by boat again. In Greece, Mustafa spent three months in refugee camps. After ten more months of travel through Greece, he was finally relocated to France. This map was made in Athens at the city plaza by Mustafa and two artists.

Analyzing the Map

The map is not a perfect geographic representation of the way the countries of Syria, Lebanon, Turkey, and Greece actually look on a map. You can go look on Google Maps for yourself to compare. *Why do you think the artists decided on this map layout?*

You'll also notice that the map uses color and shading. *What does this color and shading represent? What is its purpose?* There are also dashed lines and different shaped dots marking locations on the map. *Why are there two different shapes? What do you think the circle dots represent? What about the pentagon (five-sided) shapes for places like Alexandria and Larissa? What does the dashed line represent?*

Mustafa's exact words and experiences are recorded in black marker on the map. The words and boxes help us understand what Mustafa was thinking and feeling along each part of the journey. *Where did Mustafa have particularly bad experiences? Which places brought him more hope and joy?*

There are several phrases written along the path in French. The brown words describe time frames. *"Trois ans"* means three years. *"Trois mois"* means three months. *"Dix mois"* means ten months. There are also some descriptive words to help us understand how Mustafa was traveling from place to place.
- *"Exil au Liban"* → exile in Lebanon
- *"traversée de Turquie en Grece"* → crossing from Turkey to Greece
- *"vie dans les camps grecs trois mois"* → life in the Greek camps three months

The Power of Counter-Maps

This map is part of a technique called "deep mapping." These maps focus on the stories of the travelers and in particular, their movements and connection, instead of focusing on the political borders of countries. A deep map accentuates emotions, identity, and fears that are associated with a person's personal history.

A map is never neutral. Every map tells a story, and this includes the choices that the mapmaker has made. We should ask ourselves: *Which story is being told? Who is the author? What is not being said? And what is the other story that the map could tell?*

Figure 43 Mission 7: Geo-Inquiry Question

Name: _____ Period: _____ Date: _____ Student #: _____

Mission #7: Geo-Inquiry Questions

Geo-Inquiry Explained

In order to make smart decisions, it is important to understand how human and natural systems are connected. Geography helps us analyze patterns and make connections from a spatial perspective. Asking a good, geographic question is the first step to taking action on an issue that's important to you. Geo-Inquiries answer three main questions:

- Where is it?
- Why is it there?
- Why should we care?

Task

1. A Geo-Inquiry Question asks us to think about where things are and how they are connected to other things and why that is important. For the list below, put a checkmark next to the question that can be classified as a Geo-Inquiry Question.

- 1. What types of bees are found there?
- 2. What are the mechanics of bird flight?
- 3. Why do monarch butterflies migrate to Mexico?
- 4. When was this building built?
- 5. Why are pandas black and white?
- 6. Where is the library located?
- 7. How might the use of weed killers affect the migration paths of monarch butterflies?
- 8. How has the game of baseball changed over time?
- 9. How do neighborhoods change between ▮▮▮▮ Avenue and ▮▮▮ Street?
- 10. Why do so many people use smartphones?
- 11. How does the damming of the Mississippi River affect those who live downstream?

- 12. What is the most accurate way for scientists to measure temperature?
- 13. What types of businesses are found on ▮▮▮ Avenue?
- 14. Where is the best place to look for authentic Mexican food?
- 15. Which gas station is the closest?
- 16. Why are some stores often located near each other no matter where you are?
- 17. What is the best soil for growing watermelons?
- 18. How will the closing of the mall affect the number of people who visit the area?
- 19. Why are most large sports fields not found in downtown areas?
- 20. Why is cursive not taught in most schools?

1

Name: _____ Period: _____ Date: _____ Student #: _____

Task
Your counter-map project needs to be driven by a good Geo-Inquiry question. Think about topics we've discussed in our community. What's important to you? Brainstorm a topic to investigate using the prompts below.

2. What topic or issue in our community are you interested in exploring?

_____
_____
_____
_____

3. What do you know about this topic?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Name: _____   Period: _____   Date: _____   Student #: _____

4. What are some things you need to know about this topic? Write at least five questions you could ask about this topic.

1. _____
   _____
   _____

2. _____
   _____
   _____

3. _____
   _____
   _____

4. _____
   _____
   _____

5. _____
   _____
   _____

5. Looking at your list of questions above, circle 3 that you think are the most interesting.

6. Why do you think these questions are interesting?

_____
_____
_____

3

Name: _____ Period: _____ Date: _____ Student #: _____

Test Your Geo-Inquiry Question

7. Answer the following questions by checking yes or no.

Could you answer your question quickly using a map, Google search, or other tool?	☐ Yes	☐ No
Do you care about the answer to your question?	☐ Yes	☐ No
Is your question important to your community?	☐ Yes	☐ No
Can you think of information or data that would help you answer this question?	☐ Yes	☐ No
Will you be able to find this information and collect this data?	☐ Yes	☐ No
Will the answer to your question better help you understand how to address a community issue or solve a local problem?	☐ Yes	☐ No
Will you be able to use this question to make a positive change in your community?	☐ Yes	☐ No

If you answered yes to the first question or no to any of the others, you should revise your question. You can repeat this process as many times as you need until you are satisfied with your Geo-Inquiry question.

8. Write the final version of your Geo-Inquiry question here. This will be the question that drives your counter-map final project.

_____
_____
_____
_____
_____
_____

Figure 44 Mission 8: Counter-Map Draft

Name: _____   Period: _____   Date: _____   Student #: _____

Mission #8: Counter-Map Draft

Creating a Counter-Map Draft
A rough draft is a starting place for seeing how your data relates spatially. As you gather data, you can play around with different ways to visualize it. Do not worry about being perfect or neat. This is a draft, and it will change!

Reflection
1. How have you decided to visualize the data you are collecting?

_____
_____
_____
_____
_____
_____
_____
_____

2. Why did you decide to visualize it this way?

_____
_____
_____
_____
_____
_____
_____
_____

1

Name: _____   Period: _____   Date: _____   Student #: _____

3. Think about the components of your map. Use the checklist below as a guide. Some of these components might be important for telling your story, but others might not!

☐ Does your map support your question?
☐ Is the purpose of the map clear?
☐ Is the location the map is showing clear?
☐ Is the map easy to understand?
☐ Is there a title for the map?
☐ Did you include a legend to explain any symbols you used?
☐ Does the color scheme help make the map more readable instead of distracting from the map?
☐ Are labels used where needed to make things more clear?
☐ Is everything spelled correctly?
☐ Are any images or drawings the right size and easily visible?
☐ Is the text readable (font size and type)?
☐ Are the authors listed?
☐ Is the date included?

4. Who is your intended audience for this counter-map? How will that affect the way that you design the map?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Name: _____   Period: _____   Date: _____   Student #: _____

Analyzing Your Data

5. What kind of information and data have you collected to answer your question?

_____
_____
_____
_____
_____

6. Does the information and data you've collected seem credible? Explain your reasoning.

_____
_____
_____
_____
_____

7. Do you see any patterns, trends, or clusters in the visual you created? Describe them.

_____
_____
_____
_____
_____
_____
_____

8. Do you think any of the things you measured depend on what they are near on the map? What evidence supports this?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

9. Do you notice any connections between the different types of information and data you're collecting? If so, describe how they might be connected. What evidence supports this?

_____
_____
_____
_____
_____
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_____
_____
_____
_____
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_____

10. Which of these patterns or trends will help you answer your Geo-Inquiry question?

_____
_____
_____
_____
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_____
_____
_____
_____
_____

Discussion

11. Write the answer to your Geo-Inquiry question. Give evidence to support your answer.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Figure 45 Mission 9: Counter-Map Final

Name: _____   Period: _____   Date: _____   Student #: _____

Mission #9: Counter-Map in Action

Now that you have completed your counter-map, reflect on the decisions you made along the way and how your map has changed since your first draft. You will want to have Assessment #8 in front of you as you complete the following prompts.

Reflection
1. How did you visualize the data you collected?

_____
_____
_____
_____
_____
_____
_____
_____

2. Why did you decide to visualize it this way?

_____
_____
_____
_____
_____
_____
_____

1

Name: _____   Period: _____   Date: _____   Student #: _____

3. Think about the components of your map. Use the checklist below as a guide. Some of these components might be important for telling your story but others might not!

- ☐ Does your map support your question?
- ☐ Is the purpose of the map clear?
- ☐ Is the location the map is showing clear?
- ☐ Is the map easy to understand?
- ☐ Is there a title for the map?
- ☐ Did you include a legend to explain any symbols you used?
- ☐ Does the color scheme help make the map more readable instead of distracting from the map?
- ☐ Are labels used where needed to make things more clear?
- ☐ Is everything spelled correctly?
- ☐ Are any images the right size and easily visible?
- ☐ Is the text readable (font size and type)?
- ☐ Are the authors listed?
- ☐ Is the date included?

4. Who is your intended audience for this counter-map? How did that affect the way that you designed the map?

_____
_____
_____
_____
_____
_____
_____
_____
_____

Name: _____ Period: _____ Date: _____ Student #: _____

Analyzing Your Data

5. What kind of information and data did you collect to answer your question?

_____
_____
_____
_____
_____

6. Is your data and information credible? Explain your reasoning.

_____
_____
_____
_____
_____

7. Do you see any patterns, trends, or clusters in the visual you created? Describe them.

_____
_____
_____
_____
_____
_____

8. Do you think any of the things you measured depend on what they are near on the map? What evidence supports this?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

9. Do you notice any connections between the different types of information and data you're collecting? If so, describe how they might be connected. What evidence supports this?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

4

Name: _____ Period: _____ Date: _____ Student #: _____

10. Which of these patterns or trends helped you answer your Geo-Inquiry question?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Discussion
11. Write the answer to your Geo-Inquiry question. Give evidence to support your answer.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Appendix B: Research Forms

Figure 46 IRB Letter of Approval

UNI / University of Northern Iowa.

Office of Research & Sponsored Programs

February 24, 2023

Rachel Hansen
University of Northern Iowa
Cedar Falls, IA 50614

Re: Approval IRB 23-0001

Dear Investigator(s):

Your study, Mapping for Impact: A Learning Progression for Counter-Mapping, was approved by the UNI IRB through the review procedures authorized by 45 CFR 46.104, effective July 20, 2022. You are required to adhere to the procedures and study materials approved during this review, as well as to follow IRB policies and procedures for human subject research posted on the IRB website.

If you need to make changes to your study design, samples, procedures, or study materials, please email Lisa Ahern lisa.ahern@uni.edu to request approval of the changes before they are implemented, and attach any revised study materials with edits highlighted. You may expect a response within a couple of days.

Your study will not require annual review and approval by the IRB. However, you will receive an annual study update request, which will ask if the study is still active and if any problems have arisen. Advisors: If your student has graduated, please reply to the annual update request on the student's behalf.

Problems or adverse events related to your research that were not anticipated must be reported promptly after being discovered, either within 7 or 14 days, depending on the seriousness of the event, as outlined on the *Reporting Problems and Adverse Events* page. Examples include unexpected injury or emotional stress for study participants, missteps in the consent process, or breaches of confidentiality. The IRB will advise on any next steps that might be necessary.

If you have questions about the application process, please feel free to contact me at lisa.ahern@uni.edu or 319-273-6148.

Sincerely,

Lisa M. Ahern

Lisa Ahern
IRB Administrator
Associate Director Research & Sponsored Programs

Research & Sponsored Programs / 213 East Bartlett Hall / Cedar Falls, Iowa 50614-0394 / P 319-273-3217 / F 319-273-2634 / rsp.uni.edu

Figure 47 In-Person Script for Participant Recruitment

In-Person Script for Initial In-Class Recruitment

Hi, my name is Rachel Hansen, and I am conducting a study with the University of Northern Iowa. I will be researching about the kinds of learning pathways students take when trying to learn new geographic thinking skills. The study will take place within the Introduction to Social Studies course over the next nine weeks but will remain entirely separate from the class grade. I am asking you to include some of your assignments in my research study. If you participate, there is no additional work that you need to do. I am only asking permission to include assignments you will already be completing. For this class, you will be required to complete 9 assignments over the course of the year. Your participation in my research would involve allowing me to include those assignments in my study. Although the assignments are required as part of this class, your participation in the study is completely voluntary and you can withdraw at any time. Whether you participate in the study or not, everyone will still complete all the assignments. In other words, the assignments are required for the class, but your participation in the study is not. You get to decide if you want to participate in the study. It is entirely up to you, and no one will be upset with you if you decide you do not want to be in the study. Your grade will not be affected in any way.

So that you better understand the study, we are going to read over the Parental Permission and Assent Form together, and then you will have an opportunity to ask me questions about it before you take it home to your parents. Your parents will also receive an email letting them know that you'll be bringing home this form today after school.

Figure 48 Email Script for Guardian Consent

Email and Letter Invitation to Parents

Hello everyone!

I'm Rachel Hansen, and I will be working with your child enrolled in the freshman social studies course for the fall semester. ███ ███████████████████████████████ complete my master's in Geography at the University of Northern Iowa. As part of my program, I'm conducting a study of the new geography curriculum we've designed for the freshman social studies course. I am asking students and their parents to allow me to include some of their completed assignments in my research. If your child participates, there is no additional work that they will need to complete or answer. I am only asking permission to include assignments they will already be completing. This study will help us understand if we're giving students the very best instruction possible to prepare them for the rest of high school, as well as life beyond ████.

Your student was sent home today with a Parental Permission and Assent Form for you to sign that will include all the details about your child's participation. Their participation in the study is completely voluntary and entirely separate from their grade in the class. Regardless of whether or not students choose to participate, all students will complete the same assignments that are required for the class this semester. Once you've had a chance to read the Parental Permission and Assent Form, please feel free to reach out to me directly by email (rahansen@uni.edu) with any questions you might have. I am happy to discuss the study in further detail!

If you have questions about your child's rights as a research participant, you can contact the IRB (Research) Administrator at UNI using the phone number 319-273-6148.

Thank you for all that you do! I'm looking forward to a wonderful semester of learning alongside your students.

Best regards,

Rachel Hansen

Graduate Student
Department of Geography
University of Northern Iowa

Figure 49 Phone Script for Guardian Consent

Phone Script for Contacting Parents without Email

Hi, my name is Rachel Hansen, and I will be working with your child enrolled in the freshman social studies course for the fall semester. Do you have a minute to speak with me right now?

[If <u>yes</u>, continue with script. If <u>no</u>, ask when a good time would be to reconnect.]

███
████████████████████████ master's in Geography at the University of Northern Iowa. As part of my program, I'm conducting a study of the new geography curriculum we've designed for the freshman social studies course. I am asking students and their parents to allow me to include some of their completed assignments in my research. If your child participates, there is no additional work that they will need to complete or answer. I am only asking permission to include assignments they will already be completing. This study will help us understand if we're giving students the very best instruction possible to prepare them for the rest of high school, as well as life beyond ████.

Your student was sent home today with a Parental Permission and Assent Form for you to sign that will include all the details about your child's participation. Their participation in the study is completely voluntary and entirely separate from their grade in the class. Regardless of whether or not students choose to participate, all students will complete the same assignments that are required for the class this semester. Once you've had a chance to read the Parental Permission and Assent Form, please feel free to reach out to me directly by phone at 319-594-2614 with any questions you might have. I am happy to discuss the study in further detail!

If you have questions about your child's rights as a research participant, you can contact the IRB (Research) Administrator at UNI using the phone number 319-273-6148.

Thank you for all that you do! I'm looking forward to a wonderful semester of learning alongside your students.

Do you have any questions about the form or the study that I can answer right now?

Thank you for your time!

Figure 50 Assent and Consent Form

UNIVERSITY OF NORTHERN IOWA
PARENTAL PERMISSION & ASSENT FORM

Project Title: Mapping for Impact: A Learning Progression for Counter-Mapping
Researcher: Rachel Hansen, Department of Geography, University of Northern Iowa

Invitation to Participate: Your child is invited to participate in a research study conducted through the University of Northern Iowa. Parents and guardians, please review this form together with your child. The following information is provided to help you and your child make an informed decision about whether or not to participate. I am asking you and your child to allow me to include some of their required assignments for my research study. If they participate, there is no additional work that they will need to complete or answer. I am only asking permission to include assignments they will already by completing for the course.

Nature and Purpose: We want to understand how students go about learning new skills in geography.

Explanation of Procedures: Over the course of a nine-week geography unit, your child will complete nine different mapping assignments as part of their required coursework. After each assignment, your child will be asked questions about what they are learning about geography along the way. These reflection questions are part of their required class assignments and will take 10 to 15 minutes to complete. If your child participates in this research, both paper and electronic copies of your child's ungraded assignment will be provided for the researcher by the classroom teacher at the conclusion of the nine-week grading period. The researcher will not have access to student scores on individual assignments or grades for the class, and all identifying information will be removed before the researcher receives the assignments from the classroom teacher.

Privacy and Confidentiality: Information obtained during this study which could identify students will be kept confidential. Your child's identity will be protected by removing their name from the assignments before the researcher has access to them. Each student will be assigned a unique code in place of their name. Electronic data created from the assignments will be stored on a UNI Google Drive that requires multi-factor authentication from the researcher to access. All paper copies of assignments will be stored in a locked filing cabinet in a locked office. The summarized findings with no identifying student information may be published in an academic journal, presented at a scholarly conference, or shared with staff in the Muscatine Community School District.

Discomforts, Risks, and Costs: Risks to participation are minimal and are similar to those experienced in day-to-day life.

Benefits and Compensation: Your child will receive no direct benefits from participating in this research, but this study may generate important information about how students learn geography that will support improvements in the course in the future.

Right to Refuse or Withdraw: Your child's participation is completely voluntary. They are free to withdraw from participation at any time or to choose not to participate at all. If your child chooses to participate now, they can always change their mind later.

Questions: If you have questions about your child's participation in this study or about the study in general, please contact Rachel Hansen at rahansen@uni.edu or 319-594-2614. For answers to questions about the rights of research participants and the research review process at UNI, you may contact the office of the IRB Administrator at 319-273-6148.

Parent Agreement:

I am fully aware of the nature and extent of my child's participation in this project as stated above and the possible risks arising from it. I have had all my questions answered and permit my child to participate in this study, as indicated by my signature below.

Parent Signature:

_____   _____
Signature of Parent or Guardian   Date

_____
Printed Name of Parent or Guardian

Student Agreement:

I have read and discussed this form with my parents, and I am willing to be in this study, as indicated by my signature below. I know that I do not have to participate in this study and that I can change my mind later. No one will be upset with me if I decide that I do not want to be in the study, and my grade in the class will not be affected in any way.

Student Signature:

_____   _____
Signature of Student Participant   Date

_____
Printed Name of Student Participant

_____   _____
Signature of Researcher, Rachel Hansen   Date

_____   _____
Signature of Advisor, Dr. Alex Oberle   Date

Figure 51 Demographic Survey

Demographic Survey

Directions
Please answer the following questions about yourself. This information will be helpful in the study. Your name will not be collected to protect your privacy. Instead, you will be assigned a Study ID #, which you can write in the top right-hand corner. No one will be able to identify you. Your answers will be kept confidential.

Questions

1. **What is your age? (Please circle.)**

   11 years   12 years   13 years   14 years   15 years   16 years   17 years   18 years

2. **What grade are you in? (Please circle.)**

   9th grade   10th grade   11th grade   12th grade

3. **How would you describe yourself?**

   ☐ Female
   ☐ Male
   ☐ Non-binary
   ☐ Prefer to self-describe (please print): _____

4. **What is your race/ethnicity? (Please check all that apply.)**

   ☐ White
   ☐ Black or African American
   ☐ American Indian or Alaska Native
   ☐ Chinese
   ☐ Filipino
   ☐ Asian Indian
   ☐ Vietnamese
   ☐ Korean
   ☐ Japanese
   ☐ Native Hawaiian or Other Pacific Islander
   ☐ Other Asian (please print): _____
   ☐ Some other race (please print): _____

5. **Are you of Hispanic, Latino, or Spanish origin?**

   ☐ No, not of Hispanic, Latino, or Spanish origin

   ☐ Yes, Mexican, Mexican American, or Chicano
   ☐ Yes, Puerto Rican
   ☐ Yes, Cuban
   ☐ Yes, other Hispanic, Latino, or Spanish origin (please print): _____

Figure 52 Mission Reflection Form

Name: _____ Period: _____ Date: _____ Student #: _____

Mission Reflection #_____

Directions
After you've completed each mapping mission, reflect on the questions below.

Reflection
1. What was the goal of the mission?

_____
_____
_____
_____
_____
_____
_____
_____

2. How did you go about accomplishing it?

_____
_____
_____
_____
_____
_____
_____
_____

1

Name: _____ Period: _____ Date: _____ Student #: _____

3. What did this mission teach you about geography?

_____
_____
_____
_____
_____
_____
_____
_____

4. How could you use what you learned in this mission in the community?

_____
_____
_____
_____
_____
_____
_____
_____
_____

2

Figure 53 End-of-Course Survey

Geography Reflection

Think about the map you made for your final to answer these questions.

* Required

1. First Name *

   _____

2. Last Name *

   _____

3. What problem was your map trying to solve? Or what story was it trying to tell? *

   _____
   _____
   _____
   _____
   _____

4. Based on your map, what is the solution to the problem? *

   _____
   _____
   _____
   _____
   _____

5. How could someone use your map to make decisions or improvements in the school or community? *

_____

_____

_____

_____

_____

6. Are you doing anything with your map to take action on an issue in the school or community? *

Mark only one oval.

◯ Yes

◯ No

◯ Maybe in the future

◯ Other: _____

Taking Action

7. How are you using your map to take action on an issue ? *

_____

_____

_____

_____

_____

Appendix C: Instruments for Data Analysis

Figure 54 Scorecard for Data Entry

If there is no artifact to assess that standard, write "No Data"

Student Number: _____   Pilot Study: _____   Age: _____   Grade: _____

Gender: _____

Race: _____

	NGS Standard 1 Using Maps	NGS Standard 2 Mental Maps	NGS Standard 3 Spatial Analysis	C3 Dimension 4 Taking Action
Mission 1 Mental Map				
Mission 2 Campus Map		Not Assessed		
Mission 3 Asset Map		Not Assessed		
Mission 4 Mural Map		Not Assessed		
Mission 5 Environmental Justice		Not Assessed		
Mission 6 Counter-Map Case Study		Not Assessed		
Mission 7 Geo-Inquiry Questions		Not Assessed		
Mission 8 Counter-Map Reflection		Not Assessed		

Table 38 Standards-Aligned Assessments by Mission and Question

Assessment	Questions & Prompts		Standards Assessed
Mission 1: Mental Map	1	Draw a mental map of the community from memory.	Mental Maps
	2	What landmarks and features did you include in your map? Why?	Using Maps Mental Maps Spatial Analysis
	3	What kind of symbols did you use to create the map? Why did you make those decisions?	Using Maps Mental Maps
	4	What is the most important part of your map?	Mental Maps
	5	What did you leave out that you also think is important?	Mental Maps
	6	Compare your mental map with a classmate. What similarities and differences exist in your maps?	Using Maps Mental Maps Spatial Analysis
	7	What do these maps say about your experiences here compared to your classmate's? List at least 2 comparisons.	Mental Maps
Mission 2: Campus Map	1	After looking at satellite imagery of the school campus on Google Maps, walk around the campus and jot down notes about what you see. Based on your observations, create a map of campus that might be useful to new students.	Using Maps
	2	Consider including the following components in your map. For each component you decide to include in your map, check the box. For every component, briefly describe why you did or did not include it in your map.	Using Maps
	3	What landmarks and feature did you include in your map? Why?	Using Maps Spatial Analysis
	4	Which map components are included in the "official" campus map?	Using Maps
	5	Compare your campus map with the official map used by the school. What similarities and differences exist? Discuss why you think the mapmaker made different design choices in the "official" campus map.	Using Maps Spatial Analysis
	6	Which map do you think is more effective—your map or the professionally-drawn map? Explain your reasoning.	Using Maps Spatial Analysis Taking Informed Action
Mission 3: Asset Map	1	Create a map of resources available to residents in the community. 1. Plot resources from the Student Services brochure on the map. 2. Add any resources you feel are missing. 3. Use the colored stickers to categorize community resources.	Using Maps Spatial Analysis
	2	What kinds of local resources are available to residents here? Who are some of the key resource providers?	Spatial Analysis
	3	What patterns or trends to you notice in the distribution of these resources? Are they clustered in certain areas or spread out?	Spatial Analysis

Assessment	Questions & Prompts		Standards Assessed
Mission 3: Asset Map	4	What might explain the patterns and trends you observed in the map?	Spatial Analysis
	5	What person or organization might be interested in using this map? Explain your reasoning.	Using Maps Spatial Analysis Taking Informed Action
	6	Compare your asset map with another group. What organizations seem really important to the community? What resources do we need more of in this community?	Using Maps Spatial Analysis Taking Informed Action
Mission 4: Mural Map	1	Collect images and coordinates of murals in the community. 1. Use Survey123 to take a picture of the mural and record its location. 2. Use ArcGIS Online to create a map of murals in the community. 3. Use color to categorize the murals by location and type.	Using Maps
	2	Create a bar graph that tells the story of the murals. You can chart the number of murals by location or type. 1. Label the Y-axis with the number of murals. 2. Label the X-axis with the location or type of mural. 3. Give the graph a title that explains what it is showing.	Using Maps
	3	What patterns or trends do you notice in the distribution of murals? Are they clustered in certain areas or spread out? Are there certain kinds of murals in particular locations?	Using Maps Spatial Analysis
	4	What might explain the patterns and trends you observed on the map?	Using Maps Spatial Analysis
	5	Suggest a location for a new mural based on your analysis of the map and graph. Where should the mural be located? How should the mural be designed?	Using Maps Spatial Analysis Taking Informed Action
	6	Compare your mural map with a classmate. What similarities and differences exist in your maps?	Using Maps Spatial Analysis
	7	Imagine you are visiting town for the first time. What would be your first impression of our town based on the murals?	Using Maps
	8	How do the murals contribute to your sense of community? Give 2 to 3 examples.	Using Maps
Mission 5: Environmental Justice	1	Analyze the extent to which environmental justice or injustice exists in our community by using maps, graphs, and GIS.	Using Maps Spatial Analysis
	2	What patterns or trends do you notice in the distribution of income? Which regions have low, middle, and high incomes? Where are they located?	Spatial Analysis
	3	What do you notice about income in the neighborhoods located near the factory?	Spatial Analysis
	4	What patterns or trends do you notice in the distribution of education levels? Which regions have low, middle, and high levels of education? Where are they located?	Spatial Analysis
	5	What do you notice about the level of education in the neighborhoods located near the factory?	Spatial Analysis

Assessment		Questions & Prompts	Standards Assessed
Mission 5: Environmental Justice	6	What patterns or trends do you notice in the distribution of white, non-Hispanic people? Which regions have low and high concentrations of white people?	Spatial Analysis
	7	What do you notice about the number of white people in neighborhoods located near the factory? Is this similar or different from the number of white people in other parts of the community?	Spatial Analysis
	8	What patterns or trends do you notice in the distribution of Hispanic/Latino people? Which regions have low and high concentrations of Hispanic/Latino people?	Spatial Analysis
	9	What do you notice about the number of Hispanic/Latino people in neighborhoods located near the factory? Is this similar or different from the number of Hispanic/Latino people in other parts of the community?	Spatial Analysis
	10	What patterns or trends do you notice in the distribution of Black, non-Hispanic people? Which regions have low and high concentrations of Black people?	Spatial Analysis
	11	How does this map compare to the other maps of racial and ethnic groups in the community?	Spatial Analysis
	12	Describe the overall trend in sulfur dioxide levels from 2000-2018 in this community.	Using Maps
	13	Do you recognize patterns or trends in the population that live near sources of air pollution in the community? Consider income, education level, and race/ethnicity in your response.	Using Maps Spatial Analysis
	14	Based on this geographic information, to what extent does environmental justice exist in the community regarding clean air?	Using Maps Spatial Analysis
	15	Compare your analysis with a classmate. What similarities and differences exist in your analysis of environmental justice?	Using Maps Spatial Analysis
Mission 6: Counter-Map Case Study	1	Choose a counter-map to study from *This Is Not an Atlas*. Explore different ways people map stories about their communities.	Using Maps
	2	Does the map have these components? If the component is present, check the box and then briefly describe it.	Using Maps
	3	Who made the map?	Using Maps
	4	What was the topic of the counter-map?	Using Maps Spatial Analysis
	5	How did the mapmaker design the map? What choices did they make?	Using Maps
	6	What makes it a "counter-map"? Look back at the definition on the front page. Apply it to the map you studied.	Using Maps Taking Informed Action
	7	What story or message do you think the mapmaker was trying to convey? How do you know?	Using Maps Spatial Analysis Taking Informed Action

Assessment		Questions & Prompts	Standards Assessed
Mission 6: Counter-Map Case Study	8	Compare your counter-map with a classmate who chose a different one. What similarities and differences exist in these maps?	Using Maps Spatial Analysis Taking Informed Action
Mission 7: Geo-Inquiry Question	1	A Geo-Inquiry Question asks us to think about where things are and how they are connected to other things and why that is important. For the list below, put a checkmark next to the question that can be classified as a Geo-Inquiry Question.	Using Maps
	2	What topic or issue in our community are you interested in exploring?	Taking Informed Action
	3	What do you know about this topic?	Taking Informed Action
	4	What are some things you need to know about this topic? Write at least five questions you could ask about this topic.	Using Maps Spatial Analysis Taking Informed Action
	5	Looking at your list of questions above, circle 3 that you think are the most interesting.	Using Maps Spatial Analysis Taking Informed Action
	6	Why do you think these questions are interesting?	Taking Informed Action
	7	Answer the following questions by checking yes or no. 1. Could you answer your question quickly using a map, Google search, or other tool? 2. Do you care about the answer to your question? 3. Is your question important to your community? 4. Can you think of information or data that would help you answer this question? 5. Will you be able to find this information and collect this data? 6. Will the answer to your question better help you understand how to address a community issue or solve a problem? 7. Will you be able to use this question to make a positive change in your community?	Using Maps Spatial Analysis Taking Informed Action
	8	Write the final version of your Geo-Inquiry question here. This will be the question that drives your counter-map final project.	Using Maps Spatial Analysis Taking Informed Action
Mission 8: Counter-Map	1	How have you decided to visualize the data you are collecting?	Using Maps
	2	Why did you decide to visualize it this way?	Using Maps
	3	Think about the components of your map. Use the checklist below as a guide. Some of these components might be important for telling your story, but others might not!	Using Maps
	4	Who is your intended audience for this counter-map? How will that affect the way that you design the map?	Using Maps
	5	What kind of information and data have you collected to answer your question?	Using Maps Spatial Analysis

Assessment	Questions & Prompts		Standards Assessed
Mission 8: Counter-Map	**6**	Does the information and data you've collected seem credible? Explain your reasoning.	Using Maps Taking Informed Action
	7	Do you see patterns, trends, or clusters in the visual you created? Describe them.	Using Maps Spatial Analysis
	8	Do you think any of the things you measured depend on what they are near on the map? What evidence supports this?	Using Maps Spatial Analysis
	9	Do you notice any connections between the different types of information and data you're collecting? If so, describe how they might be connected. What evidence supports this?	Using Maps Spatial Analysis
	10	Which of these patterns or trends will help you answer your Geo-Inquiry question?	Using Maps Spatial Analysis Taking Informed Action
	11	Write the answer to your Geo-Inquiry question. Give evidence to support your answer.	Using Maps Spatial Analysis Taking Informed Action

Table 39 Variables for Data Analysis

Categorical Variables (8)	Standards Scores by Mission (25)				Average Scores (5)
StudyID	UsingMaps1	MentalMaps1	SpatialAnalysis1	TakingAction1	UsingMapsAvg
PilotGroup	UsingMaps2		SpatialAnalysis2	TakingAction2	SpatialAnalysisAvg
Age	UsingMaps3		SpatialAnalysis3	TakingAction3	TakingActionAvg
Grade	UsingMaps4		SpatialAnalysis4	TakingAction4	AverageScore
Gender	UsingMaps5		SpatialAnalysis5	TakingAction5	CompletionRate
Race	UsingMaps6		SpatialAnalysis6	TakingAction6	
Completion100	UsingMaps7		SpatialAnalysis7	TakingAction7	
Completion96	UsingMaps8		SpatialAnalysis8	TakingAction8	

Figure 55 Codebook for Quantitative Analysis

Description: Data from a sample of adolescents enrolled in a geography curriculum pilot.

Format: A dataset with 46 observations of the following 38 variables.

StudyID	Study ID number assigned to each student
PilotGroup	1=1st quarter pilot group, 2=2nd quarter pilot group
Age	Age (years)
Grade	9=freshman, 10=sophomore, 11=junior, 12=senior
Gender	F=female, M=male, N=non-binary
Race	Asian, Black, Latino, White
Completion100	1=students who completed all 25 scores, 0=students with at least 1 or more missing scores
Completion96	1=students who completed at least 24 out of 25 scores, 0=students at least 2 or more missing scores
UsingMaps1	Evaluation of NGS Standard 1 for Mission 1: Mental Map 0=No evidence, 1=Identify properties and functions of maps, 2=Describe uses of maps, 3=Analyze maps to ask or answer questions, 4=Communicate solutions using map data
MentalMaps1	Evaluation of NGS Standard 2 for Mission 1: Mental Map 0=No evidence, 1=Draw a mental map, 2=Interpret information in mental maps, 3=Compare mental maps to evaluate perceptions, 4=Create community maps to answer geographic questions
SpatialAnalysis1	Evaluation of NGS Standard 3 for Mission 1: Mental Map 0=No evidence, 1=Describe spatial organization using distance, direction, or location, 2=Describe patterns and trends in spatial data, 3=Analyze processes that influence spatial distribution, 4=Synthesize multiple sources of data sources to understand the consequences of spatial organization
TakingAction1	Evaluation of C3 Dimension 4 for Mission 1: Mental Map 0=No evidence, 1=Identify community assets or problems, 2=Describe potential solutions to a community problem, 3=Apply geographic knowledge to advocate about a community issue, 4=Take informed action based on synthesis of geographic data
UsingMaps2	Evaluation of NGS Standard 1 for Mission 2: Campus Map 0=No evidence, 1=Identify properties and functions of maps, 2=Describe uses of maps, 3=Analyze maps to ask or answer questions, 4=Communicate solutions using map data

`SpatialAnalysis2`	Evaluation of NGS Standard 3 for Mission 2: Campus Map 0=No evidence, 1=Describe spatial organization using distance, direction, or location, 2=Describe patterns and trends in spatial data, 3=Analyze processes that influence spatial distribution, 4=Synthesize multiple sources of data sources to understand the consequences of spatial organization
`TakingAction2`	Evaluation of C3 Dimension 4 for Mission 2: Campus Map 0=No evidence, 1=Identify community assets or problems, 2=Describe potential solutions to a community problem, 3=Apply geographic knowledge to advocate about a community issue, 4=Take informed action based on synthesis of geographic data
`UsingMaps3`	Evaluation of NGS Standard 1 for Mission 3: Asset Map 0=No evidence, 1=Identify properties and functions of maps, 2=Describe uses of maps, 3=Analyze maps to ask or answer questions, 4=Communicate solutions using map data
`SpatialAnalysis3`	Evaluation of NGS Standard 3 for Mission 3: Asset Map 0=No evidence, 1=Describe spatial organization using distance, direction, or location, 2=Describe patterns and trends in spatial data, 3=Analyze processes that influence spatial distribution, 4=Synthesize multiple sources of data sources to understand the consequences of spatial organization
`TakingAction3`	Evaluation of C3 Dimension 4 for Mission 3: Asset Map 0=No evidence, 1=Identify community assets or problems, 2=Describe potential solutions to a community problem, 3=Apply geographic knowledge to advocate about a community issue, 4=Take informed action based on synthesis of geographic data
`UsingMaps4`	Evaluation of NGS Standard 1 for Mission 4: Mural Map 0=No evidence, 1=Identify properties and functions of maps, 2=Describe uses of maps, 3=Analyze maps to ask or answer questions, 4=Communicate solutions using map data
`SpatialAnalysis4`	Evaluation of NGS Standard 3 for Mission 4: Mural Map 0=No evidence, 1=Describe spatial organization using distance, direction, or location, 2=Describe patterns and trends in spatial data, 3=Analyze processes that influence spatial distribution, 4=Synthesize multiple sources of data sources to understand the consequences of spatial organization
`TakingAction4`	Evaluation of C3 Dimension 4 for Mission 4: Mural Map 0=No evidence, 1=Identify community assets or problems, 2=Describe potential solutions to a community problem, 3=Apply geographic knowledge to advocate about a community issue, 4=Take informed action based on synthesis of geographic data
`UsingMaps5`	Evaluation of NGS Standard 1 for Mission 5: Environmental Justice 0=No evidence, 1=Identify properties and functions of maps, 2=Describe uses of maps, 3=Analyze maps to ask or answer questions, 4=Communicate solutions using map data

SpatialAnalysis5	Evaluation of NGS Standard 3 for Mission 5: Environmental Justice 0=No evidence, 1=Describe spatial organization using distance, direction, or location, 2=Describe patterns and trends in spatial data, 3=Analyze processes that influence spatial distribution, 4=Synthesize multiple sources of data sources to understand the consequences of spatial organization
TakingAction5	Evaluation of C3 Dimension 4 for Mission 5: Environmental Justice 0=No evidence, 1=Identify community assets or problems, 2=Describe potential solutions to a community problem, 3=Apply geographic knowledge to advocate about a community issue, 4=Take informed action based on synthesis of geographic data
UsingMaps6	Evaluation of NGS Standard 1 for Mission 6: Counter-Map Case Study 0=No evidence, 1=Identify properties and functions of maps, 2=Describe uses of maps, 3=Analyze maps to ask or answer questions, 4=Communicate solutions using map data
SpatialAnalysis6	Evaluation of NGS Standard 3 for Mission 6: Counter-Map Case Study 0=No evidence, 1=Describe spatial organization using distance, direction, or location, 2=Describe patterns and trends in spatial data, 3=Analyze processes that influence spatial distribution, 4=Synthesize multiple sources of data sources to understand the consequences of spatial organization
TakingAction6	Evaluation of C3 Dimension 4 for Mission 6: Counter-Map Case Study 0=No evidence, 1=Identify community assets or problems, 2=Describe potential solutions to a community problem, 3=Apply geographic knowledge to advocate about a community issue, 4=Take informed action based on synthesis of geographic data
UsingMaps7	Evaluation of NGS Standard 1 for Mission 7: Geo-Inquiry Questions 0=No evidence, 1=Identify properties and functions of maps, 2=Describe uses of maps, 3=Analyze maps to ask or answer questions, 4=Communicate solutions using map data
SpatialAnalysis7	Evaluation of NGS Standard 3 for Mission 7: Geo-Inquiry Questions 0=No evidence, 1=Describe spatial organization using distance, direction, or location, 2=Describe patterns and trends in spatial data, 3=Analyze processes that influence spatial distribution, 4=Synthesize multiple sources of data sources to understand the consequences of spatial organization
TakingAction7	Evaluation of C3 Dimension 4 for Mission 7: Geo-Inquiry Questions 0=No evidence, 1=Identify community assets or problems, 2=Describe potential solutions to a community problem, 3=Apply geographic knowledge to advocate about a community issue, 4=Take informed action based on synthesis of geographic data
UsingMaps8	Evaluation of NGS Standard 1 for Mission 8: Counter-Map 0=No evidence, 1=Identify properties and functions of maps, 2=Describe uses of maps, 3=Analyze maps to ask or answer questions, 4=Communicate solutions using map data

|	
SpatialAnalysis8	Evaluation of NGS Standard 3 for Mission 8: Counter-Map 0=No evidence, 1=Describe spatial organization using distance, direction, or location, 2=Describe patterns and trends in spatial data, 3=Analyze processes that influence spatial distribution, 4=Synthesize multiple sources of data sources to understand the consequences of spatial organization
TakingAction8	Evaluation of C3 Dimension 4 for Mission 8: Counter-Map 0=No evidence, 1=Identify community assets or problems, 2=Describe potential solutions to a community problem, 3=Apply geographic knowledge to advocate about a community issue, 4=Take informed action based on synthesis of geographic data
UsingMapsAvg	Average score for all missions evaluating NGS Standard 1 0=No evidence, 1=Identify properties and functions of maps, 2=Describe uses of maps, 3=Analyze maps to ask or answer questions, 4=Communicate solutions using map data
MentalMapsAvg	Average score for all missions evaluating NGS Standard 2 0=No evidence, 1=Draw a mental map, 2=Interpret information in mental maps, 3=Compare mental maps to evaluate perceptions, 4=Create community maps to answer geographic questions
SpatialAnalysisAvg	Average score for all missions evaluating NGS Standard 3 0=No evidence, 1=Describe spatial organization using distance, direction, or location, 2=Describe patterns and trends in spatial data, 3=Analyze processes that influence spatial distribution, 4=Synthesize multiple sources of data sources to understand the consequences of spatial organization
TakingActionAvg	Average score for all missions evaluating C3 Dimension 0=No evidence, 1=Identify community assets or problems, 2=Describe potential solutions to a community problem, 3=Apply geographic knowledge to advocate about a community issue, 4=Take informed action based on synthesis of geographic data
AverageScore	Average score for all missions on all standards. Reported as an integer from 0 to 4.
CompletionRate	Average number of standards with scores entered divided by the total number of scores (25). Reported as an integer from 0 to 1.

Table 40 Shapiro-Wilk Test of Normality

		Statistic	df	Sig.
Mission 1	Using Maps	.770	41	<.001
	Mental Maps	.816	42	<.001
	Spatial Analysis	.357	41	<.001
	Taking Action	.233	39	<.001
Mission 2	Using Maps	.715	42	<.001
	Spatial Analysis	.288	41	<.001
	Taking Action	.428	40	<.001
Mission 3	Using Maps	.708	44	<.001
	Spatial Analysis	.746	45	<.001
	Taking Action	.711	44	<.001
Mission 4	Using Maps	.889	42	<.001
	Spatial Analysis	.619	41	<.001
	Taking Action	.794	41	<.001
Mission 5	Using Maps	.850	46	<.001
	Spatial Analysis	.705	46	<.001
	Taking Action	.803	43	<.001
Mission 6	Using Maps	.684	43	<.001
	Spatial Analysis	.871	42	<.001
	Taking Action	.687	36	<.001
Mission 7	Using Maps	.837	35	<.001
	Spatial Analysis	.881	34	.002
	Taking Action	.755	35	<.001
Mission 8	Using Maps	.810	44	<.001
	Spatial Analysis	.856	43	<.001
	Taking Action	.868	42	<.001

Note. Data is displayed by standard scores within each assessment.

Appendix D: Results Tables & Figures

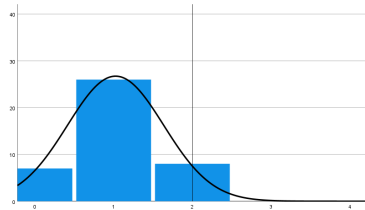**Figure 56** Boxplot: Using Maps Mission Scores
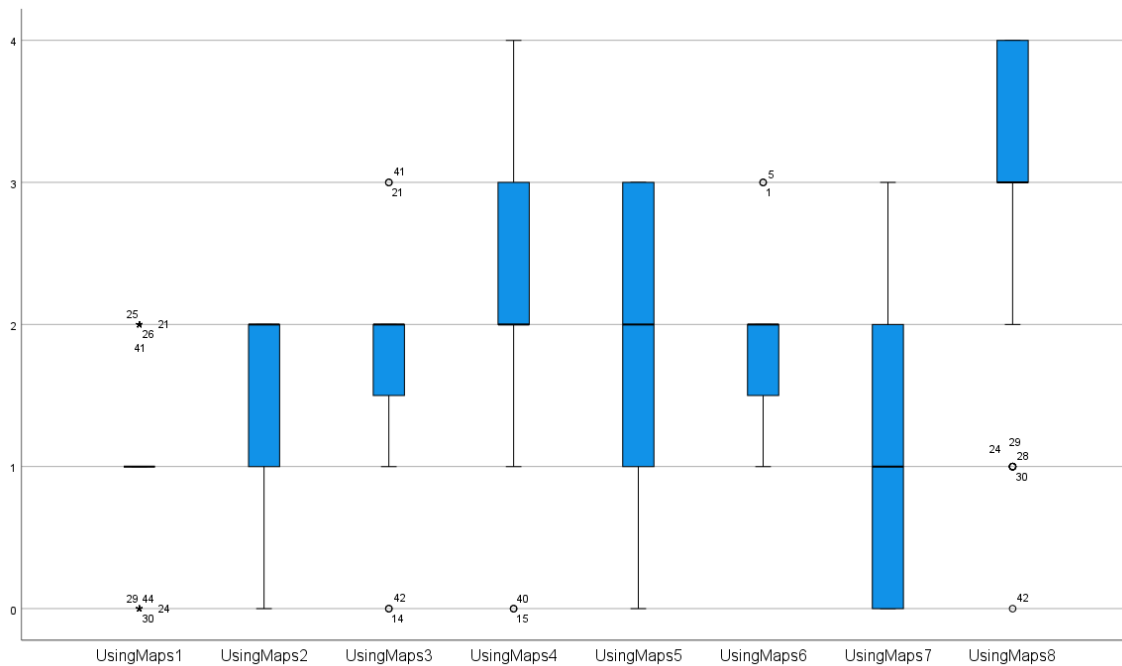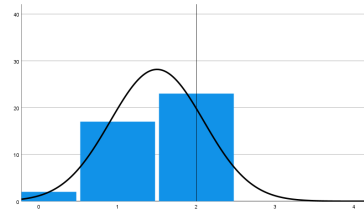

Figure 57 Boxplot: Mental Maps
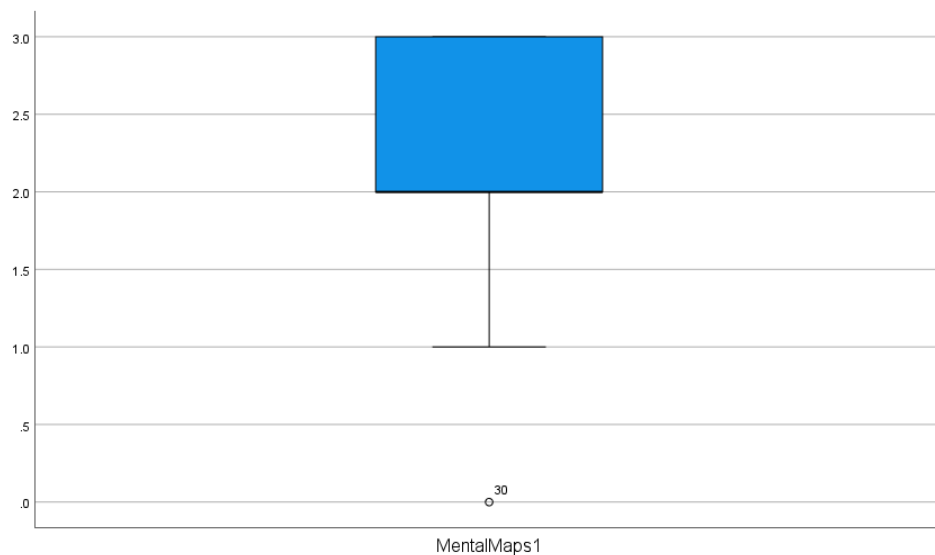
Figure 58 Boxplot: Spatial Analysis Mission Scores
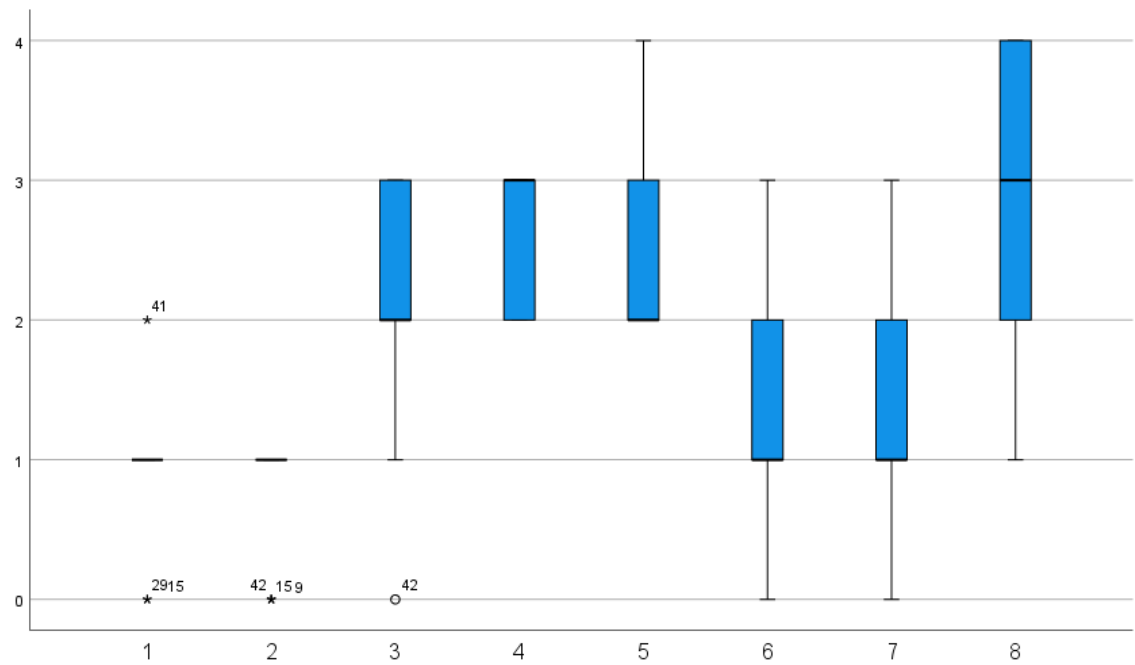
Figure 59 Boxplot: Taking Informed Action Mission Scores
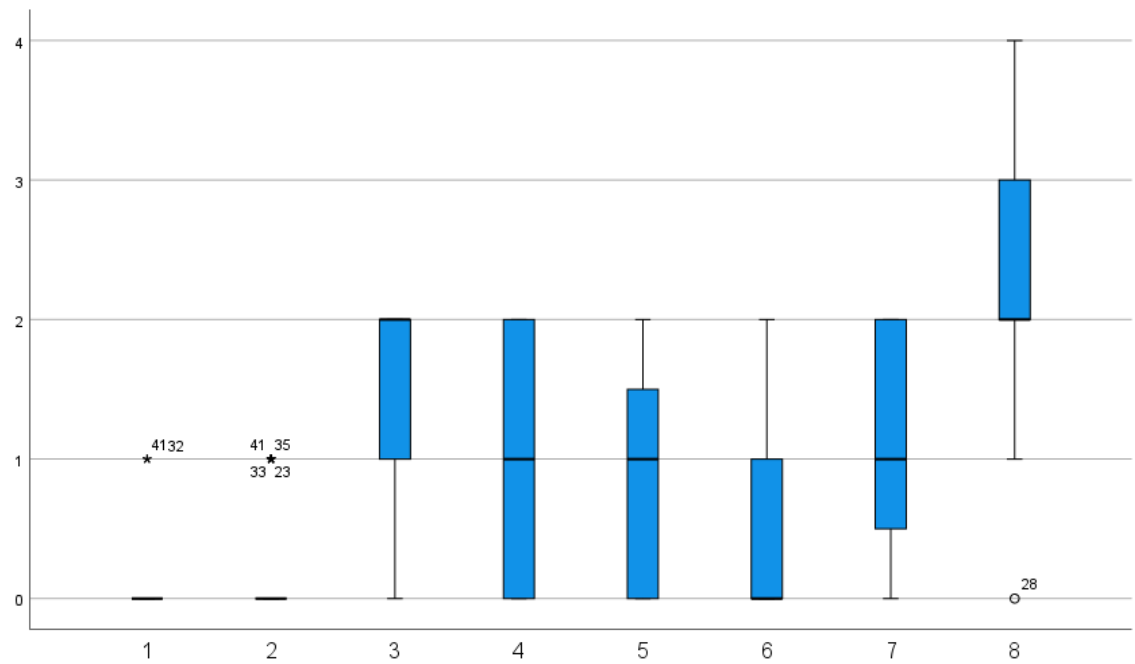
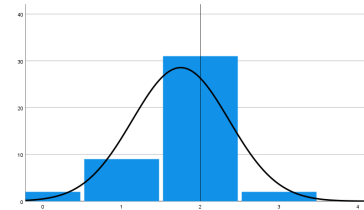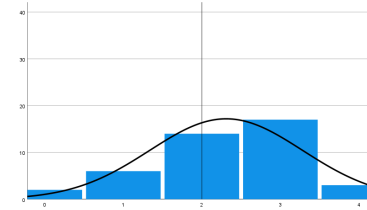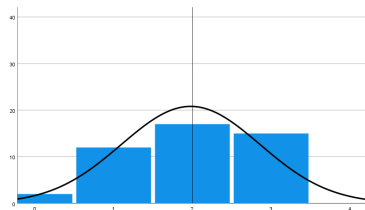**Figure 60** Histograms Over Time: Using Maps
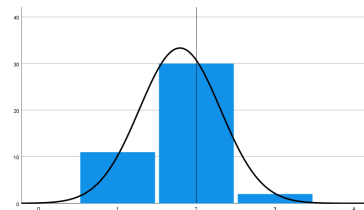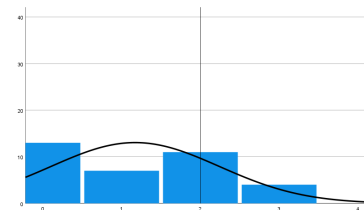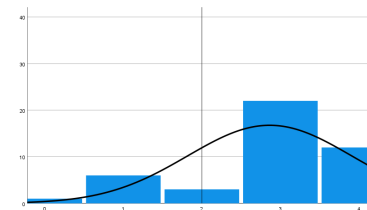
Figure 61 Histograms Over Time: Spatial Analysis
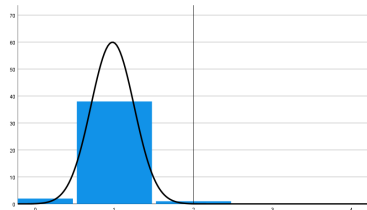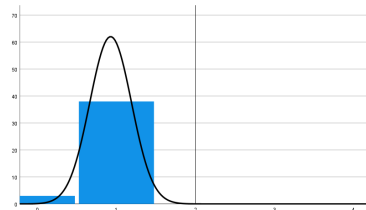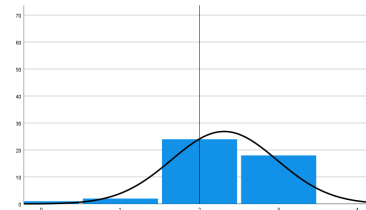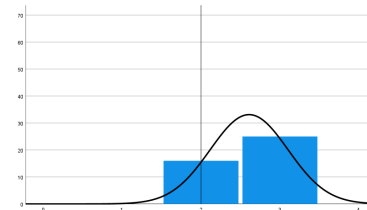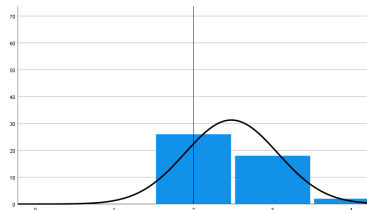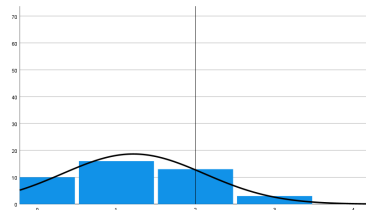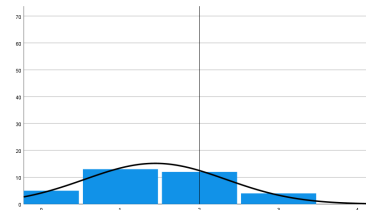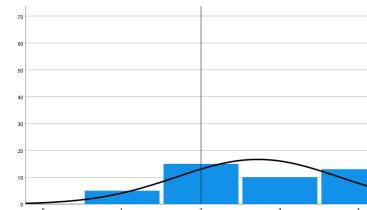
Figure 62 Histograms Over Time: Taking Action
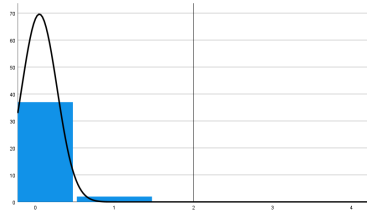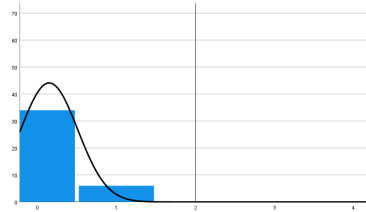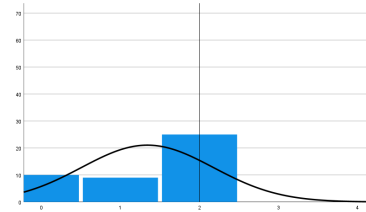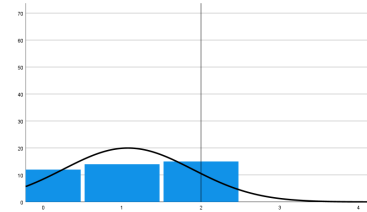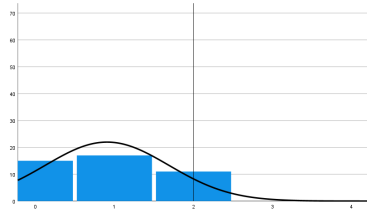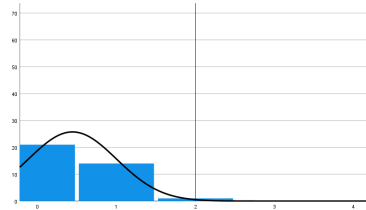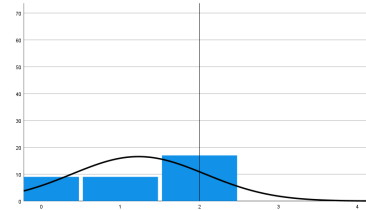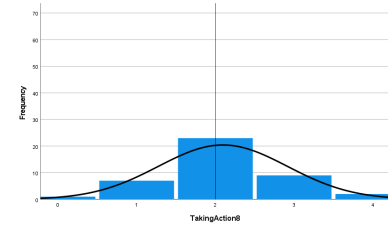
Figure 63 Histogram: Mental Maps
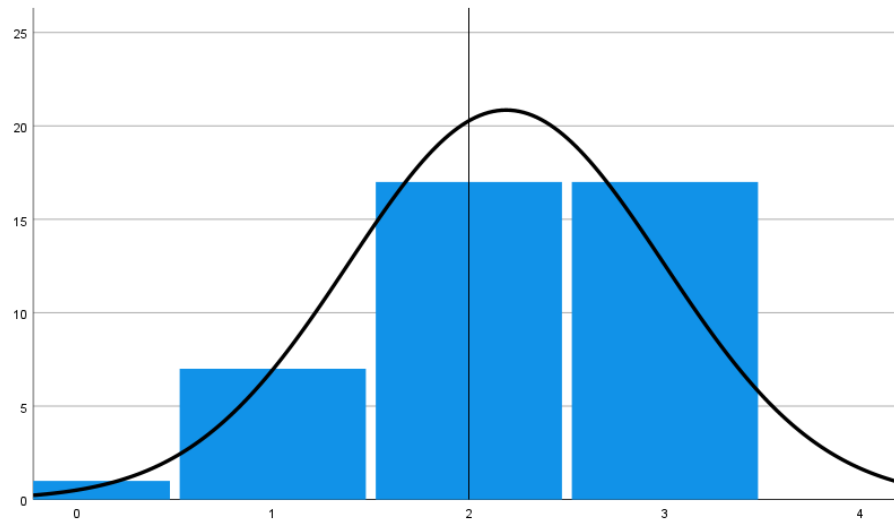
Table 41 Choropleth Table: Using Maps Mission Scores

Mission 1: Mental Map	Mission 2: Campus Map	Mission 3: Asset Map	Mission 4: Mural Map	Mission 5: Env. Justice	Mission 6: Case Study	Mission 7: Geo-Inquiry Question	Mission 8: Counter-Map
1	2	2	3	3	3	2	4
1	2	2	3	2	2	0	2
1	2	2	3	3	2	2	3
2	1	2	3	2	2	2	3
2	2	2	2	3	3	2	3
2	2	2	3	3	2		3
		2	4	3	2		4
1	2	1	3	1	2	0	2
0	1	2	1	2	1		3
			1	1	1	0	
1	2	2	3	3	2	2	4
1	1	1	1	2	1	1	3
1	1	2	3	2	2	2	4
2		0	1	1			1
0	1	1	0	0	1	0	3
1	2	2	3	3	2	0	4
1	1	1	2	0	1	0	3
1	2	2	3	3	2	2	4
1	2	2	3	3	2	0	3
1	1	2	3	2	2	1	4
2	2	3	3	2	2	1	3
1	1		2	3	2	0	1
0	2	2	2	2	2	1	3
0	2	1	2	2	1	1	1
2	2	2	3	3	2		3
2	1	2		1	1	0	
1	2	2	2	2	2		2
1	1	1	3	1	2		1
0	2	2	1	1	1	0	1
0		1	2	2	1	2	1
1	2	2	2	1	2		3
1	2	2	3	2	2		3
1	2	2	2	1	2	1	3
1	1	2	2	3	2	2	4
1	2	2	2	3	2	2	4
1	2	2		3	2	3	3
	1	2	3	2			3
1	2	2		2	2	3	3
1	1	2	2	1		0	3
1	0	1	0	1	2	1	3
2	2	3	4	3	2	3	4
1	0	0		1	1	0	0
	1	2	1	2	2	3	3
0	1	2	4	2	2	2	4
	1	1	2	1	1		3
1	1	2	2	2	2	0	4

Table 42 Choropleth Table: Spatial Analysis Mission Scores

Mission 1: Mental Map	Mission 2: Campus Map	Mission 3: Asset Map	Mission 4: Mural Map	Mission 5: Env. Justice	Mission 6: Case Study	Mission 7: Geo-Inquiry Question	Mission 8: Counter-Map
1	1	2	2	3	2	1	4
1	1	2	2	2	1	1	2
1	1	2	2	2	0	1	3
1	1	3	3	3	1	3	3
1	1	2	3	3	2	1	4
1	1	3	3	4	0		3
		3	3	3	0		4
1	1	3	3	2	1	0	
1	0	3	2	2	1		2
		1	2	3	1	1	
1	1	3	3	3	2	2	4
1	1	2	3	2	0	1	2
1	1	2	3	2	2	3	4
1		2	2	2			2
0	0	2	2	2	0	1	3
1	1	3	3	3	3	2	4
1	1	1	3	2	1	2	3
1	1	2	3	3	2	2	4
1	1	2	3	3	1	0	2
1	1	2	3	3	2	2	4
1	1	3	3	2	2	2	3
1	1		3	2	1	1	1
1	1	2	2	2	2	1	2
1	1	3	2	2	1		2
1	1	3	3	3	2		2
1	1	2		2	1	0	
1	1	3	2	2	2		2
1	1	2	2	2	0		2
0	1	3	2	2	1	0	1
1		2	2	3	1	1	1
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1	1	2	3	2	1		2
1	1	2	3	2	2	2	2
1	1	2	3	3	1	2	4
1		3	3	3	2	0	4
1	1	2		4	3	3	4
	1	3	3	3			2
1	1	2		3	1	2	3
1	1	2	3	2		1	2
1	1	3	2	2	0	1	1
2	1	3	3	2	3	2	4
1	0	0		2	0	1	1
	1	3		3		3	3
1	1	2	3	2	2	2	3
	1	2	2	3	0		3
1	1	3	3	2	0	2	4

Table 43 Choropleth Table: Taking Informed Action Mission Scores

Mission 1: Mental Map	Mission 2: Campus Map	Mission 3: Asset Map	Mission 4: Mural Map	Mission 5: Env. Justice	Mission 6: Case Study	Mission 7: Geo-Inquiry Question	Mission 8: Counter-Map
	0	2	2	1	1	2	3
0	0	0	1	1	0	1	2
0	0	1	0	2	1	2	2
0	0	2	2	1	1	0	2
0	1	2	1	1	0	2	2
0		2	2	2			2
		2	2	2		2	3
0	0	2	1	0	1	2	2
0	0	1	0	1	0	2	2
			0	0		1	
	1	1	1	1	0	1	4
0	0	0	0	0			
0	0	2	1	0	0	1	3
0		0	0	0	0		1
0	0	2	0	1	0		2
0	0	2	2	1		2	3
0	0	0	0	0	0	0	2
0	0	2	2		0	2	3
	0	1	1	2	1	0	1
0	0	1	1	1		2	2
0	0	2	2	2	2	1	2
0	0		1	0	0	1	1
0	1	2	1	2		2	2
0	0	0	1	0		2	1
0	0	2	1	1	0	0	2
0	0	1			0	0	
0		0	2	2	1		1
0	0	0	0	0	0		0
0	0	2	1	1	0	1	
0		2	2	1	1	1	1
0	0	2	2	1	1		2
1	0	2	2	2	0		2
0	1	2	0	1	0		2
0	0	2	1	0	1	0	3
0	1	1	2	2	1	2	3
0	0	2		2	1	2	2
	0	2	2				2
0	0	2		0	0	2	2
0	0	0	1	0		0	2
0	0	2	0	0	1	0	2
1	1	2	2	1	1	2	3
0	0	0		0	0	0	1
0	0	2		1	0	2	3
0	0	1	2	2	0	2	2
0	0	0	0	0	0		2
	0	1	0	1	1	1	4

Table 44 Jonckheere-Terpstra Tables: Mental Maps Scores on Mission 1 by Gender

Total N	42
Test Statistic	150.00
Standard Error	36.776
Standardized Test Statistic	-2.107
Asymptotic Sig. (2-sided test)	.035

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.ᵃ
Male-Female	102.000	33.333	-2.565	.005	.015
Male-Nonbinary	23.000	6.088	1.314	.094	.283
Female-Nonbinary	25.000	9.613	.000	.500	1.000

* Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (1-sided tests) are displayed. The significance level is .050.
   a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 45 Jonckheere-Terpstra Tables: Using Maps Scores on Mission 2 by Gender

Total N	42
Test Statistic	150.000
Standard Error	35.065
Standardized Test Statistic	-2.338
Asymptotic Sig. (2-sided test)	.019

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.ᵃ
Male-Nonbinary	12.500	6.110	-.573	.283	.850
Male-Female	118.000	31.784	-2.328	.010	.030
Nonbinary-Female	19.500	8.376	-.537	.296	.887

* Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (1-sided tests) are displayed. The significance level is .050.
   a.   Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 46 Jonckheere-Terpstra Tables: Taking Action Scores on Mission 2 by Gender

Total N	40
Test Statistic	159.500
Standard Error	22.978
Standardized Test Statistic	-2.220
Asymptotic Sig. (2-sided test)	.026

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Male-Female	127.500	21.156	-2.127	.017	.050
Nonbinary-Female	17.000	7.391	-.812	.208	.625
Male-Nonbinary	15.000	.000	.000	.500	1.000

* Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
  Asymptotic significances (1-sided tests) are displayed. The significance level is .050.
  a.   Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 47 Jonckheere-Terpstra Tables: Taking Action Scores on Mission 3 by Gender

Total N	44
Test Statistic	157.500
Standard Error	37.915
Standardized Test Statistic	-2.440
Asymptotic Sig. (2-sided test)	.015

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Male-Nonbinary	15.500	6.568	.076	.470	1.000
Male-Female	124.000	34.407	-2.441	.007	.022
Nonbinary-Female	18.000	9.226	-.867	.193	.579

* Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
  Asymptotic significances (1-sided tests) are displayed. The significance level is .050.
  a.   Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 48 Jonckheere-Terpstra Tables: Using Maps Scores on Mission 2 by Race

Total N	42
Test Statistic	81.000
Standard Error	32.651
Standardized Test Statistic	-3.782
Asymptotic Sig. (2-sided test)	<.001

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
White-Asian	10.000	10.967	-1.732	.042	.250
White-Black	5.000	7.592	-1.251	.105	.632
White-Latino	50.000	27.506	-3.454	<.001	.002
Asian-Black	1.000	.000	.000	.500	1.000
Asian-Latino	10.000	.000	.000	.500	1.000
Black-Latino	5.000	.000	.000	.500	1.000

* Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (1-sided tests) are displayed. The significance level is .050.
    a.   Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 49 Jonckheere-Terpstra Tables: Spatial Analysis Scores on Mission 4 by Race

Total N	41
Test Statistic	274.000
Standard Error	30.456
Standardized Test Statistic	2.643
Asymptotic Sig. (2-sided test)	.008

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Black-Asian	.500	.000	.000	.500	1.000
Black-Latino	7.500	2.828	.707	.240	1.000
Black-White	24.500	6.481	1.620	.053	.316
Asian-Latino	3.500	2.828	-.707	.240	1.000
Asian-White	24.500	6.481	1.620	.053	.316
Latino-White	213.500	26.631	2.234	.013	.076

* Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (1-sided tests) are displayed. The significance level is .050.
    a.   Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 50 Jonckheere-Terpstra Tables: Taking Action Scores on Mission 5 by Race

Total N	43
Test Statistic	139.000
Standard Error	36.672
Standardized Test Statistic	-2.222
Asymptotic Sig. (2-sided test)	.026

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
White-Latino	107.500	30.836	-1.686	.046	.275
White-Asian	13.000	11.546	-1.386	.083	.497
White-Black	2.500	8.037	-1.493	.068	.406
Latino-Asian	13.500	.536	.536	.296	1.000
Latino-Black	2.000	3.195	-1.095	.137	.820
Asian-Black	.500	.707	-.707	.240	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (1-sided tests) are displayed. The significance level is .050.

a. *Significance values have been adjusted by the Bonferroni correction for multiple tests.*