



# Cartographic Perspectives

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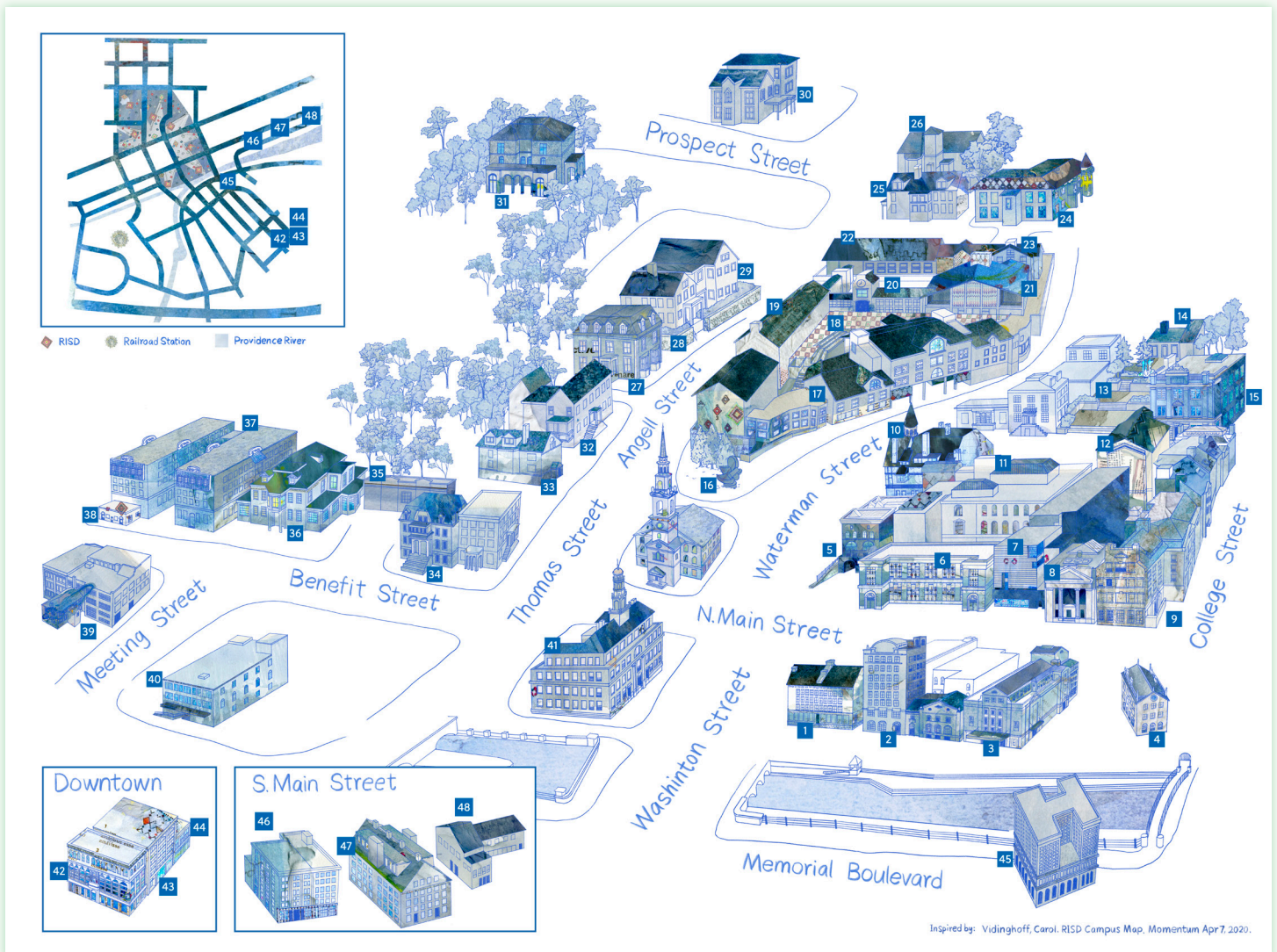
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## ABOUT THE COVER



Inspired by: Vidinghoff, Carol. RISD Campus Map. Momentum Apr 7, 2020.

Created by RISD Illustration MFA alumna Yimiao Wang, RISD CRY is an online participatory map where the RISD community marks the places on campus where they've cried. Alongside the digital map, the project includes physical sign-in forms across campus, a Google Doc submission form, and illustrated responses based on participants' comments. You can find RISD CRY on Instagram @risd\_cry, or visit the project at [www.risdcry.com](http://www.risdcry.com).



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## LETTER FROM THE EDITOR

Welcome to the third and final issue of *Cartographic Perspectives* for 2025. First and foremost, I would like to inform readers that Margot Carpenter has decided to step down from her co-editorial role handling the Cartographic Collections section of the journal; I wish to thank her publicly for all of the work she has done behind the scenes handling that section. In her place, Jack Swab has graciously agreed to co-edit that section alongside Garrett Dash Nelson, who remains in place.

Turning to the present issue, it contains two peer-reviewed pieces, entries in the Practical Cartographer's Corner and Views on Cartographic Education sections, and six book reviews. First off, Merritt et al. have used a mixed-methods approach to look at “second-order” climate beliefs in the United States (“beliefs about what others believe,” 6). In a heartening conclusion, at least for cartographers, they find evidence that the use of maps can produce a “decrease in false beliefs” (19). Further, they find that people tend to vastly underestimate the concerns others have with respect to climate change; something, I'd argue, speaks poorly of the media environment and framing of the issue (perhaps a follow-up study might explore that).

Next, Bachmann and Kaiser ask the rather significant—and as they note, not terribly well studied—question of “how might web mapping contribute to the learning of geographical thinking through interactivity?” at the secondary school level (29). Their study finds, also rather hearteningly, that interactivity is “likely to contribute to the learning of geographical thinking through map interpretation” (29). I strongly recommend this article not only to scholars, but also to teachers, as well as anyone else interested in working with secondary school students using maps; of particular note, they offer empirical evidence that while background technical ability plays an early role in understanding, that decreases over time—a handy study to have on hand when needing to justify the use of a new mapping technology in an educational setting!

What I particularly appreciate from the authors of both of these pieces is how upfront they are about the intrinsic limitations of their studies. Too often, we derive grand claims about society writ large, despite relying on restricted study groups (usually students). These studies are forthright about their limitations, grounded in their conclusions, and still produce hopeful and productive areas for future work.

In the Practical Cartographer's Corner, Sui and Lessani explore the design principles behind effective use of kashida justification in map labeling. I had, previously, not been familiar with kashidas and their elegant use in Arabic map labels. The authors explain the technique, offer practical tips on how to create them in digital GIS environments, and follow with design advice on their use.

The six book reviews run the gamut from a fascinating academic text on the history and significance of ocean route mapping by Caputo (reviewed here by Johnson) to a more traditional *Atlas of Iowa* by Shepard et al. (reviewed by Guo). Sui's review of Short's *The Rise and Fall of the National Atlas in the Twentieth Century* left me particularly intrigued by the author's use of the concept of the "ideological state apparatus" which I strongly associate with Althusser (1970), but here developed in pursuit of more inclusive, participatory maps that foreground often marginalized voices (75). Reyes's *Conducting a Map Collection Review* (reviewed by our new editor, Jack Swab) provides a concrete set of processes to follow when faced with the daunting task of library deaccession; while Shepard's *Mapping with Altitude* reviews approaches towards handling altitude and verticality in map representation (reviewed by Balram). Finally, *The Infographics Lab 2023–24 Anthology* (reviewed by Phillips) offers a reflective, introspective analysis of the output of University of Oregon's prestigious data and design lab. Phillips calls out, in particular, the chapter on "slow mapping," a praxis I find increasingly important in a world beset by AI.

Finally, in *Views in Cartographic Education*, Ramsey offers a reflection upon and advice for the creation of formal mentoring programs (here, the one NACIS recently instituted). A quote I wish all readers to see is simply that "Organizations are usually more than happy to let you create something, as long as you are willing to step up to lead it" (65) as I think it embodies the ethos and importance of NACIS (and, by extension, *Cartographic Perspectives*). We are an organization fundamentally built by members to serve members. In these extremely uncertain times—where many organizations are facing existential crises as a result of rapidly shifting financial terrain—I think it's important to end 2025 by recalling that. NACIS is its membership and *Cartographic Perspectives* is here to serve them. So, in conclusion, if there are ideas (even wholly new sections) that you think would serve the NACIS community, please, reach out to me. A fully open-access journal with no page fees is an anomaly in this world of for-profit scholarly production regimes; let's treasure and foster its growth together.

See you in 2026 with new policies, a new special issue (organized by Will B. Payne and Eve McGlynn) and much more!

As always, thank you.

***Jim Thatcher***



# Using Interactive Maps to Reveal the Content of Second-Order Climate Change Beliefs

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*Although there is extensive research on first order climate change beliefs, second-order beliefs (perceptions about what others believe) are an understudied and potentially highly influential factor tied to a lack of climate policy action. This map reading study employs a pre- and post-map observational design to investigate how interactive maps can reveal and update second-order climate change beliefs. Participants first completed a pre-map survey detailing their climate change beliefs and estimating public support for climate policies. Participants then completed map reading tasks on an interactive web map that visualized county-level climate change opinions in North Carolina, while their eye movements were recorded with an eye tracker. A post-map survey gauged participants' reactions to the actual climate opinions, accompanied by map usability questions. The results showed a widespread underestimation of actual climate policy support among participants. Participants commonly used a set of environmental and humanistic concerns to justify the content of their own beliefs, but when asked to rationalize others' beliefs using the map, they used conspiratorial or ideological explanations to describe others who were more skeptical of climate policy. Additionally, participants exhibited egocentric bias, focusing more on their home counties and those with extreme climate change opinions when exploring the web map. The research underscores the potential of interactive maps to improve the understanding of second-order climate change beliefs and emphasizes opportunities for enhancing their ability to communicate the broad public support that exists for many climate policies.*

**KEYWORDS:** web cartography; web map usability; climate change communication

## INTRODUCTION

MAPS ARE INCREASINGLY USED TO COMMUNICATE information about climate change and are an important medium for disseminating messages and stories about it to the public and policymakers. However, partisan polarization remains at record levels, which has led to controversies and debates over climate policy. Despite abundant research on first-order (individual-level) beliefs, second-order beliefs (beliefs about what others believe) remain an understudied and potentially highly influential factor tied to a lack of climate policy action. Climate policy debates in the United States have been framed around

Democratic support and Republican opposition, with little consideration for the heterogeneity of beliefs within those groups or the actual levels of support for different policies. While climate change opinions have been studied for the last three decades (Tuitjer et al. 2022), our study takes advantage of the growing popularity of using public opinion maps for climate change communication to understand why people believe what they do about others (Howe et al. 2015; Ballew et al. 2019; Marlon et al. 2022). We characterize the second-order beliefs about climate change among a student sample and determine how



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interactive climate change opinion maps work to reveal and update the content of these beliefs. This study is guided by the following questions: (1) How do students who

hold a range of opinions exhibit second-order beliefs about climate change? (2) Which types of web map interactions are most valuable for updating second-order beliefs?

## BACKGROUND

THE FIELD OF CLIMATE CHANGE COMMUNICATION was developed to address the stagnation in debate and action that has occurred over the last two decades (Moser 2016). Notably, it provided the empirical groundwork that is essential to understand group values, beliefs, and identities, and their role in supporting pro-climate social policy (Fielding and Hornsey 2016). In practice, climate change communication led to the development of tailored communication strategies that emphasize both the affective responses to climate stories and also the more traditional, quantitative presentations of scientific information to the public. Broad-level public acceptance of human-caused climate change is largely attributed to these efforts, and support for climate change policies among the American public is higher than ever—yet relatively few voters engage in political actions to reduce global warming (Leiserowitz et al. 2021). There are still many unanswered questions about how acceptance of climate change gets translated into action.

First-order beliefs are the beliefs that individuals hold. When it comes to climate change, they are driven by a combination of factors, like individual scientific knowledge, education level, race, gender, risk perception, exposure to extreme weather, general environmental attitudes, and religious or political affiliation (Lee et al. 2015; Lewis et al. 2019; Shao and McCarthy 2020). Political affiliation, in particular, is strongly correlated with climate change acceptance, risk perception, and support for mitigation policies (Hamilton et al. 2010; Hamilton and Saito 2015). In contrast, second-order beliefs, or beliefs about what others believe, remain an understudied and potentially highly influential factor in the current lack of significant climate policy action (Mildenberger and Tingley 2017). Individual positions toward a particular issue are identity-based, formed in response to the perceived positions of one's social in-groups and out-groups. Second-order beliefs are characterized by egocentric bias, or the assumption by an individual that others hold similar views to themselves, especially if those others are perceived as similar. These beliefs are also tied to the formation of the false consensus effect, whereby individuals overestimate the homogeneity of

group beliefs, and the pluralistic ignorance effect, whereby individuals support positions but mistakenly assume others do not. Finally, second-order beliefs have contributed to false polarization, where individuals perceive more partisan polarization than exists (Epley et al. 2004; Epley and Gilovich 2006; Miller and McFarland 1987). The net result is a general population-level underestimation of pro-climate positions and a reinforcement of weak support for climate policies (Sparkman et al. 2022).

Researchers have largely focused on first-order beliefs because they have assumed the primary importance of the information deficit model of communication, in which factors like education and communication of scientific information operate as a gateway of belief to increasing support for pro-climate policies amongst the public (Ehret et al. 2018). For example, consensus messaging about anthropogenic climate change leads to increased support for public action because it prompts an attitudinal shift in the way the public perceives the legitimacy of scientific facts (Linden et al. 2019). Under the deficit model of communication, it is the transfer of scientific information from experts to the public that needs to be improved to prompt behavioral change related to climate solutions and policy support. However, research shows that education efforts to change first-order beliefs can result in more, not less, polarization (Hart and Nisbet 2012). This is because people who possess greater policy knowledge are also more likely to have strong partisan views (Hamilton et al. 2015; Smith and Mayer 2019). Climate change also holds different meanings across different social, cultural, and historical contexts (Hulme 2009), so understanding how diverse audiences would come to support the same policies but for different reasons remains a challenge.

Competing theories in science communication recognize the importance of more active or dialogic models for understanding how scientific information is interpreted and acted upon by the public. Specifically, under cultural cognition models, belief systems are formed by both the individual-level factors mentioned above as well as top-down factors, such as social identity, elite messaging, and

cultural concerns (Fielding and Hornsey 2016; Kahan 2012). The cultural cognition theory, along with the social identity approach (which views identity as malleable and everchanging) show that individuals filter information through the lenses of worldview and social identity (Kahan et al. 2010). Literacy and education are crucial components to the public understanding of science. However, it is important to account for the ways in which people process information through culturally transmitted values, in order to understand the complete formation of their ideological development and the prevailing attitudes toward climate change policies (Farrell 2016; Hoffman 2011).

Most cartographic research on climate change to date has focused on improving the graphic design of the presentation of scientific information for a variety of audiences, with the intent centered around the effective transfer of that information to the public (Retchless and Brewer 2016; Harold et al. 2016). This research has improved the effectiveness of maps in major media outlets and scientific reports (Fish 2020). However, it has also operated under the primary assumptions of the information deficit model of communication, with static maps passively delivering expert-derived messages about climate change to the uninformed or unconcerned public. Research agendas have subsequently broadened in scope to consider how maps can be used to mobilize the public and policymakers through storytelling (Roth 2021), the extent that mapped messages are viewed as trustworthy (Griffin 2020), and

whether map designers and their audiences occupy positions of privilege that typically exclude the members of the public they are most trying to reach (Retchless et al. 2022). These examples of recent research show how the field has come to recognize the need to consider maps as more than simply a medium for the passive transfer of information.

Part of this broadening of the research paradigm is a focus on interactive maps, which offer the user the ability to manipulate a map based on a set of intended goals and specific use cases (Roth 2017; Cartwright et al. 2001). Several studies have examined how climate change information is perceived by the public when using interactive maps (Popelka et al. 2019; Retchless 2018). The results have shown that interactive maps are more effective in improving user understanding of complex subjects than static maps, although familiarity with the medium remains a challenge. Users with more interactive web map experience are more likely to understand how to navigate such maps and therefore have an easier time finding information (Davis et al. 2020). The methods of these user studies focused on both the quantitative and qualitative user reactions to geographic information and the interactions that facilitated this information transfer. The research we present in this paper uses similar methods to examine the extent to which maps can correct the mischaracterizations of others' climate change beliefs, and to further understand how interactive maps may moderate polarization, thus consolidating support for popular policies.

## MATERIALS AND METHODS

### DATA COLLECTION AND MAP READING EXPERIMENT

#### *Participant Recruitment*

WE USED AN EXPLORATORY APPROACH IN THIS RESEARCH, developing both a pre- and a post-map observational design to understand whether and how using interactive maps can reveal and update the content of map users' second-order climate change beliefs. As is common in eye tracking and other map use studies, a convenience sample ( $n=30$ ) was recruited from the student population at Appalachian State University (App State), by visiting courses to announce the study and call for volunteers. Participants from the Departments of Geography and Planning, Public Health, Sociology, Business, Economics,

History, and Outdoor Recreation were asked to participate in an eye-tracking research study about interactive maps and climate change beliefs. Volunteers did not receive any incentive for their participation.

#### *Pre-map phase*

The research was divided into three phases, beginning with a pre-map phase, and then followed by a map reading session, and a post-map phase. In the pre-map phase, participants completed an online survey screener using Qualtrics to collect demographic information and information about participants' climate change beliefs (Table 1). The pre-map survey also identified any participants who might be disqualified from eye-tracking research due to preexisting vision-related conditions. Before beginning

DEMOGRAPHIC ITEM	PARTICIPANTS (N)	SAMPLE PERCENTAGE
<b>Gender</b>		
Male	11	37%
Female	18	60%
No response	1	3%
<b>Academic year</b>		
1st year student	5	17%
2nd year student	9	30%
3rd year student	5	17%
4th year student	4	13%
Graduate student	7	23%
<b>Experience with technology</b>		
Very low experience	0	0%
Low experience	1	3%
Moderate experience	14	47%
High experience	14	47%
Very high experience	1	3%
<b>Frequency of web map use</b>		
Daily	16	53%
Weekly	13	43%
Monthly	1	3%
Yearly	0	0%
<b>Political affiliation</b>		
Very liberal	10	33%
Liberal	15	50%
Moderate	5	17%
Conservative	0	0%
Very conservative	0	0%
<b>Climate change concern</b>		
Alarmed	19	63%
Concerned	11	37%
Cautious	0	0%
Disengaged	0	0%
Doubtful	0	0%
Dismissive	0	0%

**Table 1.** Participant demographics (n = 30).

ABBREVIATION	STATEMENT
Catastrophic risk	Climate change poses a catastrophic risk to society.
Capitalist society	Climate change is a symptom of a capitalist society that has primarily prioritized economic growth and consumerism, and which has dangerously exceeded the carrying capacity of the planet.
International agreements	Sustainable economic growth can continue indefinitely with the right market-based mechanisms and international agreements.
Environmental problem	Climate change has been misdiagnosed as an environmental problem and market failure.
Carbon pricing	Climate change is a result of the failure to recognize limits to growth and can be corrected by putting a price on carbon.
Diverse policies/tech	Human ingenuity and government investment in diverse policies and technologies will lower the cost of action and protect against climate damages.
Awareness	Public awareness and acceptance of climate change are important first steps to advance climate policy.
Activism	A new public consciousness spread through grassroots activism and social protest is necessary to advance climate change solutions.
Nuclear	Government should encourage the development of nuclear energy relative to other energy sources.
Wind and solar	Government should encourage the adoption of renewables, like wind and solar, relative to other energy sources.
Natural gas	Government should encourage the development of natural gas relative to other energy sources.

**Table 2.** Abbreviated names of climate change statements presented to participants. Participant responses are seen in Figure 3.

the survey, participants provided informed consent and received an anonymized ID that was used to track their participation throughout the research study. This research was approved through the Appalachian State Institutional Review Board to ensure that all protocols for ethical research were followed, and participants were informed about research risks associated with the eye tracker.

The pre-map survey was designed to gather information about participants' computer proficiency, comfort with and understanding of interactive web maps, self-identified political ideologies, and climate change beliefs. This allowed us to gather baseline information on each participant's views before potentially influencing them during the rest of the study. Four questions from the Six Americas Super Short Survey (SASSY; Chryst et al. 2018) were used to measure participant levels of climate change concern, ranging from alarmed to dismissive. Participants were also asked to identify their political ideologies, ranging from very conservative to very liberal. Finally, we measured their support for different climate change policies and theories of social change, as well as their dominant views of nature, by asking participants to rate their level of agreement with a series of statements (Table 2) adapted from Nisbet (2014), on a scale of 1 (strongly disagree) to 5

(strongly agree). For example, participants were asked to rate their agreement as to whether "climate change poses a catastrophic risk to society." We also asked participants to rate their agreement with energy policy statements like "government should encourage the development of nuclear energy relative to other energy sources" and "government should encourage the adoption of renewables, like wind and solar relative to other energy sources."

### Web Map Design

An interactive web map showcasing the county-level climate change opinions of North Carolinians was created using a suite of open-source programming/markup languages and libraries, including HTML, JavaScript, and CSS, as well as the Leaflet.js mapping library (Figure 1). To create the map, we collected data in 2022 from the [Yale Program on Climate Change Communication](#), which provides annual climate change opinion estimates that depict the percentages of adults who support a range of statements about global warming (Howe et al. 2015). At the county level, these opinion estimates are accurate to 8 percentage points and are based on survey results from 2008–2021. They include measurements of climate change beliefs, risk perceptions, and support for different

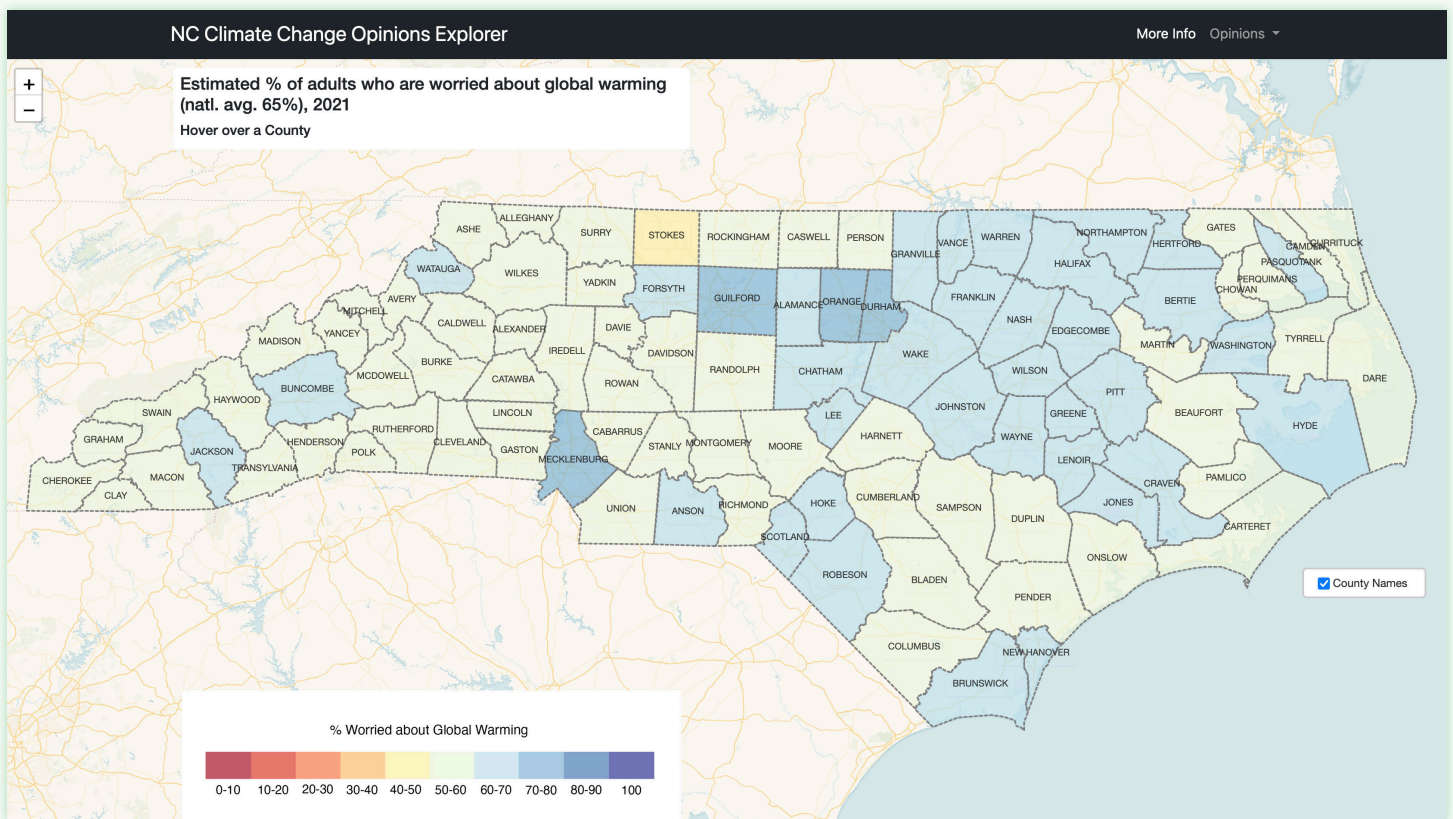


Figure 1. The NC Climate Change Opinions Explorer.

policies. Our map used three different opinion estimates. First, we used the estimated percentage of adults who are worried about climate change (a variable we will refer to as *worried*) as a baseline of general climate concern amongst North Carolinians. The second was the estimated percentage of adults who support taxing fossil fuel companies while equally reducing other taxes (*carbon tax*). Finally, we used data on the estimated percentage of adults who support the expansion of oil and gas drilling off the US coast (*offshore*). These last two datasets were chosen to relate to specific climate policies that may be considered polarizing or complex in nature, or that have been studied to be effective in mitigating climate change.

We visualized the data using choropleth symbolization. The web map also included several interactive features: a drop-down menu allowed users to toggle between the

three opinion variables. They could also mouse over and highlight each county to display the name and specific percentages of opinions in that specific county, as well as for the state at large. Users could also toggle county names on and off to aid in county identification during map use.

### Map Reading and Eye Tracking Session

In the second phase of the study, participants were invited to an in-person map reading and eye-tracking experiment lasting approximately 30 minutes. Participants consented to continue the research study and were given an overview of the experimental purpose and risks. Before viewing the web map, participants were asked to discuss their second-order climate change beliefs (Table 3). Specifically, participants were asked to estimate what percentage of the US population, North Carolina (NC) population, and the population within a county of their choice that they

IN-PERSON PRE-MAP READING SESSION PROMPTS	
<b>Variable</b>	
1. Worried: is worried about global warming.	
2. Carbon tax: think companies should be required to pay a carbon tax.	
3. Offshore drilling: support the expansion of offshore drilling for oil and natural gas off the US coast.	
<b>Second-Order Belief Estimates</b>	
1. To the best of your knowledge, what percentage of the US population... [variable]? Provide a number from 0 (no one) to 100 (everyone).	
2. To the best of your knowledge, what percentage of the NC population... [variable]? Provide a number from 0 (no one) to 100 (everyone).	
3. Pick a county in NC. We will record this county as part of your response. To the best of your knowledge, what percentage of this county... [variable]? Provide a number from 0 (no one) to 100 (everyone).	
<b>Second-Order Belief Content</b>	
1. Let's focus back on the state level. Some people in NC are/do... [variable], while others are not/do not... [variable]. We would like for you to imagine you are talking to a group of people from NC who are/do... [variable]. Specifically, imagine that you asked each of them why they are/do... [variable]. What do you think they would tell you? Please complete the following statement, focusing on what you think their responses would be. "They would say [...]."	
2. Now, we would like for you to imagine you are talking to a group of people from NC who are not/do not... [variable]. Specifically, imagine that you asked each of them why they are not/do not... [variable]. What do you think they would tell you? Please complete the following statement, focusing on what you think their responses would be. "They would say [...]."	

**Table 3.** Participants were asked to answer questions about their second-order climate change beliefs.

believe agrees or disagrees with the three variable opinion statements on climate change. Second, participants were asked to explain why they believe that groups do or do not support each statement by imagining how each group would rationalize their belief. These questions were adapted from Mildener and Tingley (2017) and provided a way to determine whether participants over or underestimate the population-level beliefs, while documenting the content of their beliefs about others before viewing the actual percentages on the map. The responses were audio recorded and later transcribed for content analysis. At this stage, participants completed a short training session and cognitive walkthrough of the interactive web map to familiarize them with the purpose, interactive functionality, and layout of the application. Participants were also given an overview of map reading tasks they would later be asked to complete.

This phase of the research also involved eye tracking, which provides a non-invasive way of collecting data about a user's gaze without interfering with normal viewing patterns (Holmqvist et al. 2011). User eye movements, when coupled with their verbal responses, can provide insight into how users interact with the different areas of the map and ultimately process the information being visualized and communicated (Jacob and Karn 2003). For example, fixations (points of attention) and durations (length of fixations) are tied to information processing and can thus indicate confusion or concentration over a particular element (Duchowski 2003).

We used a Tobii Pro Nano eye tracker, which records eye movements at a sampling rate of 60 Hz. Participants were seated ~65 cm from a 16-inch monitor and first completed a calibration exercise to ensure the accuracy and precision of eye movement data. Eye tracking was used to qualitatively assess participant fixations and durations across each of the mapped climate change opinion variables. The resulting gaze plots pinpoint common areas of interest or visual attention among the sample, thus providing insights into the processing of mapped spatial information. At the beginning of the experiment, a static version of the map was shown to each participant for each of the three climate opinion variables for 30 seconds. During this stage, we asked each participant to describe their reaction upon seeing the actual distribution of climate change opinions revealed on the web map. Participants were reminded of their percentage estimates of each opinion variable during this prompt.

Participants completed three map reading tasks that were developed to capture user insights on any tradeoffs between map usability, which determines how efficiently users can fulfill specific objectives with the map, and utility, which determines how well the map fulfills a specific needed function or purpose (Roth 2017). Users were prompted to engage in several objective-based interaction primitives, including identifying, ranking, and comparing, in order to facilitate user exploration of the patterns, and to allow us to document the affective user experience (Roth 2013). For example, the first map reading task asked participants to compare the percentages of adults who are worried about global warming (variable one) between two NC counties of their choice. The second task asked participants to identify the percentages who support paying a carbon tax (variable two) in Watauga County (the county in which App State is located). In the third task, participants ranked three listed counties in order of lowest to highest support for offshore drilling for oil and gas (variable three).

At the conclusion of each task, participants were prompted to verbally describe their thought process and interactions with the map using a cued retrospective think-aloud protocol, which had participants explain their use of reasoning after completing the map reading task. The use of retrospective questions is helpful, as many users struggle to complete map reading tasks while simultaneously providing full and accurate responses about their choices, especially when less experienced with interactive web map use (Atkins and McNeal 2018; Maudlin et al. 2020). In addition, think-aloud protocols can provide insights as to why a participant interacts with the map the way they do, which eye-tracking technology alone cannot provide (Popelka et al. 2019). All responses were audio-recorded and later transcribed for content analysis.

We developed a thematic content coding scheme using participant responses from the think-aloud protocol. We used [ATLAS.ti](#) to search for common phrases and ideas that explained participant choices in map use, areas of focus, and second-order belief content at both the county and the state level. Participant responses were organized to find similarities and differences for each question during the think-aloud protocols across map reading tasks. We gave each response at least one code, though some received more than one. Responses were then analyzed to find specific topics that participants frequently discussed

within each code. These topics provided more detail about how participants rationalized their second-order beliefs.

### *Post-Map Follow-up Usability Survey*

During the final, post-map phase, participants completed a brief online Qualtrics survey to assess the usability of the web map and to offer their open-ended responses to the maps of climate change opinions. First, participants were asked to rank, using a Likert scale, ten measures of web map usability, including how easy the web map was to use, whether they felt confident solving tasks with the web map, and if others would be able to use the web map easily. Questions were developed from the system usability scale, which has been shown to be simple, highly accurate across different sample sizes, and particularly effective at measuring participants' attitudes and preferences (Çöltekin et al. 2009). This step told us how usable the map was for

the participants and allowed us to pinpoint areas where usability could improve. Paired with the previously mentioned think-aloud protocol, we were able to analyze how usable the map was for its intended purpose and determine which types of interactions and map features were most successful. Participants were also asked to choose from a list of 100 emotions, as used by Roth et al. (2014), to gauge their affective responses to the actual distribution of climate change opinions when interacting with the web map. Participants described whether they over or underestimated the actual percentages of support for the different climate change opinions during the experimental phase. They also had the chance to describe why they may have over- or underestimated beliefs. This allowed us to explore the participant's feelings about their own second-order beliefs and gauge whether the participant was likely to update the content of these beliefs.

## RESULTS

### *PRE-MAP RESULTS*

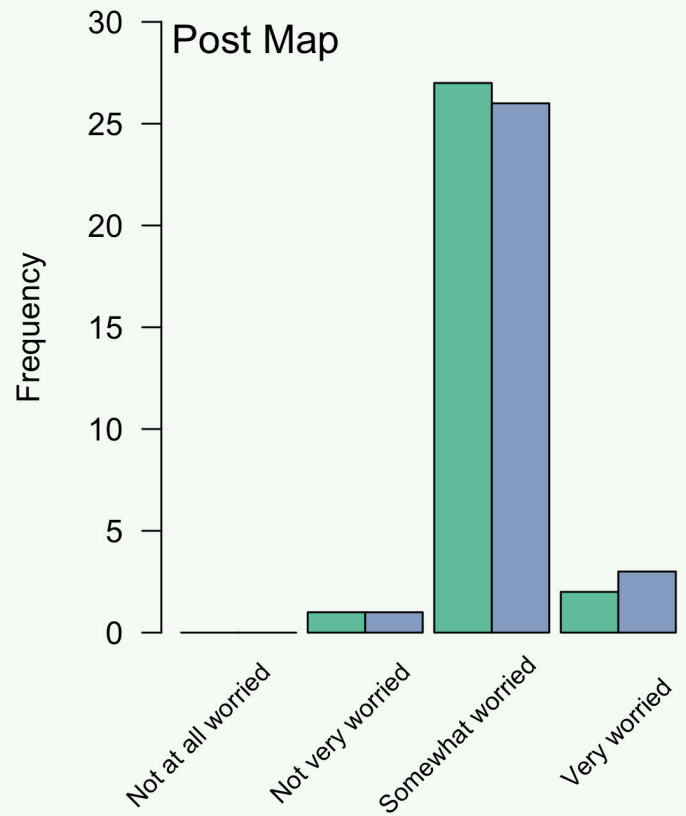
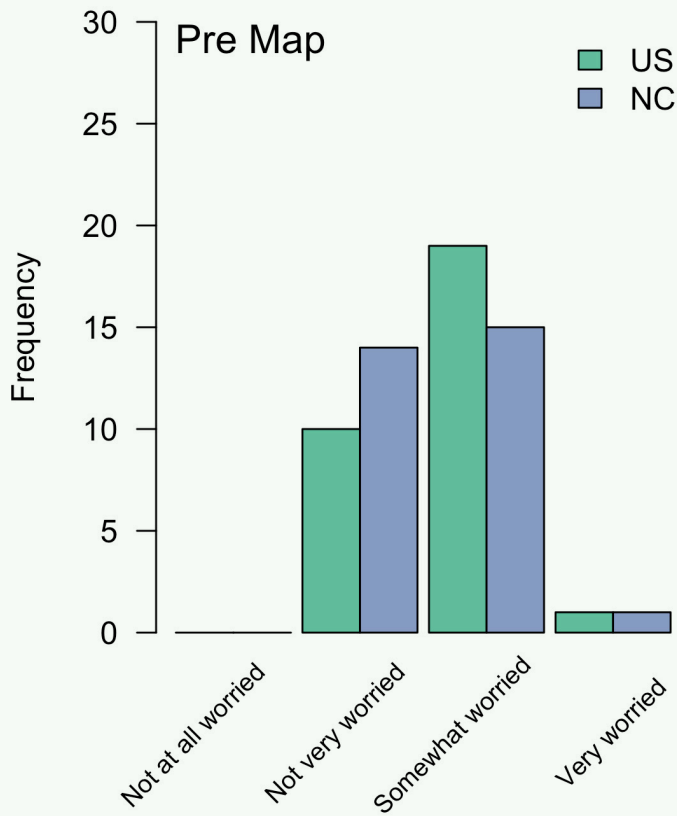
#### *First and Second-order Climate Change Beliefs*

PARTICIPANTS TOOK THE SASSY SCREENER DURING the pre-map phase of the study to allow us to measure their attitudes toward climate change (Chryst et al. 2018). Of the 30 participants in this study, 63% of participants were Alarmed, and 37% were Concerned. No participants were grouped as Cautious, Disengaged, Doubtful, or Dismissive about climate change. The sample group differed considerably from the national average estimates for the Six Americas groups at the time of the study, in which 26% were Alarmed, 27% were Concerned, 17% were Cautious, 7% were Disengaged, 11% were Doubtful, and 11% were Dismissive. Alarmed participants are convinced global warming is happening, human-caused, and an urgent threat, and they strongly support climate policies but remain unsure of how to solve the problem. Concerned participants share these traits, but they do not consider global warming to be an imminent threat.

Prior to engaging with the web map, participants were asked how they think most people feel about global warming in the US and in NC using a four-category Likert scale, ranging from not at all worried to very worried. Figure 2 shows the results, along with the answers to the same questions in the post-map phase. During the

pre-map phase, participants were generally more skeptical of North Carolinians' climate change concern than they were of the US public. 50% of participants thought NC residents were somewhat worried about global warming, while 63% thought that people in the US were somewhat worried. Likewise, the proportion of participants who thought NC residents were not very worried about global warming was higher (47%) than the participants who thought that people in the US were not very worried about it (33%). Only 3% of participants thought that people in the US and NC were very worried about global warming during this phase.

Results from the participants' agreement with Table 2's climate change statements can be seen in Figure 3. The majority of participants strongly agreed with statements tied to ecological activist framings of climate change, including the perception that it is a catastrophic risk to society, support for the adoption of renewable energy, and the need for activism to increase public support for these policies. Participants were on average more neutral about climate change statements that advocated for smart growth and reform. For example, 43% and 46% of participants selected that they neither agreed nor disagreed with the government supporting the adoption of natural gas and nuclear energy, respectively, when compared to other energy sources. However, the majority of participants strongly



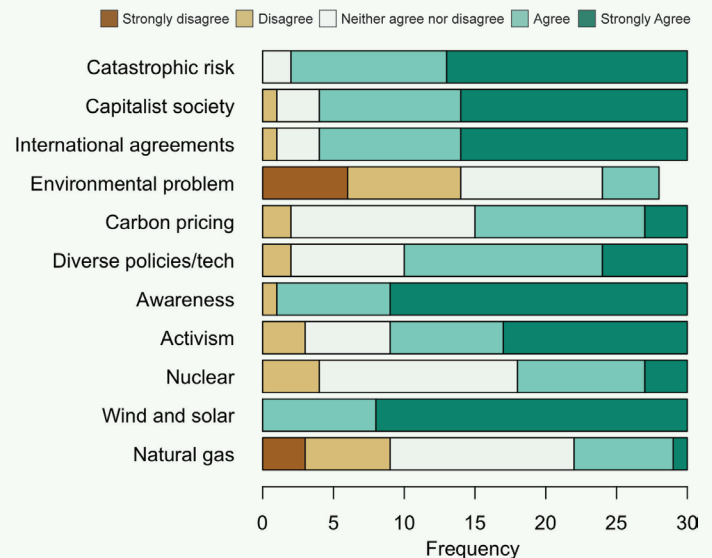
**Figure 2.** Participants were asked how they think most people feel about global warming in the US and NC during the pre-map phase and post-map phase (after viewing the climate change opinion estimates).

agreed that “sustainable economic growth can continue with the right market-based mechanisms and international agreements.” Finally, the sample was more conflicted about statements tied to ecomodernist perspectives and solutions to climate change. When asked whether “climate change has been misdiagnosed as an environmental problem,” the majority of participants either disagreed, strongly disagreed, or felt neutral. Yet a majority of participants agreed or strongly agreed that government investment in diverse sets of policies and technologies would lower the cost of action and protect against climate change harms.

## IN-PERSON SESSION RESULTS

### National and State Level Estimations

During the in-person session, participants were asked to report their estimates of support at the national and state levels for each metric (worried, carbon tax, and offshore drilling; Figure 4). While the study was conducted in 2023, actual survey data from the [Yale Program on Climate Change Communication](#) were at that time available up through the year 2021. This means that differences in participant estimations and the national and state



**Figure 3.** Participants ranked their level of agreement with a range of statements related to climate change, including views of nature, models of social change, and framing of the problem and its solutions. The wording of each statement can be found in Table 2. There were no participants who strongly agreed with the “Environmental problem” statement.

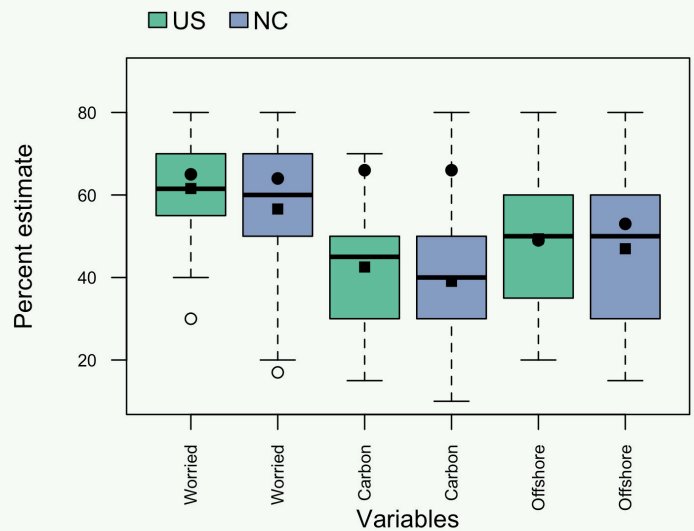
averages may potentially be due to the age of the survey data. When asked what percentage of the US population is worried about climate change, participants on average estimated 62%. The actual national average was 65%, which means that our participants underestimated. At the state level, participants estimated an average of 57%, believing that North Carolinians were less likely than the average American to be worried. The true state average in 2021 was 64%, which again reflects another underestimation by the participants.

Likewise, participants also underestimated support for carbon taxation. Participants on average estimated that 43% supported this policy nationwide, much lower than the true survey figure of 66%. The same is true for the state level, where participant estimates averaged 40% and actual statewide support in 2021 was 66%. Finally, participants also estimated support for offshore drilling in the US and NC. At the national level, survey estimates put support for offshore drilling at 49%, and our survey participants likewise suggested 49% support on average. At the state level, participants believed on average that 47% of NC residents support offshore drilling, whereas the actual percentage is 53%.

### Content of Second-order Beliefs

Participants were asked to verbalize how they believed others would explain why they do or do not support each of the climate change opinion variables, and these responses were recorded and later coded. Results of the content analysis can be seen in Figure 5. The overarching codes for all responses include themes of environment, weather, people, beliefs, responsibility, and economics. Of the 30 participant responses, 23 (77%) discussed environmental reasons to explain why they believe others are worried about climate change. Of those who gave environmental responses, 57% spoke about waterways and coastal areas, 39% spoke about agricultural concerns, and 13% spoke about wildlife-related concerns. When participants were asked what other people would say to explain why they are not worried about climate change, all responses fell under the *beliefs* code. 33% said that others would say that climate change is natural, 33% that climate change is not real, and 27% that it “wouldn’t affect me.”

Two common codes were identified when participants verbalized how others would explain their support for a carbon tax: *responsibility* and *environment*. The majority



**Figure 4.** Participants estimated the percentage of adults in the US and NC that support specific climate change opinions. Box and whisker plots show the minimum, first quartile, median, third quartile, and maximum estimates. Square symbols depict the mean estimate and circle symbols depict the actual percentages.

of participants thought others believed that corporations need to take responsibility for their emissions. Other responses indicated emissions reductions (20%) and pollution impacts (7%) as environment-related reasons for supporting a carbon tax. Conversely, when participants were asked what they thought others who do not support a carbon tax would say, the responses shared mainly fell under the *economic* code, with 40% indicating that others would believe a carbon tax to be ineffective, 20% discussing disagreement with government interference, and 20% sharing that others might believe it could negatively affect businesses. 13% of participants said that people who do not support a carbon tax held those beliefs because it is not a corporation’s responsibility to pay taxes on carbon emissions, and another 13% said that people do not believe in climate change and therefore do not support a carbon tax.

Lastly, when participants were asked to explain their second-order beliefs related to offshore drilling for oil and natural gas, *economics* and *environment* were used as the principal reasons. For example, economic codes were applied to 28 of the 30 participant responses that explained why others would support offshore drilling. 54% of responses suggested that others would argue that offshore drilling would help make the country more prosperous; similarly, 37% mentioned a need for state-side (i.e., domestically produced) resources. Roughly 16% of respondents believed others thought that offshore drilling is



**Figure 5.** Common sets of codes were applied to group the participant responses explaining why they thought others do or do not support each of the climate change opinions. Coded responses were also separated according to specific topics falling within each code.

needed to bring more jobs to the country. When asked to verbalize why others do not support offshore drilling, 29 of the responses were categorized with an environmental code. 53% of the responses said that others would be concerned about waterways and coastal areas, 43% said others were concerned about human-made disasters, like oil spills, and 33% were concerned about wildlife. 16% of the responses were classified as economics-related, primarily because they thought others would be interested in ways to reduce reliance on fossil fuels.

### Map Reading

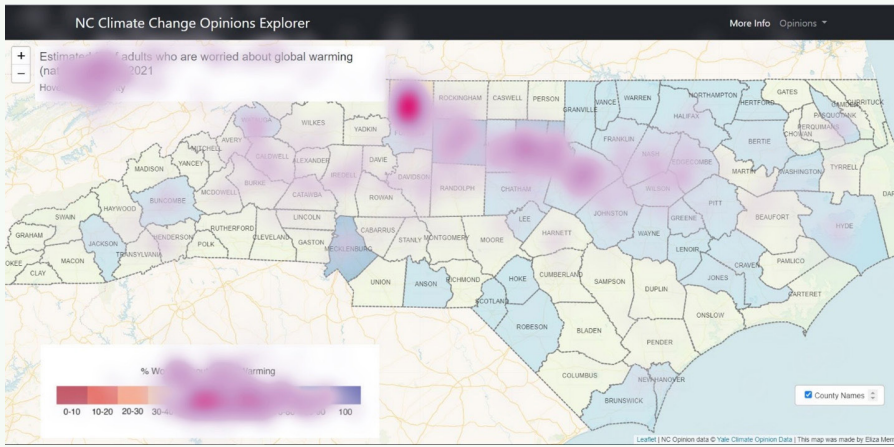
The first map reading task had participants select two NC counties of their choice to compare the percentage of adults who were worried about global warming in each. The counties chosen most frequently were Stokes (n=10) and Watauga (n=8). Participants were asked why they chose the counties they did, and when the results were later analyzed, four common codes emerged: home, school, extreme, and interested. For this question, participant responses could belong to multiple categories. The largest category was interested, with 50% of participants choosing counties they wanted to know more about. Additionally, participants chose their home counties (40%) or because they attended school at App State in Watauga County (20%). The extreme code was applied when participants chose counties because they appeared to have the highest or lowest levels of worry about climate change across the state. 23% of participant responses were coded with this tag. Combined, the home and school tags comprise the largest code groups, indicating that participants chose to examine their own map location first.

After reviewing the map, participants were asked to describe how their estimates of each metric in the pre-map phase compared to the actual climate change opinion survey results. Using ATLAS.ti, we coded whether participants' expectations were higher than, similar to, or lower than the values seen on the map. We also separately coded responses with a tag to mark if participants indicated that they were surprised by what they saw. Some of the participant responses did not fit within any of these codes, which accounts for the response rates less than 100%, described below. For the estimated percentage of people who are worried about global warming, 13% were coded as higher, 43% were coded as similar, and 23% were coded as lower. 23% of participants were also surprised by the distributions that they saw on the map. For carbon taxing,

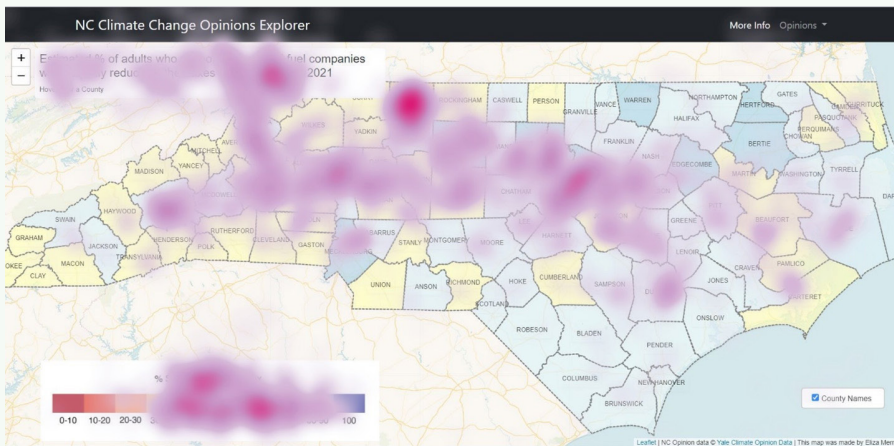
17% of responses were coded as higher, 23% similar, and 37% of responses were coded lower, meaning that participants expected support to be lower than what was seen on the map. 33% of participant responses were coded as surprised, meaning that more participants were surprised by the actual support for carbon taxing than by the percentage of people worried about global warming. For offshore drilling, 33% of responses were coded with higher, 23% were coded similar, and 10% were coded with lower. Participants generally expected there to be more support for offshore drilling than exists. 37% of responses were coded with surprise, indicating that participants were the most surprised by the levels of support for offshore drilling.

Eye tracking was used to understand common patterns of visual attention during map reading tasks, which were then paired with participant verbal responses about their map use and interactions. Figures 6, 7, and 8 show the participant gaze heat maps across all three opinion variable maps. During map use, participants focused heavily on the map elements, including the title, information box, and legend. They also focused heavily on data extremes, where different county populations exhibited relatively low or high percentages of worry about or support for each opinion variable, as shown in the choropleth symbolization. For example, participants fixated on Stokes County for long durations across all three opinion variables. Stokes County is marked by the lowest percentages of climate worry and support for pro-climate policies in NC, as indicated by yellow to red hues in the diverging color palette. Conversely, participants also fixated for longer durations on higher populated and urban counties, where populations exhibit the highest percentages of support for pro-climate policies as indicated by the more saturated blue hues. This includes Mecklenburg County, which contains the city of Charlotte, as well as Durham, Orange, and Wake Counties in North Carolina's Research Triangle area, encompassing the cities of Durham, Chapel Hill, and Raleigh. Lastly, there were also many long-duration fixations on Watauga County, indicating participant interest in climate change opinions near App State. Very few participants paid attention to other map elements, including the opinions variable drop-down menu or the county names layer control while exploring the map.

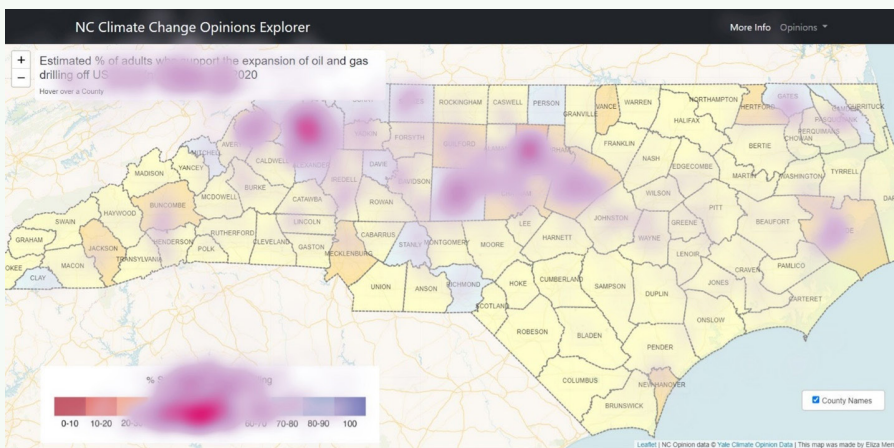
Across all map reading tasks, participants were asked how they interacted with the map to better understand their map use when solving a problem. These results were then



**Figure 6.** Heat maps depicting the visual attention patterns of participants when viewing the estimated percentages of adults *who are worried about global warming*. Color presence indicates a fixation, while durations are symbolized sequentially from light purple (shorter) to dark red (longer).



**Figure 7.** Visual attention patterns when viewing the estimated percentages of adults *who support taxing fossil fuel companies while equally reducing other taxes*.



**Figure 8.** Visual attention patterns when viewing the estimated percentages of adults *who support the expansion of offshore drilling for oil and natural gas off the US coast*.

coded, and the most commonly applied code was *knew where was*, which indicated that participants already knew the locations of the counties they were searching from prior knowledge. Participants indicated that they hovered over different counties to reveal the data values in the title control while performing map reading tasks. They also used the legend to interpret quantitative differences in the climate change opinions by class. These coded responses were the second most common type of answers. Finally, eleven participants indicated that the tasks were difficult to solve with the map’s interactive functions and resorted to a visual search of the counties to complete map reading tasks.

## POST-MAP RESULTS

### Updating Beliefs, Web Map Usability, and Emotions

At the conclusion of the experiment participants completed a brief survey. We asked participants—again, after viewing the map—a series of follow-up questions related to the actual distribution of climate change opinions. First, participants selected how they thought others in the US and NC felt about global warming, from not at all worried to very worried (Figure 2). For the US, only one participant (3%) felt that people were not very worried about climate change, as compared to 33% in the pre-map phase. Twenty-seven (90%) felt that people were somewhat worried, up from 63%. Finally, two participants (7%) felt that people were very worried, up from one participant (3%) in the pre-map phase. For NC, one participant felt that people were not very worried about global warming (3%, down from 47% prior to viewing the map). Twenty-six felt that people were somewhat worried (87%, up from 50%), and three felt that people were very worried (10%, up from

3%). Thus, there was a substantial increase in the number of participants who thought that most people are somewhat worried about climate change in both the US and NC after viewing the map. These values increased by 8 participants at the national level, and 11 at the state level. Likewise, there was also a decrease in the number of participants who thought that most people are not very worried about climate change.

Second, we asked participants to describe whether or not they were surprised by the actual distributions of climate change opinions in NC, with 23 participants indicating that they were surprised (77%), and seven indicating that they were not (23%). Participants also described whether or not they had expected the climate change opinions to be like their own when viewing the map. Out of the 30 participants, 11 participants had expected others' beliefs to be similar to their own (34%), 15 participants had expected others' beliefs to be less like their own (50%), and four participants' responses indicated neither more nor less (13%). Overall, participants exhibited a decrease in false beliefs after interacting with the map and seeing the actual distribution of climate change opinions when compared to the pre-map phase of the study. Participants were also generally surprised at the results because they expected climate change opinions to be different from their own, indicating pluralistic ignorance of the actual distribution of opinion.

To address map usability, participants were asked to choose features on the map that were most helpful for them to interact with the map (Figure 9). Data visualization was selected as the most helpful feature to understand the distribution of climate change opinions across



**Figure 9.** Participants selected the most helpful map features from a list of interface design choices and map interactions after completing the map reading tasks.

the state, with 28 participants choosing this option from the list. Participants also chose mouseover features 24 times, indicating that was the second most helpful map interaction. Fourteen participants chose the interface design as being helpful. Additionally, participants selected emotions that they felt represented their map use during the experiment to further understand affective responses to the mapped climate change opinions (Table 4). From this list, 64 emotions were chosen at least once. Positive valence emotions were selected most frequently, including calm, surprised, curious, okay, and satisfied. Negative valence emotions were chosen less frequently after interacting with the maps. For example, the first overtly negative emotion to show on the list is *rushed*, which ranked 29<sup>th</sup> with 3 choices.

## DISCUSSION

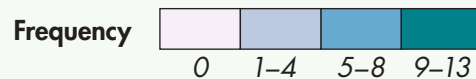
### MAGNITUDE AND CONTENT OF SECOND-ORDER BELIEFS ABOUT CLIMATE CHANGE

THE PRE-MAP PHASE OF THE STUDY ESTABLISHED participants' demographics, technological proficiency, political leanings, and climate change beliefs. Overall, the convenience sampling method resulted in the recruitment of a predominantly liberal, majority female, and technologically proficient student sample. This means that our experimental results stem from varying political views

from people on the left side of the political spectrum, which is generally associated with greater climate concern and pro-climate policy support (Ehret 2018). In addition, participants were alarmed or concerned about climate change at much higher rates than the national average. We noted that most participants' views aligned primarily with an "ecological activist" framing of climate change, meaning that they think it is a symptom of a capitalist society that has over-prioritized economic growth and dangerously exceeded the carrying capacity of the planet (Nisbet

Accepted	Content	Exhausted	Jealous	Quixotic
Accomplished	Cranky	Flirty	Jubilant	Recumbent
Aggravated	Crappy	Frustrated	Lazy	Refreshed
Alone	Crazy	Full	Lethargic	Rejected
Amused	Crushed	Geeky	Listless	Rejuvenated
Angry	Curious	Giddy	Lonely	Relaxed
Annoyed	Cynical	Giggly	Loved	Relieved
Anxious	Dark	Gloomy	Mad	Resolute
Apathetic	Depressed	Good	Melancholy	Restless
Ashamed	Determined	Grateful	Mellow	Rushed
Awake	Devious	Groggy	Mischievous	Sad
Bewildered	Dirty	Grumpy	Moody	Satisfied
Bittersweet	Disappointed	Guilty	Morose	Shocked
Blah	Discontent	Happy	Motivated	Sick
Blank	Ditzy	High	Naughty	Silly
Blissful	Dorky	Hopeful	Nauseous	Sleepy
Bored	Drained	Hot	Nerdy	Smart
Bouncy	Drunk	Hungry	Numb	Stressed
Calm	Ecstatic	Hyper	Okay	Surprised
Cheerful	Energetic	Impressed	Optimistic	Sympathetic
Chipper	Enraged	Indescribable	Peaceful	Thankful
Cold	Enthralled	Indifferent	Pessimistic	Tired
Complacent	Envious	Infuriated	Pissed off	Touched
Confident	Exanimate	Irate	Pleased	Uncomfortable
Confused	Excited	Irritated	Predatory	Weird

**Table 4.** Participants selected from a list of emotions to best describe their mood when completing the map reading tasks.



2014). This is important because ecological activists often connect extreme weather events with climate change, even when the attribution of specific events may be uncertain and made with low-to-medium confidence at best. In fact, many participants cited the impacts of extreme weather events as a reason for explaining why others in NC would be worried about climate change, yet still underestimated the percentage of people they thought held this view, thereby demonstrating a false consensus in overestimating the amount of people who are not worried about it.

This study identified common patterns in the content of second-order beliefs. In general, when participants were speaking about pro-climate policies and ideas, several major themes emerged as reasons why they thought others in NC would hold these opinions. The largest theme was

environmental in nature, where participants were concerned about coastal areas, agriculture, wildlife, and other environmental impacts of human-caused disasters. Other themes were related to economic concerns and the need for corporate responsibility to address the issue through a carbon tax. These sentiments are directionally consistent with the literature on second-order beliefs among left-leaning individuals, who are more likely to support a policy for climate or environmental reasons (Bergquist 2020; Hamilton 2010; Hamilton et al. 2015).

When speaking about people in NC who are more dismissive of climate change, two major themes emerged. First, many participants thought segments of the public held those views for economically related reasons. This was especially the case when they were asked about those who

oppose a carbon tax and who support offshore drilling for oil and gas. For example, participants frequently cited a carbon tax as a limiter of economic prosperity for business and cited the perceived need for abundant oil and gas resources in local economies as reasons why others would hold these opinions. Second, many participants thought the percentages of people in NC who were more dismissive of climate change held those views due to a set of belief-related concerns around climate skepticism. For example, participants thought that others would question the reality and anthropogenic influence of climate change and therefore question the need for specific policies. Others thought that people who were more dismissive of climate change and climate-related policies were engaging in a set of conspiratorial, ideological, or religious rationales for not being worried about the issue.

This study identified a large gap between the magnitude of participants' false second-order beliefs and the reality of climate change opinions in NC. Participants were likely to underestimate the percentage of adults that were worried about climate change and to underestimate the support for a carbon tax. Participants were also likely to overestimate support for offshore drilling at the national level. Therefore, participants believed that fewer people agreed with their own first-order beliefs, further contributing to false polarization. This finding is consistent with literature suggesting a general population underestimation of support for pro-climate policies (Mildenberger and Tingley 2017). Sparkman et al. (2022) concluded that Americans are living in a "false social reality" due to a shared misperception about how others think or behave around climate change. In this study, most participants were similarly surprised by the actual distribution of climate change opinions across the state, showing how second-order beliefs have reinforced pluralistic ignorance of actual popular support for climate policies (Epley et al. 2004; Epley and Gilovich 2006; Miller and McFarland 1987).

## INTERACTIVE WEB MAP USABILITY AND USER PREFERENCES

During the in-person phase of the study, participants were asked why they interacted with the map in the way they did. Participants gave overwhelmingly positive ratings for map usability. It is important to note that all participants reported high levels of technological proficiency and frequency of web map use, which suggests they are more likely to understand, and have an easier time interacting

with, the web map than others who have less experience with them (MacEachren et al. 1998). Participants indicated that the most helpful map element for understanding others' beliefs was the data visualization (including the choropleth symbolization). This is consistent with participants' tendencies to refer to the diverging color palette in the legend while exploring the map during the think-aloud protocol.

Participants provided their rationale for exploring different parts of the map when solving the map reading tasks. Across all climate change opinion variables depicted on the map, participants most frequently chose to focus on a given county during a map reading task because it was their home county or because they currently lived in Watauga County to attend App State. Participants were able to use map interactions in the context of the map reading tasks to put climate change opinions into their own personal context before responding to the tasks. Allowing users to manipulate maps based on their own data exploration preferences creates a more personal understanding of the map, as well as the phenomena it is portraying.

We also found evidence in support of spatial optimism bias, where participants perceive their own locations to be less vulnerable to climate extremes than those that are far away (Retchless 2018). During the map reading tasks, many participants shared sentiments that the mountains of western NC, where App State is located, would experience fewer climate change impacts. In reality, the region remains vulnerable to hydroclimatic extremes, ranging from floods to droughts and their subsequent socio-environmental impacts (Labosier and Quiring 2013). Participants were far more concerned about, and more likely to discuss the implications of climate change in, coastal areas. They were also concerned about climate effects on agricultural areas in central and eastern NC. Participants also used the geographic location of interest as a rationale for focusing on specific counties when completing map reading tasks, and frequently chose to compare counties that are geographically located on opposite sides of the state. However, participants also interacted with counties directly adjacent to one another. Often, these participants would be curious as to why two geographically similar places had differing levels of support for the climate change policies or had differing levels of worry about it. These are two common ways that participants interacted with the web map while exploring climate opinions, and may suggest common use patterns among larger populations of map users.

Finally, participants focused on counties with the most extreme levels (i.e., low and high percentages) of worry about climate change or support for climate-related policies when solving the map reading tasks. Many commented during the think-aloud protocol that they used the legend and color palette to assist with identifying these locations. In this case, participants were especially drawn to Stokes County, which had the lowest support for carbon taxes and the lowest levels of worry across the state, as well as the highest levels of support for offshore drilling. The heatmap fixations and durations paired with a high rate of open-ended responses that mention being drawn to extreme counties clearly show this phenomenon. Stokes County has a relatively small population, with an estimated **44,520 people in 2020**. However, the tendency of participants to focus attention there could reinforce false beliefs about statewide support because people have a tendency to better remember highly salient events (Madan 2014). Conversely, participants also focused attention on counties with the greatest support across all three metrics, which generally correspond to Orange (148,696 people), Durham (324,833 people), Mecklenburg (1,115,482 people), and Wake counties (1,129,410 people). NC counties are relatively similar by area when compared with those in many western states, which could pose future problems for interpreting mapped climate change opinion estimates in those locations. We welcome future map studies that would specifically compare differences in the interpretation of climate opinions using other symbolization techniques, like proportional symbols or dot density symbols.

Emotional responses to climate information have received much attention in recent years due to the recognition that visualization and communication make climate change more tangible and relatable for individuals (Fish 2020). Participants in this study overwhelmingly chose emotions with positive valence, such as calm, relief, and surprise, which suggests that users had good experiences interacting with the web map by discovering that their first-order beliefs are not as uncommon as they suspected. Emotions can be indicators of mood and affective responses to storytelling within a map (Roth 2021). Exploring the emotional responses to maps has the potential to increase understanding and provide insights regarding how spatial information can better communicate the human experience (Griffin and McQuoid 2012). When viewing and discussing the political views of others in the perceived social outgroup relative to their own beliefs, individuals tend to have intensely negative emotional responses, like

contempt, fear, and disgust (Prinz 2021). Public opinion maps may have the potential to moderate polarization on controversial topics due to their ability to generate more positive affective responses when public support is greater than originally perceived.

In this study, participants updated their second-order beliefs from the pre- to post-map, demonstrating a reduction in false beliefs and misperceptions about what others think and do. There was a substantial increase in the number of participants who thought that US and NC residents were somewhat worried about global warming from pre- to post-map. There was also a decrease in the number who thought these groups were not very worried. Participants were also more skeptical of NC's climate change concern during the pre-map phase than of the US as a whole. This is interesting because an estimated 64% of North Carolinians are worried about global warming, according to the Yale Program on Climate Change Communication, a value which is only 1% less than the national average at the time of the study (Howe et al. 2015). Despite our participants being overall worried about climate change, they thought that few others were prior to viewing the map, demonstrating the pluralistic ignorance effect where one believes others do not believe what they do. Furthermore, scientific knowledge about climate change is inversely correlated with climate change anxiety (Zacher and Rudolph 2023). Our research suggests climate change opinion maps are a useful tool to alleviate the concern about insufficient public or policymaker support for different climate policies among young ecological activists who are alarmed about global warming. Reducing the false perception of weak climate policy support has the potential to depolarize policy discussions, including by refocusing some of the anxiety and grief about it, which has increased in younger populations (Holthaus 2023; Shaw and Bonnett 2016).

## LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

There are several limitations that should be discussed in the context of the results. First, this study used an exploratory research design, favoring a natural observational experiment, rather than one with experimental control groups, to examine common patterns that emerged. In addition, methods were primarily qualitative, with eye tracking, surveys, and interviews used to examine the how participants interacted with the map, along with the content of their second-order beliefs. The results should

not be interpreted as causal inferences, nor should we draw any statistical conclusions about the changes in belief from pre- to post-map. In addition, this study used a small, convenience sample of students from App State, who were mostly attending classes adjacent to the subject of the environment. App State consistently receives national recognition for its leadership in sustainability, **listing over 2,000 courses** that incorporate the topic, and the university considers it as a major driver in student enrollment. Participants were alarmed and concerned about climate change, and they were already experienced with map reading and technology. As a result, we caution the reader from drawing more generalizable conclusions about population groups not represented in the study. While the results replicated the larger nationally representative surveys on second-order belief, future research should purposefully sample students who are less proficient with web maps and who are politically conservative and hold doubtful or dismissive views of climate change to verify the reduction in false beliefs through map reading. In addition, we identified several misperceptions that politically liberal and ecologically activist-oriented students hold about others who are more dismissive of climate change. This purposeful sample would show whether there are differences in the accurate perception of others' beliefs across a range of views. Finally, a further limitation of our research is tied

to the think-aloud protocol used during the map reading tasks. It is possible that participants forgot, or insufficiently described, on how they interacted with the map, and a concurrent think-aloud protocol may have revealed more about their interactions.

Despite its limitations, this study highlights the ability of interactive web maps to update second-order beliefs, which may, in turn, lead to an increased understanding of climate change and climate change policy. However, we recommend attention be paid in the future towards the specific use cases of climate change opinion maps as they are implemented in the public sphere. Specifically, more research is needed to outline the public's understanding of maps as elite forms of messaging that may reinforce polarization, as has been shown with other forms of media communication (Hart and Nisbet 2012). Retchless et al. (2022) provide a recent discussion of the roles of power and privilege in engaging with climate change maps. If climate change opinion maps are to be effective in communicating the results of the larger, national-level surveys and models, then future work in cartography should account for the diversity of political thought and worldviews that influence the public framing of climate change and trust in science more broadly (Kaurov et al. 2022; Hulme 2009).

## CONCLUSION

THIS STUDY SHOWS HOW INTERACTIVE WEB MAPS have the potential to correct mischaracterizations of others' beliefs about climate change. We used a set of exploratory methods common to user studies in cartography to provide insights about the content of second-order beliefs and the map reading process with an interactive web map of climate change opinions in North Carolina. The results from this small student sample were similar to those from larger, nationally representative studies in that participants do not accurately estimate the actual percentages of popular support for climate change opinions. However, this study also focused on the content of second-order beliefs among a sample of ecologically activist-oriented and politically left-of-center students to find out why they underestimated popular support for these opinions. Participants primarily used environmental concerns to explain their own beliefs but focused on a set of ideological factors to explain the beliefs of those they thought were more dismissive of climate change policies. The results of our eye tracking and interviews showed that, during map reading

tasks, participants used the choropleth symbolization to focus on data extremes and counties that were important to them, including home counties and counties they attend school in, showing evidence of egocentric bias and spatial optimism bias that contributed to false polarization. Participants exhibited overwhelmingly positive emotional responses to the web map and found data visualization and interactions, like mouseover events and tooltips, most helpful in completing map reading tasks. Cartographers should continue to examine the intended use cases and contexts of climate change opinion maps to improve their communication effectiveness. Furthermore, user studies provide a way to more deeply understand how a range of user values and beliefs affects map use. This effort would add to the scope of cartography's attention to climate change. We conclude that interactive maps have the potential to moderate polarization on controversial topics, like climate change, that are otherwise subject to pluralistic ignorance effects that can dampen policy support.

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## REFERENCES

- Atkins, Rachel M., and Karen S. McNeal. 2018. "Exploring Differences among Student Populations during Climate Graph Reading Tasks: An Eye Tracking Study." *Journal of Astronomy and Earth Sciences Education* 5 (2): 85–114. <https://doi.org/10.19030/jaese.v5i2.10219>.
- Ballew, Matthew T., Anthony Leiserowitz, Connie Roser-Renouf, et al. 2019. "Climate Change in the American Mind: Data, Tools, and Trends." *Environment: Science and Policy for Sustainable Development* 61 (3): 4–18. <https://doi.org/10.1080/00139157.2019.1589300>.
- Bergquist, Parrish, Matto Mildenerger, and Leah C. Stokes. 2020. "Combining Climate, Economic, and Social Policy Builds Public Support for Climate Action in the US." *Environmental Research Letters* 15 (5): 054019. <https://doi.org/10.1088/1748-9326/ab81c1>.
- Cartwright, William, Jeremy Crampton, Georg Gartner, et al. 2001. "Geospatial Information Visualization User Interface Issues." *Cartography and Geographic Information Science* 28 (1): 45–60. <https://doi.org/10.1559/152304001782173961>.
- Chryst, Breanne, Jennifer Marlon, Sander van der Linden, Anthony Leiserowitz, Edward Maibach, and Connie Roser-Renouf. 2018. "Global Warming's 'Six Americas Short Survey': Audience Segmentation of Climate Change Views Using a Four Question Instrument." *Environmental Communication* 12 (8): 1109–22. <https://doi.org/10.1080/17524032.2018.1508047>.
- Çöltekin, Arzu, Benedikt Heil, Simone Garlandini, and Sara Irina Fabrikant. 2009. "Evaluating the Effectiveness of Interactive Map Interface Designs: A Case Study Integrating Usability Metrics with Eye-Movement Analysis." *Cartography and Geographic Information Science* 36 (1): 5–17. <https://doi.org/10.1559/152304009787340197>.
- Davis, Corey, Heather Aldridge, Ryan Boyles, Karen S. McNeal, Lindsay Maudlin, and Rachel Atkins. 2020. "Visually Communicating Future Climate in a Web Environment." *Weather, Climate, and Society* 12 (4): 877–96. <https://doi.org/10.1175/WCAS-D-19-0152.1>.
- Duchowski, Andrew T. 2003. *Eye Tracking Methodology: Theory and Practice*. London: Springer-Verlag. <https://doi.org/10.1007/978-1-4471-3750-4>.
- Ehret, Phillip J., Leaf Van Boven, and David K. Sherman. 2018. "Partisan Barriers to Bipartisanship: Understanding Climate Policy Polarization." *Social Psychological and Personality Science* 9 (3): 308–18. <https://doi.org/10.1177/1948550618758709>.
- Epley, Nicholas, and Thomas Gilovich. 2006. "The Anchoring-and-Adjustment Heuristic: Why the Adjustments Are Insufficient." *Psychological Science* 17 (4): 311–18. <https://doi.org/10.1111/j.1467-9280.2006.01704.x>.
- Epley, Nicholas, Boaz Keysar, Leaf Van Boven, and Thomas Gilovich. 2004. "Perspective Taking as Egocentric Anchoring and Adjustment." *Journal of Personality and Social Psychology* 87 (3): 327–39. <https://doi.org/10.1037/0022-3514.87.3.327>.
- Farrell, Justin. 2016. "Corporate Funding and Ideological Polarization about Climate Change." *Proceedings of the National Academies of Science* 113 (1): 92–97. <https://doi.org/10.1073/pnas.1509433112>.
- Fielding, Kelly S., and Matthew J. Hornsey. 2016. "A Social Identity Analysis of Climate Change and Environmental Attitudes and Behaviors: Insights and Opportunities." *Frontiers in Psychology* 7 (121): 1–12. <https://doi.org/10.3389/fpsyg.2016.00121>.

- Fish, Carolyn S. 2020. "Cartographic Content Analysis of Compelling Climate Change Communication." *Cartography and Geographic Information Science* 47 (6): 492–507. <https://doi.org/10.1080/15230406.2020.1774421>.
- Griffin, Amy L., and Julia McQuoid. 2012. "At the Intersection of Maps and Emotion: The Challenge of Spatially Representing Experience." *Kartographische Nachrichten* 62 (6): 291–99.
- Griffin, Amy L. 2020. "Trustworthy Maps." *Journal of Spatial Information Science* 20: 5–19. <https://doi.org/10.5311/JOSIS.2020.20.654>.
- Hamilton, Lawrence C., and Kei Saito. 2015. "A Four-Party View of US Environmental Concern." *Environmental Politics* 24 (2): 212–27. <https://doi.org/10.1080/09644016.2014.976485>.
- Hamilton, Lawrence C., Chris R. Colocousis, and Cynthia M. Duncan. 2010. "Place Effects on Environmental Views." *Rural Sociology* 75 (2): 326–47. <https://doi.org/10.1111/j.1549-0831.2010.00013.x>.
- Hamilton, Lawrence C., Joel Hartter, Mary Lemcke-Stampone, David W. Moore, and Thomas G. Safford. 2015. "Tracking Public Beliefs About Anthropogenic Climate Change." *PLoS ONE* 10 (9): e0138208. <https://doi.org/10.1371/journal.pone.0138208>.
- Harold, Jordan, Irene Lorenzoni, Thomas F. Shipley, and Kenny R. Coventry. 2016. "Cognitive and Psychological Science Insights to Improve Climate Change Data Visualization." *Nature Climate Change* 6 (12): 1080–89. <https://doi.org/10.1038/nclimate3162>.
- Hart, P. Sol, and Erik C. Nisbet. 2012. "Boomerang Effects in Science Communication: How Motivated Reasoning and Identity Cues Amplify Opinion Polarization About Climate Mitigation Policies." *Communication Research* 39 (6): 701–23. <https://doi.org/10.1177/0093650211416646>.
- Hoffman, Andrew J. 2011. "Talking Past Each Other? Cultural Framing of Skeptical and Convinced Logics in the Climate Change Debate." *Organization and Environment* 24 (1): 3–33. <https://doi.org/10.1177/1086026611404336>.
- Holmqvist, Kenneth, Marcus Nystrom, Richard Andersson, Richard Dewhurst, Halszka Jarodzka, and Joost van de Weijer. 2011. *Eye Tracking: A Comprehensive Guide to Methods and Measures*. Oxford: Oxford University Press.
- Holthaus, Leonie. 2023. "Feelings of (Eco-) Grief and Sorrow: Climate Activists as Emotion Entrepreneurs." *European Journal of International Relations* 29 (2): 352–73. <https://doi.org/10.1177/13540661221136772>.
- Howe, Peter D., Matto Mildenerger, Jennifer R. Marlon, and Anthony Leiserowitz. 2015. "Geographic Variation in Opinions on Climate Change at State and Local Scales in the USA." *Nature Climate Change* 5 (6): 596–603. <https://doi.org/10.1038/nclimate2583>.
- Hulme, M. 2009. *Why We Disagree about Climate Change: Understanding Controversy, Inaction and Opportunity*. Cambridge: Cambridge University Press. <https://doi.org/10.1017/cbo9780511841200>.
- Jacob, Robert J. K., and Keith S. Karn. 2003. "Eye Tracking in Human – Computer Interaction and Usability Research: Ready to Deliver the Promises." In *The Mind's Eye: Cognitive and Applied Aspects of Eye Movement Research*, edited by Jukka Hyönä, Ralph Radach, and Heiner Deubel, 573–605. Oxford: Elsevier Science BV. <https://doi.org/10.1016/b978-044451020-4/50031-1>.
- Kahan, Dan. 2012. "Why We Are Poles Apart on Climate Change." *Nature* 488 (7411): 255. <https://doi.org/10.1038/488255a>.
- Kahan, Dan M., Hank Jenkins-Smith, and Donald Braman. 2010. "Cultural Cognition of Scientific Consensus." *Journal of Risk Research* 14 (2): 147–74. <https://doi.org/10.1080/13669877.2010.511246>.
- Kaurov, Alexander A., Viktoria Cologna, Charlie Tyson, and Naomi Oreskes. 2022. "Trends in American Scientists' Political Donations and Implications for Trust in Science." *Humanities and Social Sciences Communications* 9: 368. <https://doi.org/10.1057/s41599-022-01382-3>.

- Labosier, Christopher F., and Steven M. Quiring. 2013. "Hydroclimatology of the Southeastern USA." *Climate Research* 57 (2): 157–71. <https://doi.org/10.3354/cr01166>.
- Lee, Tien Ming, Ezra M. Markowitz, Peter D. Howe, Chia-Ying Ko, and Anthony A. Leiserowitz. 2015. "Predictors of Public Climate Change Awareness and Risk Perception around the World." *Nature Climate Change* 5 (11): 1014–20. <https://doi.org/10.1038/nclimate2728>.
- Leiserowitz, Anthony, Edward Maibach, Seth Rosenthal, et al. 2021. "Politics and Global Warming." New Haven, CT: Yale Program on Climate Change Communication.
- Lewis, Gregory B., Risa Palm, and Bo Feng. 2019. "Cross-National Variation in Determinants of Climate Change Concern." *Environmental Politics* 28 (5): 793–821. <https://doi.org/10.1080/09644016.2018.1512261>.
- Linden, Sander van der, Anthony Leiserowitz, and Edward Maibach. 2019. "The Gateway Belief Model : A Large-Scale Replication." *Journal of Environmental Psychology* 62: 49–58. <https://doi.org/10.1016/j.jenvp.2019.01.009>.
- MacEachren, Alan M., Francis P. Boscoe, Daniel Haug, and Linda W. Pickle. 1998. "Geographic Visualization: Designing Manipulable Maps for Exploring Temporally Varying Georeferenced Statistics." *Proceedings IEEE Symposium on Information Visualization*, 87–94. <https://doi.org/10.1109/infvis.1998.729563>.
- Madan, Christopher R., Elliot A. Ludvig, and Marcia L. Spetch. 2014. "Remembering the Best and Worst of Times: Memories for Extreme Outcomes Bias Risky Decisions." *Psychonomic Bulletin & Review* 21: 629–36. <https://doi.org/10.3758/s13423-013-0542-9>.
- Marlon, Jennifer R., Xinran Wang, Parrish Bergquist, et al. 2022. "Change in US State-Level Public Opinion about Climate Change: 2008 – 2020." *Environmental Research Letters* 17 (12): 124046. <https://doi.org/10.1088/1748-9326/aca702>.
- Maudlin, Lindsay C., Karen S. McNeal, Heather Dinon-Aldridge, Corey Davis, Ryan Boyles, and Rachel M. Atkins. 2020. "Website Usability Differences between Males and Females: An Eye-Tracking Evaluation of a Climate Decision Support System." *Weather, Climate, and Society* 12 (1): 183–92. <https://doi.org/10.1175/WCAS-D-18-0127.1>.
- Mildenberger, Matto, and Dustin Tingley. 2017. "Beliefs about Climate Beliefs: The Importance of Second-Order Opinions for Climate Politics." *British Journal of Political Science* 49 (4): 1279–1307. <https://doi.org/10.1017/S0007123417000321>.
- Miller, Dale T., and Cathy McFarland. 1987. "Pluralistic Ignorance : When Similarity is Interpreted as Dissimilarity." *Journal of Personality and Social Psychology* 53 (2): 298–305. <https://doi.org/10.1037//0022-3514.53.2.298>.
- Moser, Susanne C. 2016. "Reflections on Climate Change Communication Research and Practice in the Second Decade of the 21st Century: What More is There to Say?" *Wiley Interdisciplinary Reviews: Climate Change* 7 (3): 345–69. <https://doi.org/10.1002/wcc.403>.
- Nisbet, Matthew C. 2014. "Disruptive Ideas: Public Intellectuals and Their Arguments for Action on Climate Change." *Wiley Interdisciplinary Reviews: Climate Change* 5 (6): 809–23. <https://doi.org/10.1002/wcc.317>.
- Popelka, Stanislav, Alena Vondrakova, and Petra Hujnakova. 2019. "Eye-Tracking Evaluation of Weather Web Maps." *International Journal of Geo-Information* 8 (6): 256. <https://doi.org/10.3390/ijgi8060256>.
- Price, Jennifer C., Iain A. Walker, and Fabio Boschetti. 2014. "Measuring Cultural Values and Beliefs about Environment to Identify Their Role in Climate Change Responses." *Journal of Environmental Psychology* 37: 8–20. <https://doi.org/10.1016/j.jenvp.2013.10.001>.
- Prinz, Jesse. 2021. "Emotion and Political Polarization." In *The Politics of Emotional Shockwaves*, edited by Ana Falcato and Sara Graça da Silva, 1–25. Cham, Switzerland: Palgrave Macmillan. [https://doi.org/10.1007/978-3-030-56021-8\\_1](https://doi.org/10.1007/978-3-030-56021-8_1).

- Retchless, David P. 2018. "Understanding Local Sea Level Rise Risk Perceptions and the Power of Maps to Change Them: The Effects of Distance and Doubt." *Environment and Behavior* 50 (5): 483–511. <https://doi.org/10.1177/0013916517709043>.
- Retchless, David, Carolyn Fish, and Jim Thatcher. 2022. "Climate Change Communication beyond the Digital Divide: Exploring Cartography's Role and Privilege in Climate Action." *Journal of Environmental Media* 3 (1): 101–23. [https://doi.org/10.1386/jem\\_00074\\_1](https://doi.org/10.1386/jem_00074_1).
- Retchless, David P., and Cynthia A Brewer. 2016. "Guidance for Representing Uncertainty on Global Temperature Change Maps." *International Journal of Climatology* 36 (3): 1143–59. <https://doi.org/10.1002/joc.4408>.
- Roth, Robert E. 2013. "An Empirically-Derived Taxonomy of Interaction Primitives for Interactive Cartography and Geovisualization." *IEEE Transactions on Visualization and Computer Graphics* 19 (12): 2356–65. <https://doi.org/10.1109/TVCG.2013.130>.
- . 2017. "User Interface and User Experience (UI/UX) Design." *Geographic Information Science & Technology Body of Knowledge* (2nd Quarter 2017 Edition). <https://doi.org/10.22224/gistbok/2017.2.5>.
- . 2021. "Cartographic Design as Visual Storytelling : Synthesis and Review of Map-Based Narratives, Genres, and Tropes." *The Cartographic Journal* 58 (1): 83–114. <https://doi.org/10.1080/00087041.2019.1633103>.
- Roth, Robert E., Richard G. Donohue, Carl M. Sack, Timothy R. Wallace, and Tanya M. A. Buckingham. 2014. "A Process for Keeping Pace with Evolving Web Mapping Technologies." *Cartographic Perspectives* 78: 25–52. <https://doi.org/10.14714/cp78.1273>.
- Shao, Wanyun, and Angela F. McCarthy. 2020. "Understanding Evangelical Protestant Identity, Religiosity, Extreme Weather, and American Public Perceptions of Global Warming, 2006–2016." *Geographical Review* 110 (4): 485–504. <https://doi.org/10.1080/00167428.2019.1702427>.
- Shaw, Wendy S., and Alastair Bonnett. 2016. "Environmental Crisis , Narcissism and the Work of Grief." *Cultural Geographies* 23 (4): 565–79. <https://doi.org/10.1177/1474474016638042>.
- Smith, E. Keith, and Adam Mayer. 2019. "Anomalous Anglophones? Contours of Free Market Ideology, Political Polarization, and Climate Change Attitudes in English-Speaking Countries , Western European and Post-Communist States." *Climatic Change* 152: 17–34. <https://doi.org/10.1007/s10584-018-2332-x>.
- Sparkman, Gregg, Nathan Geiger, and Elke U. Weber. 2022. "Americans Experience a False Social Reality by Underestimating Popular Climate Policy Support by Nearly Half." *Nature Communications* 13: 4779. <https://doi.org/10.1038/s41467-022-32412-y>.
- Tuitjer, Leonie, Peter Dirksmeier, and Lars Mewes. 2022. "Geographies of Climate Change Opinion." *Geography Compass* 16 (5): e12619. <https://doi.org/10.1111/gec3.12619>.
- Zacher, Hannes, and Cort W. Rudolph. 2023. "Environmental Knowledge Is Inversely Associated with Climate Change Anxiety." *Climatic Change* 176 (4): 32. <https://doi.org/10.1007/s10584-023-03518-z>.



# Investigating Web Mapping's Contribution to Students' Learning of Geographical Thinking

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*Research on the use of online maps in geography education underlines their potential to foster geographic thinking. However, the role of interactivity in this process has not been considered in educational settings. To address this issue, the contribution of web mapping to students' taxonomy is investigated. Our methodology combines analysis of student productions, mouse tracking, spatiotemporal clustering, statistical modeling, and focus groups. The data collection was carried out in three stages in a class of 20 students aged 14–15 years, using three online mapping interfaces with similar interactive features. Students' productions were evaluated using scores based on criteria constructed from Bloom's revised taxonomy to analyze their learning. Students' scores were compared to the way they interacted with the online maps. Results show how students master the tool over time. Temporal and spatial patterns of interactive behavior, and their impact on learning, were evident. Several of the cartographic interactions that we studied—such as spatial navigation and the display layer of attributes—had a positive impact on student learning when used moderately and intermittently, whereas juxtaposition only contributed positively when used occasionally. Focus group analysis complemented and contextualized our results by highlighting other factors such as students' emotions and their issues in interpreting the maps. As a result, we consider this exploratory research to provide an appropriate and useful methodological combination for further research into how digital tools contribute to learning.*

**KEYWORDS:** web mapping; interactivity; geovisualization; learning; geography education; statistical learning; geographical thinking; mouse and map tracking

## INTRODUCTION

GEOSPATIAL TECHNOLOGIES (GSTs), SUCH AS ONLINE mapping, are now widely available in various media (tablets, computers, smartphones) and are used in many contexts with practices resulting from the development of Geoweb 2.0 (Mericskay 2016). The growing number of resources for consulting and producing geographic information online reinforces the need to educate students on issues related to map interpretation and geographical thinking.

Web mapping is one of a number of digital technologies that are transforming teaching and learning practices in the school environment, though the progress of this digital transformation varies depending on the country and the institutional constraints. Research on the implementation of digital mapping (GIS or web mapping) in

schools highlights the potential of these tools to support the learning of geographical thinking by suggesting appropriate uses and underlining the role of context (De Miguel González and De Lázaro Torres 2020; Favier and van der Schee 2014; Jadallah et al. 2017; Jo et al. 2016). However, studies on the use of GSTs in geography education (from elementary school to university) do not address in depth how *interactivity* might influence the learning of geographical thinking. And yet, the interactivity of these digital tools is one of the key features that may influence the learning process.

*Interactivity* in geovisualization refers to the different ways of presenting information to a user within an interface, in response to that user's choices (Crampton 2002; Edsall et al. 2009). According to Roth (2012), *cartographic*



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*interaction* refers to the dialogue between a user and a web map through a computing device.

Interactivity is a key parameter which conditions learning by allowing users to explore, analyze, and synthesize (MacEachren 2004). It enables students to grasp the complexity of geographical phenomena, and contributes to knowledge generation and decision-making by encouraging thinking based on the creation and confrontation of hypotheses with the help of visualization (Çöltekin et al. 2018; MacEachren et al. 2004). In the research field of geovisualization, interactivity has long been a focus of study (Andrienko et al. 2010; Çöltekin et al. 2018; Çöltekin et al. 2017; Crampton 2002; Krygier et al. 1997; Roth 2012) and its impact on cartographic interpretation and knowledge construction remains a central research issue requiring further investigation (Roth et al. 2017). But, to our knowledge, no research has focused on the school context. As a result, the case study we present here investigates the following research question: How might web mapping contribute to the learning of geographical thinking through interactivity?

One of the concerns related to the implementation of these interactive tools, which has been identified as an obstacle

both in the literature and by teachers, is technical mastery: efficient use of the interactivity of online maps requires technical skills. Although many studies have demonstrated the potential of these tools at school, the changing influence of this parameter over time needs to be analyzed. Our two research hypotheses, which take this into consideration, are:

- H1. The technical ability required to use online mapping tools does not hinder student learning progress.
- H2. Interactivity contributes to students' geographical thinking by fostering the mobilization of higher cognitive processes.

In this article, we investigate our research question and hypotheses through a combination of mouse and map tracking, analysis of students' productions, and focus groups. Our aim is to illustrate how the use of different types of interactions is not a hindrance to learning, but is in fact likely to contribute to the learning of geographical thinking through map interpretation. We also explore how these interactions mobilize different cognitive processes and types of knowledge, as defined by Bloom's revised taxonomy.

## GEOSPATIAL TECHNOLOGIES AND GEOGRAPHY EDUCATION

THE INTRODUCTION AND DEPLOYMENT OF GEOSPATIAL technologies—including virtual globes, remote sensing, and WebGIS—in geography education is driving changes in teaching and learning practices (De Miguel González and De Lázaro Torres 2020; Favier and van der Schee 2014). Geospatial technologies provide a new way of addressing geographic issues while working on students' spatial skills and geographic knowledge (De Miguel González et al. 2019). The use of WebGIS in place of desktop GIS has reinforced this trend (Kerski and Baker 2019). Empirical studies claim that the features and functions of these geospatial technologies meet the needs of the investigative and problem-solving approaches that are increasingly popular and widespread in education. In addition, such geomedia contribute to student motivation and interest while fostering spatial skills and geographical thinking (De Miguel González and De Lázaro Torres 2020; Jadallah et al. 2017; Jo et al. 2016; National Research Council 2006). Geospatial technologies can also play a significant role in learning and teaching during

fieldwork, while supporting group work and thus peer learning (Holloway et al. 2021).

Originally available as desktop software, GSTs are now also accessible on smartphones and tablets. These applications are used for field trips in the earth sciences (Fletcher et al. 2022; Lundmark et al. 2020), as well as projects in human geography, such as the collection of data for narrative mapping (Holloway et al. 2021). However, GST usage itself does not contribute to learning. To achieve this, the use of GSTs must be paired with geographic knowledge mobilization activities (Metoyer and Bednarz 2017). It should also be noted that these tools are not the only way to learn spatial skills and spatial reasoning (Jadallah et al. 2017).

Despite the advantages of GSTs (accessibility, multi-device use, adaptability to educational approaches, interface flexibility, user-friendliness) several limits may hinder GST use and require consideration. The technical

ability of students and instructors to handle these technologies remains a persistent constraint, despite the use of less-technical WebGIS instead of desktop GIS. Teachers and learners can also be reluctant to use GSTs. Some of them are not inclined to change their current habits due not only to potential difficulties in handling these digital tools but also to their own negative preconceptions.<sup>1</sup> The training time required for teachers and students to familiarize themselves with these tools may be a hindrance to their implementation, efficient use during activities, and student learning. Our observation in classrooms and with (future) teachers, as well as the literature, confirm these limitations (De Miguel González and De Lázaro Torres 2020; Holloway et al. 2021; Hong 2017; Walshe 2017).

Research in geography education highlights the potential of tools such as virtual globes and online GIS to support learning geographical thinking (Baker et al. 2015; Kerski and Baker 2019; National Research Council 2006; Schulze 2021), but most of these studies have been carried out with university students (Holloway et al. 2021). There are also research initiatives at the secondary school (De Miguel González and De Lázaro Torres 2020) and high school levels (Healy and Walshe 2020). However, few studies are devoted to elementary schools (Jadallah et al. 2017) or to teacher education (Walshe 2017).

## GEOGRAPHICAL THINKING & MAP INTERPRETATION TAXONOMY –

GEOGRAPHICAL THINKING RELIES ON SPATIAL thinking (Metoyer and Bednarz 2017). Spatial thinking is a combination of three cognitive skills: using tools of representation, knowing concepts of space, and applying processes of complex reasoning (National Research Council 2006). Geographical thinking involves geographical knowledge related to the concept of space and is exercised, with the help of spatial thinking, to solve geographical problems (Metoyer and Bednarz 2017). Geographical thinking can, for example, consist in identifying and explaining a spatial distribution by linking it to social and economic factors.

Learning is defined here as a process and a product which combines mediation and cognition. Cognition refers to all intellectual information processing activities and their products (Vienneau 2017) including “internal mental

In these studies dedicated to geography education, GSTs are used within the fields of human and physical geography. They use a range of research designs and methodologies, including surveys, criterion-based production analysis such as the Learning Progression Model from De Miguel González and De Lázaro Torres (2020) and spatial ability tests: Spatial Thinking Ability Test (Jo et al. 2016) from Lee and Bednarz (2012), Cognitive Ability Test (Jadallah et al. 2017), spatial visualization and orientation skills and spatial relations content (Metoyer and Bednarz 2017). Focus groups are also employed to underline the contribution of these tools to geographical thinking. Nevertheless, these studies do not take into consideration the potential involvement of interactivity, despite it constituting a fundamental feature of the investigated tools such as WebGIS.

Roth (2013) highlights the need for further investigation of the contribution of interactivity to the visualization of geographic information and by implication to knowledge construction. Yet, to date, the role of interactivity on student learning has not been the subject of research in geovisualization. Therefore, in this article, we intend to examine the impact of interactivity on teaching geography in a secondary school (i.e., students aged between 12 and 15).

structures and processes involved in perception, attention, thinking and reasoning, learning, memory, and linguistic and nonlinguistic communication” (Montello 2009, 1824). Learning is also characterized by interactions between the learner and their environment which are mediated by tools or humans and are supported by cognition. As a result, mediation refers to the action of a tool or a human in the process of learning (Vienneau 2017). In this study, the learning of geographical thinking is evaluated during the process of map interpretation. From our perspective, map interpretation is a cognitive process in which the map has a mediation role during learning. Map interpretation is related to the features of both the map and the reader. A number of parameters may influence this process, such as semiotics, the projection system, perception and visualization, the reader’s cognitive abilities, and their emotions (Montello et al. 2018).

1. They may believe that Wi-Fi performance in their schools is not sufficient for using digital tools, or that planning digital activities will be too time-consuming.

Map interpretation Cartographic Language		The Knowledge Dimension				Major Types of Knowledge (KN)
		KN1 Factual knowledge	KN2 Conceptual knowledge	KN3 Procedural knowledge	KN4 Metacognitive knowledge	
The Cognitive Process Dimension	CG1 Remember	Learn	Obtain information	Articulate	Connect	<p><b>KN1</b> : The basic elements students must know to be acquainted with a discipline or solve problems in it.</p> <p><b>KN2</b> : The interrelationships among the basic elements within a larger structure that enable them to function together.</p> <p><b>KN3</b> : How to do something, methods of inquiry, and criteria for using skills, algorithms, techniques, and methods.</p> <p><b>KN4</b> : Knowledge of cognition in general as well as awareness and knowledge of one's own cognition.</p> <p><b>Cognitive process (CG)</b></p> <p><b>CG1</b> : Retrieve relevant knowledge from long-term memory.</p> <p><b>CG2</b> : Construct meaning from instructional messages, including oral, written, and graphic communication.</p> <p><b>CG3</b> : Carry out or use a procedure in a given situation.</p> <p><b>CG4</b> : Break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose.</p> <p><b>CG5</b> : Make judgments based on criteria and standards.</p> <p><b>CG6</b> : Put elements together to form a coherent or functional whole; reorganize elements into a new pattern or structure.</p>
	CG2 Understand	Learn	Obtain information	Articulate	Connect	
	CG3 Apply	Learn	Obtain information	Articulate	Connect	
	CG4 Analyze	Learn	Obtain information	Articulate	Connect	
	CG5 Evaluate	Learn	Obtain information	Articulate	Connect	
	CG6 Create	Learn	Obtain information	Articulate	Connect	

Knowledge dimensions and cognitive process retrieved from : KRATHWOHL, 2002.  
Inspired by RAYNAL ET RIEUNIER, 2012, pp. 114-116 and adapted from : Bachmann, 2020.

Figure 1. Map interpretation taxonomy adapted from Bachmann (2020, 38).

In order to investigate learning in this context, we employed a map interpretation taxonomy (Bachmann 2020) based on Bloom's revised taxonomy (Anderson and Krathwohl 2001). Originating from the field of educational sciences, Bloom's revised taxonomy is used not only in research frameworks (De Miguel González and De Lázaro Torres 2020; Favier and van der Schee 2014; Schulze 2021) but also by teachers to evaluate and build students' learning. The use of Bloom's revised taxonomy was also inspired in part by Saint-Marc et al. (2017). They present the results of an experiment where mouse tracking is used and discuss the contextualization of their findings by employing cognitive processes identified in Bloom's revised taxonomy. This approach has been adapted to the needs of the current study, which consists in investigating the role of interactivity on learning with the help of a map, with mouse and map tracking being employed here to examine interactivity.

Criterion
C1: The student masters cartographic language.
C2: The student retrieves relevant information from the map.
C3: The student coherently links information from the map.
C4: The student problematizes information and relations generated from map interpretation by mobilizing his/her knowledge in a relevant and coherent way.
C5: The student identifies his or her difficulties in completing the task and how easy it was.

Table 1. Taxonomic score criteria.

We employed a map interpretation taxonomy to build activities and assess student performances. The definition of the levels of knowledge and cognitive processes mobilized during map interpretation are detailed in the Appendix (see Figure 1). Four components, in particular, stand out as related to map interpretation ability: master cartographic language, obtain information, connect, and problematize.

Each of these components was then transformed into a criterion (see Table 1) to analyze the students' productions and assign a taxonomic score. As shown in Figure 2, these criteria are based on different levels of knowledge and

cognitive processes. As a result, each question answered by the students allowed us to assess their mobilization of one or more levels of knowledge and cognitive processes defined in the map interpretation taxonomy. In summary, this taxonomy allows us to analyze the contribution of interactive cartographic features, i.e., the interactivity of the online maps used by the students, on the learning achieved according to the mobilization of cognitive processes and knowledge levels. For feasibility purposes in terms of data collection and analysis, metacognition was isolated and studied using a separate questionnaire after each activity.

TAXONOMIC SCORES Scores structured by cognitive process and map interpretation components (Bachmann, 2020)		The Knowledge Dimension			
		KN1 Factual knowledge	KN2 Conceptual knowledge	KN3 Procedural knowledge	KN4 Metacognitive knowledge
The Cognitive Process Dimension	CG1 Remember	C1 SCORE: MASTER CARTOGRAPHIC LANGUAGE			C5 SCORE: METACOGNITION
	CG2 Understand				
	CG3 Apply	C2 SCORE: OBTAIN INFORMATION			
	CG4 Analyze	C3 SCORE: CONNECT			
	CG5 Evaluate	C4 SCORE: PROBLEMATIZE			
	CG6 Create				

Figure 2. Taxonomic scores, based on Bachmann (2020, 38).

# METHODOLOGY

IN THIS SECTION, WE DISCUSS THE RESEARCH DESIGN, data collection, and transformation of tracking data. Figure 3 summarizes all the procedures implemented and the materials collected: data on mouse cursor and map movements, students' productions, and focus groups.

## RESEARCH DESIGN AND DATA COLLECTION

At the time of data collection, the use of digital technology, and in particular web mapping in the classroom, was uncommon in the teacher's school with which we partnered. The implementation of such geomedias in schools in general was in its early stages in the Canton of Vaud, in the French-speaking region of Lake Lemman, Switzerland, where the school was located. However, our partner teacher, also a teacher educator, had a strong interest in setting up innovative ways of learning which differed from

usual practices. He was involved in both economics and geography education in his school, supporting a cross-disciplinary approach in his teaching to highlight links between these disciplines while maintaining the stipulated curriculum.

The students in this study were between the ages of 14 and 15. They had been taught geography since elementary school and also as part of their secondary education. These students came from different classes and met together to study economics. As such, our sample (n = 20) included students who had experienced various teaching practices. They were using an online map for the first time in a classroom setting.

This class met several times a week in the fall and spring. This made it possible to collect data on several occasions

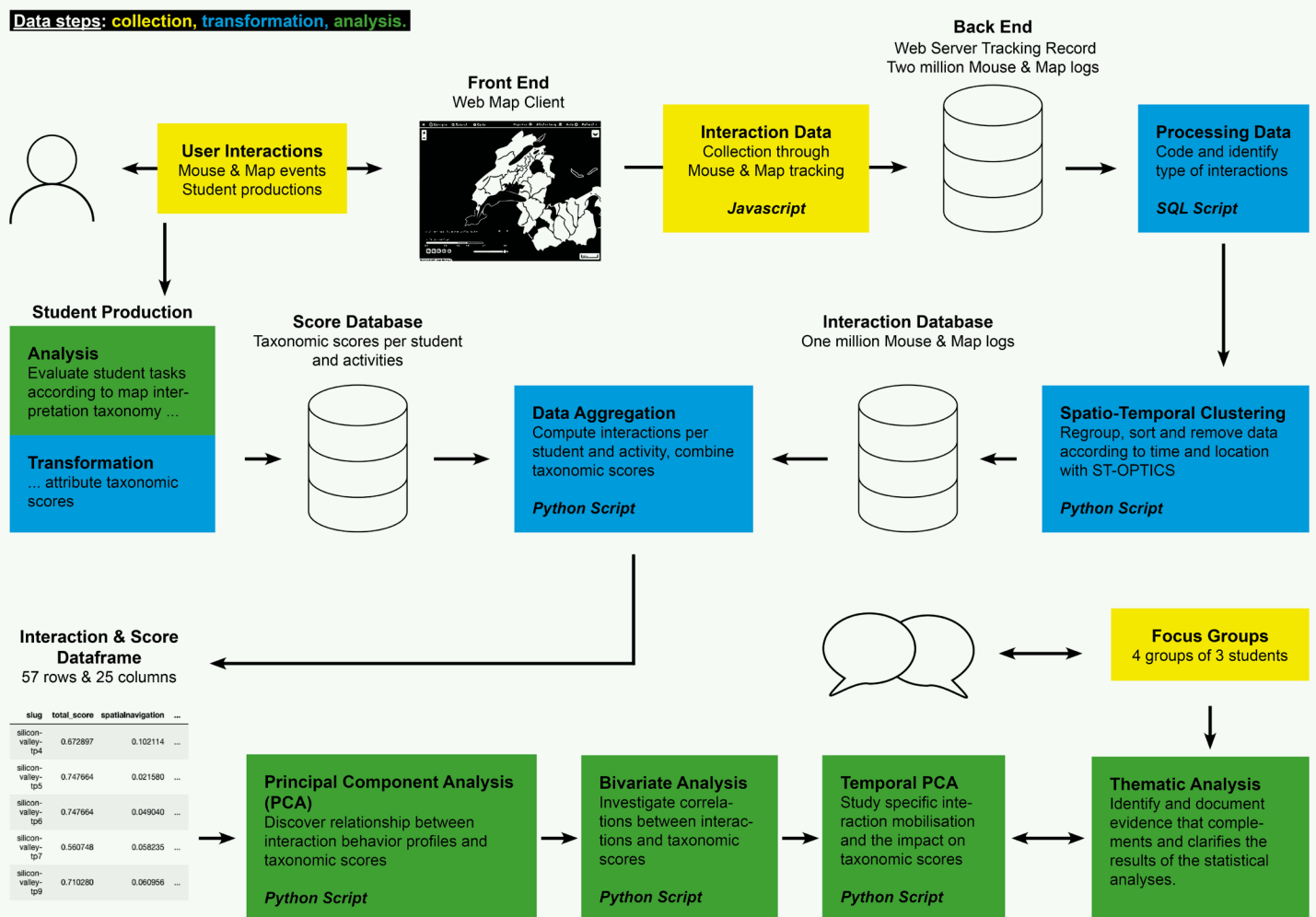


Figure 3. Data Collection Processing and Analysis Steps

and study how technical ability, and the effects of interactivity on learning geographical thinking, changed over time. We worked with this class while emphasizing geographical thinking in the activities and incorporating economics concepts. The data collection took place over three different activities between November 2020 and April 2021. The first activity focused on global trade, the second on Silicon Valley, and the last on commodity trading in Switzerland. Forty-five minutes (maximum fifty) were allocated to each activity. During these activities, students conducted an inquiry based on the above-mentioned themes. This investigation was based on questions to which the student provided answers using indicators and layers provided through an online map (Figure 4 shows an example).

Each of these questions was based on a taxonomic score (see Figure 2). Students' responses were then evaluated according to the criteria presented in Table 1. The meta-cognition score (C5) was collected separately. Students filled out a survey after each activity, with questions focused on their reflexivity about their learning. This refers

to their ability to identify their difficulties and their ability to carry out the activities critically and objectively, as well as their ability to implement strategies to overcome their challenges. The right side of Figure 4 shows the relationship between the questions and the taxonomic scores circled in red (C1, C2, C3, C4).

The sample activity shown in Figure 4 involved investigating features of Silicon Valley to discover why companies active in new technologies are located there. To this end, students could consult provided indicators (maps and histograms) for the year 2019 (average household income, employment in the information sector, employment in scientific and technical services, population with a bachelor's degree or higher) as well as layers on the Big Five tech firms, California universities, and the list of Silicon Valley counties. A neutral base map and an aerial view were available to the students.

All of these activities were carried out using a web mapping website specifically developed for this research. Each activity uses the same interface, with an identical

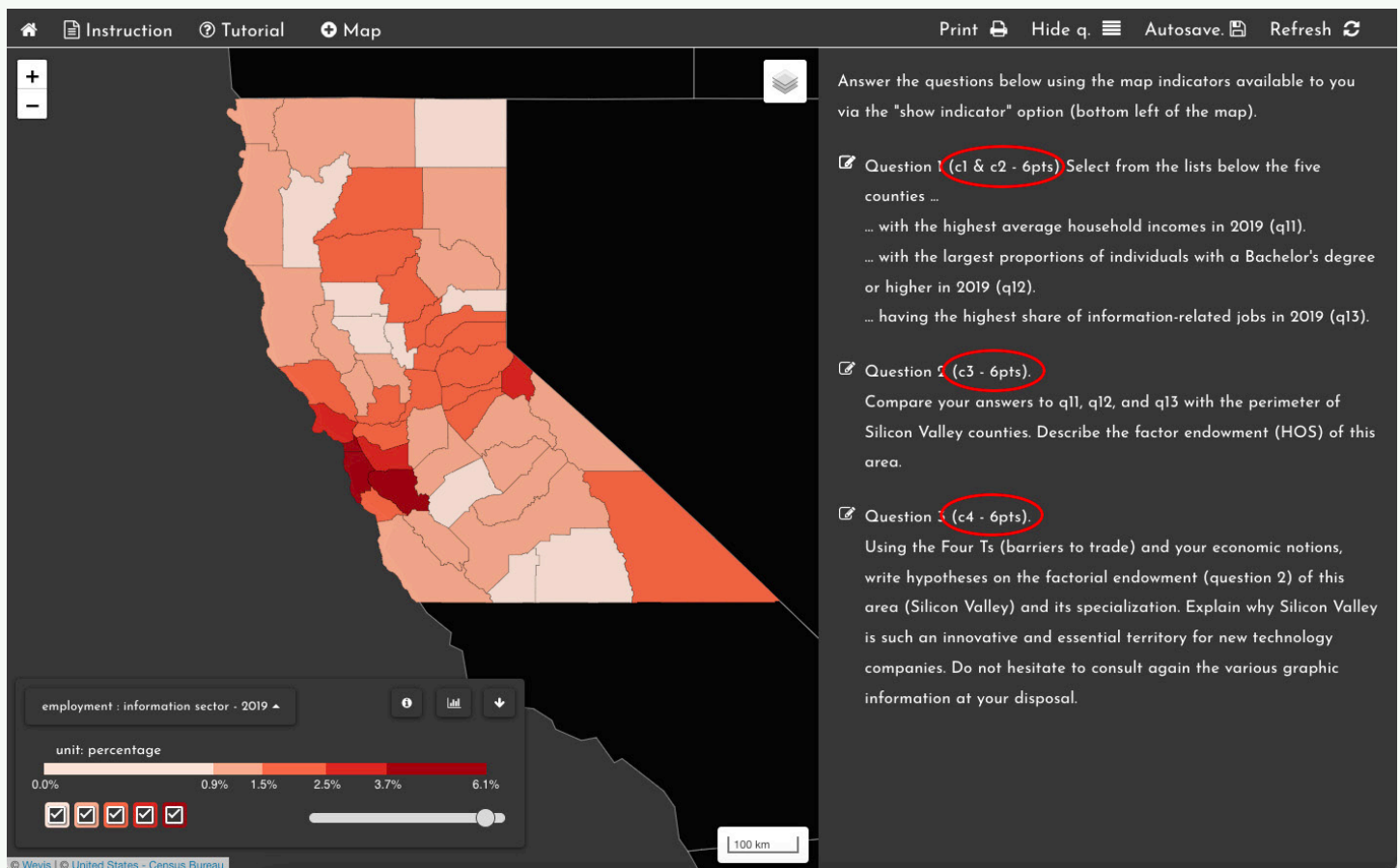


Figure 4. Silicon Valley web map.

KIND OF INTERACTIVITY	INTERACTION INDICATORS (present in all three activities)	FEATURES
Interaction with the data representation	spatial navigation	move on the map without modifying the perimeter and display the attributes of the indicator by mouseover
	spatial navigation zoom	zoom on the map
	spatial navigation move	change of map perimeter
	display layer attribute	displaying the attributes of an indicator (map or chart)
	edit layout	change the display of the data representation
Interaction with data	highlight	data highlighting
	load data	data selection and loading
Contextual interaction	juxtaposition	juxtaposition of layers or several indicators on the same or different map or via a chart
	exploration	display of the instruction, the tutorial, navigation outside the map and chart containers

**Table 2.** Interactivity and interactions implemented on the website.

cartographic background and interactive functionalities, as well as a set of questions built using the map interpretation taxonomy. Between the three activities, only the indicators and maps differed. These were produced according to themes chosen by the teacher. Various kinds of cartographic representations (choropleths, proportional symbols, colored proportional symbols) were implemented and evaluated by the students. Histograms and line graphs were also included. Different interactive graphical features were implemented to evaluate the contribution of these maps to the students' learning. The choice of these features was inspired by our own practice and experience, and can be theorized using previous work by Roth (2012) and Crampton (2002). Table 2 presents interactivity and interactions in all the three activities.

Two main issues had to be addressed during data collection: teaching and research adequacy, as well as uncertainty brought by the pandemic context. Firstly, data collection had to be carried out in the context of the teacher's program. Web maps were therefore developed to include specific cartographic indicators linked to teaching subjects. Secondly, only the teacher and the researcher were present during the activities with the students. It was thus

impossible to collect and supervise specific time-limited tasks as a classical laboratory setting. Furthermore, the aim was to obtain data that reflected the school environment and constraints.

### MOUSE & MAP TRACKING COLLECTION AND TRANSFORMATION

To keep track of the students' interactions with these online maps, mouse tracking and map tracking were integrated into the online mapping site. For the last fifteen years, researchers in psychology and cognitive science have been using this technique to investigate the cognitive processes at work during an action involving significant contributions. Among other things, this method has been used to explore judgment and decision-making, social cognition, and language processing (Kieslich et al. 2019; Schoemann et al. 2021; Stillman et al. 2018; Wulff et al. 2019). The association between cognition and mouse tracking is derived from the assumption that cognitive processes determine the motor activity and consequently the movements of the mouse (Hehman et al. 2015; Spivey and Dale 2006).

We also implemented map tracking, which is the collection of coordinates recording the user's interactions with the map. This method of data collection is sometimes used in geovisualization (McArdle et al. 2015). However, eye tracking is a more widespread method than the combination of mouse tracking and map tracking to investigate how maps and interaction contribute to knowledge building and decision making (Çöltekin et al. 2010; Golebiowska et al. 2020; Ooms et al. 2014). Mouse tracking is sometimes employed as a complement to eye tracking to obtain additional information, but rarely by itself. These combinations of monitoring methods are mainly used in the context of evaluation and design of cartographic interfaces (Çöltekin et al. 2009; Ooms et al. 2015; Manson et al. 2012). Compared to map tracking, mouse tracking does not seem to have been widely used in geovisualization, but it provides some interesting information on how users interact with web maps.

Mouse and map tracking data were processed with spatio-temporal clustering (STC), which is used in spatial data mining to regroup data with similar location and temporal patterns. This process can highlight trends or patterns in databases with geographical coordinates—usually longitude and latitude. The cluster analysis used in this study was an unsupervised procedure that did not require a priori understanding (Ansari et al. 2020). Despite

the wide application of STC in the real world (Ansari et al. 2020), it has not, to our knowledge, been used to study digital media in schools.

Based on the nature of the data collected (mouse tracking and map tracking), event clustering was chosen. Event clustering allows the detection of similar groups of points, according to their spatial and temporal features, and even other features (Kisilevich et al. 2010). The ST-OPTICS method (Ankerst et al. 1999) was employed for its ability to detect clusters of varying density. Working with spatio-temporal data requires several steps before and after the clustering. First, data needs pre-processing to ensure validity and completeness. Then data mining, such as exploratory data analysis, is used to calibrate the algorithm (minimum sample and temporal interval). Approximately two million mouse movements and map events were collected. This sample was processed to identify all the different interactions. Then, spatio-temporal clustering was applied to eliminate noise and reveal clusters of points, which allowed us to discover interactivity behavior patterns as students interpreted the digital map. These transformations and selections resulted in a sample size of one million records. This large amount of data was transformed into one dataset with every student and activity ( $n = 57$ ) and their use of interactivity.

## RESULTS

THE FIRST PART OF OUR RESULTS RELIES ON STATISTICAL analyses. In this section we examine the relationships between interactions and taxonomy scores to assess the role of key parameters of our two hypotheses—technical ability and interactivity—and the evolution of their influence on the learning of geographical thinking over the three activities. We begin by describing the evolution of these variables over the three activities, followed by an investigation of the relationships between these variables using PCA and bivariate analysis. Then the results of the statistical analyses are complemented with data from focus groups.

### STATISTICAL ANALYSES OF INTERACTIONS AND TAXONOMIC SCORES

The following data shows the evolution of all the scores and interactions. Around one million interactions were

analyzed. Based on the tracking recorder logs, a significant decrease of interactions (-96.6%) happened between the first (~576,000 logs) and the last (~18,000 logs) activity. Unsurprisingly, *spatial navigation* (41.97%) and *display layer attributes* (18.43%) were the most commonly employed interactions, as students were required to explore and interpret the map data to perform their tasks. Table 3 shows the interaction logs. As we will see later on in the statistical analysis (PCA and bivariate), interaction contribution to learning was not related to the mobilization percentages.

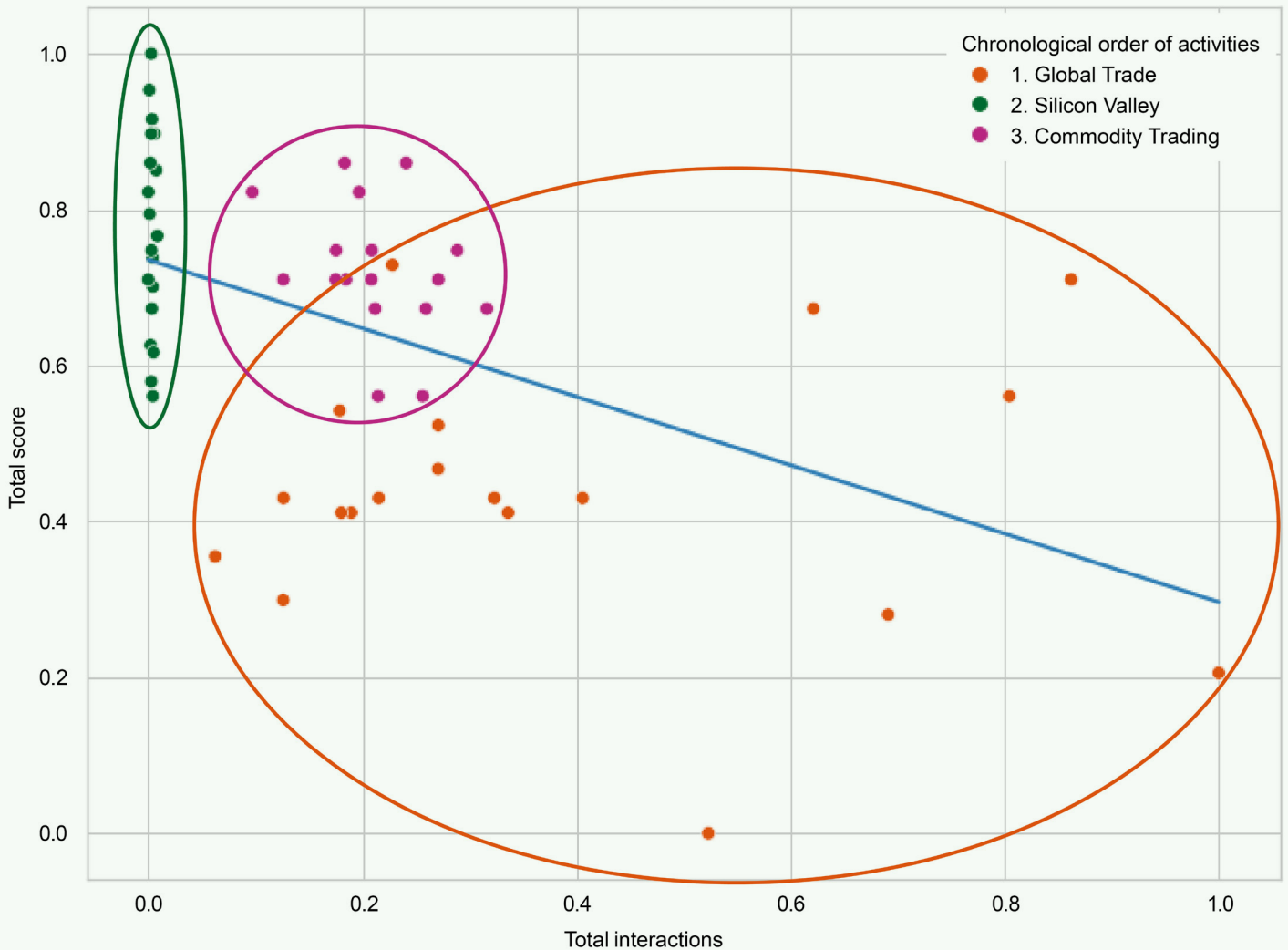
In each activity, students answered similar questions that focused on the same components of map interpretation (see Figure 2) and they were assessed with the same criteria (see Table 1). Mastery of cartographic language (C1\_score) and information extraction (C2\_score) were the least challenging for students, in contrast to

Interaction	Juxtaposition	Edit layout	Spatial Navigation zoom	Highlight	Load data	Spatial Navigation Move	Exploration	Display Layer Attributes	Spatial Navigation
Percent	1.30	1.31	1.78	5.26	5.56	8.06	16.33	18.43	41.97

**Table 3.** Interaction logs.

metacognition (C5\_score), analysis (C3\_score), and problematization (C4\_score). Between the first and the second activity, all taxonomic scores increased. Analysis and problematization improved between the second and last activity. In summary, across all activities, the components of map interpretation that were most difficult for students (connect and problematize) displayed the largest average score increases (+2 and +2.38 points respectively). These results show that the students improved their mobilization of higher cognitive processes during the three activities, as suggested by one of our hypotheses. The next step in the

analysis was to identify the interactions that may promote the mobilization of these cognitive processes. The comparison and modeling of total interactions and scores per activity per student (Figure 5) reveals homogenization in terms of mobilization of interactivity. This trend is paired along with an interaction decrease and an increase in total score. It might be explained by a learning effect related to repeated similar activities. This highlights to some extent the importance of tool mastery and it reveals, by extension, the presence of technical ability.



**Figure 5.** Interaction selection and taxonomic scores.

PC1: technical ability (45%). PC2: investigation and comparison factor (21%). PC3: synthesis ability (12%).

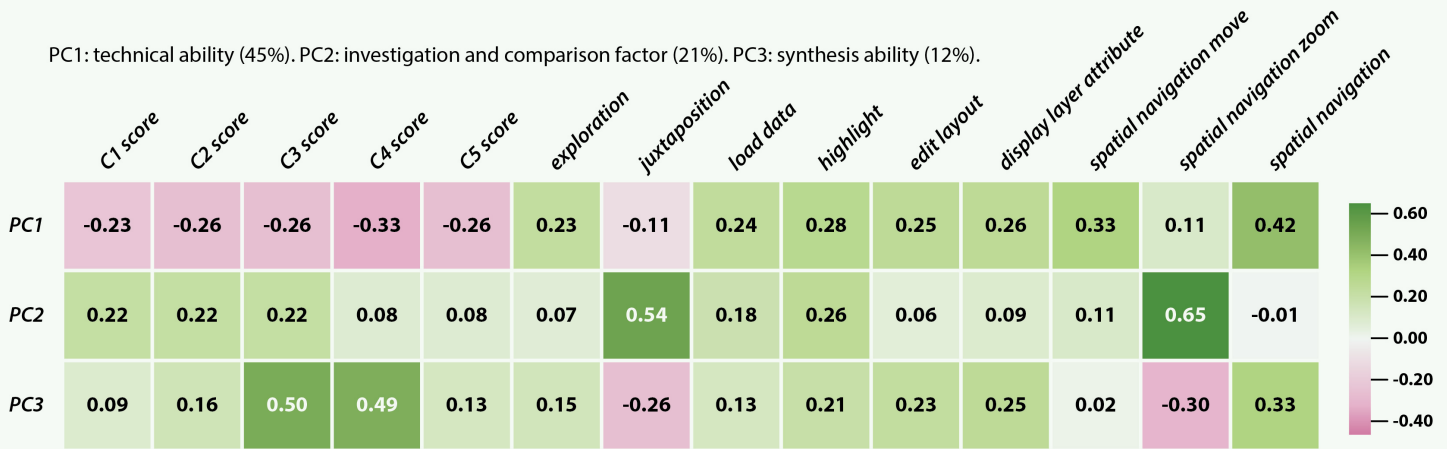


Figure 6. PCA correlation matrix.

We used principal component analysis (PCA) to examine the relationships between scores and interactions in depth. The goal here was to further discover the influence of interactivity on learning geographical thinking. PCA distinguished three factors related to students' interactive behaviors and learning using the interactive variables and taxonomy scores. These three factors summarized around 78% of the information in our sample. The examination of the correlation matrix in Figure 6 reveals the following factors:

1. **Technical ability** (45%) illustrates an effective use of the interactive features of the web mapping interface, with a positive contribution to learning. The positive values of the interactive variables (except *juxtaposition* and *spatial navigation zoom*) are opposed to the negative values of the scores. Therefore, the higher the use of the various interface features, the lower the taxonomic scores obtained.
2. **Investigation and comparison** (21%) is associated with searching, comparing, and linking information behavior. It is related to the following interaction indicators: the high mobilization of *spatial navigation zoom* and *juxtaposition*, and the slight use of *highlight*. These indicators had a moderate impact on several taxonomic scores: master cartographic language (C1), obtain information (C2), and connect (C3).
3. **Synthesis ability** (12%). This factor shows the influence of students' connecting and problematization abilities on the use of most of the interactive

features. *Juxtaposition* and *spatial navigation zoom* (the important variables of the second factor) are not included. As a result, it would appear that students with better analytical and synthesis skills use certain interactive features that allow them to link the characteristics of the cartographic indicators: *spatial navigation*, *display layer attribute*, and *highlight*.

The PCA results support the previously observed role of technical ability in modeling interactions and taxonomic scores. It also suggests that the contribution of interactivity to learning is likely to be related not only to the mobilization of one or more kinds of interactivity (featured in Table 2), but also to associations between these kinds. In addition, this PCA reveals the significant influence of the following interactive variables and taxonomic scores: *spatial navigation*, *spatial navigation zoom*, *juxtaposition*; connect (C3 score) and problematize (C4 score).

To study the changing role of technical skill, the related PCA factor was transformed into a variable, in order to analyze its influence over all taxonomic scores during the three activities, using bivariate modeling. Observing the evolution of the overall points in these three activities representing total scores and factor 1 (technical ability) indicates a distribution reduction in their perimeter over the activities (see Figure 7).

This probably reflects a dynamic of homogenization of behaviors over time: i.e., the adoption of interactive practices that lead to an increase in taxonomy scores that are more or less marked depending on the students. Modeling of PCA factor 1, technical ability, indicates a strong

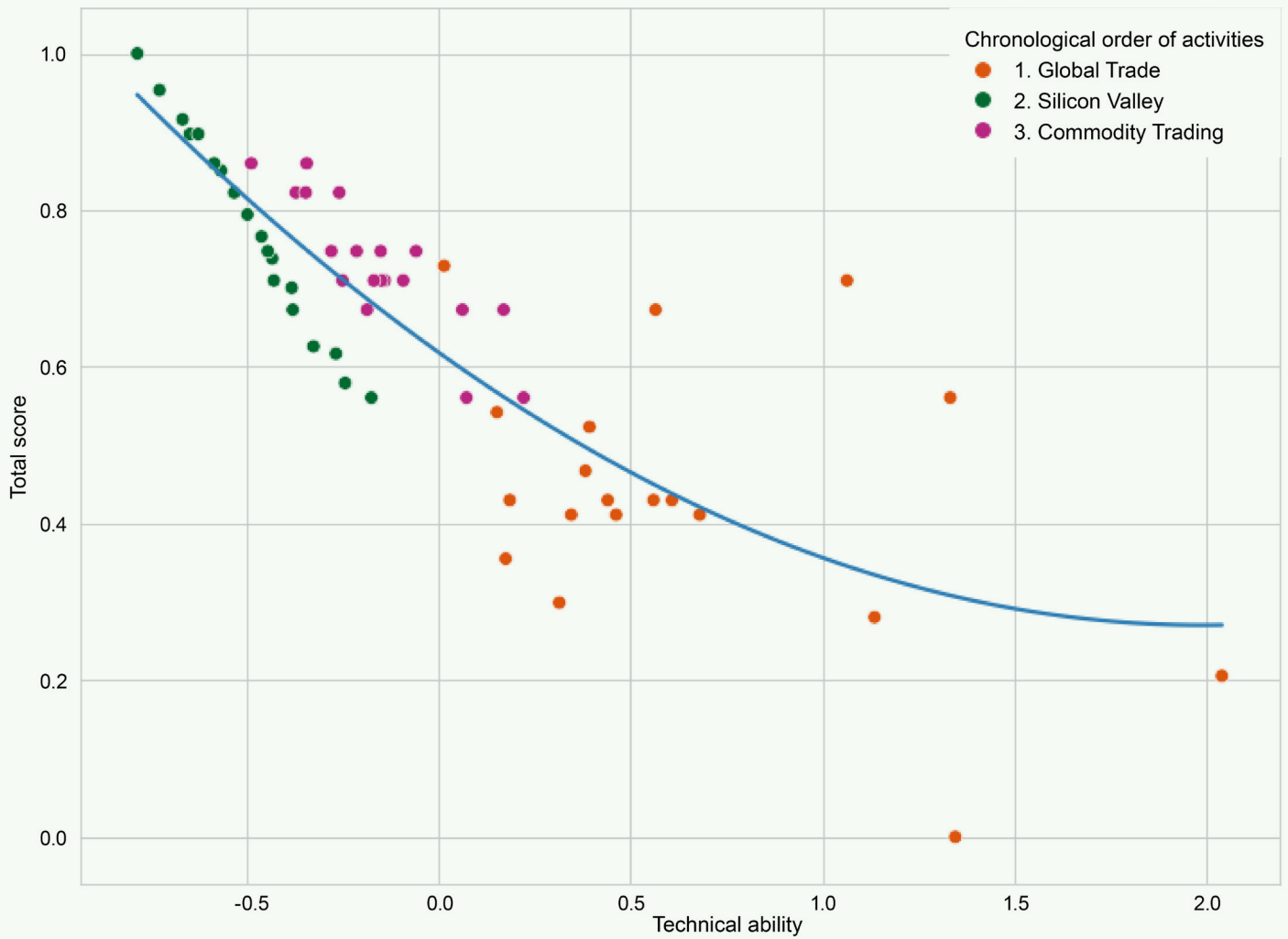


Figure 7. Non-linear regression of technical ability and taxonomic total score.

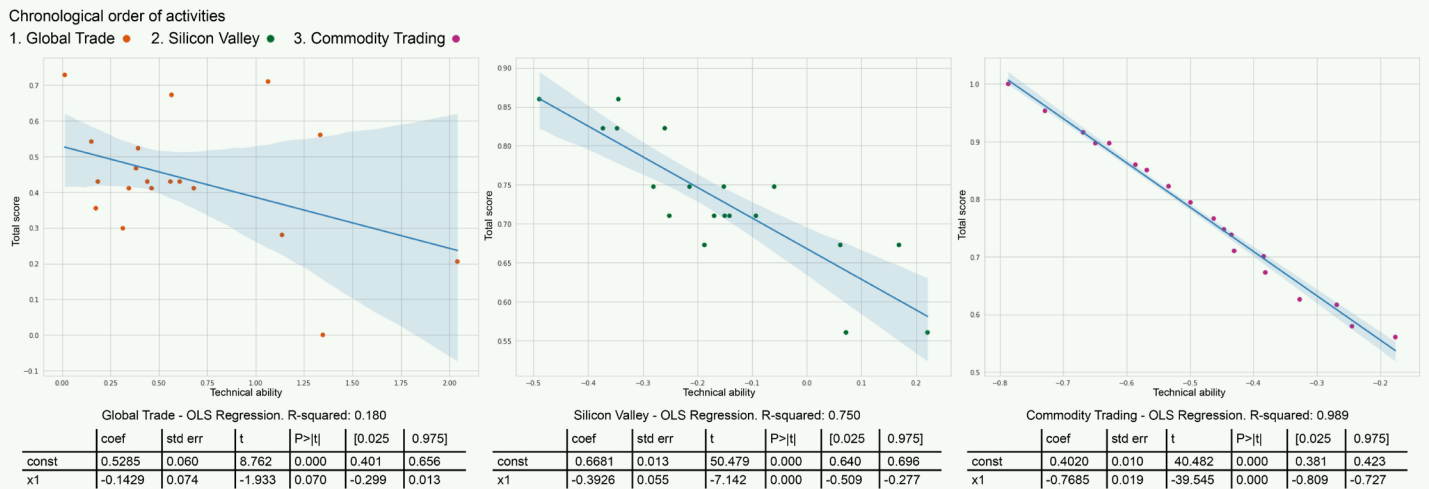


Figure 8. Linear regressions of technical ability and taxonomic total score per activity.

correlation ( $R^2$ ) of 0.71. The distribution points out that a high mobilization of interactivity does not equal a high taxonomy score.

Separate modeling of the points from each activity indicates a decrease in the dispersion of the data with subsequent activities (see standard errors in Figure 8), as well as a clear reduction in the influence of technical skill on the taxonomic total score. This decrease is underlined by the values of the slopes of the linear regressions. In the first activity, we observe a significant dispersion. In the second activity, we observe the appearance of a significant negative correlation between the technical skill and the scores. Finally, in the third activity, the influence of the technical ability on the taxonomic total score decreases significantly.

Regarding problematization and connection taxonomic scores, the statistical correlation (linear regression) with technical ability is significant ( $R^2$  of 0.71 and 0.52 respectively). All other taxonomic scores indicate a moderate R-squared correlation (~0.44). Therefore, the more a task mobilizes demanding cognitive processes and higher levels of knowledge, the more technical ability plays a preponderant role. However, as for the total taxonomic score, the same trend of reduction of this parameter's influence during the three activities is observed on the bivariate modeling of the taxonomic scores.

Endogenous	Exogenous	Degree of Regression	Coefficient(s)	$R^2$
total score	spatial navigation	2	-1.54, 1.29	0.49
total score	display layer attributes	2	-1.5012, 1.4259	0.37
total score	juxtaposition	1	-0.1818	0.36
total score	edit layout	3	-2.77, 7.8, -5.54	0.34
C4 score	juxtaposition	1	-0.25	0.39
C5 score	display layer attributes	2	-1.62, 1.45	0.37
C3 score	spatial navigation	3	-1.91, 1.78	0.37
C4 score	spatial navigation	2	-1.96, 1.73	0.37
C2 score	spatial navigation	2	-1.52, 1.32	0.35

**Table 4.** Bivariate analysis results ( $p$ -value < 0.05).

These results illustrate the evolving influence of technical ability on learning and partially confirm our first hypothesis (H1). At first, this parameter has some importance in the progression of learning, but its influence decreases considerably and disappears by the last activity. This finding indicates that technical ability to use an interactive map does not hinder student learning in our experiment.

The following analysis focuses on the second hypothesis (H2). It involves examining the role of interactivity in the mobilization of higher cognitive processes. Initially, we investigated all interactions mentioned in Table 2 to identify which may contribute to learning through taxonomic scores. As Table 4 shows, bivariate analysis ( $p$ -value < 0.05) reveals that the following interactions could have a moderate impact on the mobilization of higher cognitive processes, in order of importance and frequency: *spatial navigation*, *juxtaposition*, and *display layer attribute*. The selection of these interactions is conditioned to a value of the correlation rate higher than 35% in at least one model.

The next step in the analysis is to examine the mobilization of these interactions in time and space. In other words, it is a question of more precisely locating the parts of the interface that are mobilized and at what time and frequency. To conduct this analysis, we separated the interactions for each of the activities into time windows of 5 minutes each,

and applied a separate PCA to each of the interaction types with the time intervals as variables (these PCAs are referred to as temporal PCAs in the remainder of this text). The analysis was done simultaneously on all three activities, with the time starting at zero for each activity. Students had, at maximum, 50 minutes of time to complete each activity. The results of these analyses depict different behavioral profiles of the technical ability factor revealed during the initial PCA. The temporal PCAs of four of these interactions—*spatial navigation*, *display layer attribute*, *spatial navigation move*, and *highlight*—suggest that when they are mobilized in a moderate and intermittent

way throughout the activity, it has a moderate to significant positive impact on the scores and the mobilization of higher cognitive processes. The temporal PCA results of the *juxtaposition* interaction differ from those four however, in the temporal structure of the factors obtained. This interaction also contributes to supporting the activation of higher cognitive processes. Indeed, a slight mobilization of those processes would lead to a moderate impact on problematization and connecting. Our observations are summarized in Figure 9, which show interactive mobilization behaviors that contributed the most to student learning.

Examination by interaction and by score using bivariate modeling (Table 4) and temporal PCAs (Figure 9) underlines the prominent part played by specific interactions from the various kinds of interactivity (see Table 2) in the mobilization of the higher cognitive processes present in problematization (C4 score) and connecting (C3 score). Temporal PCAs highlight interactive behavioral patterns that imply higher taxonomic scores. These analyses bring evidence in favor of our second hypothesis (H2).

### THEMATIC ANALYSIS WITH FOCUS GROUP

A focus group was assembled by selecting students according to their taxonomic scores, to obtain a panel composed of students with varied learning outcomes (5 girls and 7 boys). All participants voluntarily agreed to participate in the focus groups. Due to school-related constraints, only four twenty-minute focus groups were conducted, after the conclusion of all three activities. Each group consisted of three students, who responded unprepared to questions related to their experience with the three online maps. The questions (which can be found in the Appendix) concerned the role of interactivity in their learning, cartographic and

graphic interpretation (mobilization of taxonomic levels depicted in the map interpretation taxonomy), the difficulties encountered during the tasks, and how to overcome them (metacognition) such as mastering the web map interface. The focus groups also included a debriefing where students could express themselves freely. We chose thematic analysis to identify recurring themes in the students' comments (Hay 2005). A first coding grid based on the components of the map interpretation taxonomy, interactivity, and technical ability was used in our initial analysis. Following this initial analysis, other codes emerged and made it possible to identify other key themes related to task features and contexts.

From this analysis, we obtained information on the possible influence of technical ability and interactivity as well as other factors related to the progression of learning (H1) and the mobilization of higher cognitive processes (H2). These other factors reflect the context of the tasks and its role in learning geographical thinking. The purpose of these thematic analyses was to reveal and document evidence that complements and clarifies the results of the statistical analyses with student feedback.

The use of a web map as part of a teaching session was new to all students. A time of adaptation and initiation was therefore necessary. From the second activity, students claim to have understood how the site worked. This confirms the existence of the learning effect observed in one of the statistical analyses (see Figure 8) and underlines that technical ability is not a hindrance to learning despite the *school practices* discussed further.

Because I didn't really know how it worked, so I wasn't used to it. Instead of looking at the

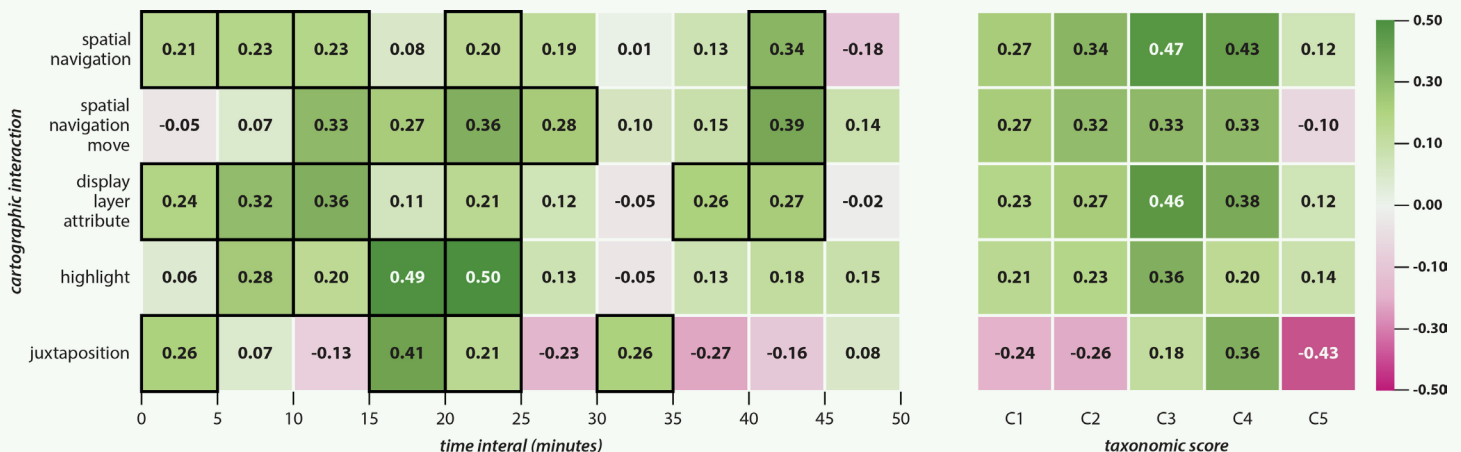


Figure 9. Interactive behaviors with the most contribution to learning.

questions, I tried to understand first, to see all the possibilities to see how it worked. Then, little by little, I started to use the graphics more and more. (Focus Group 4: Student 2)<sup>2</sup>

But I think, after [the first activity] I was more familiar with the website too, the way it works. (FG1: S2)

From the perspective of mobilizing interactivity, students mention different behaviors. Students took advantage of some interactive features to facilitate their work. One of these features corresponds to one of the cartographic interactions highlighted during the statistical analyses: the juxtaposition of two maps, which allows comparing and analyzing two cartographic indicators. Using this interaction, they were able to conduct analyses through comparisons.

I also liked the [double] maps very much, finally, because they allow you to compare two indicators, which is more practical than having to select one and look at the other all the time, because you can see both at the same time. (FG2: S1)

Other interactive features related to the other types of interactivity were mentioned, such as highlighting certain classes, and displaying the attributes of the indicators. All three kinds of interactivity (see Table 2) were used to perform tasks. *The combination of the three types of interactivity* is also a parameter to consider, as the first PCA revealed. The students' feedback reveals other factors that influenced learning and the mobilization of higher cognitive processes. The first is related to indicator representations. It is related to the *semiological and semiotic features of the graphic representation types* (maps, charts). Students encountered interpretive difficulties when graphic representations combined two pieces of information such as colored proportional symbol maps. Proportional symbol maps also generated abstraction barriers in terms of perceived size difference, but not unanimously. In the first two activities, students had access to scatterplots, a bar chart (Silicon Valley), and a line chart (global trade). In the third activity, only proportional symbol and choropleth maps were available. In the second activity, some students relied on the bar chart to answer the questions. The choropleth map was the representation most preferred by the majority of students. Its visual attractiveness could

affect its readability. Thus, the *visual aesthetic factor* may influence students' preference for this type of representation. Another one of the non-trivial factors in this type of school-based study is the role of *school practices* in relation to digital tools and maps. Students had not previously encountered the use of online maps in assessments.

Well, for me, it was the first time that I had ever done an exercise like that. I had never seen a digital map. So I had to take my time to see how it worked and all that. (FG1: S2)

But uh, it was really interesting and it was a change from what we usually do, we don't do this kind of thing often, it's tests that we have, assessments or we have to learn something by heart or we have knowledge that we have acquired during the courses and then we transcribe it, we transcribe what we have learned, etc. But here, we had a support that helped us answer certain questions. So it's a different approach from what we usually do and I think it's really cool. (FG4: S1)

The difficulty associated with this novelty was also amplified by the use of web maps to answer questions requiring analysis and synthesis skills. Students had never been confronted with this type of activity in class. They emphasized their difficulties in answering questions requiring an analysis of different information (connection component) and the creation of hypotheses (problematization component). These statements correspond to the evolution of the taxonomic scores mentioned. Nevertheless, some of them were very satisfied to be able to connect facts retrieved from map interpretation.

It also taught me that, well, first of all, I liked making links between things and that I find it interesting to be able to make links. And then, it will also improve, to put precisely as [S2] says, to make the links between the various, the cards and then the information which one knows, then the questions, then the logical things. Because we hadn't really had such a developed analysis of a question. (FG1: S1)

The *intellectual complexity factor* of these questions was likely reinforced by the lack of prior similar experiences.

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2. The focus groups were conducted in French. The comments mentioned here have been translated by the authors into English.

Students had difficulty answering the last two questions in the task that require analysis, evaluation, and creation.

The last two questions were actually a problem for me. Afterwards, why? Well, it's because I didn't understand them. Well, I didn't understand what was expected of the answer, maybe I didn't understand the question. (FG1: S2)

Nonetheless, on several occasions, students mentioned different strategies such as retrieving information using juxtaposition (see FG2: S1). The implementation of these strategies emphasizes students' *metacognitive ability*, which increased during the three activities. The last parameter which may have a contribution on learning and map interpretation, positive (pleasure, motivation) and negative (stress and anxiety) *emotions* were mentioned by the students.

## DISCUSSION

THE TAXONOMIC SCORES OF THE DIFFERENT MAP INTERPRETATION components improved, despite the difficulties students had in using the interface at the beginning of the three activities. Studies have pointed out that technical ability may be a hindrance to the use of GSTs (Hong 2017; Walshe 2017). Our findings indicate that technical ability is not a barrier to student learning, even if some adaptation time is required. The progression of overall taxonomic scores from the beginning to the end of the experiment reflects this, as does the statistical modeling of interactions and total scores. The weight of technical ability gradually disappears and highlights a learning effect that becomes stronger over time. This finding is in line with strategies to manage the cognitive load during learning—for example, to use a kind of pretraining to manage the complexity of the learning task at hand (Clark and Mayer 2016). While this has already been reported in previous research (De Miguel González and De Lázaro Torres 2020), our study helps to illustrate this progression (see Figures 5, 7, and 8). Our results contribute to the body of research by providing evidence that web maps support learning geographical thinking by students in secondary schools (De Miguel González et al. 2019; Favier and van der Schee 2014; Metoyer and Bednarz 2017). Confronting our second hypothesis with the analyses, we also found that the web map may mobilize higher cognitive processes. While (digital) maps are generally employed for illustrative

So since I, like, I'm a little bit lame in computers and all that, then as soon as they say you have to do that on the computer or like that, I feel every time I'm completely off the mark and then, the fact to have succeeded in understanding this site, to have found information and all that, that reassured me a little bit, to say to myself in fact finally, that's OK. (FG3: S1)

Despite the difficulties linked to school practices, the mastery of the interactive tool, and the intellectual complexity of the questions, the students still experienced a progression in their learning (see FG1: S1). Nevertheless, given the few focus groups conducted, it is difficult to precisely assess the influence of these additional factors. It is interesting to note, though, that these focus groups allow us to partially confirm and complement a part of the statistical results regarding our hypothesis evaluation while highlighting additional parameters that contextualize the students' learning.

purposes in geography class, taxonomic score progressions highlight students' ability to activate them in analysis and problematization activities.

Our study results highlight several insights and recommendations for the use of web maps in school geography. As we observed with the evolution of scores and interactions, the repetition of similar activities while varying the themes allowed the students to improve their ability to interpret a web map, to analyze, and to problematize. In light of this observation and of the current state of school practices, the use of web maps cannot be carried out as an isolated activity. ***A succession of similar activities leads to a better appropriation of the tool and better learning.*** The progression of taxonomy scores confirms the students' improving ability to use web maps during analysis and problematization tasks. Moreover, during the focus groups, the students repeatedly suggested that this type of activity should be implemented from the beginning of secondary I (the first year of Swiss secondary school, for students 12 years old). According to them, these activities allow them to acquire skills in mastering digital tools that could be useful in their future academic or professional training.

The semiotic and semiological difficulties revealed by the students argue for the ***implementation of a progressive initiation to the types of data representation*** from the least to

the most abstract and according to their criterion of visual aesthetics (i.e., visually attractive), in the following order: choropleth map, proportional symbols, colored proportional symbols.

The data collection and the results of the analysis confirmed that the *map interpretation taxonomy* (see Figures 3 and 4) **could be used to build and evaluate web-based map activities**. Therefore, it could be deployed by (future) secondary I geography teachers. By distinguishing the cognitive processes and levels of knowledge mobilized during cartographic interpretation, the taxonomy helps to set up activities according to the teaching needs and progress of the students. Moreover, this taxonomic differentiation allows (future) teachers to build an evaluation and to follow the evolution of the students' learning. To this end, we advocate the communication of evaluation criteria and comments and the implementation of graphical representations to allow students to monitor their progress.

The recommendations for the development of adapted web mapping interfaces for students are mainly based on the three factors revealed by the PCA (technical ability, ability to investigate and compare, ability to synthesize). Our recommendations are as follows: facilitate mastery of the tool and foster investigation, comparison, and synthesis skills.

Regarding the technical skill, the aim is to facilitate a quick learning curve to reduce the time needed to master the tool, and thus allow students to concentrate on the cartographic interpretation. As a result, the overloading of the interface by providing many interactive features should be avoided. Moreover, the students we observed are used to smartphones and tablets, as opposed to desktop computers. Some of them also encountered difficulties in writing text on a keyboard. During data collection, the availability of tutorials or explanations provided by the researcher or teacher did not result in us observing significant changes in how students used the interface. Therefore, one approach would be to think in terms of user experience and interface without intermediary or external help. As we have seen, the students encountered semiotic and semiological difficulties in interpreting the maps, linked to the type of representation. The majority preferred choropleth maps, feeling that these maps were easier to understand. They also mentioned the use of bar charts on some occasions. This may be related to the representations they usually see in and out of school. Therefore, we propose introducing students to these activities with **a combination of**

**minimal representations of choropleth maps and bar charts**. Other types of data representations may also eventually be deployed, but students must first be able to rely on adapted representations to support their learning. Instructors could consider making certain other types of representations available, but hidden in the interface and revealed over time, as part of a gradual introduction to more abstract types of data representation—such as from a choropleth map to a colored proportional symbol map, as we suggest in one of our previous teaching recommendations.

Fostering investigation, comparison, and synthesis requires **the implementation of a combination of interactive features from the three types of interactivity** (see Table 1). The results of the statistical analyses and the focus groups underline this. In addition to *spatial navigation* and *loading data*, the integration of the following interactive features is required: *display layer attribute*, *highlight*, and *juxtaposition*. The display of attributes informs students about the extent and spatial distribution of the phenomena represented. Highlighting the data (via a simultaneous map and graph, or with only a map) focuses the student's attention on certain spatial features. To further develop this work, it would be interesting to combine these two cartographic interactions and to study their contribution to learning. *Juxtaposition*, despite its limited use in activities, has an important influence on the ability to compare and problematize. In this respect, one of the most promising interactive features is the provision of two maps side by side on the same screen.

Nevertheless, using web maps does not mean successful or better learning (Jadallah et al. 2017). Task design plays a significant role (Favier and van der Schee 2014). The use of the cartographic interpretation taxonomy (see Figure 2) in collaboration with the partner teacher enabled us to develop intellectually varied tasks. However, there are several limits to be taken into consideration, which add nuance to the significance of the results and the findings. Field access and data collection conditions were challenged by the constraints of the COVID pandemic. The work discussed here is an exploratory case study and thus the context of the experiment plays a significant role. The experimental conditions were kept as close to the field as possible to obtain similar data to the reality of teaching. We did not use a protocol that separated the tasks in time according to the levels of knowledge and cognitive processes identified in our map interpretation taxonomy. While the division of the tasks follows an intellectual progression, the students

did not necessarily answer the questions in the suggested order. Another limitation is the relatively small sample size ( $n = 20$ ) which prevents the results from being generalized, but nonetheless provides leads from which other, larger studies could be conducted. Moreover, the inference from mouse movements to cognition is debated in the literature. Design factors of the mouse tracking procedure may hinder the manifestation of cognition through movement (Grage et al. 2019; Schoemann et al. 2019). The partner teacher in this research is perhaps not typical of his colleagues: his keen interest in setting up innovative ways of learning differ from usual practices. Finally, the layout was modified during the three activities according to feedback from students and the teacher to meet their needs. Despite the minor extent of the modifications made, this element may have led to bias in the data collection.

Nonetheless, we still consider our theoretical and methodological approach to be relevant, as it opens interesting research perspectives. Here are a few suggestions for achieving this:

- a precise order of execution and division of tasks as well as a fixed time (determined following an exploratory survey),
- a group of participants numbering at least 100,
- the use of one or more control groups to guarantee the significance of the results,
- ensuring that the mouse tracking device limits interference between mouse movement and cognition (Grage et al. 2019; Schoemann et al. 2019), and
- reducing the interactive visualization options in order to better evaluate and analyze the contribution of interactivity to learning.

It would also be possible and interesting to limit experiments to specific interactive functionalities to better understand their influence on learning, as highlighted by our study on juxtaposition. Finally, a study with a similar methodology, comparing static and interactive maps, could use eye tracking to gather data on their respective contributions to learning.

## CONCLUSION

THIS EXPLORATORY STUDY IS A FURTHER STEP IN THE research undertaken so far to better understand the role of interactivity on the construction of knowledge in geovisualization, and on learning geographical thinking in geography education. Our research differs from previous studies by focusing on the effect of interactivity on learning with qualitative and statistical analysis. To the best of our knowledge, this essential feature of web maps has not yet been investigated among secondary I students. The results highlight interactive behaviors and interactions that contribute to student learning. The statistical results—PCA and bivariate—provide interesting information about how the mobilization of interactions supported student learning. They highlight that the contribution of cartographic interactions is related to a combination of all three types of interactivity (see Table 2). Temporal PCAs were performed to identify interactive behaviors that were most likely to enhance student learning. These analyses provided information on the frequency of mobilization of the interactive features. The temporal PCAs of four of these interactions—*spatial navigation*, *display layer attribute*, *spatial navigation move*, and *highlight*—reveal that when one of these four interactions is mobilized in a moderate and intermittent way throughout the activity, it has a moderate

to a significant positive impact on the scores. The *juxtaposition* analysis differs, suggesting that only a slight mobilization may lead to a moderate impact on problematization and connecting. These observations are summarized in Figure 9, which shows the interactive behaviors with the most contribution to learning. Focus groups complement and partially confirm the results revealed by the statistical analyses. While supporting the influence of technical ability and interactivity on learning geographical thinking, they highlight the involvement of other factors. This additional information points towards the importance of activity context through school practices and the intellectual complexity of the tasks. The focus groups revealed several details of students' interactions with the web maps: their difficulties in interpreting specific graphs, ability to identify obstacles and work around them (metacognitive ability), visual aesthetic preferences, and the role of both positive (pleasure, motivation) and negative (stress, anxiety) emotions. According to the state of the art by Montello et al. (2018) in this respect, emotions play a central role in the map interpretation. Further investigations would be necessary to evaluate more precisely the respective weight of these factors revealed by the focus group analysis. At this stage, these are only indications. The combination of

analysis and data collection methods allowed us to better understand the role of interactivity by confirming and complementing our statistical results, while highlighting the existence of other learning factors through the focus groups. These focus groups highlighted other factors missing from the hypotheses related to the context of the

experiment and student characteristics. We are convinced that this type of methodological and theoretical articulation is appropriate and relevant to study the contribution of web mapping, and possibly digital tools on students' learning.

## REFERENCES

- Anderson, Lorin W., and David R. Krathwohl, eds. 2001. *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. New York: Longman.
- Andrienko, Gennady, Natalia Andrienko, Urska Demsar, et al. 2010. "Space, Time and Visual Analytics." *International Journal of Geographical Information Science* 24 (10): 1577–1600. <https://doi.org/10.1080/13658816.2010.508043>.
- Ankerst, Mihael, Markus M. Breunig, Hans-Peter Kriegel, and Jörg Sander. 1999. "OPTICS: Ordering Points to Identify the Clustering Structure." In *Proceedings of the 1999 ACM SIGMOD International Conference on Management of Data*, 49–60. New York: ACM. <https://doi.org/10.1145/304182.304187>.
- Ansari, Mohd Yousuf, Amir Ahmad, Shehroz S. Khan, Gopal Bhushan, and Mainuddin. 2020. "Spatiotemporal Clustering: A Review." *Artificial Intelligence Review* 53 (4): 2381–2423. <https://doi.org/10.1007/s10462-019-09736-1>.
- Bachmann, Julien. 2020. "Cartographie 2.0 et géographie scolaire: une démarche théorique et méthodologique d'évaluation de l'apprentissage." *Géo-Regards* 13: 29–47.
- Baker, Tom R., Sarah Battersby, Sarah W. Bednarz, et al. 2015. "A Research Agenda for Geospatial Technologies and Learning." *Journal of Geography* 114 (3): 118–30. <https://doi.org/10.1080/00221341.2014.950684>.
- Clark, Ruth Colvin, and Richard E. Mayer, eds. 2016. *E-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning*. 4th ed. Hoboken, NJ: John Wiley & Sons. <https://doi.org/10.1002/9781119239086>.
- Çöltekin, A., S. I. Fabrikant, and Martin Lacayo. 2010. "Exploring the Efficiency of Users' Visual Analytics Strategies Based on Sequence Analysis of Eye Movement Recordings." *International Journal of Geographical Information Science* 24 (10): 1559–75. <https://doi.org/10.1080/13658816.2010.511718>.
- Çöltekin, Arzu, Susanne Bleisch, Gennady Andrienko, and Jason Dykes. 2017. "Persistent Challenges in Geovisualization – a Community Perspective." *International Journal of Cartography* 3 (sup1): 115–139. <https://doi.org/10.1080/23729333.2017.1302910>.
- Çöltekin, Arzu, Benedikt Heil, Simone Garlandini, and Sara Irina Fabrikant. 2009. "Evaluating the Effectiveness of Interactive Map Interface Designs: A Case Study Integrating Usability Metrics with Eye-Movement Analysis." *Cartography and Geographic Information Science* 36 (1): 5–17. <https://doi.org/10.1559/152304009787340197>.
- Çöltekin, Arzu, Halldór Janetzko, and Sara Fabrikant. 2018. "Geovisualization." *Geographic Information Science & Technology Body of Knowledge*. 2<sup>nd</sup> Quarter 2018 edition. <https://doi.org/10.22224/gistbok/2018.2.6>.
- Crampton, Jeremy W. 2002. "Interactivity Types in Geographic Visualization." *Cartography and Geographic Information Science* 29 (2): 85–98. <https://doi.org/10.1559/152304002782053314>.
- De Miguel González, Rafael, and Maria Luisa De Lázaro Torres. 2020. "WebGIS Implementation and Effectiveness in Secondary Education Using the Digital Atlas for Schools." *Journal of Geography* 119 (2): 74–85. <https://doi.org/10.1080/00221341.2020.1726991>.

- De Miguel González, Rafael, Karl Donert, and Kostis Koutsopoulos, eds. 2019. *Geospatial Technologies in Geography Education*. Key Challenges in Geography. Cham, Switzerland: Springer International Publishing. <https://doi.org/10.1007/978-3-030-17783-6>.
- Edsall, Robert, Gennady Andrienko, Natalia Andrienko, and Barbara Buttenfield. 2009. "Interactive Maps for Exploring Spatial Data." In *Manual of Geographic Information Systems*, edited by Marguerite Madden, 837–58. Bethesda, MD: ASPRS.
- Favier, Tim T., and Joop A. van der Schee. 2014. "The Effects of Geography Lessons with Geospatial Technologies on the Development of High School Students' Relational Thinking." *Computers & Education* 76: 225–36. <https://doi.org/10.1016/j.compedu.2014.04.004>.
- Fletcher, Andrew, Steven Kickbusch, and Henk Huijser. 2022. "Authentic Learning Using Mobile Applications and Contemporary Geospatial Information Requirements Related to Environmental Science." *Journal of Geography in Higher Education* 46 (2): 185–203. <https://doi.org/10.1080/03098265.2020.1850657>.
- Golebiowska, Izabela, Tomasz Opach, and Jan Ketil Rød. 2020. "Breaking the Eyes: How Do Users Get Started with a Coordinated and Multiple View Geovisualization Tool?" *The Cartographic Journal* 57 (3): 235–48. <https://doi.org/10.1080/00087041.2019.1660513>.
- Grage, Tobias, Martin Schoemann, Pascal J. Kieslich, and Stefan Scherbaum. 2019. "Lost to Translation: How Design Factors of the Mouse-Tracking Procedure Impact the Inference from Action to Cognition." *Attention, Perception, & Psychophysics* 81: 2538–57. <https://doi.org/10.3758/s13414-019-01889-z>.
- Hay, Iain, ed. 2005. *Qualitative Research Methods in Human Geography*. 2nd ed. New York: Oxford University Press.
- Healy, Grace, and Nicola Walshe. 2020. "Real-World Geographers and Geography Students Using GIS: Relevance, Everyday Applications and the Development of Geographical Knowledge." *International Research in Geographical and Environmental Education* 29 (2): 178–96. <https://doi.org/10.1080/10382046.2019.1661125>.
- Hehman, Eric, Ryan M. Stoller, and Jonathan B. Freeman. 2015. "Advanced Mouse-Tracking Analytic Techniques for Enhancing Psychological Science." *Group Processes & Intergroup Relations* 18 (3): 384–401. <https://doi.org/10.1177/1368430214538325>.
- Holloway, Paul, Therese Kenna, Denis Linehan, et al. 2021. "Active Learning Using a Smartphone App: Analysing Land Use Patterns in Cork City, Ireland." *Journal of Geography in Higher Education* 45 (1): 47–62. <https://doi.org/10.1080/03098265.2020.1802703>.
- Hong, Jung Eun. 2017. "Designing GIS Learning Materials for K–12 Teachers." *Technology, Pedagogy and Education* 26 (3): 323–45. <https://doi.org/10.1080/1475939X.2016.1224777>.
- Fontanabona, Jacky, ed. 2002. *Cartes et modèles graphiques: analyses de pratiques en classe de géographie*. Didactiques des disciplines. Paris: INRP.
- Jadallah, May, Alycia M. Hund, Jonathan Thayn, Joel Garth Studebaker, Zachary J. Roman, and Elizabeth Kirby. 2017. "Integrating Geospatial Technologies in Fifth-Grade Curriculum: Impact on Spatial Ability and Map-Analysis Skills." *Journal of Geography* 116 (4): 139–51. <https://doi.org/10.1080/00221341.2017.1285339>.
- Jo, Injeong, Jung Eun Hong, and Kanika Verma. 2016. "Facilitating Spatial Thinking in World Geography Using Web-Based GIS." *Journal of Geography in Higher Education* 40 (3): 442–59. <https://doi.org/10.1080/03098265.2016.1150439>.
- Kerski, Joseph J., and Thomas R. Baker. 2019. "Infusing Educational Practice with Web GIS." In *Geospatial Technologies in Geography Education*, edited by Rafael de Miguel González, Karl Donert, and Kostis Koutsopoulos, 3–19. Cham, Switzerland: Springer International Publishing. [https://doi.org/10.1007/978-3-030-17783-6\\_1](https://doi.org/10.1007/978-3-030-17783-6_1).

- Kieslich, Pascal J., Felix Henninger, Dirk U. Wulff, Jonas M. B. Haslbeck, and Michael Schulte-Mecklenbeck. 2019. "Mouse-Tracking: A Practical Guide to Implementation and Analysis 1." In *A Handbook of Process Tracing Methods*, 2nd ed., edited by Michael Schulte-Mecklenbeck, Anton Kuehberger, and Joseph G. Johnson. New York: Routledge.
- Kisilevich, Slava, Florian Mansmann, Mirco Nanni, and Salvatore Rinzivillo. 2010. "Spatio-Temporal Clustering." In *Data Mining and Knowledge Discovery Handbook*, edited by Oded Maimon and Lior Rokach, 855–74. Boston, MA: Springer US. [https://doi.org/10.1007/978-0-387-09823-4\\_44](https://doi.org/10.1007/978-0-387-09823-4_44).
- Krathwohl, David R. 2002. "A Revision of Bloom's Taxonomy: An Overview." *Theory Into Practice* 41 (4): 212–18. [https://doi.org/10.1207/s15430421tip4104\\_2](https://doi.org/10.1207/s15430421tip4104_2).
- Krygier, J. B., Catherine Reeves, David DiBiase, and Jason Cupp. 1997. "Design, Implementation and Evaluation of Multimedia Resources for Geography and Earth Science Education." *Journal of Geography in Higher Education* 21 (1): 17–39. <https://doi.org/10.1080/03098269708725407>.
- Lee, Jongwon, and Robert Bednarz. 2012. "Components of Spatial Thinking: Evidence from a Spatial Thinking Ability Test." *Journal of Geography* 111 (1): 15–26. <https://doi.org/10.1080/00221341.2011.583262>.
- Lundmark, Anders Mattias, Lars Eivind Augland, and Simen Varkøy Jørgensen. 2020. "Digital Fieldwork with Fieldmove - How Do Digital Tools Influence Geoscience Students' Learning Experience in the Field?" *Journal of Geography in Higher Education* 44 (3): 427–40. <https://doi.org/10.1080/03098265.2020.1712685>.
- MacEachren, Alan M. 2004. *How Maps Work: Representation, Visualization, and Design*. 1st edition. New York: The Guilford Press.
- MacEachren, A. M., M. Gahegan, W. Pike, et al. 2004. "Geovisualization for Knowledge Construction and Decision Support." *IEEE Computer Graphics and Applications* 24 (1): 13–17. <https://doi.org/10.1109/MCG.2004.1255801>.
- Manson, Steven M., Len Kne, Kevin R. Dyke, Jerry Shannon, and Sami Eria. 2012. "Using Eye-Tracking and Mouse Metrics to Test Usability of Web Mapping Navigation." *Cartography and Geographic Information Science* 39 (1): 48–60. <https://doi.org/10.1559/1523040639148>.
- McArdle, Gavin, Ali Tahir, and Michela Bertolotto. 2015. "Interpreting Map Usage Patterns Using Geovisual Analytics and Spatio-Temporal Clustering." *International Journal of Digital Earth* 8 (8): 599–622. <https://doi.org/10.1080/17538947.2014.898704>.
- Mérenne-Schoumaker, Bernadette. 2014. "Lire et Réaliser Des Cartes et Des Croquis Cartographiques." In *Faire Aimer et Apprendre l'histoire et La Géographie Au Primaire et Au Secondaire*, edited by David Lefrançois, Stéphanie Demers, and Marc-André Éthier, 35–53. Québec: Editions Multimondes.
- Mericskay, Boris. 2016. "La cartographie à l'heure du Géoweb: Retour sur les nouveaux modes de représentation spatiale des données numériques." *Cartes & géomatique* 229–230: 37–50.
- Metoyer, Sandra, and Robert Bednarz. 2017. "Spatial Thinking Assists Geographic Thinking: Evidence from a Study Exploring the Effects of Geospatial Technology." *Journal of Geography* 116 (1): 20–33. <https://doi.org/10.1080/00221341.2016.1175495>.
- Montello, Daniel R. 2009. "Cognitive Research in GIScience: Recent Achievements and Future Prospects." *Geography Compass* 3 (5): 1824–40. <https://doi.org/10.1111/j.1749-8198.2009.00273.x>.
- Montello, Daniel R., Sara Irina Fabrikant, and Clare Davies. 2018. "Cognitive Perspectives on Cartography and Other Geographic Information Visualizations." In *Handbook of Behavioral and Cognitive Geography*, edited by Daniel R. Montello, 177–196. <https://doi.org/10.4337/9781784717544.00018>.
- National Research Council. 2006. *Learning to Think Spatially*. Washington, DC: National Academies Press. <https://doi.org/10.17226/11019>.

- Ooms, Kristien, Arzu Cöltekin, Philippe De Maeyer, et al. 2015. "Combining User Logging with Eye Tracking for Interactive and Dynamic Applications." *Behavior Research Methods* 47 (4): 977–93. <https://doi.org/10.3758/s13428-014-0542-3>.
- Ooms, Kristien, Sara Fabrikant, Arzu Coltekin, and Philippe De Maeyer. 2014. "Eye Tracking with Geographic Coordinates: Methodology to Evaluate Interactive Cartographic Products," [https://www.researchgate.net/publication/280705884\\_Eye\\_tracking\\_with\\_geographic\\_coordinates\\_Methodology\\_to\\_evaluate\\_interactive\\_cartographic\\_products](https://www.researchgate.net/publication/280705884_Eye_tracking_with_geographic_coordinates_Methodology_to_evaluate_interactive_cartographic_products).
- Raynal, Françoise, and Alain Rieunier. 2012. *Pédagogie, dictionnaire des concepts clés: apprentissage, formation, psychologie cognitive*. 9e éd. rev. et augm.. Issy-les-Moulineaux: ESF.
- Roth, Robert E. 2012. "Cartographic Interaction Primitives: Framework and Synthesis." *The Cartographic Journal* 49 (4): 376–95. <https://doi.org/10.1179/1743277412Y.0000000019>.
- Roth, Robert E. 2013. "Interactive Maps: What We Know and What We Need to Know." *Journal of Spatial Information Science* 6: 59–115. <https://doi.org/10.5311/JOSIS.2013.6.105>.
- Roth, Robert E., Arzu Çöltekin, Luciene Delazari, et al. 2017. "User Studies in Cartography: Opportunities for Empirical Research on Interactive Maps and Visualizations." *International Journal of Cartography* 3 (sup1): 61–89. <https://doi.org/10.1080/23729333.2017.1288534>.
- Saint-Marc, Cécile, Marlène Villanova-Olivier, Paule-Annick Davoine, Cicely Pams-Capoccioni, and Dorine Chenier. 2017. "Enseignements du test utilisateur d'une géovisualisation dynamique. Des améliorations possibles pour les expériences en cartographie." *Cartes & géomatique* 233 (September): 45–53.
- Schoemann, Martin, Malte Lüken, Tobias Grage, Pascal J. Kieslich, and Stefan Scherbaum. 2019. "Validating Mouse-Tracking: How Design Factors Influence Action Dynamics in Intertemporal Decision Making." *Behavior Research Methods* 51: 2356–77. <https://doi.org/10.3758/s13428-018-1179-4>.
- Schoemann, Martin, Denis O'Hora, Rick Dale, and Stefan Scherbaum. 2021. "Using Mouse Cursor Tracking to Investigate Online Cognition: Preserving Methodological Ingenuity While Moving toward Reproducible Science." *Psychonomic Bulletin & Review* 28: 766–87. <https://doi.org/10.3758/s13423-020-01851-3>.
- Schulze, Uwe. 2021. "'GIS Works!'—But Why, How, and for Whom? Findings from a Systematic Review." *Transactions in GIS* 25 (2): 768–804. <https://doi.org/10.1111/tgis.12704>.
- Spivey, Michael J., and Rick Dale. 2006. "Continuous Dynamics in Real-Time Cognition." *Current Directions in Psychological Science* 15 (5): 207–11. <https://doi.org/10.1111/j.1467-8721.2006.00437.x>.
- Stillman, Paul E., Xi Shen, and Melissa J. Ferguson. 2018. "How Mouse-Tracking Can Advance Social Cognitive Theory." *Trends in Cognitive Sciences* 22 (6): 531–43. <https://doi.org/10.1016/j.tics.2018.03.012>.
- Vienneau, Raymond. 2017. *Apprentissage et enseignement: Théories et pratiques*. 3e édition. Montréal: Gaëtan Morin.
- Walshe, Nicola. 2017. "Developing Trainee Teacher Practice with Geographical Information Systems (GIS)." *Journal of Geography in Higher Education* 41 (4): 608–28. <https://doi.org/10.1080/03098265.2017.1331209>.
- Wiegand, Patrick. 2006. *Learning and Teaching with Maps*. London: Routledge.
- Wulff, Dirk U., Jonas M. B. Haslbeck, Pascal J. Kieslich, Felix Henninger, and Michael Schulte-Mecklenbeck. 2019. "Mouse-Tracking: Detecting Types in Movement Trajectories." In *A Handbook of Process Tracing Methods*, 2nd ed., edited by Michael Schulte-Mecklenbeck, Anton Kuehberger, and Joseph G. Johnson. New York: Routledge.

# APPENDIX

## TASKS AND TAXONOMIC SCORES

For each activity's data collection, the students were given a brief text that provided context for the questions. A glossary of terms that might be difficult to understand was also provided.

Activity	Tasks	Criteria
Global Trade	Examine the first statistical indicator (set of data processed to provide information on variations over time and space) on imported cotton, using the various display options available to you and answer the questions below: <ul style="list-style-type: none"> <li>• What is the temporal evolution of cotton imports worldwide from 1960 to 2020?</li> <li>• And the locations of cotton imports worldwide from 1960 to 2020?</li> </ul>	C1, C2
	Carry out the same operations for the second indicator, per capita income. Then describe the evolution and distribution of this indicator on a global scale from 1960 to 2020. <ul style="list-style-type: none"> <li>• What is the temporal evolution of per capita income in the world from 1960 to 2020?</li> <li>• And what are the locations of per capita income in the world from 1960 to 2020?</li> </ul>	C1, C2
	Formulate explanatory hypotheses on the links between locations and the temporal evolution of these two indicators, particularly in terms of factor endowment (type of production factors) and your economic knowledge.	C3, C4
Silicon Valley	Select from the lists below the five counties . . . . . . with the highest average household incomes in 2019 (q11). . . . with the largest proportions of individuals with a Bachelor's degree or higher in 2019 (q12). . . . having the highest share of information-related jobs in 2019 (q13).	C1, C2
	Compare your answers to q11, q12, and q13 with the perimeter of Silicon Valley counties. Describe the factor endowment (HOS) of this area.	C3
	Using the Four Ts (barriers to trade) and your economic notions, write hypotheses on the factorial endowment (question 2) of this area (Silicon Valley) and its specialization. Explain why Silicon Valley is such an innovative and essential territory for new technology companies. Do not hesitate to consult again the various graphic information at your disposal.	C4
Commodity Trading	Identify the districts in French-speaking Switzerland where the concentration of productive organizations active in commodities trading is greatest by selecting districts from the list below (2 districts). In which territory is the concentration of productive organizations active in commodities trading located? Select the title that best describes this concentration (5 suggestions).	C1, C2
	Following on from the study of the Silicon Valley cluster in our last assessment, could you say that the concentration of productive organizations active in commodities trading would also be a cluster? Write your answer, giving at least two reasons, based on your economic knowledge and the map indicators available on the website.	C3
	Picture the economic development (jobs, sales, income, etc.) of the region (where there is a high concentration of productive organizations active in commodities trading) and its influence on a global and regional scale over the next 20 years. Once again, use the map indicators and your economic knowledge. What are your hypotheses? Write down at least one hypothesis on the economic development and at least one on the future influence of this territory.	C4

In the analysis of student productions, points were awarded separately according to criteria. For statistical analysis purposes and to avoid bias, points were scaled between 0 and 1.

## METACOGNITION SURVEY & SCORE

After each activity, students answered a survey. Following the last activity, additional questions were added to produce a written feedback report. As not all students were able to take part in the focus groups, it was important that they all had the opportunity to express themselves at least in writing.

Global Trade	<p>Write a text about:</p> <ul style="list-style-type: none"> <li>Your difficulties in completing tasks using the web map. Don't forget to explain the reasons for these difficulties.</li> <li>How easy it was for you to complete the tasks using the online map. Don't forget to explain why it was so easy.</li> <li>Also mention what you liked and didn't like, and why.</li> </ul>
Silicon Valley	
Commodity Trading	<ul style="list-style-type: none"> <li>Following these three activities around web mapping and the economy, do you feel you've made any progress? If so, in what area do you feel you have made progress? In each case, explain what enabled you to do so.</li> <li>Do you feel you were unable to overcome certain difficulties? If so, which ones and why? Don't forget to explain the reason(s).</li> <li>As a result of these three activities, do you feel you've strengthened one or more of your skills (map reading, graphic analysis, etc.)? If so, which ones? For what reasons?</li> <li>Do you feel that these three activities have provided you with useful knowledge for your everyday life, or even for the future (academic, civic and professional)? If so, which ones?</li> <li>Do you have any other comments on these activities? Any suggestions?</li> </ul>

## FOCUS GROUP

As mentioned in the article, not all students took part in the focus groups. The questions below were used to guide the interviews, while taking care to allow the students to express themselves.

Questions
Which representations/visualizations (chart/map) helped you most in completing the tasks? For which reasons?
On the contrary, which representations/visualizations did you find difficult? Why?
Which visualization features (i.e., the different types of interactive display) helped you most in completing the tasks? Why?
On the contrary, which visualization features didn't help you get the job done? For which reasons?
What difficulties did you encounter when using web maps? Why?
Which questions did you find most difficult? Why?
How would the activities have been carried out with paper maps? What would be the advantages and disadvantages based on your experience?

Do you think these web maps helped you to understand certain things about the themes studied?

To what extent are web maps a good way of understanding economic and geographical phenomena?

Do you work in the same way in other classes (e.g., online tools, web maps, criteria grid)?

What do you recall from these three activities? What conclusions do you spontaneously draw? What did you learn?

## MAP INTERPRETATION TAXONOMY<sup>1</sup>

Given its use in research and teaching fields (Favier and van der Schee 2014; De Miguel González and De Lázaro Torres 2020; Saint-Marc et al. 2017), Bloom's renewed taxonomy was selected to describe the intellectual operations and knowledge mobilized for map interpretation. It provides us with a tool for analyzing the contribution of online maps to learning. Within the cartographic interpretation process, it enables us to assess not only simple learning operations, such as localization, but also more complex learning operations requiring intellectual activity of high cognitive intensity, such as the evaluation and creation of hypotheses to explain the occurrence and distribution of a spatial phenomenon. Our taxonomy was developed based on possible uses of maps in schools by students aged 12 to 15. This selection is based on uses proposed by geography education researchers (Fontanabona 2002; Mérenne-Schoumaker 2014; Wiegand 2006). After grouping these different uses into different ability categories, we proceeded to identify the cognitive processes and levels of knowledge mobilized when exercising these abilities. The result of this work is presented below.

The first component of map interpretation skill, mastering map language, focuses on the ability to use cartographic language. Cartographic language is based on the articulation of two sub-components: the verbal language and the graphic language of the map.<sup>2</sup> Learning these languages requires the acquisition of factual and conceptual knowledge (CN1, CN2).<sup>3</sup> Cognitive operations of memorization and comprehension are used to achieve this, notably through comparisons (CG1, CG2). As an example, these operations are carried out when reading the map legend. The reader assimilates the meaning of the symbols on

the map to interpret the discourse conveyed by the map. The articulation of these languages is based on procedural knowledge (CN3) and metacognitive knowledge (CN4). It involves using reading procedures for geographic information to articulate verbal and graphic language to be able to interpret the map. This may prove difficult for students since each of these languages has its own semiotic logic. To achieve this articulation, the individual must not only have knowledge of their own learning processes, but must also be able to recognize, through their ability to manage learning, what they have learned and what they lack. Of course, this ability is also required in the other components of map interpretation.

The ability to use these two sub-components together allows us to reach a first level of map interpretation, enabling us to obtain information from the map. To this end, the cognitive dimension CG3 is mobilized. It consists in employing a reading method to extract factual geographic information. Connecting features of geographic phenomena and their interactions with space requires the cognitive dimension of analysis (CG4). It aims to highlight the links that enable us to account for spatial interactions. The last component, problematization, involves both evaluation (CG5) and creation (CG6). Problematizing includes exercising judgment and critical thinking—i.e., defining the geographic problem(s) depicted, developing, and assessing related hypotheses, and then synthesizing using geographic thinking.

Performing these map-interpretation skills involves a combination of the various intellectual operations listed in the map-interpretation taxonomy. However, particularly

1. Adapted and translated from Bachmann (2020).

2. Graphic language is essentially iconic, relying as it does on a resemblance between the sign and its referent. Verbal language, found notably in place names, spatial markers, and legends, follows a sequential logic (Fontanabona 2002). Mastering graphic language requires learning the rules of graphic semiology. It offers a synoptic overview, even though the interpretation and learning of these rules takes place sequentially.

3. To lighten the text, we have chosen to refer to cognitive processes and levels of knowledge using abbreviations (see Figure 2).

in classroom map use, these intellectual operations are not necessarily carried out in a linear order, although some of them are required (notably mastery of cartographic language). The reader's thinking may lead them to follow

paths that alternate the use of different levels of knowledge and cognitive processes, depending on the task at hand. In this way, cartographic interpretation and elaboration processes are characterized by a certain iterativity.



# Design Principles of Kashida Justification: A Unique Technique in Arabic and Persian Mapping

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## 1. INTRODUCTION

CALLIGRAPHY IN THE ARABIC SCRIPT IS RENOWNED for its artistic elegance and functional adaptability, serving as a vital cultural and aesthetic element across groups that use this writing system, including Arabic- and Persian-speaking societies. Beyond its role in manuscripts and architecture, Arabic calligraphy has historically influenced cartography, where its fluidity and flexibility have contributed to both the artistic and practical aspects of map design. Certain letters in the Arabic script are usually joined to the following letter through horizontal lines. *Kashidas* are an elongation of those connecting strokes, and are used to increase the space between letters for text justification purposes, resembling a type of text ligature (Benatia et al. 2006). Kashida justification has played a significant role in Arabic and Persian mapmaking traditions (Berry 1999) and has been used to elongate map labels in order to more clearly connect them to the features they refer to, akin to how labels in the Latin script are often tracked to fill a space.

With the rise of digital cartography, mapping practices have undergone a fundamental transformation. The development of geographic information systems (GIS) and web-based mapping platforms has expanded cartographic applications globally, including in regions where the Arabic script is often used, such as West Asia and North Africa (Sun and Liu 2021). However, while digital mapping tools offer increased accessibility and efficiency, their design has primarily been shaped by Western cartographic conventions, particularly those based on the Latin script (Bittner and Glasze 2021). Subsequently, key typographic traditions, such as kashida justification, have been largely overlooked in contemporary digital mapping environments.

Despite the dominance of digital platforms, printed map production remains relevant in several regions, including the United Arab Emirates and Iran, where local publishing houses continue to produce highly detailed and widely used maps (e.g., Explorer Publishing House and Gitashenasi-Novin Publishing House). A significant contrast emerges when comparing these locally produced maps with Western-introduced counterparts: whereas many Western-made maps that use the Arabic script rely on standardized label placement without typographic elongation, locally made Arabic and Persian maps frequently employ kashida justification to integrate text more seamlessly into geographic features. The absence of robust support for kashida justification in mainstream GIS software underscores broader limitations in the internationalization of cartographic typography.

This article starts with a brief historical overview of kashida justification in Arabic and Persian mapmaking, while also assessing the current technological challenges in implementing this practice within digital cartographic platforms. We argue that existing typography customization options in widely used mapping tools fail to fully accommodate Arabic calligraphic principles (Benatia et al. 2006). In response, we present some practical solutions for cartographers seeking to incorporate kashida justification in contemporary mapping workflows. These include a step-by-step technical approach to applying kashida in Persian map labels, using the Caspian Sea as a case study.

Throughout this article, the term “Arabic” refers to the shared script rather than the Arabic language itself, acknowledging its use in Persian, Dari, Kurdish, Pashto, Urdu, and other languages across various regions (Doctor et al. 2022).



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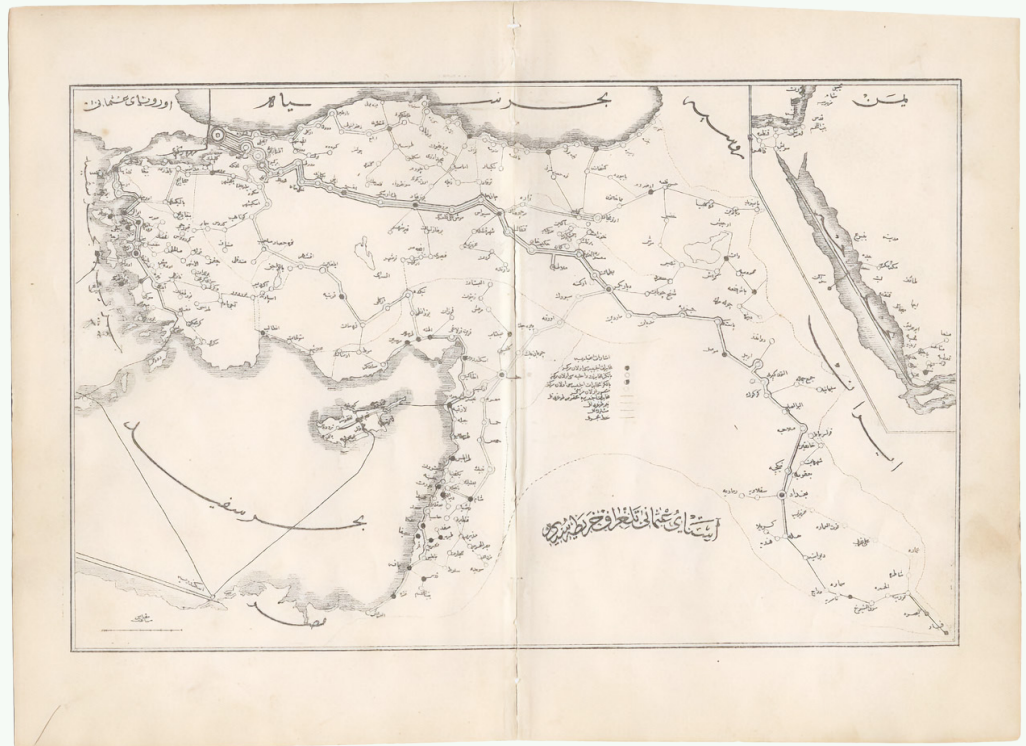
## 2. KASHIDAS ON THE MAP

KASHIDA JUSTIFICATION HAS BEEN WIDELY USED IN cartography both in the past and in the present. The history of kashida justification is just as long as the history of Arabic calligraphy, and is intertwined with the Islamic faith, along with Arabic and Persian mapmaking (Shafir 2016). For example, on the Ibn Hawqal map (Figure 1) made by Abu al-Qasim, an important tenth-century cartographer in the famous Balkhi School of Geographers, kashida justification was practiced in multiple places across the river Nile. In two places on the lower Nile, pairs of labels were placed in intersection, with extended strokes spanning across the river. A similar design can be found in the upper Nile, where the label that translates as “Country of Nubia, Dongola, and Alwa” was placed with a kashida extension in the middle, crossing the river. In this example, using kashida extension provides an aesthetically pleasing option to make the labels span across the river line and emphasize the label equally on both banks of the river, while maintaining the readability and continuity of words written in Arabic.

The kashida traditions were also practiced by Ottoman cartographers during the nineteenth and early twentieth century, blending with newly introduced European cartographic techniques (Karamustafa 1992; Figures 2–3). On these maps, historical traditions were preserved, using kashidas to span large geographic features, such as oceans, deserts, and large regions. Although the Arabic script for Ottoman Turkish was replaced with a Latinized Turkish alphabet after the republic was established in 1923, kashidas are still practiced in the Arabic and Persian world, passing down this tradition into modern times. The following section of this article discusses the current state of kashida justification and how we can replicate this tradition on mapping platforms and software.



**Figure 1.** Ibn Hawqal Map, tenth century. Some of the kashida-justified labels are shown across the River Nile in the red box of the figure. From the National Museum of Iran Library, via [Wikimedia Commons](#).



**Figure 2.** Ottoman Empire telegraph map, nineteenth century. Kashida-justified labels are placed on several physical features and countries.



Figure 3. Arabic labeling with kashida justification on an 1890 Ottoman map of the Middle East.

### 3. NON-LATIN LABELS IN GIS

THERE ARE SEVERAL FUNDAMENTAL CHARACTERISTICS of Arabic script that differ from the Latin script, including: (1) the right-to-left orientation of text, (2) the ability of individual characters to change their form based on their position within a word, and (3) the use of optional diacritical marks to indicate pronunciation (Kokoschka 2020). While these features were initially viewed as challenging to implement digitally, modern Unicode systems have successfully automated them with minimal errors.

However, despite advances in handling basic functionalities, issues with kashida insertion persist. Kashidas, which are used for text justification, often require manual adjustments due to incomplete support in software like Adobe InDesign and Microsoft Word. Furthermore, not all software applications are fully compatible with the Arabic script display, presenting additional challenges for users.

Since the very early stages of GIS development, questions about label placements and hand-lettering have been important topics of discussion among Western cartographers regarding Latin scripts (Wesson 2017; Gammelin 2022). However, unlike Latin typography, Arabic receives much less attention, and mapmakers have faced continued technical limitations—especially regarding kashidas—when customizing map labels (Benatia et al. 2006). Consequently, while many GIS platforms have historically supported a wide range of common typographic features from the Latin script, they generally disregarded the Arabic script.

However, that has recently begun to change, and we have seen a rise in internationalization within GIS software. For example, in QGIS, certain script-specific design decisions can be made by using Python libraries, which also provides support for building plugins to implement these decisions. Simple commands such as adjusting text orientation are available within the *Labels* panel under the *Properties* pop-up window. Additionally, in recent products such as ArcGIS Pro, Esri now includes an “Internationalization” section in the label properties panel (Figure 4), in addition to Arcade and Python expressions. The “Internationalization” section satisfies the basic requirements to have non-Latin scripts displayed in ArcGIS Pro, offering five options for users to customize text and glyph orientations. However, it can be unclear how to use these options to properly manage labels in different languages, and unfortunately, as of the time of writing, none of these instructions are clearly documented on the ArcGIS Pro [documentation website](#).

Given these internationalization options and their shortcomings, is it possible to use kashidas within ArcGIS Pro? The answer is partially yes. If the label is positioned in a straight line by adjusting the settings in the *Position* section of the *Label Properties* panel, the user can use the option “Spread labels,” (a term that does not correctly describe kashida justification), to automatically generate kashidas (Figures 4–5). Of course, the user has no

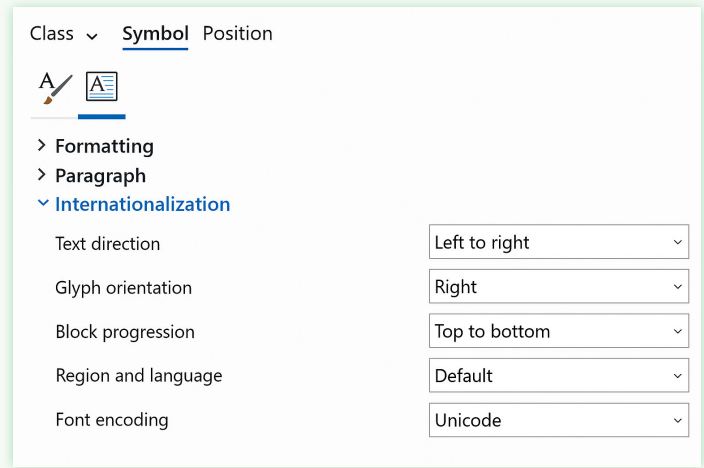


Figure 4. Internationalization options with ArcGIS Pro.

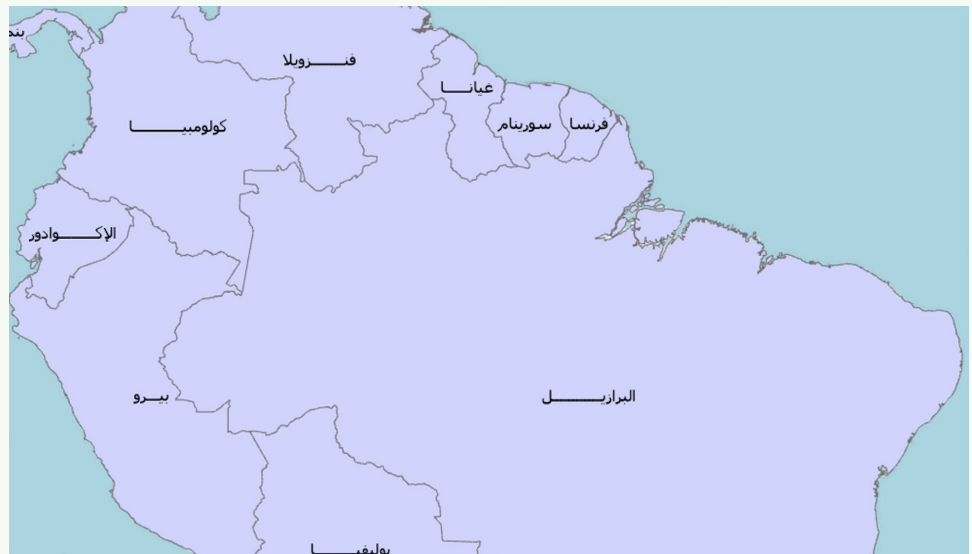


Figure 5. A screenshot of kashida justification enabled by using ArcGIS Pro’s “Spread labels” option in the *Label Properties* panel.

freedom to adjust the location and length of the kashida on the labels. Additionally, the label engine cannot generate kashida on a curved label, even if the user enables letter spreading.

Another approach is to build and improve typographic models based on contextual linguistic structures. Chinese labels are typically composed of a few characters arranged in a vertical position, with ample space separating characters. Based on that characteristic, new methods have been designed to place Chinese labels specifically for line features and polygon features to ensure that a label can be spaced over a feature, while another label can cross the space between characters (Cheng et al. 2013). A similar principle can be adapted to Arabic typography using

kashidas—elongation strokes used to justify or stretch Arabic script without altering meaning. Like the spaces between Chinese characters, kashidas offer flexible space within words that can be adjusted to optimize label placement. By calculating and dynamically adjusting kashida lengths, we can create typographic models that not only enhance the aesthetic alignment of Arabic labels along

linear features, but also make room for adjacent labels. Lastly, emerging plugin development, as demonstrated in QGIS’s handling of non-Latin text, can provide tools for Arabic-specific text customization. Libraries like *kashida* or *HarfBuzz* can further improve font rendering and compatibility (Bhonsle 2022).

## 4. A NON-GIS WAY TO HANDLE KASHIDAS?

SINCE IT REMAINS CHALLENGING, AND OFTEN IMPOSSIBLE, to perfectly replicate kashida justification within GIS platforms, perhaps the most straightforward solution is to approach this as a graphic design problem. Below, we outline practical methods for handling kashidas through font styling. First, though, we provide some general recommendations for using kashidas.

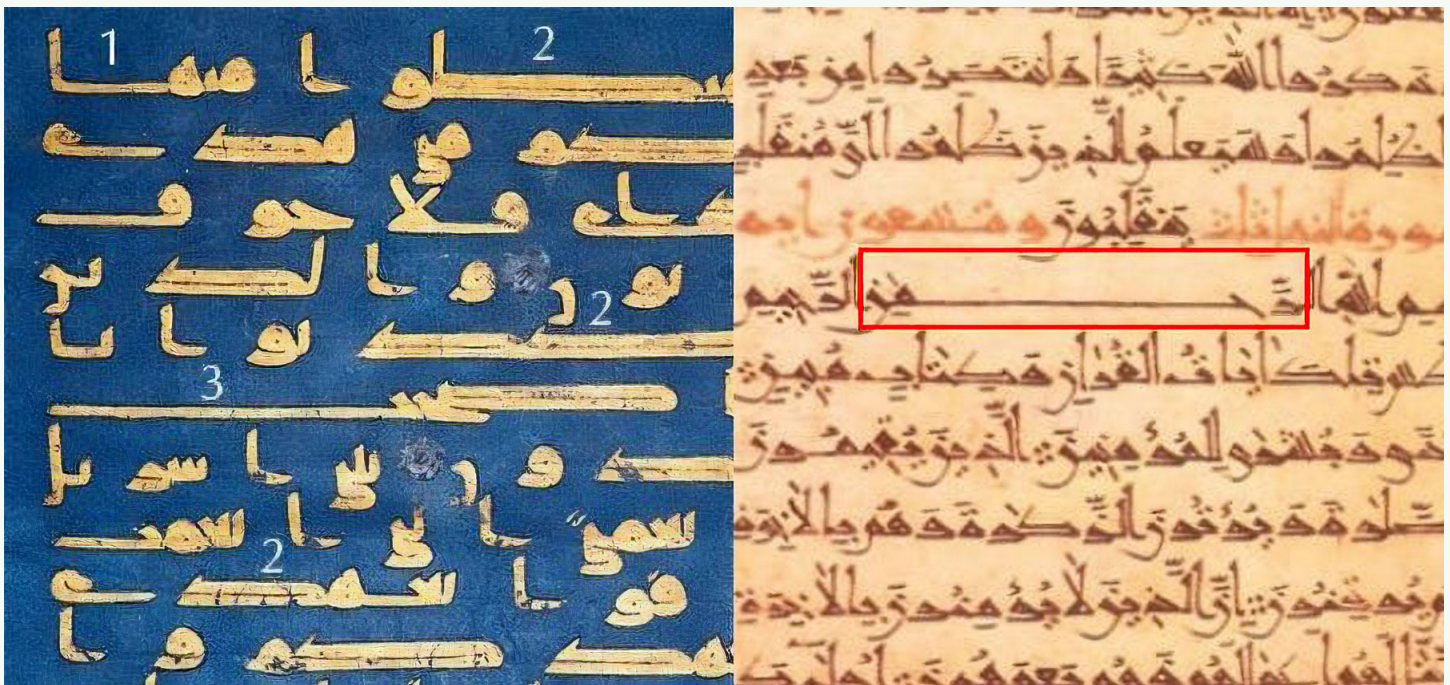
Stretchable (kashida)	Non-Stretchable
ض ص ش س خ ح ج ث ت پ ب غ ع ی ن م ل گ ک ق ف ظ ط	ا ژ ز ر ذ د

**Table 1.** This table presents Arabic and Farsi/Dari letters.

### RECOMMENDATIONS AND PRECAUTIONS

In Table 1, we present the letters that can be written with kashidas and the letters that can’t. For those unfamiliar with the Arabic script, subtle variations can be difficult to spot, so we recommend the following validation methods:

- Consult a native speaker of a language that uses the Arabic script (Persian, Arabic, Urdu, etc.) to review the work.
- Generative AI language models and web-based Arabic calligraphy generators can also assist in replicating the flexibility of this elegant writing system.



**Figure 6.** Kashida justification is more commonly found in the Kufic script (left, *Blue Qur’ân*), but it can also appear in other scripts. On the right, in the Naskh script, a kashida is inserted into the word *Rahmân* (red box), a sacred title of Allah, to indicate the beginning of a new chapter (*sura*) in the *Qur’ân* (Medlej 2021).

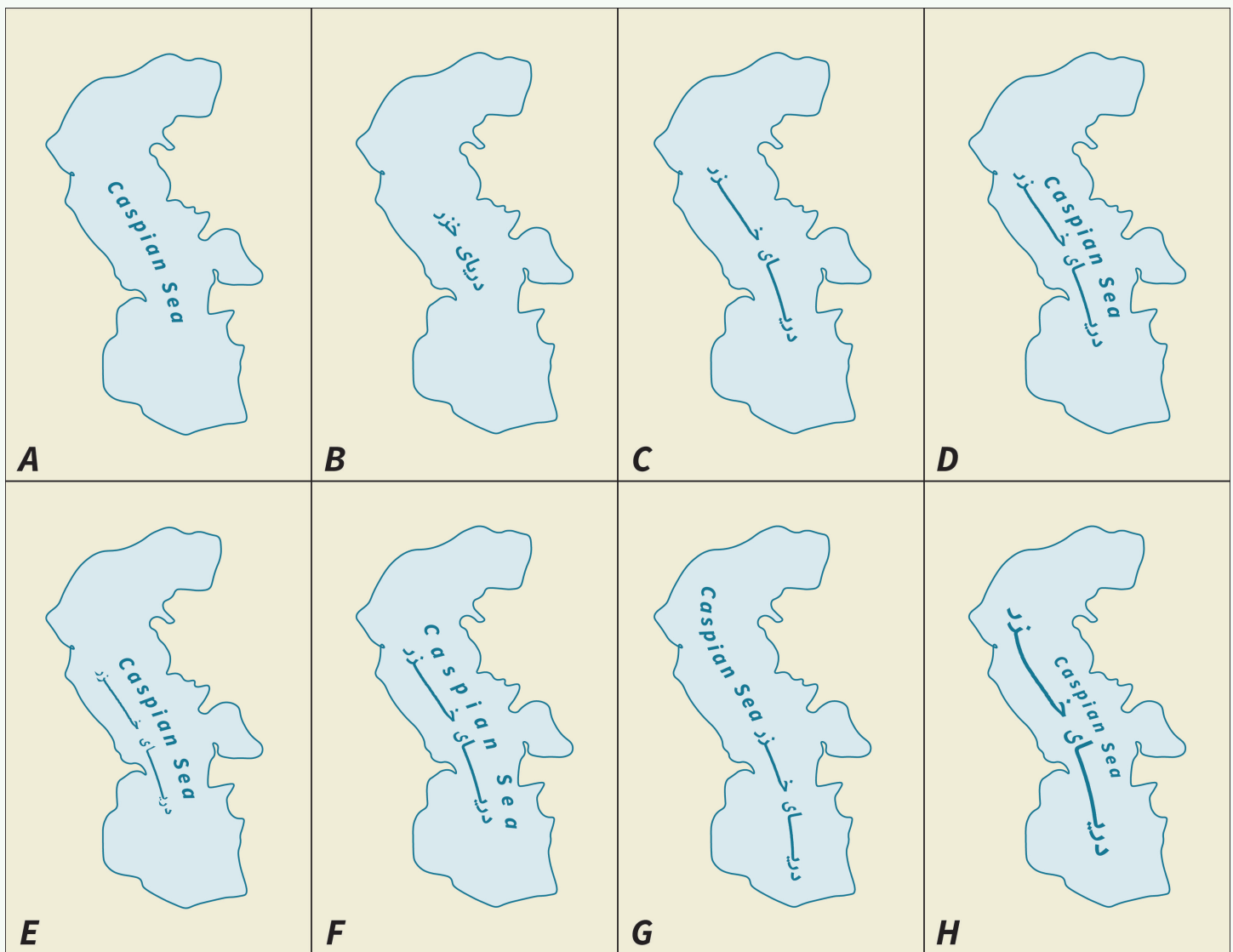
- Check similar maps with the same keywords in Arabic styles and carefully examine their kashida placements.

As we previously discussed, automatically placing kashidas can be challenging due to several characteristics. First, certain letters, such as **ب**, **و**, and **ر**, cannot be elongated with kashidas. Second, kashida placement should not be over-used: it is important not to use kashidas in every potential place that it can be added. Adding kashidas to very short words or in positions that do not represent a natural break is not recommended, as this can reduce readability. Third, the use of kashidas is heavily dependent on calligraphic styles. They are more commonly found in texts written in the Thuluth and Kufic styles, both of which are often used

in ornamental religious contexts. However, kashidas are rather uncommon in Nastaliq, Diwani, and Naskh styles (Figure 6), as these scripts rely on smooth and flowing strokes (Naeem et al. 2021). Fourth, it is also important to remember that kashidas must be placed within words, not between words, and they should not be used on isolated letters.

### MANUAL PRACTICES

Technically, there are ways to manually overcome the limitations of ArcGIS, which does not automatically include kashidas on curved labels. One approach is to use Adobe Illustrator. By using the pen tool to draw a curve, cartographers can easily apply Arabic text along curved



**Figure 7.** Variations on labeling the Caspian Sea. (A) Label in English with tracking applied, (B) label in Persian, (C) label in Persian with two kashidas, (D) label in Persian with kashidas and in English. The bottom row shows map label placement in both scripts but with a different label placement strategy in each example.

lines. They can then manually insert kashidas between letters by typing the kashida character (Shortcut: Shift + J) using an Arabic keyboard. Alternatively, the *Glyphs* panel in Illustrator may be used to locate and insert a manual kashida character from the font being used. However, the cartographer should remember to observe the precautions and recommendations mentioned earlier regarding proper kashida placement.

In Figure 7, we offer an example of labeling the Caspian Sea in Persian. In Persian, this feature is written as دریای خزر (Daryâ-ye Khazar, Khazar Sea). Thus, if we compare how the label is placed in English (Figure 7A) and in Persian (Figure 7B), we notice that it is harder to fill the vast polygon area of the Caspian Sea using the Arabic script than it is using Latin characters to which some tracking has been applied.

In this scenario, we can include kashidas to make the map more visually pleasing. Then, the question is where to place them? In the word دریای (Daryâ-ye), the characters د and ر cannot be given kashidas (Table 1). But notice the middle portion یا, composed of the interconnected letters ی (yâ) and ا (alif). While ا cannot be given a kashida, ی is a letter that normally extends to the next letter on its left (the ا in this case), and it can be given a kashida.<sup>1</sup> So, the best, and only, location to place a kashida within دریای (Daryâ-ye) is within the portion یا. Similarly, in the next word خزر (Khazar), we can extend the line connecting the first letter خ to the left, creating a kashida. From these examples, you can observe that the essence of the kashida is to simply extend lines that already exist in the script. With this approach, we add two kashidas to elongate دریای خزر (Figure 7C).

If the map requires labels in multiple scripts, ensure consistency in character and paragraph styling across all scripts, with similar weight and placement (Figure 7D). Even when using a typeface that supports multiple scripts, visual inconsistencies can arise due to differences in text orientation, thickness, height, letter spacing, justification, serifs, and more. This is a common issue that occurs when placing English text alongside other scripts. When pairing it with Arabic script, it is important to appropriately adjust the tracking of the English text and the kashidas of

the Arabic text, to maintain visual harmony. Figure 7 also provides several additional examples:

- **7E:** When comparing English and Persian labels, it is evident that the Persian label is significantly smaller than the English label and is less legible. However, this is not necessarily a problem if the map primarily targets English speakers—just as 7H offers an example of showing the Persian label larger and English label smaller, a reasonable choice for a map for Persian speakers. Additionally, the Persian label uses a cursive pen style in stroke endings that doesn't pair as well with the sans-serif style of the Latin characters used in the English label.
- **7F:** Compared to the Persian label, there is excessive tracking in the English label, making it less aesthetically pleasing. However, unlike the previous example on legibility, letter spread is subjective and does not follow a universally recognized design principle.
- **7G:** Both scripts are placed on the same label line. This practice has been commonly used in published maps in the Arabic and Persian-speaking regions. It is also a valid label placement design.
- **7H:** Compared to the English label, the Persian label is larger and more spread out. This practice can be applied when the primary audience of this map is in Persian-speaking places, ensuring the Persian label is recognized more quickly than the English label in this context.

## OTHER SCRIPTS?

The visual harmony created by kashidas between letters effectively fills empty spaces on maps and suggests opportunities to apply this technique in labeling other scripts, extending horizontal strokes between letters. Other forms of similar justification exist in Devanagari, Thai, Tibetan, and Syriac scripts. Similarly, Abi Aad (2013) examined stroke-connecting practices in East Asian calligraphy, such as in traditional Chinese and Japanese works, and envisioned ways to incorporate kashidas into Latin scripts.

1. The letter 'ی' at the end of 'دریای' is in its isolated form, following the 'ا' in 'یا'. The letter ی takes on different shapes depending on its position within a word. For instance, it appears as ی in isolated form, ی in initial position, ی in medial position, and ی in final position, illustrating its position-dependent contextual forms.

## 5. CONCLUSION

BEFORE THE SPREAD OF DIGITAL MAPPING, THE PRIMARY tools for traditional cartography across Eurasia were paper, rulers, and pens. These instruments allowed for customizable configurations of map labels. However, the digital mapping and publishing technologies which replaced them were invented in the West and still reflect Western epistemologies. Western-led GIS software and platform development tends to prioritize typographic practices dominated by Latin scripts (Kokoschka 2020).

While technical challenges currently limit the replication of kashidas, the practice of kashida justification remains prevalent in modern Arabic and Persian mapmaking.

For instance, Iranian maps continue to extensively utilize kashida justification, driven by state-led cartographic production, institutions, and printing efforts (Figures 8–9). Various studies have also explored possibilities for implementing more dynamic justifications in Arabic typography (Bayar and Sami 2011; Azmi and Alsaiani 2014).

Kashida justification is renowned for its elegance and beauty. We hope that the methods proposed here serve as temporary solutions and that, eventually, kashidas can be automatically applied across various label placements within GIS software and platforms.



**Figure 8.** Kashida justification used in a map of Iran under the Safavi Dynasty. This map was published in 1970 by Sahab Geographic and Drafting Institute.



**Figure 9.** Kashida justification used on the labels of Persian Gulf, Arabian Sea, Caspian Sea, etc. in a printed map of Iran for sale. This is a recent map published by Andishe-Kohen Publications, located in Tehran.

## REFERENCES

- Abi Aad, Antoine. 2013. "Applying Arabic Kashida to Latin Letters in Display Typography." [https://www.typoday.in/2013/spk\\_papers13/antoine-abi-aad-typographyday2013.pdf](https://www.typoday.in/2013/spk_papers13/antoine-abi-aad-typographyday2013.pdf).
- Azmi, Aqil M., and Abeer Alsaiari. 2014. "A calligraphic based scheme to justify Arabic text improving readability and comprehension." *Computers in Human Behavior* 39: 177–186. <https://doi.org/10.1016/j.chb.2014.07.003>.
- Bayar, Abdelouahad, and Khalid Sami. 2011. "Towards a Dynamic Font Respecting the Arabic Calligraphy." In *Handbook of Research on E-Services in the Public Sector: E-Government Strategies and Advancements*, edited by Abid Thyab Al Ajeeli and Yousif A. Latif Al-Bastaki, 359–388. Hershey, PA: IGI Global. <https://doi.org/10.4018/978-1-61520-789-3.ch028>.

- Berry, Daniel M. 1999. "Stretching letter and slanted-baseline formatting for Arabic, Hebrew, and Persian with ditroff/ffortid and dynamic PostScript fonts." *Software: Practice and Experience* 29 (15): 1417–1457. [https://doi.org/10.1002/\(SICI\)1097-024X\(19991225\)29:15%3C1417::AID-SPE282%3E3.0.CO;2-F](https://doi.org/10.1002/(SICI)1097-024X(19991225)29:15%3C1417::AID-SPE282%3E3.0.CO;2-F).
- Benatia, Mohamed Jamal Eddine, Mohamed Elyaakoubi, and Azzeddine Lazrek. 2006. "Arabic text justification." *TUGboat* 27 (2): 137–146.
- Bhonsle, Archit Sachin. 2022. "Generating Datasets with Glyph-level Annotations for Devanagari Text Recognition." In *2022 5th International Conference on Advances in Science and Technology (ICAST)*, 83–87. Piscataway, NJ: IEEE. <https://doi.org/10.1109/icast55766.2022.10039665>.
- Bittner, Christian, and Georg Glasze. 2021. "Who maps Middle Eastern geographies in the digital age? Inequalities in web 2.0 cartographies in Israel/Palestine." In *Media and Mapping Practices in the Middle East and North Africa: Producing Space*, edited by Alena Strohmaier and Angela Krewani, 45–70. Amsterdam: Amsterdam University Press. <https://doi.org/10.2307/j.ctv1hw3z0w.6>.
- Cheng, Boyan, Qiang Liu, and Xiaowen Li. 2013. "A Cartographic Labeling Method in Chinese Characters." In *International Conference on Geo-Informatics in Resource Management and Sustainable Ecosystem*, 296–303. Berlin: Springer Berlin Heidelberg. [https://doi.org/10.1007/978-3-642-41908-9\\_30](https://doi.org/10.1007/978-3-642-41908-9_30).
- Doctor, Raiomond, Alexander Gutkin, Cibu Johny, Brian Roark, and Richard Sproat. 2022. "Graphemic normalization of the Perso-Arabic script." In *Grapholinguistics in the 21st Century—2022*, 315–76. Brest, France: Fluxus Editions. <https://doi.org/10.36824/2022-graf-gutk>.
- Gammelmin, Janne. 2022. "Type on maps: Legibility in typeface design for topographic maps." Master's thesis: Aalto University.
- Karamustafa, Ahmet T. 1992. "Introduction to Islamic maps." In *The History of Cartography. Volume 2, Book 1: Cartography in the Traditional Islamic and South Asian Societies*, edited by J. B. Harley and David Woodward, 3–11. Chicago: University of Chicago Press.
- Kokoschka, Alina. 2020. "'The Script Does Not Respond'—Arabic Script's Difficulties in the Digital Realm. A Visual Approach." *CyberOrient* 14 (2): 38–63. <https://doi.org/10.1002/j.1804-3194.2020.tb00002.x>.
- Medlej, Joumana. 2021. "Creative Arabic Calligraphy: Kashida, Ta'jīm, and Tashkīl." *Envato tuts+*. <https://design.tutsplus.com/tutorials/creative-arabic-calligraphy-kashida-tajim-and-tashkil--cms-23240>.
- Naeem, Ayesha, Amna Chaudhry, and Banafsha Rajput. 2021. "Infusion of Calligraphy in Modern World of Design." In *International Conference on Computational Intelligence and Knowledge Economy (ICCIKE)*, 192–197. Piscataway, NJ: IEEE. <https://doi.org/10.1109/iccike51210.2021.9410790>.
- Shafir, Nor. 2016. "Mapping the Medieval World in Islamic Cartography [Audio podcast]." *Ottoman History Podcast*. <https://www.ottomanhistorypodcast.com/2016/01/islamic-cartography.html>.
- Sun, Qun, and Haiyan Liu. 2021. "Digital Cartography." In *Advances in Cartography and Geographic Information Engineering*, edited by Jiayao Wang and Fang Wu, 327–54. Singapore: Springer Singapore. [https://doi.org/10.1007/978-981-16-0614-4\\_9](https://doi.org/10.1007/978-981-16-0614-4_9).
- Wesson, Christopher. 2017. "Lettering and labelling on maps." In *The Routledge handbook of Mapping and Cartography*, edited by Alexander Kent and Peter Vujakovic, 346–367. London: Routledge. <https://doi.org/10.4324/9781315736822-30>.



# Creating a Mentor Program

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## BACKGROUND

WHILE SIPPING COFFEE IN CARPETED HALLWAYS OR waiting in queues to refill my cup, I find side chats to often be the most memorable parts of a conference. Don't get me wrong—the presentations, map galleries, and training sessions have their merits—but it's in these informal, in-between moments that pearls of insight often emerge. It begins simply: **someone informally seeks knowledge or clarification from someone with a little more experience in a particular area.** From there the idea grows layer by layer, and these freeform conversations can lead to unexpected insights and surprising collaborations, or even grow into brand-new programs. This article introduces you to one such program. I invite you to read through the full details on your first pass, and note that the bolded portions have been selected to serve as key takeaways for easy review later.

In October of 2021, I attended my first NACIS conference, in Oklahoma City. Due to the COVID pandemic, the organization was trying new a hybrid option that led to a significantly smaller in-person attendance. This reduced conference size benefited me, as I was afforded the opportunity for conversations with many seasoned NACIS folks in small groups, which I find less intimidating. These side chats boosted my confidence in the possibility of a career in digital cartography. At the time, I was a non-traditional student (in my thirties), halfway into a (digital mapping) Master's program at the University of Kentucky, years after my initial BS and MS. Completely changing my career was unnerving. Could I make a major career shift with this degree? Would I be able to get on my feet before my young family was affected, since we needed two incomes to make ends meet? Did I miss the boat by not starting out in cartography in undergrad? **I didn't know anyone who followed my same path, and really needed input from someone with a little more experience.** While in Oklahoma City, I inquired of NACIS

veterans about whether the organization had ever had a mentor program—one that could allow space for me to ask these questions of others. They had not, but did say it was an interesting idea that could undoubtedly gain support.

I myself had previously participated in a couple of rounds of professional mentorship within the local university I worked at. These had given me points of contact to help navigate the university system, and to ask broader questions about the professional world at large. I saw how beneficial it was to have access to a mentor who had my best interests in mind and could teach me tips and tricks gleaned from years of experience. My mentors often helped silence the little voice of doubt in my mind, validating my thoughts, concerns, and direction. I wish every career path was guaranteed a built-in mentorship across its entire arc, and I wanted something like that for my journey into cartography.

Fast forward to spring of 2022, when NACIS put out a call for nominations for its Board of Directors, with a term starting that fall. I ran for the board with a platform containing several ideas, but the one that resonated most with colleagues, and which I most hoped to execute, was starting a mentor program for NACIS members. In the fall, I returned to the annual conference, this time as a newly elected board member. I had a delightful conversation with a member who affirmed the value of and excitement around the program. You never know what those side chats, especially with someone you barely know, can lead to. (Spoiler: months later this person would accept my invitation to co-coordinate the mentor program, enter the brilliant Kate Leroux.)

With that boost of confidence, I returned home post-conference to feverishly craft the beginnings of a program. The immediate dive into the drafting of the program was



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a result of two factors. One was me trying to continue riding the conference energy rather than being depressed at its conclusion for the year; it would take another 365 days before we were all together again. The second factor was that I wanted to have a program proposal ready to discuss before the next NACIS board meeting.

For the initial bones of the NACIS mentor program, I referenced documents from my prior mentorship experiences, because **no one should reinvent the wheel. I copied ideas or processes** that would benefit the program I imagined, and skipped what wouldn't. As the beginning of December rolled around, I was able to share the initial drafts with Kate. **Having a co-coordinator was critical.** This is not to say a program can't be created alone; I just hesitate to recommend it. Collaboration allows for more ideas to be considered, and collaborators can rely on each other's strengths. When I pulled together novel-length documents, Kate was spectacular at making them clear and concise. When I would wander and overexplain, Kate would reel me back in. When a presentation needed to be given, we collaborated until it could all be covered in the right amount of time with supporting visuals. (Insert my eternal thanks to my co-coordinator here.)

After Kate's revisions of the draft documents, we proposed our pilot program to the board in mid-December, aimed

to launch in the spring of 2023. Fun fact, **organizations are usually more than happy to let you create something, as long as you are willing to step up to lead it.** The board was excited about the prospect and gave us feedback on our documents. Having **review and feedback from folks invested in the organization helped keep the program aligned with the organization's own goals.** In mid-January we published the documents online, opened the application survey, and announced the mentor program to NACIS members via email newsletters, Slack channels, and LinkedIn posts.

What you have read thus far is the origin story for the NACIS Mentor Program. It was almost selfish, truly. I wished for access to something that didn't yet exist (others might call this identifying a gap): I, as a student, had questions that I wanted to ask of those more experienced than myself, but didn't feel comfortable outright cold emailing professionals I had never met or only chatted briefly with. I figured I wasn't alone in this matter. Then, in Oklahoma City, I found a unique group of experienced professionals who I had heard would be willing to give input to me and others like me. There just needed to be a structure to bring people together for the implementation of the program based on a few files/documents.

## GENERAL TIPS

IN THE EVENT YOU OR SOMEONE YOU KNOW IS INTERESTED in starting a similar program, I have a few tips to offer regarding the creation of the documents that built the program.

**Tip 1: Take the pressure off by reminding yourself these documents will, and should, continue to evolve in the future.** What is put in ink today need not be set in stone. Acknowledging this permits more freedom in knowing that if something is omitted by accident or misses the target, it could always be altered later. Our short turnaround, which involved launching the program only months after drafting the initial documents, was only possible because of the knowledge that nothing had to be perfect from day one.

**Tip 2: Stay in line with your organization's goals/brand.** These are a great place to launch from when creating the

structure of your program. It gives you a touchstone to come back to and ask yourself: does this structure accomplish or support the overall goal(s)? For our program we focused on two of NACIS's stated objectives (as they were in 2022):

- Promote communication, coordination, and cooperation among the producers, disseminators, curators, and users of cartographic information (from the NACIS constitution).
- Broaden opportunities and inclusivity for underrepresented and historically marginalized groups within the society (from the NACIS DEI Statement).

**Tip 3: Documents are scaffolding for the mentorship relationship, not a full curriculum.** We knew the field of cartography was vast, with many subfields and paths, and

so in order to make the program relevant to all of these variations, we'd have to be flexible in our documents. The program could not follow a strict structure in the way that a degree program outlines specific courses. We also knew we'd have folks who had not participated in a mentoring program before and might like guidance on how mentoring works, in general. Our documents initially included:

- **A Fact Sheet** (two pages): A bulleted overview that described how the program fulfilled NACIS's objectives, outlined goals for the program, described roles for mentors and mentees, listed expectations, listed important dates or deadlines, and gave a dedicated program contact email.
- **Program FAQs** (one page): Here we answered the top ten questions we thought we were most likely to get. Who could be a mentor or mentee? How many months was the program? How many meetings would there be (in person/virtual)? What would it cost (the program was free, to make it widely accessible)? What type of commitment would this require, and could someone exit the program early? What support would pairs have?
- **Handbook** (six pages): This had some overlap with the Fact Sheet and FAQs, but expanded upon responsibilities of both the mentor/mentee, and suggested meeting topics (including goals and guidelines for each meeting, followed by steps to be taken between meetings). Examples can be seen in the sidebar.

**Tip 4: Have a survey** as the application to the program. In my previous mentor programs, there was a formal but basic application to participate. That application didn't ask any questions to get information about what a participant was looking for in the program, or their background, both of which could help in the pairing process. Using a survey invites participants to share their interests and goals, giving organizers the information needed to match mentors and mentees effectively. **Use a mix of fixed response questions and open-ended questions for pairing. Use the same survey for both mentor and mentee candidates.** Open-ended questions give people space to tell their story—what they hope to gain, what they can offer, and why they want to be involved. You'll learn more from a

## AN EXPANDED EXAMPLE OF ONE HANDBOOK TOPIC

### Meeting 1: Introductions

*Goal:* Get to know each other and establish meeting guidelines.

#### Proposed Topics:

- Share information about your life stories to help get to know one another.
- Discuss both of your career and educational backgrounds.
- Discuss how you both came to NACIS.
- Discuss 3 talents/hobbies you have related to your work or your life interests.
- Share mapping projects you're proud of or are working on.
- Discuss your goals and objectives for the mentorship program (i.e., Why do you want to have a mentor/mentee? What made you decide to participate?)

#### Guidelines:

- When, where, and how will we meet that both mentor/mentee will be comfortable? (Whatever meeting platform they prefer.)
- How will we schedule meetings and who will be responsible for setting up meeting links?
- How will we communicate between meetings?
- Will there be any fixed agenda items to discuss at every meeting?
- How will we exchange feedback?
- Next Steps: Schedule date, time, and place of next meeting.

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## ABBREVIATED EXAMPLES OF OTHER HANDBOOK TOPICS

**Meeting 2:** Introductory Career Conversation—discuss or outline the mentee's proposed career.

**Meeting 3:** Career Planning—talk through a 2- or 5- or 10-year plan and how the mentee plans to achieve professional success.

**Meeting 4:** Healthy Life/Work Balance—visit the previous meeting interval plans and how it can be achieved without sacrificing personal/family life.

**Meeting 5:** Identifying Professional Opportunities—identify what professional opportunities would be beneficial to mentee's career goals.

**Meeting 6:** Upcoming Professional Challenges—anticipate upcoming professional challenges and plan as best they can.

thoughtful paragraph than from a simple checkbox. Our fourteen-question survey included:

- Three logistical questions (name, email, time zone).
- Career focus questions that let the respondent pick from approximately twenty options that were based on common responses to previous NACIS conference surveys. Respondents chose one primary focus and were allowed to designate multiple others as secondary interests.
- A few open-ended questions to identify the potential alignments between prospective mentors and mentees (their hopes for the program, personal strengths, and identities or salient lived experiences they optionally wanted to mention).
- An option to share a link to a candidate's LinkedIn profile, resume, or CV, to help in pairing.

**Tip 5: Have a post-program survey to assess participants' experiences.** Remember, the program isn't set in stone, and this is a great opportunity to improve documents and program details. Again, I suggest using the same survey for both mentor and mentee. Some other tips:

- Keep it brief, so that people are more likely to answer it.
- I also recommend permitting anonymous responses so folks can be honest about what might need to change.
- For ease of summarizing data and looking at trends, ask as many quantitative questions as possible (number of meetings completed, average length of meetings, level of comfort in mentor/mentee pairing, etc.).
- It's also helpful to offer a few open ended questions so that you can get sound bites for promoting or modifying the program based on feedback (How was your overall experience? Was anything missing from the program? etc.).
- You may want to ask respondents for their permission to use open ended response questions in future presentations.

- Since one of our goals was to “broaden opportunities . . . for underrepresented and historically marginalized groups within the society,” we included some questions at the end for statistical analysis of the populations being served by the program (gender, age range, education, etc.).

**Tip 6: Draft newsletter and email announcement templates.** This saves time later when communicating with mentors and mentees at key times. You might have one for announcing the opening of program applications, or end of the program approaching, etc. Remember to update these each year so they remain relevant, and store them in a well-organized, shared location so they can be easily accessed and reused in the future.

**Tip 7: Create a brief video or presentation to announce the program.** When a program is brand new, it helps to have a brief summary that you can direct folks to. With social media today, videos or presentations garner more attention than a static document. We hosted our [2023 intro video](#) on YouTube, but you can place it anywhere your goal participants can access it.

**Tip 8: Create a program timeline backwards.** We started out knowing we wanted to summarize the final survey information for a presentation at the NACIS annual conference in October. October is also when members roll on or off the board, so it would be convenient to have the program wrap up around that time. Working backwards from that date, and incorporating personal schedules of the program coordinators, we determined rough deadlines. For example, we wanted one month to review the post-program survey. But before that, we would need to allow one month for people to fill out the post-program survey. And so on. This led us to a start date in the spring, which would allow time for people to hear about the program, sign up, be notified of their pairings, engage in mentorship, fill out the survey, and let us prepare a presentation.

**Tip 9: Have a dedicated email for program communications.** This keeps institutional knowledge and documents in one place as program coordinators roll on or off the program. New coordinators can be given access to the email account as needed. It's also a non-personal email, so folks' private emails do not get bogged down in program communications, and they can maintain their personal privacy.

## PROGRAM FLOW

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ONCE THE BONES WERE ESTABLISHED (OCTOBER–December 2022) our first year flowed from program launch (January 2023) to participants being paired and notified (March 2023), and then to the asynchronous mentoring during March–August 2023. The bulk of our organizing work was completed at the time of pairing notifications in March 2023. With the exception of rare instances of emails from participants (issues in making initial contact with mentee or maintaining consistent meetups), our coordinator inbox was quiet. It was practically crickets, which can really make a person nervous. **You have to accept that sometimes no news is good news.** During the first year, we created a private Slack channel dedicated to the participants. Its intent was to provide a location for them to collaborate, share resources they may have showcased during their meetings, and ask questions. As coordinators, we tried to kickstart conversations by providing thought provoking posts and questions in the Slack, and shared some links to videos or web sites related to mentoring. Again, we heard little but crickets. You may experience this if you have a program similar in structure. **Don't worry, when folks have something to say, they will speak up.** Once the mentoring period was done, the post-program survey (emailed around September 2023) gave us the feedback we needed to understand how the program went during the

period of radio silence from our participants. We received responses from 74% of mentors and 48% of mentees. For specific information on the feedback we received, you can watch the presentation Kate and I gave at the [October 2023 NACIS conference in Pittsburgh](#).

Overall, our first year's feedback survey was mostly positive. It felt good to hear back that, even in its first iteration, the program was considered beneficial by its participants. The richest information came at the end of the survey, in honest responses to open-ended questions: What would folks want done differently if participating again? Did it feel like the program was lacking something? These comments from our participants, combined with our own experiences running the program, helped us as we modified the program details during the off season (October–December 2023). We received excellent feedback not just from the survey, but also from our audience after we presented the survey/program results at the NACIS annual conference in Pittsburgh. Multiple comments from our presentation were incorporated as adjustments for the second year in 2024. I can't express enough how important it is to share your findings so you can get input from the group you are serving.

## PROGRAM ADJUSTMENTS

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ALL OF THIS GREAT FEEDBACK LED US TO MAKE THE following adjustments to the mentorship program.

**Adjustment 1:** We created an **opt-out email template** accessible from the program website. In the first year, a few participants exited the program without notifying their mentor or mentee. We suspected this was due to discomfort, uncertainty about what to say, nervousness around ending the partnership. To address this, we introduced a pre-written email template participants could send to program coordinators when leaving the program without needing craft an explanation. This allows program coordinators to communicate to the counterpart on the mentee's behalf, helping avoid situations where someone was left in the dark. During year two our opt-out email template was utilized, which I consider a success. Even using it once helps ensure that participants feel seen and respected, rather than left wondering or forgotten.

**Adjustment 2:** Many NACIS members requested the mentee portion of the program be open to mid-career individuals instead of only early career. This was requested during informal conversations, in responses on the final survey, and when we presented our results in Pittsburgh. We **opened the program up the next year to both early career (less than five years' experience) and mid-career (more than five years' experience) mentees.**

**Adjustment 3:** Some participants requested two **dedicated private Slack channels (one for mentors only; one for mentees only)** to foster open discussion among the group of mentees or group of mentors. It was also commented in feedback that not everyone wanted another communication app. So, the new Slack channels and group Slack channel remained a means to optionally enhance the program and were not mandatory.

**Adjustment 4:** Mentors and mentees alike felt as though the participant community was very quiet and wanted more community building. So, the next year we **hosted a virtual meeting** in March, to introduce the program, share introductions, and answer initial questions. This kickoff meeting included an interactive slide presentation prepped in advance, but provided space for all to communicate. Presentation contents included:

- An introduction to the program coordinators.
- Guest speaker opportunities for NACIS committees to tell participants about NACIS scholarships, awards, publication opportunities.
- Icebreaker polling questions sprinkled throughout the presentation, with live views of online survey responses for participants. Questions like: where everyone was participating from, single words they hoped to gain from the program (examples: insight, guidance), ranking program benefits in order of most important to least, what folks like about mapping most, and an open anonymous forum to ask questions if they preferred to stay muted.
- A program overview (logistics, resources, mentorship best practices, recommendations from previous year's participants, and participant introductions), which took up the bulk of the meeting.

**Adjustment 5:** After presenting our findings from the first year in October of 2023, the floor was opened up for questions and comments. A NACIS member inquired if the program had given any thought to opening up to small group mentoring. The program coordinators considered how to best implement this option and agreed to incorporate the **ability for participants to indicate if they were interested in one-on-one mentorship and/or small group mentoring** on the next year's initial application, and some participants did choose to use the group format in subsequent years. This adjustment would prove useful in 2024 and 2025, as each year we received more applications from mentees than mentors.

**Adjustment 6:** During the second-year application process, a participant reached out to request their need for an **American Sign Language** interpreter for the kickoff meeting and their virtual mentoring sessions. We reached out to a Sign Language organization in Kentucky known for interpreting and translation. After learning the organization's requirements and confirming it would fit our needs, we signed a contract based on the number and length of meetings. The procedure was fairly simple. We would give a couple weeks of notice of when an interpreter would be needed in a virtual meeting, and forward the ASL Interpreter organization the virtual meeting link. We highly recommend having a contract in place like we did in advance of a request (payments were based on whether an interpreter was requested, there was not a holding fee just to be on reserve) so that when the need arises you are ready to roll to support your participants.

## PAIRING PROCESS

THE DOCUMENTS, TIPS, AND PROGRAM ADJUSTMENTS are all pretty straightforward. The portion that I, as a program coordinator, was most concerned with was having a consistent and equitable structure for pairing participants while still allowing some flexibility for shifting of pairs. The method used for the first two years had three main concepts considered for pairing. First and foremost, we wanted to pair participants based on the interests they indicated in the application survey. The more answers a mentor or mentee had in common, the more likely we thought they'd be a good fit. This included skill-based pairing (based on skills the mentee wanted to develop and the mentor's areas of self-reported expertise) and career goal pairing (what experience the mentor had in the

mentee's goal field). The next area we considered was how well a potential mentor-mentee pair's open-ended responses fit together. The structured multiple-choice questions didn't always paint the entire picture of what participants were seeking, so we looked to the open-ended questions to learn more about what they were hoping for out of the program. Was a mentee seeking someone who recently moved from one field to another? Or perhaps someone who started their own freelance business and could give specifics on business management? Finally, the pairs were narrowed down based on logistics: Did both participants agree to a one-to-one mentorship or small group setting? What time zones were the participants in the proposed pair(s) working across?

The pairing process was conducted by the two program coordinators and a third assisting reviewer. To plan proposed pairings, we found it easiest to use a spreadsheet, with one tab per person. Each tab had the names of the proposed mentor and mentee(s); if it was a group or one to one pairing; time zones; number of commonalities that aligned in the initial survey; and a field for explaining other factors that influenced why that pairing was proposed. One program coordinator would start by reviewing the applicant survey responses, and would then fill in the first tab of the proposed pairings spreadsheet. The reviewer would then assess the proposed pairings, provide their recommended shifts and proposals. Finally, the second program coordinator would review suggested pairs and provide the final participant pairings. Why did we have three people instead of only the two program coordinators? Why didn't we have more than three involved? We found three to

be a happy medium. We had a hard rule that a program coordinator participating in the program themselves (as mentor or mentee) was not permitted to provide input on their own pairing, so having a third person always permitted a minimum set of two eyes to propose pairings and eliminate unconscious bias in the pairing while a coordinator still participated in the program. We could always have had more reviewers, but you have to remember to leave buffer time so that each person has time with the applications and proposed pairs to make thoughtful recommendations. Additionally, we emphasized to applicants that their confidentiality would be protected, so that they could provide us open and honest answers. Confidentiality is easier to maintain when fewer people are involved. But this also is highly dependent upon the folks in the position of reviewing the applications, so be sure your reviewers are capable of maintaining confidentiality as well.

## ADDITIONAL HURDLES

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DESPITE THIS THOUGHT-OUT PAIRING PROCESS, AS well as the level of effort that went into organizing the program in general, there still remain a few persistent hurdles, in my opinion.

**Hurdle 1: The perfect pairing does not exist.** Pairing is certainly a large hurdle to overcome for a program like this. While some matches may be obvious, sometimes a good choice doesn't come out of the survey data. From the perspective of the program coordinator, you may have a lofty goal of pairing every participant no matter what, but I'm here to tell you to watch out for this mentality. Instead of forming pairs that have few commonalities, it can be better to ask folks who don't necessarily have a great match to reapply next year, and prioritize the reapplicants. Keep in mind that it's not a perfect system and there is no such thing as the perfect pairing. Even if a pair looks good on paper, their communication styles, temperaments, or learning styles might end up conflicting. One item of feedback from the 2025 post-program survey was that participants might value knowing why they were paired. Sharing a bit of this reasoning up front might help them find common ground faster and potentially avoid an early disconnect.

**Recommendation:** Try your best, but understand nothing is perfect.

**Hurdle 2: Creating community requires time.** It takes consistent effort and buy-in from many parties, and it's not built overnight. Building a community around an asynchronous program, one that runs only six months, is a challenge I never felt we truly conquered. We attempted to build community with Slack the first two years, though there was little to no engagement. The virtual kickoff meeting that we introduced in the second year was well received, and if routine virtual gatherings occurred with break out rooms, I believe that more community could be built. However, getting numerous folks together for a regular virtual meeting across multiple time zones is tough. The mentoring program itself is already occupying valuable time for both parties, and to get most of them to agree to even more feels unlikely. Plus, with virtual meetings becoming so common post-COVID, folks end up with virtual meeting burnout. The best chance for community building is likely to be found in the group mentoring sessions. Those folks are building more connections than in the one-on-one mentoring sessions, and have more participants to reach out to after the six-month program ends in the future.

**Recommendation:** Don't try to push a new virtual community, and be cautious of providing too much of a time sink for a program that is supposed to focus primarily on the mentor/mentee partnership. Accept that there may be a limitation to how much community can be built around an

ephemeral program. Take comfort in knowing that even if the cohort of participants each year doesn't stay closely connected, a secondary community is continually forming within the organization—built naturally through the ongoing networking and shared growth of mentor—mentee pairs over time.

**Hurdle 3: Recruiting mentors can be tough.** Each year, gathering enough mentors is a huge obstacle. Many folks have interest in being a mentor but not the confidence. When we contacted people individually to encourage them to participate, some replied that they didn't think anyone would want to hear from a person who did not have a degree in cartography or related fields. Some expressed concern that no one would be interested in what they had to say, as they had retired and felt their knowledge was outdated. Others thought they simply didn't know enough to mentor someone else.

Group mentoring did assist in relieving this shortage in our second year. This was a year in which more mentees were interested because of the conversations surrounding the program in the first year, and our efforts to report on it during the off season. This was also the first year that we had mid-career folks as mentees, so we might have lost some potential mentors who had experience, but also wanted to participate as a mentee themselves this time around.

**Recommendation:** Keep the group mentoring. It provides relief for the mentor-mentee imbalance, but also will capture an audience of participants who are not comfortable in a one-on-one setting. Group mentoring should be limited to 2–3 mentees, so as not to overburden the mentor. Know that mentor shortages mean that you might not be able to pair every prospective mentee, and you can instead recommend that they reapply next year, where they'll have priority in getting paired. Seek out additional specific mentors as applications roll in if there's a gap in mentors of a certain field. Some folks just need the personal invitation to apply. Provide a bit of confidence-building into your

communications when recruiting mentors at the same time that you are announcing the program is accepting applications. State things like:

- Mentees benefit from hearing how folks navigated the twist and turns of a mentor's real world career path. It's not just about titles or degrees.
- Mentees often are interested in the historical context and perspective of how a field has changed and evolved. It's not just a discussion about the latest and greatest technological advances.
- If you've ever wished you'd had someone to talk to earlier in your career, you already know how powerful it could be to make this connection as a mentor. It's not about perfection.

**Hurdle 4: Knowledge transfer.** During the first year, a vast portion of our effort went into the development of the program at large. We did not, however, create a firm plan for how (or specifically when) to transfer the program coordinator positions to new leaders, and something like this can severely hinder program continuity. The program coordinator positions need to be rotated among members interested in the growth and longevity of the program, and folks committing to serve should be available for multiple years. This ensures that the program always has at least one coordinator who is knowledgeable about the details, understands the documents and changes each year, and can transfer that knowledge over a period of time to new coordinators.

**Recommendation:** Have a three-year rotation of program coordinators in place, with new folks being aware of the commitment before joining. The first year they could serve as the third reviewer. The second year, they could step up as a program coordinator. Finally, in the third year they can step in as lead program coordinator. And, in their first year out of the program, they can perhaps serve as someone the current coordinators can ask questions of.

## WHY

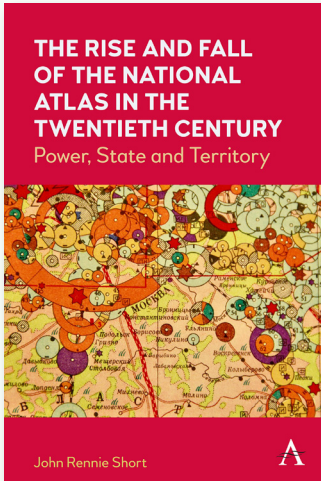
IF YOU HAVE READ THIS FAR INTO THE ARTICLE AND see the path laid out before you of how our program was created, yet you are still hesitating to participate or create one yourself, maybe this last bit will provide some inspiration.

Mentors offer so much more than just advice on the technical aspect of a career or job; they carry with them their life experiences and a wealth of knowledge from simply navigating the world they live and work in. In their post-program survey, many mentees commented about the

*connection* they made with their mentor or group, rather than any technical skills they learned. Not one of them used the survey to rave or rant about the degree their mentor happened to obtain (or lack). If anything, they were more excited about having a mentor who faced challenges and who didn't necessarily have all the answers, because the mentees identified with the mentor in that respect. The uncertainties, decisions, and lessons learned are exactly what they needed to hear. No one needs to have all the answers to be a mentor or to start a mentoring program.

Sometimes, it's just about the effort made in listening to mentees, and asking them the right questions, that can be the most impactful. Just like there is no one traditional cartographic educational/career path, there is no one true way to create or participate in a mentor program. By designing an iterative, evolving mentorship, you can transform the uncertainty of the next mentees into direction for the next set of professionals to empower themselves and discover their own potential.





## THE RISE AND FALL OF THE NATIONAL ATLAS IN THE TWENTIETH CENTURY

By John Rennie Short

Anthem Press, 2022

182 Pages, 55 maps and figures

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**Review by:** Zhaoxu Sui, The Pennsylvania State University

John Rennie Short's *The Rise and Fall of the National Atlas in the Twentieth Century* offers a compelling review and analysis of many of the official national atlases that have been published around the world; presenting pictures of atlas pages as well as stories, narratives, and ideological surroundings, underlying, and extending beyond the atlases themselves. Short—emeritus professor at the University of Maryland, Baltimore County, with research interests that include geopolitics and cartographic representations—draws connections between political institutions, histories, social changes, and the various things each nation has chosen to showcase in their national atlas. In preparing this work, he drew on over one hundred individual atlases, published by nations from around the world and with governments of all forms and ideologies (Figure 1).

It is often said that all maps reflect and express power, and that national atlases are perhaps some of the most explicit of all in making, showcasing, and expressing national agendas. Short, himself, writes that

The national atlas is a complex text. It is a scientific document, a tool of legitimation, a spatial claim, a textual appropriation of territory and an attempt to foster, encourage, and create a national community . . . it is an element in national ideological constructions encased in global scientific discourses. (2)

Short construes a national atlas as a rhetorical expression of the “cartographic power” of the state, a tool that can be

used to envision state territories, consolidate national communities, and administer physical and social landscapes. His construal is supported by studies in critical cartography and critical political geography—studies that view maps not as natural or neutral representations, but instead as made-up arguments revealing the will of political powers, states, or nations.

Although this study primarily concerns national atlases created in the twentieth century, it does not ignore how the genre evolved alongside concepts of nationalism in Europe. Officially sponsored cartographic projects can be traced as far back as the fifteenth and sixteenth centuries in England and France, where maps of cities, fortifications, croplands, and pastures assisted landowners and rulers in administering and defending their realms. These early precursors to modern national atlases are discussed in Chapter 2, “The Early National Atlas,” while Chapter 3, “Cartographic Anxieties and the Emergence of the Modern National Atlas,” carries this history on into the pre-modern era. As European states gradually consolidated and modernized, previously indeterminate frontier zones gave way to territorial claims that were precisely demarcated both on maps and on the ground. This was also, and especially, true in the New World, where the collapse of the Spanish colonial empire gave birth to new states with serious “cartographic anxieties” about their uncertain and often unstable borders. Many of these states enthusiastically embraced the “cartographic power” of a national atlas to legitimize their own territorial claims and challenge the claims of others. Short describes how Venezuela,



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**Figure 1.** A map of the subject countries of the twentieth century national atlases included in Short’s bibliography (159). Map by Zhaoxu Sui.

Peru, and Mexico each encompassed disputed territories in their national atlases and leveraged these depictions to consolidate their national identity—a use of cartographic power to secure territories that is still commonly practiced today in national atlases.

In Chapter 4, “Cartographic Ruptures and the National Atlas,” Short shows that national atlases need not come only from existing national states, but could contribute, as a catalyst and predictor, to the formation of new states. The *National Atlas of Finland*, for instance, was published while Finland was still an integral part of the Russian Empire. It showcased the uniqueness of Finland and served as an expression of Finnish nationalism that harmonized with the growing nationalist movements arising across Europe during the nineteenth century. Similarly, the first *Polish Atlas*—produced during World War I and published in 1918—was displayed at the Paris Peace Conference and was a key reference document supporting the re-birth of an independent Poland. Throughout the century, and across the world, national atlases have come to be seen as crucial documents for all nations, be they newly independent or as-yet aspirational; born of war, revolution, or negotiation. Political ruptures seemed to lead to the production of national atlases.

Chapter 5, “National Atlas,” places national atlases into international discourses. Short points out that almost all twentieth century national atlases tend to conform to a common “mapping language”—a broadly standardized set of conventions recognizable as associated with, and appropriate to, such publications. This standardized mapping language forms an integral part of an international discourse that transcends the readers’ various linguistic differences and cultural backgrounds and frames their understanding of the material presented. He also notes that throughout the century many states published separate versions of their national atlases in English—even when English was not one of that country’s national languages. This, too, is in line with what Short identifies as the international national atlas discourse: as the twentieth century’s most commonly used language, an English version could be accessible to more audiences and communities around the world.

In Chapter 6, “The Physical World of the National Atlas,” the author discusses how states used cartographic power to encircle, manage, and administrate physical spaces. Beginning in the early modern period, writers on a wide range of physical and environmental topics worked to define and refine vocabulary and grammar with which

to describe the natural world. In fact, we can say that through their efforts these people essentially “produced” those sciences. In a parallel development, Short argues that states also came up with standards to describe and constantly construct physical spaces and environments in their national atlases; a process he has described as “a co-production of science and the state” (85). National atlases employ these conventions to describe and explain the changes, alteration, and/or commodification of physical environments through narratives ranging from socialist economic planning in Soviet Union to the deracialization of land ownership in Kenya. These environments and processes, however, are often dynamic and contested, and despite their presentation in any one national atlas, one can find the same physical realities being depicted and labeled differently in different atlases across countries or editions.

Having shown how national atlases constantly construct physical spaces, Short turns, in Chapter 7, to “The Social World of the National Atlas,” the way national atlases have portrayed their own populations in order to “produce” a vision of the country’s human society. For example, he draws attention to certain generalized and abstract maps of social statistics in some early national atlases that purported to address such questions as where “moral” people lived or how diseases spread through particular populations—pointing out that these visual depictions can never be neutral or objective because every step of the collection, categorization, and rendering of the underlying data is filtered through prevailing state agendas. Many statistical atlases, in describing social categories, mixed together races, ethnicities, and languages: for example, he presents a map of South Africa showing classes for both “Afrikaans-speaking people” (a language) and “Native Groups” (an ethnicity). Divisions such as these are more securely based on ideological precepts than on scientific methods. Sometimes the categories do change between editions, but they all demonstrate the way national atlases construct the social landscapes that serve ruling classes’ best interests.

The text closes with Chapter 8—“The End of the National Atlas?”—a short summation followed by a look to the future of national atlases. Despite the decline of printed national atlases in recent decades, the rise of digital publication formats and portals allows Short to anticipate a new trend of producing something that he calls a Polyphonic Participatory Atlas, a step to advance the function of the national atlas as an “ideological state apparatus” (150) and

provide a “participatory portal” (151) to give voices to different peoples that are usually obscured and racialized in traditional top-down state manifestations, an idea very similar to that of participatory mapping.

Throughout this book, Short consistently argues that national atlases are more than mere compilations of maps made by governments. Alongside his comprehensive review and descriptions of the maps and atlases, he engages in a critical analysis of how these maps reflected national wills and agendas, and, by contextualizing their contents and presentations, shows how the atlases themselves modified the construal of the world they supposedly depicted. For example, the 2000 edition of *Atlas Nacional do Brasil* showcases many topics, ranging from capital flows in and out of Brazil to negative aspects of economic development on infant health and mortality. Short argues that the critical examination of the Brazilian economy presented in this edition of the atlas, in the light of the country’s unmentioned domestic and geopolitical situation, is a way to revisit the country under the previous military dictatorship. Similarly, his in-depth analysis of the role played by the early Finnish and Polish atlases in bringing into existence independent Finnish and Polish states after the First World War, works to illuminate the role national atlases played in the emergence of numerous other nation-states in subsequent years.

Short’s comparisons of multiple editions of the national atlas of single countries also serve to uncover patterns of socio-political change. In his Chapter 4 comparison of different editions of the national atlas of Canada, he shows that the privately produced 1905 edition of *The Imperial Atlas of the Dominion of Canada and the World* depicts Canada as a wilderness making up one constituent part of a world-wide British Empire. By contrast, the following year’s edition, now entitled *Atlas of Canada* and produced by the Government of Canada’s Department of Interior, shows Canada as an independent country—highlighting its progress in urbanization and infrastructure while deemphasizing the imperial connection. Short regards this change to be indicative of the gradually changing status of Canada from that of a hard-won British possession to that of a dynamic, diverse, autonomous nation. These kinds of chronological comparisons also exist in other chapters. In the colonial *Atlas of the Gold Coast*, published in 1949, a large percentage of the atlas content concerns export-oriented commodities like cocoa and palm oils, whereas the 1960s era *Atlas of Ghana* focuses on more

everyday goods for the people living there as citizens of free Ghana. Having these atlas contents compared in different years of publishing helps us enrich our understanding of how modern states continuously evolve and adjust such self-perceived properties as territories, goods, and international relations, and how those subtle ideological shifts are captured by political states in these atlases.

Short does not limit his study to national atlases produced in Western countries but heavily discusses those of the many newly independent countries in Africa and Asia. However, the *absence* of twentieth century national atlases of France, the United Kingdom, Italy, Switzerland, and Germany is notable. Is it because these countries do not publish national atlases, or did Short simply not, for some reason, care to discuss them? Given that these countries were technical, colonial, and/or ideological leaders of modern Western cartography, one suspects that a discussion of the evolution of their national atlases in these countries would be intriguing or at least deserving of mention.

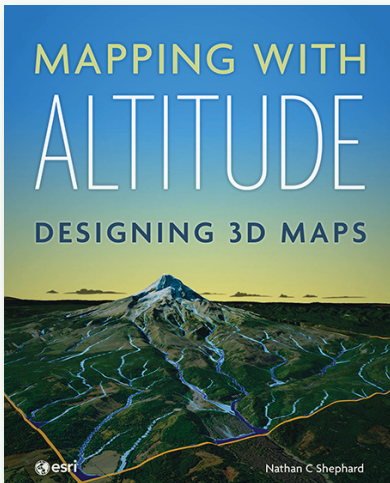
There is little discussion in this book of the dramatic technical transition cartography underwent over the course of the twentieth century. The carefully crafted and drafted handmade maps in prestigious national atlases were effectively superseded by the products of digital technologies, as were the processes of collecting and collating the underlying physical and social source data. Short briefly

mentions this finding in his last chapter, but this transition deserves—along with the role of the state in regulation and censorship—to be more carefully examined in its material contexts.

Similarly, this also leads into the challenges Short introduces in his last chapter — the one about the future — such as envisioning a more interactive and participatory format for national atlases. I anticipated learning more on how the increase of digital literacy among people and government officials influenced their national atlas map-making decisions and how national atlases could carve out their own niche—defining the purposes and audiences to be served in this new era of digital maps, and the contributions they can make to contemporary discourse.

In general, *The Rise and Fall of National Atlas in the Twentieth Century* is an enlightening read for cartographers, geographers, historians, and anyone interested in maps and geopolitics. It spans multiple knowledge disciplines from history, sociology, geography, and geopolitics, offering comprehensive observations and critical analysis about national atlases as projects condensed of political wills. It also inspires atlas collectors like me to revisit and compare atlases published by states, marking every cartographic design decision and every text to uncover deeper messages behind these pages.





## MAPPING WITH ALTITUDE: DESIGNING 3D MAPS

By Nathan C. Shephard

Esri Press, 2024

280 pages

Softcover: \$84.99, ISBN: 978-1-58948-553-2

eBook: \$84.99, ISBN: 978-1-58948-554-9

**Review by:** Shivanand Balram, Simon Fraser University

WE LIVE IN AN INHERENTLY THREE-DIMENSIONAL (3D) world, yet traditional cartography has been predominantly organized around two-dimensional (2D) maps. In this new book, *Mapping with Altitude: Designing 3D Maps*, Nathan Shephard makes the case that the evolving complexity of the modern world, together with advances in digital mapping technologies and the demand for more immersive use cases, has now made 3D maps increasingly useful, relatable, desirable, and perhaps even necessary, to both technical and non-technical users. Shephard's goal is to “catalog and explain the many challenges and opportunities available for today's new generation of 3D cartographers and to define a series of general rules that can simplify the many design choices available” (vii), and he draws on his extensive experience as a project team leader working in 3D—and even 4D—research at Esri to deliver an informed view of the theoretical and practical aspects of this topic.

Each of the book's sixteen chapters draw on principles from 2D cartography to provide a strong conceptual basis for understanding and explaining 3D maps, presented in easily digestible portions of content offered at a level of detail calculated to keep the reader engaged. The ease of understanding each chapter is enhanced by text boxes highlighting important concepts, copious colour illustrations, a chapter summary, and (for some chapters) key tips. The author makes his case for 3D maps in Chapters 1 and 2, using examples to illustrate some of the new affordances 3D renderings create, such as vertical/elevation

information and the capability to move around the digital scenes as one would navigate in the real world. The inevitable challenges related to scale, projection, hidden content, and scene navigation are also identified and discussed.

In Chapters 3, 4, and 5, he progresses to the structural components of 3D scenes and maps. While 3D maps in many ways resemble 2D maps—panoramas or birds-eye views, for example—3D scenes are more like stage sets or immersive environments, providing a digital world with realistic (physical models and rendering), thematic (cartographic themes and styles), and mixed-reality (combinations of realistic and thematic) content types where the user is able to wander around and explore the inside of the world presented. Cartographic 3D products can be output as either static or interactive maps or scenes, or as scripted animations. As an example, both static maps and static scenes can be output as 2D images but the scene can also be output as a physical 3D model using a 3D printer. These chapters also address the variety of considerations that must be kept in mind when deciding which outputs would be the most appropriate.

Chapter 6 provides a comprehensive overview on how digital surfaces or meshes serve as the foundational building blocks underlying every scene, on top of which the other content is rendered. Various surface types, such as elevation, as well as thematic or statistical surfaces, are discussed; including their attributes such as visual quality and display performance. The role of traditional cartographic



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effects such as exaggeration, offset, extruded elevation, hillshading, and transparency are all contextualized within the 3D environment.

In Chapters 7 through 12, the discussion moves through the various ways that visual content can be displayed in a scene. These chapters are focused on the technical and creative challenges that arise from the key concerns for data resolution, visual seaming effects, and connecting multiple levels of detail. At a fundamental level, content can be displayed by *draping*—where vector and raster spatial data layers are overlaid on the scene, conforming to the elevations of the surface—and one can also drape text and labels to, for example, support navigation in these virtual worlds. The need to represent 3D objects verisimilarly, so as to bring the 3D world closer to reality, constitutes the next level; and this is where the familiar cartographic geometry types of location points, linear paths, and polygon areas come into focus. In 3D scenes this basic set of geometries expands to create 3D models formed by an integrated collection of modelled faces. Anchor points play a crucial role in locating objects in this 3D world—defining their position, say, above a defined base height and in relation to subsequent deformations arising from viewpoint changes and scaling as one zooms in and out. Once a 3D object is represented, it can be symbolized in multiple different ways to improve the map’s message and storytelling. The object’s form—its shape, extrusion, rotation, scale, texture, and colour—can be defined and edited, and further refined by tweaking dimensions such as transparency, highlighting, and shading, as well as applying a photograph or other image texture to its surface. Animated symbols capturing changes and movements can also be used to increase the level of realism experienced by an end-user navigating the immersive 3D world. In addition, the book discusses numerous ways to aid clarity and/or navigation in the 3D scene or map by adding, editing, or even animating, the displayed text and labels that appear either in the scene itself or on the interface screen.

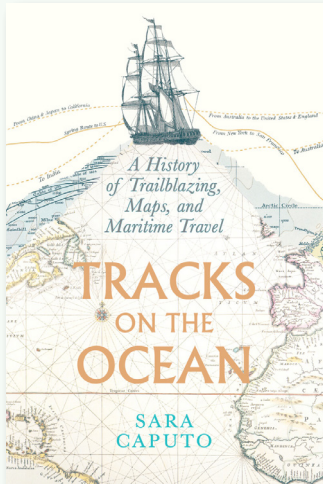
The 3D display discussion extends, in Chapters 13 and 14, to tackling the display of volumes and to representing time. Volumetric data plays an especially important role in 3D mapping when representing spatial depth, density, and sub-surface structures. There are many display options for representing time, such as static content, individual animated slices, and space-time cubes.

In the final two chapters (15 and 16) the discussion ties back to some of the earlier chapters dealing with the structural components of a 3D scene, but focusing instead on an exploration of the process of combining individual data layers to develop the complete 3D map and effective navigation controls to “better communicate your content to the users” (231). In his “Afterword,” Shephard distills the book’s key messages into six general tips for constructing well-designed scenes, and he concludes with a call to action for mapmakers to know about and use 3D cartography to “explain any data set in the world to any audience in the world” (260).

Overall, this is an excellent book. Shephard has assembled an engaging text that skilfully touches, in effective depth and breadth, on many of the key topics encountered in 3D mapping. The readability of the book is enhanced by clear illustrations, informative highlighted text boxes, succinct chapter summaries, and useful key tips. *Mapping with Altitude* would be suitable as either a reference resource for seasoned cartographers or as a textbook for upper-level cartography students looking to extend their work to 3D representations.

While the book achieves its stated objectives of cataloguing and explaining 3D mapping challenges and opportunities, and of providing some useful design rules, there were a few elements I wish would have been present. First, it would have been beneficial to have an end of chapter list of references and/or citations so that interested readers can pursue further in-depth explorations of specific topics of interest. Second, some interactive and engaging learning assets such as hands-on exercises or website simulations would have allowed readers to have a stronger connection between the conceptual and the practical. Third, it would have been beneficial to have a chapter dedicated to an extended discussion of ethical responsibilities in cartography, with a focus on how they might apply to 3D mapping—specifically: data privacy and security, representation bias, environmental impacts, and the role of artificial intelligence in digital mapping. The lack of these elements does not, however, detract from the excellent overall contribution this book makes to the GIS, cartography, 3D mapping, and spatial visualization communities. Perhaps the author will consider these suggestions when preparing a second edition.





## TRACKS ON THE OCEAN: A HISTORY OF TRAILBLAZING, MAPS, AND MARITIME TRAVEL

By Sara Caputo

The University of Chicago Press, 2024

310 pages, 60 figures, 24 color plates

Hardcover: \$37.50, ISBN 978-0-226-83792-5

Paperback: \$20.00, ISBN 978-0-226-84554-8

eBook: \$36.99, ISBN 978-0-226-83793-2

**Review by:** Eric D. M. Johnson, Virginia Commonwealth University

In *Tracks on the Ocean*, Sara Caputo focuses on the development and meanings of “journey lines” or “tracks”—those representations of individual maritime journeys that began to appear on European maps and charts at the start of the sixteenth century. While she does recount the history and development of these lines as a map convention, she is most interested in exploring the ways that “the ‘track’ has embedded itself in Western understandings of space and movement” as “a practice, a convention and a conceptual and visual device” (3).

In order to take us with her on that exploration, Caputo—senior research fellow and director of studies in history at Magdalene College at the University of Cambridge—has compiled a remarkable body of research that she has cooked down into a relatively brief two hundred pages of narrative. That said, those pages are not an easy read: this is a university press publication written by an academic and, primarily intended for fellow academics. It covers a great deal of territory, time, symbolism, and human conceptions of the nature of space; often dashing back and forth between those ideas within the span of a few paragraphs.

The book is divided into seven chapters. The first offers a relatively straightforward overview of the ways in which the (primarily Western) world conceived of and represented records of travel in ancient and medieval times. Rather than adopting the Euclidean, top-down, “aerial” view we so often use today, the ancient Greeks and Romans instead

“usually saw their surroundings in a linear, ‘path-shaped’ way: from their own point of view” (19). Caputo describes this conceptual approach as “hodological”—experiencing, and mapping, space as “lived”—as opposed to “cosmographic,” where space is “represented.”

In the centuries that followed Classical antiquity—even up to the fifteenth and early sixteenth centuries—the world was primarily depicted hodologically in both text and graphics, and “view from above” graphic representations of individual tracks were not yet to be found. In the late thirteenth century, however, “two separate and decisive innovations prepared the ground for tracks. Within the same decade or so, in the 1290s, we encounter *both* the first proper storytelling route on a map and the first instance of maritime mapping” (35, emphasis in original). The ground is also thereby prepared for the remainder of the book.

In the second chapter, Caputo examines the sixteenth century maps she sees as the earliest identifiable examples of ship’s tracks—representing, for the first time, an individual vessel’s journey on the seas—and further explores their antecedents. She suggests four roots for the emergence of these journey lines: the well-established practice of representing paths and roads on land; the rise of portolan charts, a form of nautical chart characterized by the presence of rhumb lines that trace compass directions; the pictorial tradition of inserting a drawing of a ship in the middle of the sea; and a similar tradition of showing



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journey lines in Asian mapping (although, for this fourth root, the author is careful to tease out the differences between Eastern and Western practices). The remainder of the chapter tells of the evolution of journey tracks and their representation, the pivot from the hodological viewpoint to a cosmographic one, and the challenges of representing journeys taken across a three-dimensional sphere on two-dimensional maps.

Having established that, by the eighteenth century, the ship's track was a well-developed technical tool, Chapter 3 moves from maps to an examination of the history and meaning of the *on-board* practice of recording a ship's journey rather than the after-the-fact recordation outlined in the previous chapter. "The original manuscript line . . . was drawn alongside the voyage—*by* the voyage, we could almost say, as the ship itself turned into a scientific instrument"—and not only a scientific instrument, but an instrument of empire. Thus, "[a] route line was no longer just the means of *representing* human dominion over the seas, but the means of *establishing* it, in real time" (77, emphasis in original). The fraught constructs of "exploration" and "discovery" are examined in detail, as are their attendant legacies of violence against the indigenous populations that occupied the places Europeans so often had seen as "virgin."

The fourth chapter turns away from technical and practical matters of the development of ship's tracks and considers the ship track's role in storytelling—blending, as they do, "the supposed trustworthiness of science with the drama of fiction, the 'objectivity' of instruments with the glitter of personality" (102). This chapter explicates the rise in popularity of maritime stories in eighteenth- and nineteenth-century Europe and the United States and the ways that tracks helped tell those tales, becoming themselves "article[s] of popular consumption" (110). Tracks were well-positioned to make inroads at a time—especially the in the Victorian era—when the sciences themselves were popular in the middle-class public sphere.

Chapter 5 turns again to the practicalities and technicalities of recording tracks, only noting that the emphasis in the nineteenth century changes from "the mapping of territory" to "the mapping of individual behaviour." In other words, "[o]ver the course of the nineteenth century, we witness a major change in the nature and function of tracks: they evolve from tools of surveying into tools of surveillance" (138–139). The work of an individual navigator can

now be judged as individual output. Example maps are offered—from eighteenth-century storms to World War II rescues at sea—in which the track is used by outsiders to examine and question specific choices being made by individual actors.

Chapter 6 concerns the tracks drawn—not by naval personnel, as so many of the previous examples had been—but by laypeople: passengers and crew of steamship lines and other private persons. These would be their *own* tracks, not just those of "heroes, explorers, and sailors" (167). Having introduced steamships to the story, Caputo travels for a while with these new vessels and their modern ability to travel in speedy straight lines, ignoring adverse or calm wind, exploring their meaning and symbolism and their role in slicing up the sea in new ways. She observes that "these weren't simply shipping lanes, but shipping *lines*" (176), set routes running on set schedules for the first time ever. Here, too, we learn about the creation of the Suez Canal and the laying of transoceanic cables—both of which are forms of track—along with their significance to trade and importantly, if briefly, their environmental impact.

The seventh and final chapter further emphasizes the individual, only now the focus isn't on "relatively powerful white men," but is instead those who were so often left off the pages of received histories. This chapter focuses on "put[ting] the track into its context: historically, who got to claim tracks, who didn't, and why?" (192). We spend some time with a look at women's own experiences as track-makers, wayfinders, and participants in the maritime world. Caputo also touches on the indigenous peoples who assisted and at times accompanied the European explorers, in particular considering indigenous seafarers in the Pacific at some length. She concludes by considering tracks as "countertracks": "not only can they be made by new, unintended users, but they can also be *read* by unintended users" (208). Tracks can help a "fresh eye" to see and learn new things, such as the environmental impact of all these ship journeys.

These many stories and ideas are supported throughout the book by a remarkable degree of research in archives, books, and journals spanning sources in English, Italian, Spanish, French, and more. Some 650 endnotes, a good half of which reference multiple works, point to the depth of Caputo's documentary effort. Many of the maps she references are available digitally through URLs included in

the footnotes and credits. There are sixty black and white figures, most of them maps or charts, and twenty-four color plates of particularly significant cartographic works.

*Tracks on the Ocean* offers a good deal of interest to the engaged reader. The sheer scope of the effort is impressive, touching upon two millennia in the history of journey tracks and exploring scores of ideas about what these tracks do and might mean. Again, this work is not simply Caputo's idle thoughts alone: she has pulled hundreds of resources together to support her narratives. Any specific aspect that might interest a given reader—whether it be compelling stories drawn from twentieth-century naval records or the idea that tracks tracing the journeys of the famous fifteenth-century Chinese admiral Zheng He were more illustrations of common sea routes than they were tales of his individual exploits—can be chased down through her endnotes.

Caputo does a lovely job of introducing new ideas through lively historical vignettes, which put individual faces on what might otherwise be abstract concepts. And speaking of illustration, the maps, plates, and other figures she includes alongside the narrative are very well-chosen indeed, bringing to life the ideas she explores and the history she shares. Indeed, several times I found myself wishing I could zoom in, the better to see the wonderful cartographic work being shared to emphasize a given point. (Thank goodness for those URLs in the illustration credits!)

I appreciated, too, the number of themes that threaded their ways throughout the work. She often touched on the ocean as an apparently “trackless” place, expounding on how it was experienced and felt in different eras and by different people. Ideas of exploration and discovery, including how those notions developed and for whom they were so often reserved, helped frame a number of points. That journey tracks were not merely technical or symbolic tools but could and should in fact be considered cultural artifacts is the compelling driver of the whole work.

But all that said, not everything about the book was successful. As mentioned at the outset, this is very much an academic book written by an academic, evidently for an audience of her peers. At times it felt very much that it was written to be in conversation with other specific, perhaps even named, specialists rather than for—as she proposes in her acknowledgments (219)—a broader audience. Perhaps I shouldn't ding a university press publication too

strongly in that regard, but it feels like a missed opportunity to widen her reach.

A few times, too, Caputo seems to promise depth in areas that in fact only got light treatments. The early journey maps of the East, for instance, came up a few times, but she did not explore non-Western mapping in real depth. She also failed to close the deal on some of her arguments: staying with the East, again, in Chapter 2, she mentions Asian maps as one “root” of Western journey maps, but there was no strong evidence of an actual connection offered. Another area that got several mentions but no deep analysis was the environment and its relationship with ships' tracks (real or imagined). It was almost as if she felt—understandably—that it would be improper not to talk about environmental impacts in the twenty-first century, but she failed to assemble the evidence for her ideas about it to the same degree she did for her earlier discussions. This same incompleteness stood out in the lack of discussion of how race and class excluded people “from the club of legitimate track-makers” (198).

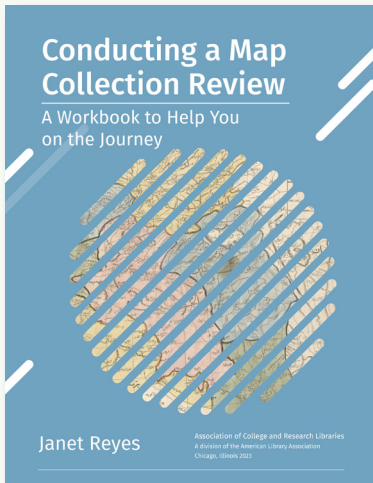
Finally, as a practical book-related matter, I found it frustrating that this deeply-researched book didn't have a standalone bibliography. The endnotes were of the standard form of “first reference gets full citation and any following get a shortened author/title/page citation.” Because she looked at so many works and sometimes circled back to them well after their initial introduction, it often became very hard to find the full publication she was referencing.

At times, too, Caputo failed to give a quick capsule definition of the concepts she introduced. For instance, she wrote, “to some extent, hydrographical tracks were intentionally ‘universal’ (at least within the European world, and its narrow Enlightenment definitions of ‘universality’)” (121) without ever explaining what “Enlightenment definitions of ‘universality’” actually were. Similarly, at one point she writes that Admiral Hugh Cloberry Christian “inevitably acquired a certain reputation as a Jonah among the most superstitious seamen” (142) without ever explaining that a “Jonah” is a person believed to bring bad luck, especially on board a ship. There are also a few examples in which she emphasized in her text the wonderful qualities of a specific map that illustrated a point she was making, but the map itself never appears as a figure; it may be that permissions couldn't be secured, but it is frustrating not to see what she sees.

As impressive a research feat as this book is, and as compelling as many of the points and vignettes are, I found it to be a little *too* broad and scattered to be truly engaging. Caputo jumps from idea to illustration to historical personality and back and forth again, often making it a challenge to follow the main threads of her points. The

book offers a little bit about many things, and as such, many readers will find tidbits that will interest them. But ultimately, it felt like a mosaic built of a large number of glittering or colorful or strikingly textured pieces, but one whose overall picture, when the viewer steps back, can never be clearly made out.





## CONDUCTING A MAP COLLECTION REVIEW: A WORKBOOK TO HELP YOU ON THE JOURNEY

By Janet Reyes

Association of College and Research Libraries, 2023

71 pages

eBook: Free, ISBN 978-0-8389-3943-7

Download at [bit.ly/ACRLMapReview](http://bit.ly/ACRLMapReview)

**Review by:** Jack Swab, University of Tennessee, Knoxville

WHILE MOST READERS OF *Cartographic Perspectives* are well-aware of the decline in print maps, many may be surprised to learn about how many physical maps are discarded by academic libraries every year. While libraries remain the storehouse of our collective memory, many are increasingly conscious of the costs of maintaining “legacy” print collections. In addition to the money needed to acquire physical items and the labor of cataloging them, these materials incur perpetual, ongoing costs for physical storage (including building construction and maintenance, climate and pest control, shelving, etc.). From a budgetary perspective, print collections are costly, making many academic libraries eager to shed unneeded physical items whenever possible.

Map libraries are especially tempting and easy targets for deaccession, more officially called “collection review” projects. Physical maps take up an extensive amount of floor space and many map collections are not fully cataloged. Moreover, with the decline in usage of physical maps in the academy and in society at large, along with mass scanning projects at major map libraries, the reasons for maintaining a physical map collection have declined significantly. The cartographic holdings of many institutions often fall into one of two categories. The first, usually smallest, portion of the collection is comprised of maps of regional/local significance, heavily used maps, and rare map holdings. The bulk of the collection is often made up of maps that are duplicated by holdings in other map libraries (e.g., road maps, USGS topos, and Army Map

Service/Defense Mapping Agency maps), many of which may be readily available online. This second category often takes up significant space while seeing only limited use. Properly stewarding collections like these is a daunting task, and what Reyes seeks to do with this workbook is provide a straightforward approach for how to reassess one’s map collection.

This is an especially significant task—in recent years map librarian jobs have largely been converted to GIS librarian positions, and, increasingly, these employees are coming from non-library-science backgrounds. This often means that the GIS librarian—whose primary responsibility is GIS assistance—also has a secondary role in providing oversight for the physical map collections. There are significant learning curves when transitioning into a library, and there may not be time for new employees to “search the literature” for relevant information and best practices to guide a collection review process appropriately. Indeed, as Reyes notes in her biography, she, herself, falls into this category of a GIS/map librarian without formal library training. Appropriately then, her workbook addresses the needs of this audience and does so well, with easy-to-understand language and helpful tips scattered throughout. The workbook is organized into thirteen main sections which proceed chronologically through the entire review cycle—planning, execution, and conclusion—plus three appendices that provide examples of worksheets and best practices for organizing and executing a physical collection review.



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Reyes has smartly kept many instructions broad and simple, allowing workbook users to adapt these practices to their own needs, while ensuring that users understand the magnitude of the project they are undertaking. She does a good job of highlighting the “out-of-collection” pressures and sticking points in library administration and across campus that might hinder the progress of the collection review. For example, Section 2, entitled “Potential Partners,” helps readers understand which other library employees may need to be consulted (everyone from security to Human Resources). Other parts, such as Section 8 (“Project Planning”) help the reader think through how to plan and allocate staff time to complete the map review in great detail. These are important items to highlight, as map collections often require a significantly large amount of complex work. Map cases can hold—depending on a variety of factors such as map size, rarity, and condition—anywhere from 25–150 map sheets, so even a few map cases could hold thousands of maps, necessitating proper planning and time management. In addition, as Reyes notes, map libraries often have items in many other formats, such as CDs, aerial photos, globes, classroom maps, technical literature, and so on. These different collections require additional oversight to ensure that they, too, are reviewed properly.

As a workbook, Reyes provides useful questions, worksheets, and tables to help users document their local conditions and prompt critical thought about how to undertake the review. This is one of the key strengths of this publication—while there are other texts that delve more deeply into some of these subjects, Reyes provides an easy template through which a librarian can undertake and guide themselves through a map collection review. Moreover, the guide is written in such a way that a reader could utilize specific sections of the workbook without undertaking an entire collection review. While not designed as a primer to map librarianship, aspects of the workbook provide a good overview on how to familiarize oneself with map libraries, with the materials they often hold, and with some of the common processes for managing a physical map collection. It is also possible to use aspects of this workbook to help inform the planning for other major map library projects such as a retrospective cataloging project or the moving of a map library. As Reyes states on the “How to Use this Workbook” page: “Some content may be spot-on for your circumstances; in other sections you may need to modify the approach, or you can disregard what’s offered altogether” (vii).

One point of criticism of this workbook has to do with some of the implicit assumptions that Reyes seems to make. While Section 1 (“Getting Started”) explicitly asks the user to assess the motivation and desired outcomes of the collection review, much of the workbook is built around three unstated assumptions about the results of that assessment. The first—that the collection is being significantly downsized due to pressures for more space—and the second—that the collection will be physically moved to a new space—are broadly safe to make. There are only a few map libraries in the United States actively and significantly expanding their print collections and physical footprints, and collections are generally only reviewed after higher-level decisions are made about the future use of library spaces. Generally then, these decisions are ones that are likely to involve moving and/or discarding at least some maps.

However, her third assumption is that library administrators fully support and recognize the value of physical maps in libraries, and it is this assumption that is most concerning. Libraries, like any other workplace, have their own institutional politics—competing pressures within the library or on-campus may force the map collection to become the flotsam offered in exchange for less impactful cuts elsewhere. Thus, we cannot always assume that administrators have the best intentions for map collections in mind, or even that they have a good understanding of the value a physical map collection has in a digital world. As the workbook is written, the reader starts with a *fait accompli* that many maps will have to go—and the only question becomes one of how to dispose of them efficiently and properly. Even when there is consensus that the map collection needs to be downsized, the individual librarian will be constrained by the conditions under which the review takes place. If there will only be physical space for a third of the existing collection, one cannot save half of the current collection, no matter how valuable or potentially useful one may think it is.

Indeed, map librarians have acknowledged that collection reviews often come with political baggage about the value of physical maps and map-centered employees. Although many collection reviews lead to productive transformation (for example at Arizona State University, which has successfully married its physical collections to its GIS services), some reviews have been shelved or stalled by administrators due to other issues (for example at New Mexico State University, where budgetary constraints

have left a proposed transformation of the map collection in limbo; see Quinn 2022 for more information). There are also “horror stories” about abandoned collections or mass deaccessioning projects, where physical maps become a true afterthought with little direct supervision, use, or existence in a library collection. As universities continue to face budgetary and resource pressures, these neutral or negative outcomes are likely to remain possible. Unfortunately, this workbook provides little insight into how to build support for or justify the importance of a physical map collection in the face of ill-informed, apathetic, or hostile administrators.

Nonetheless, it is important to reaffirm that collection reviews are not always oppositional or prompted by cost-cutting; nor are they always negative—libraries have always reassessed and weeded collections to ensure that they remain useful to the patrons they serve. Undertaking a collection review may free resources to enhance the maps that are retained, and a collection review can be a generative exercise that helps reinvigorate how a map collection positions itself or the partnerships that it has. To this end, Reyes does a good job pointing to the various partners within the library and both on and off campus that can make a collection review a generative endeavor. As she notes, items no longer appropriate for the map collection may be transferred to other library departments, those that the library no longer wants can be offered to faculty studying that area or as gifts to other libraries, and those that no one wants can be offered as paper for the art department or as giveaways to the general community.

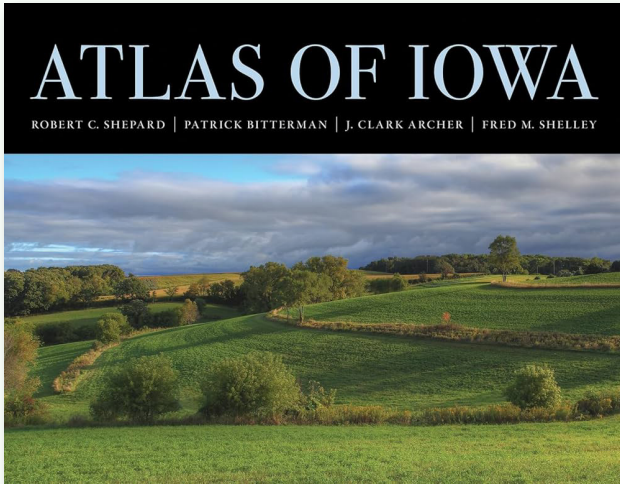
Reyes authored this workbook based on her own experience in successfully reviewing the map collection at the University of California, Riverside from 2018–2019, and to this end the workbook helps to provide an ideal model for what a map collection review can be. To her credit, the workbook provides an extensive amount of “tested” information to help the user execute the collection review with significant autonomy. For example, she highlights the numerous ways that one might construct retention criteria that assess the potential future use for a map based on institutional research interests, the map’s rarity, or other relevant features.

As a whole Reyes has made an important contribution to map librarianship through the creation of *Conducting a Map Collection Review: A Workbook to Help You on the Journey*. Chock-full of tips, useful prompts, and easy to understand language (along with being offered **online for free**), one imagines that this workbook will be used extensively by map librarians in academic settings in the coming years.

## REFERENCE

- Quinn, Todd. 2022. “Here Today, Here Tomorrow: A Case Study of Reviewing a Map Library with Eyes toward the Future.” *Journal of Map & Geography Libraries* 18 (3): 155–167 <https://doi.org/10.1080/15420353.2023.2219072>.





## ATLAS OF IOWA

by Robert C. Shepard, Patrick Bitterman, J. Clark Archer,  
and Fred M. Shelley

University of Iowa Press, 2024

240 pages, 2 color photos, 2 color images, 267 color  
maps, 48 color figures

Softcover: \$39.95, ISBN: 978-1-60938-959-8

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**Review by:** Atlas (Chenxiao) Guo (he/him), University  
of Wisconsin–Madison

DO YOU KNOW IOWA? WHETHER YOU'RE ENTIRELY unfamiliar with the area and looking for a broad overview of its natural and cultural landscapes, or a resident eager to deepen your connection to the state you cherish, the *Atlas of Iowa* is an essential read. This book provides a comprehensive look at Iowa's vibrant tapestry through a spatial and temporal lens. Through the authors' richly illustrated narrative, readers are invited to embark on a captivating virtual journey across Iowa, thoughtfully divided into six well-structured chapters.

The first chapter, "Introduction and Physical Geography," lays the groundwork for understanding the state. It begins by exploring the origin of Iowa's nickname, the Hawkeye State, followed by the histories of some of its higher education institutions, including how they named their athletic teams: University of Iowa (Hawkeyes: honoring Chief Black Hawk, a Sauk leader), Iowa State University (Cyclones: another term for tornadoes), and Iowa Western Community College (Reivers: historical Missouri River pirates). It also examines the symbolism of the state flag and unpacks the possible meaning of the word Iowa, "beautiful land," which is usually believed to originate from a Native American term approximated in French as "Aiaouez." From this engaging introduction, the chapter seamlessly transitions into a concise yet comprehensive overview of Iowa's physical geography. Topics such as landforms and geology, climatology, vegetation and land cover, and renewable energy (particularly wind power) are presented with clarity and precision. The chapter also

provides valuable insights into natural disasters, including tornadoes, floods, and derechos, emphasizing their significant impact on Iowa's landscape and communities.

The second chapter delves into the history of Iowa, vividly brought to life through a rich collection of historical and modern maps. The journey begins over 10,000 years ago, focusing on both prehistoric Iowa and on archaeological sites that reveal pre-contact Native American settlements. It then transitions to the era of Euro-American exploration and colonization that began in the fifteenth century—when Iowa was claimed at different times by both France and Spain—illustrated with historical maps from the Library of Congress. The narrative continues with Iowa's time as a US territory, highlighting its capitals, Burlington (until 1841) and Iowa City (until 1846). Finally, the chapter chronicles Iowa's path to statehood, detailing key moments such as the statehood votes of 1845–1846 and the relocation of the capital from Iowa City to Des Moines in 1857. The chapter explores a wide range of important themes, such as hydrologic systems, population migration, railroad expansion, and the surveying of counties and townships, with thematic maps providing valuable context and enhancing readers' understanding of each.

The third chapter, "Demographics," builds on the historical narrative of Chapter 2 and provides a solid foundation for the human geography topics explored in later chapters. It opens with broad discussions, including county-level population density maps dating back to 1840 and detailed



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census tract maps from the 2020 census. The chapter then examines the age structure of Iowa, highlighting trends in the proportions of residents under 15 and over 65 since 1930. It also delves into Iowa's racial and ethnic diversity, featuring maps that illustrate the distributions of foreign-born Iowans, as well as the Native American, Asian, Hispanic, and Black populations, alongside Iowans of European ancestry. For the latter, particular attention is given to the German, Czech, Scandinavian, Irish, English, and Dutch communities, offering valuable insights into the rich cultural heritage that defines the state's identity.

The fourth chapter, "Agriculture," shifts focus to Iowa's rich agricultural history and evolution, illustrated through county-level choropleth and proportional symbol maps, as well as by line charts. It traces changes in agricultural practices from 1850 to the present, with maps at fifty-year intervals. Topics range from oats and horses to corn, soybeans, wheat, hogs, cattle, and sheep, and provide a comprehensive overview of the state's agricultural staples. The chapter also highlights the Century Farm Program, run by the Iowa Department of Agriculture and Land Stewardship. This program celebrates farms that have remained within the same family for over a century, reflecting the deep roots of agriculture in Iowa. Additionally, it examines the direct and indirect costs of the agricultural system, offering insights into the challenges and complexities of modern farming in Iowa.

The fifth chapter, "Urban and Economic Geography," begins with an exploration of Iowa's transportation networks, including highways, railways, and river routes, highlighting their critical role in the state's development. The focus then shifts to urbanization, examining the growth of incorporated places and the classification of settlements as rural, micropolitan, or metropolitan. Economic themes are visualized through county-level maps of employment trends across eight industry categories for 1950 and 2000, as well as census tract data from the 2016–2020 period. The chapter also delves into income disparities, poverty levels, and both historical and contemporary agricultural trade and processing activities, providing a comprehensive view of Iowa's economic geography.

The sixth and final chapter, "Political, Religious, and Social Patterns," expands the atlas's scope to include various human dimensions. It begins with an in-depth visualization of Iowa's political landscape from 1848 to the present, with detailed maps showing US presidential

election results, congressional districts, and popular vote tallies for the House of Representatives. The Religion section provides a rich historical overview of twelve religions (including denominations), and their spatial distributions across the state. Education is another key focus, with maps depicting school district boundaries, college and university enrollments, and the proportion of the population holding higher education degrees. Health-related topics are also explored, including hospital capacities, premature death rates, and health insurance coverage. The chapter concludes with some examples of modern cultural trends, exploring Iowa's contributions to cycling sports, baseball, literature, and film, demonstrating the state's national cultural influence.

In summary, this atlas provides a comprehensive overview of Iowa, covering aspects ranging from physical geography, history, population, and agriculture to urban development, economy, politics, religion, and society, all viewed through a spatiotemporal lens. The scale of the project is evidenced by the broad coalition behind it—from institutional sponsors to contributing scholars, from state agencies to archival institutions—whose support enabled the years-long process of collecting, designing, and refining the atlas.

Although this is titled as an atlas, the text forms the foundation of its content, rather than the maps. The narrative is detailed and objective, and provides in-depth explanations of the topics it covers. Readers who invest the time and effort to thoroughly explore the text will be captivated by its richness and depth. Notable examples include the examination of Iowa's residents of European descent (Chapter 3), the stories behind the Century Farm Program (Chapter 4), the rise and fall of railway transportation (Chapter 5), and the comparisons amongst Iowans of diverse religious backgrounds (Chapter 6). These sections, even alone, serve as concise and insightful history texts.

Any text-heavy atlas faces the challenge that visually oriented readers who only look at the maps will overlook the accompanying text and thus miss some significant explanatory context, nuance, or even some entire topics. This means that the maps must, by themselves, convey the same narrative—even if somewhat less fully—as accurately and faithfully as possible without textual support, while at the same time minimizing potential bias. From this perspective, the book is undeniably successful. Each map is thoughtfully crafted, with carefully chosen

attributes and symbols, and they are seamlessly integrated within and across chapters. Together, they contribute to the unified theme of presenting a dynamic, comprehensive, and authentic portrait of Iowa, both past and present. The authors' expertise and distinguished reputations in the field are evident in their skillful handling of massive data processing and presentation tasks.

The majority of the visuals in the book are bespoke maps, thoughtfully complemented by a curated selection of rare historical maps, photographs, remotely sensed images, and statistical charts. These diverse elements work together to create a vivid and immersive sense of historical authenticity that adds depth and texture to the narrative. The seamless integration of modern and historical imagery not only enriches the storytelling, but also allows readers to draw meaningful connections between the past and present. There is a unique satisfaction in comparing these custom maps with historical maps and records, and in recognizing their remarkable consistency.

From a cartographic perspective, the book adopts traditional, yet refined, mapping techniques that harmonize effectively with the detailed textual content, enhancing both accessibility and credibility. For example, although many readers may find choropleth maps to be the most visually appealing and familiar way to represent thematic data, in the *Atlas of Iowa* they are exclusively used to represent percentages, while proportional symbols are employed to depict raw data, thus avoiding the potential biases that can arise from normalizing variables by area or population. The authors choose their symbology for each map to prioritize accuracy and strive to minimize distortions, showcasing a balance between aesthetic presentation and faithful representation of the data.

The authors, drawing on their rich expertise in cartography and GIS education (one, for example, is an emeritus professor of geography) as well as atlas production (two had coauthored the *Atlas of Nebraska* and *Atlas of the Great Plains*), applied a relatively traditional approach to represent the data rather than following trends in visual innovation. It seems to me that their intention was to provide a thorough, plain, and enduring reference work; emphasizing accuracy and comprehensiveness over novelty—offering a solid body of documentation that can stand the test of time rather than a showpiece of innovative or experimental forms of presentation.

That they consistently went with more pedestrian cartographic solutions will likely disappoint readers hoping for an atlas employing more creative, novel, or decorative visual styles. Such readers should, however, consider the reasoning behind this choice. While fancy presentations might catch the eye, they are likely better suited as supplements or alternative formats supporting, rather than replacing, the more conventional maps presented here. One must take into account risks that excessively creative designs might hinder accessibility for visually impaired readers or for those with limited familiarity with complex map styles. That said, the lack of creativity might perhaps have been taken too far on some of the maps, many of which rely on default GIS software settings, and show limited graphical refinement. Incorporating visual enhancements—such as improving the clarity of densely populated areas on census tract level maps or applying customized design elements tailored to specific mapping topics—could significantly enhance the reader's experience. Such adjustments would not only make the maps more visually compelling but also improve their usability and interpretability.

Creativity, though, is certainly not entirely absent from the atlas. A large number of custom cartographic symbols are employed on various maps, and their design is both understated and far from rigid. Examples such as the unique symbols used in the tornado maps (Figure 1-11), the innovative combination of proportional point and line symbols to depict population migration (Figure 2-14), the overlay of hydrographic layers on historical place maps (Figure 2-21) and population maps (Figures 5-5 to 5-7), are all well-conceived and refreshing. That said, some tempting opportunities for adding depth and context to the maps were left unexplored, such as careful incorporation of a shaded relief layer or of urban area overlays where appropriate. Notably, the atlas does not rely solely on cartographic representations. Non-cartographic statistical charts play a significant role in visualizing relevant variables and supporting the narrative themes, adding diversity to the visual content and enriching the reader's understanding.

In the concluding section of Chapter 6, the *Atlas of Iowa* extends beyond the traditional geographical atlas topics of topography, geology, resources, and demographics to explore diverse areas such as cycling, literature, film, and baseball, offering fresh angles to appreciate and celebrate Iowa, and adding depth and variety to its

portrayal. It is too bad that the excursion is so brief: inclusion of even more diverse and non-traditional topics as a standalone chapter could have further enriched the atlas. Nonetheless, by concluding with these distinctive themes,

the authors leave both the atlas and the state of Iowa with an open-ended narrative—one that is gently extended by the invitation in the epilogue to continue the story. A truly inspiring prospect!





## THE INFOGRAPHICS LAB 2023–24 ANTHOLOGY

By Erik Steiner, Peyton Carl, Alethea Steingisser, Mack Gray, Eden McCall, Atticus Tong, Jenna Witzleben, Maxim Johnson, Matthew Kauffman, Zoë Kleiner, Lily Lindros, Joanna Merson, Lauren Nguyen, and Clare Otcasek

University of Oregon, 2024

72 pages

eBook: Free (PDF Download)

**Review by:** Chiara Phillips (she/they), Seqana

IN AN ERA WHERE RAPID TECHNOLOGICAL DEVELOPMENT has made it easier than ever to create and share data visualizations, it has become increasingly difficult to assess the level of truth behind them. This has led many cartographers to renew their emphasis on transparent, ethical design—evaluating how accurately and effectively maps convey information, and understanding how and why maps have been, and continue to be, created. By placing these questions of process, ethics, and communication to the forefront, *The InfoGraphics Lab 2023–24 Anthology* reminds readers that cartography is political: the choices cartographers make ultimately shape how knowledge, memory, and place are envisioned and reinforced. This collection of explorations of place, cartographic musings, and firsthand accounts of the University of Oregon’s InfoGraphics Lab’s projects and culture demonstrates that modern cartography can flourish through experiential learning, shared inquiry, and intentional design.

In his “Letter from the Director,” Erik Steiner reflects on returning to the InfoGraphics Lab after a varied and distinguished professional career he humbly describes as a “15-year detour.” It was not only the Lab’s map drawers, oak table, and poster-lined walls that felt so familiar, but also the community of creative, compassionate, talented, and purpose-driven mapmakers forged by its co-founder, Jim Meacham, over the course of three decades. As Steiner explains, the InfoGraphics Lab’s commitment to high-quality research and data-driven design has steered its direction since its inception (2).

Today, the Lab is known not only for its cartographic excellence but also its experiential learning program, where students work directly with faculty and external professionals to help manage and lead professional and academic publications—including *Atlas of Oregon*, *Atlas of Yellowstone*, and *Wild Migrations*—and other ventures such as the interactive works *University of Oregon Sustainability Dashboard*, *Atlas of Essential Work*, and *Interactive Nolli Map* (13). Its success is evidenced not only by the career paths of its alumni—who can be found at prestigious organizations such as National Geographic Maps, the US National Park Service, Esri, and Apple (65–66)—but also by the work featured in the anthology. The Lab empowers members to take ownership of their work and prepare for successful careers—and the anthology is a testament to that.

In the words of contributor Peyton Carl, the 2023–24 anthology wove “the InfoGraphics Lab mission of Data, Design, and Difference into three visual elements that resonate with the theme of ecosystems” (3). For Data, they “chose a colorful mosaic to represent the human influence on our work,” because “people are fundamental to our work, and we strive to make valuable and long lasting connections and impact on our students, staff, and beyond” (3). On the subject of Design, Carl notes that

Trees are used throughout this publication to exemplify the Lab’s commitment to design and to showcase the value of our collective creativity. We



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envision that the roots represent the people that came before us, creating a foundation for current Lab members. Branches serve as a symbol of involvement, the varying disciplines and broadening experience of the team. The leaves of the tree serve as a symbol of outreach and growth of our design values beyond the InfoGraphics Lab and receptivity of others (3).

Finally, the authors “adopted rivers as a symbol to represent the cycle of leadership and interconnectedness of our team and further, how the work of our lab members extends to the support of other efforts” (3). These design elements, as simple as they may seem, highlight the interdependent community that has established the InfoGraphics Lab as a space devoted to cultivating the next generation of cartographers.

Given the Lab’s supportive, inclusive learning community and today’s evolving technological landscape, it is no surprise that the creative process itself is a recurring theme in the anthology. One particularly charming example is the “Slow Data” chapter by Lily Lindros (23–24), in the Data section. In her discussion, Lindros describes her recent turn towards creating what she terms *slow maps*: maps crafted by hand that deliberately take longer to produce than what more efficient technology could enable. Lindros argues that by slowing down both the data analysis and the map composition, she was able to notice and focus on patterns and provide deeper insights into the data she was working with (23).

Lindros was first exposed to slow mapping in an earlier research project examining white flight and real estate practice in Washington, DC. Her role involved mining hundreds of historical property documents to discover, compile, and enter relevant thematic data. Despite the tedious nature of her work, she found that the process of manually reading and sorting through countless deeds allowed her to make connections about individual real estate agents and particular practices that might never have surfaced were she simply analyzing profits and losses. Lindros mentions that while the final map took years to create, it could not have taken the form it ultimately did without her slow, methodical processing of the piles of legal papers. This experience ultimately led Lindros to embrace slowness in other endeavors, such as *Tree Chroma* (Figure 1), a cross-stitched treemap diagram based on photos of a Japanese maple tree in different seasons. Although she



Figure 1. *Tree Chroma*, by Lily Lindros (23).

started by processing her images digitally—reducing the number of colors in each image, and sorting each image’s pixels by color—she then chose to arrange the color blocks manually, before hand-stitching the results. Reflecting on her work as a data practitioner, Lindros states that “it is not only a privilege, but a responsibility, to make sure that my work makes the effort to interact more deeply with what I am representing. And that will always take time” (24).

In a culture where creation is expected to be ever faster, Lindros’s choice to deliberately slow the process down is an important reminder of what can be lost when speed and efficiency are prioritized without reflection. Her approach suggests that patience and hands-on engagement allow for a different kind of relationship to data—one where patterns are not glossed over or obscured but rather emerge gradually, through sustained attention. While it is true that many professional mapping practitioners operate under significant time pressures that militate against such deliberate pacing, and not all tasks that can be automated must be done manually, it should be noted that Lindros is not advocating going slow for its own sake. Rather, she rightfully argues for the adoption of the values of *slow mapping*—namely, close attention to, and the cultivation of, a deeper relationship with data. By redirecting focus from pure speed to depth of understanding, contemporary

cartographers can discover hidden insights that might have otherwise been overlooked.

In other parts of the anthology, that same spirit of reflection extends to questions of cartographic ethics and how cartographers represent place. A clear example of this is Jenna Witzleben’s “Tale of Two Jobs” (59–64), in the book’s Difference section, where the author describes their experience working as a Food Sovereignty Planner for the Burns Paiute Tribe while also working at the InfoGraphics Lab. As part of this work, Witzleben contributed to the InfoGraphics Lab’s not-yet-published *Monumental Denial: An Atlas of U.S. Cultural Memory and White Innocence*, which interprets and visualizes the ways US National Historic Landmarks are chosen and presented to the public so as to uphold narratives of colonialism and white supremacy (59).

Witzleben describes how the team appreciated the opportunity to challenge their own mental models around property and state boundaries. They repeatedly had to consider when to design visuals within the “worldview of the colonial nation-state (in order to depict and critique that worldview) versus when to challenge those white supremacist worldviews and depict an alternative” (59). In one example, Witzleben purposely left out US state boundaries when depicting the traditional lands of the Nüümü (Northern Paiute) alongside the much smaller reservations into which those people were forced (Figure 2). The reasoning behind this was that US state boundaries

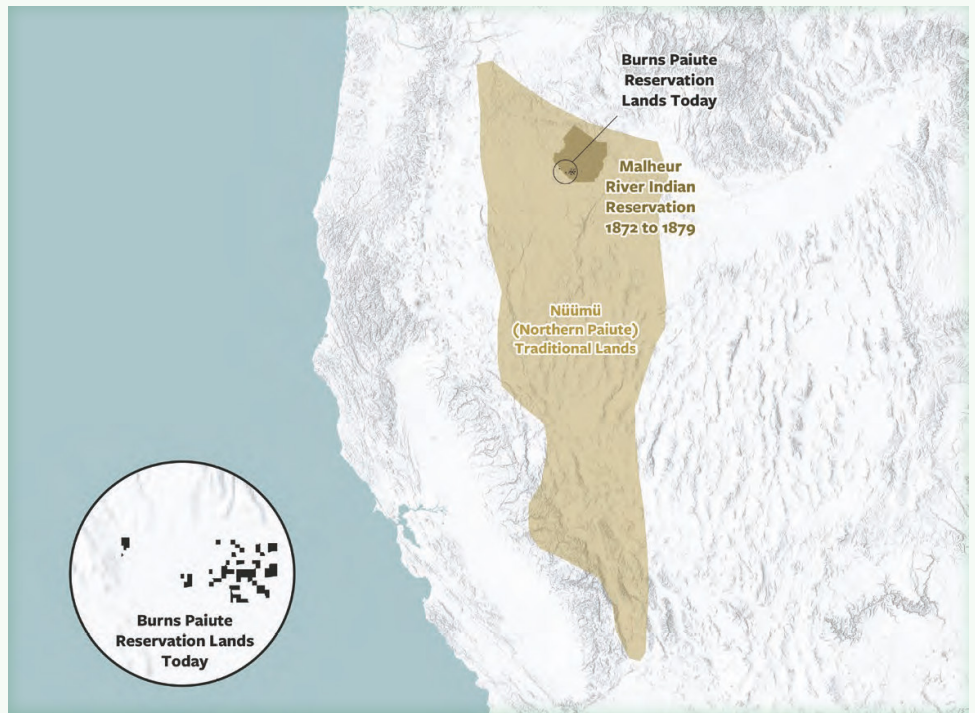


Figure 2. Land Theft over Time, by Jenna Witzleben (80).



Figure 3. Valorization Sites in Wyoming, part of the *Monumental Denial* project (61).

are themselves a colonial artifact and their inclusion would reinforce a colonial perspective (60). On another map—*Valorization Sites in Wyoming* (Figure 3)—the *Monumental Denial* team decided to include state boundaries, as they are closely linked to the processes of settler colonization that they were discussing in that section of the book (61).

Witzleben's thoughtful approach also appears in their *Food Sovereignty Assets* map (Figure 4), which approaches labeling through a different lens; in this case, areas the tribe intended to use for their food sovereignty program were deliberately left unlabeled so as to protect their privacy (60). Witzleben's decision process regarding the inclusion or omission of state boundaries or labels was one of the anthology's more powerful illustrations of the inherently political nature of maps, and how mapmakers can choose to either resist or bolster colonial frameworks. Cartography has the power to disrupt established ways of seeing, a fact which at times sits in tension with its requirement of being comprehensible to its audience who have been taught to see the world in a certain way. This essay, and others throughout the anthology, remind us that in order for mapping to be conducted well, it demands reflection and dialogue.

A quiet but revealing theme within the anthology was the struggle of perfectionism, a challenge shared by students and professionals alike. Though the term appears only twice, its presence was an undercurrent across several pieces in the collection. My impression was that many of the project descriptions could have benefited from a deeper discussion of the map-design process, particularly when critique and revision were noted as important to the final product. This processual opacity might be seen as a reflection of a broader tendency within the field of cartography to showcase polished outputs without also showing the iterative work that produces them. As a general rule, of course, the duty of a cartographer is to communicate messages clearly to end users, and workflows are not typically a part of that message. In this anthology, however—where the intended audience is cartographic peers and educators, and where those very processes are so central to the InfoGraphics Lab's functioning—more space could have been allowed for presenting and discussing the various evolutions many of the pieces went through. Future anthologies could build on this by including examples of early drafts or reflections on specific critiques alongside the final products. Such inclusions would be a valuable resource for education, for normalizing imperfection and iteration, and for fostering a culture of trust and openness about the realities of creative labor.


*Cartographic Perspectives* has been informed that the "Food Sovereignty Assets" map has been withdrawn from *The InfoGraphics Lab 2023–24 Anthology*. Readers may consult the updated *Anthology* PDF for further information.

As this map no longer appears in the *Anthology*, the map illustration has also been removed from this review. *Cartographic Perspectives* apologizes to our readers and to the review writer.

**Figure 4.** *Food Sovereignty Assets*, by Jenna Witzleben (60).

Taken as a whole, *The InfoGraphics Lab 2023–24 Anthology* demonstrates the breadth of contemporary cartography. The collection presents a creative and collaborative environment where students are encouraged to think critically about how their work impacts the world. From questions about representing ambiguity in Maxim Johnson's "Mapping Coastal Salish Tribes and their Languages" (45–46) to the life-or-death nature of map-making in Atticus Tong's "Journey to the InfoGraphics Lab" (55–58), the anthology demonstrates the wide spectrum of considerations and issues cartographers grapple with today. It will be of particular interest to prospective students considering work in data visualization and cartography, to educators seeking models for experiential programs that empower students, and to professionals curious about how the next generation is approaching questions around process and representation. As both a showcase of student work and a reflection on the political and ethical dimensions of mapping, the anthology is a valuable contribution to contemporary cartographic practice and pedagogy.





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