A Geographic Approach to Teaching and Communicating Global Change in California

About the Authors

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Editor's Summary:

This chapter describes the use of Esri *Story Maps* by a biology class at Stanford University to examine the science and human dimensions of global change in California. Working towards a goal with the Governor of California's office, students from several STEM disciplines gathered data and utilized *Storymaps* to communicate the direct impact that global change is having in different parts of the State. Students with strong STEM backgrounds explored the intersections of the science they have learned in their classes with the society they

live in. Using a scaffolded learning environment the students "flipped" the traditional classroom and working office hours. This enabled the students to use class time to work on data collection and *Storymap* creation alongside the teaching team. Through a combination of active learning strategies, community-engaged learning preparation and technical training, the students tackled the challenge of building and publishing their own *Storymap* application. This application consists of five distinct web maps that integrate environmentally focused news articles and media releases with quantitative data layers. The final composite *Storymap* is featured on the governor's office website and has received more than 6,000 views!

Science communication in an era of global change

The environmental challenges we face today are synergistic, interdisciplinary, and global in nature (Barnosky et al 2012; Barnosky et al 2014). The collective future of our planet demands that scientists and engineers develop novel technical and conceptual solutions to complex problems. At the same time, we must also develop and enrich our science communication toolkits. Further, as scientists, we view it as our responsibility to ensure that students in STEM fields (science, technology, engineering, and math) become convincing communicators. The challenges of global change present us with an opportunity to examine and modify our current science communication strategies. Enhanced communication strategies and media resources that target all spatial scales—from local to global—are necessary to enable citizens to better understand its impacts. To meet this objective we need new, engaging media for communication that allow scientists and engineers to explain complex, global scientific issues in ways that localize and personalize them. Research shows that the most effective strategies for communicating climate change, for example, are those that depict how these global forces impact a person's everyday life at local scale (Kaplan & Kaplan 1982; Kearney 1994). Such a strategy can be made even more successful when presented as a narrative rather than as a set of abstract statistics (Kearney 1994).

Global change is inherently a spatial process, with impacts varying by region and society (Barnosky et al 2012; Barnosky et al 2014). Spatial data are often used to address particular environmental problems and identify specific policy options. For example, Geographic Information Systems (GIS) can objectively determine the best route for a new irrigation channel by incorporating features of the landscape into suitability models. However, the use of spatial data to better communicate issues in the field of environmental change has been vastly underappreciated. The ArcGIS Online *Story Maps* represent a new platform to communicate information in narrative form using spatial data and other media. In the case of global change, this platform fosters communication by allowing the simultaneous display of the scientific and human dimensions of a place. Well-designed *Story Maps* should demonstrate how critical global issues are relevant to a person's everyday life. The spatial platform is ideal for engaging policy-makers with specific issues through data that combine the environmental processes (=the science) with the narrative (=the story) in a place (=the map). The resulting *Story Map* should show how people perceive global change and how policy-makers can best engage with stakeholders to enlist their input regarding local impacts and potential solutions.

Course context: Global change in California

The objective of this course was to utilize the ArcGIS Online *Story Map* environment to create engaging narratives relating to global change issues in a mapping format. Our goal was to have students explore and deploy their scientific toolkits to provide the public and policy-makers with an interactive, easily customizable communication product. Ultimately, we endeavored to teach future scientists and engineers how to communicate with policy makers and the general public.

Our course was developed in response to a science communication need identified by the governor's office of California (Gewin 2014). In order to meet this request, students collected data on current manifestations of the impacts of climate disruption, pollution, population growth, invasive species and diseases, and biodiversity loss from across the state of California to highlight the scientific and human dimensions of global change. The data help policy-makers understand how global change is influencing their constituents; to this end we had to determine the approach, strategy, and language that would best convey the impacts of global change. Students learned how to adopt a geographic framework to address a real world problem while simultaneously helping the general public to understand how global change is affecting real communities and citizens in California. The strategy of applying scientific knowledge to a real problem in a geographically relevant context has been shown to greatly improve learning experiences of STEM students, particularly female and minority students (Uriarte et al 2007).

We targeted students with strong STEM backgrounds who are planning to enter STEM-related careers but did not necessarily have training in science communication. As the course was designed to explore the intersections of science and society, it touched on many STEM fields (biodiversity science, geology, chemistry, ecology, toxicology, atmospheric science, disease/medicine, etc.) while also emphasizing the need to appreciate economic and political, and social/cultural (?) contexts. The unifying element that connected these STEM and humanities disciplines was a spatial approach supported by GIS. Learning goals were to a) provide students with a background in the scientific perspective of global change, and b) apply critical thinking skills to the sorting and accessioning of appropriate data. A desired outcome was that students would form an effective science outreach vocabulary, allowing them to communicate global change issues to scientists and the public alike, while maintaining sensitivity and respect for their audiences.

Students dissected the complexity of global change in a scientifically relevant way by breaking it down into five key forces: climate disruption, biodiversity loss, population change, pollutants, and invasive species & diseases (Barnosky et al 2012; Barnosky et al 2014; Melilo et al 2014). They learned how to discover and extract scientific data sources to produce the GIS base layers most pertinent to each key problem (for example, forest cover was used as the backdrop? The proxy? for biodiversity loss). On top of these continuous scientific layers, students included discrete data points of human stories taken from newspapers, local radio and television stations, and personal interviews. The inclusion of these human stories provided an impetus for our students to cross the campus boundary and engage with community members, the general public, and non-STEM students. Furthermore, these stories showed students the value of non-traditional data sources, particularly when used to study extremely rapid phenomena such as global change. In fact, a growing body of research suggests that people are reliable observers of their natural environment (Turner et al 2009), that people are able to detect changes to their local environments and climate (Stauss & Orlove 2003), and that persons of different livelihoods (and backgrounds?) may perceive these changes differently (Osbahr et al 2011), indicating that these human stories are a vital and accurate corollary? to the scientific data.

A spatial perspective provided the backbone for our course. Data collection was geographically-oriented, as students were each given a region of California, based on regions defined by the California Department of Fish and Wildlife. Students became experts on their assigned region and assembled significant geospatial data and relevant media reports. The unifying theme was to discover and illustrate how the scientific manifestations of global change play out in the economic and social context of their region (Figure 1).

<figure 1>

The resulting product of the course was an ArcGIS Online *Story Map*, entitled *Geographic Impacts of Global Change: Mapping the Stories of Californians* (http://tinyurl.com/o35z5ns) (Figure 2). By utilizing the capabilities of *Story Map* the students learned how to link human stories to scientific/natural processes and events. The *Story Map* produced a 'helicopter-view' of how global change influences the livelihoods of Californians, and how these environmental challenges vary across the state. The particular challenges of climate, for example, manifest themselves quite differently in the Mojave Desert than they do in the old growth forest of northwestern California, while the urbanization of southern California has clear impacts on biodiversity. One student discovered that ecosystem loss in northern California is catalyzed not by urban development, but the unique challenges relating to illegal marijuana farming.

<figure 2>

Overall course framework

Our course framework may be generalized to develop courses at both two- and four-year academic institutions (Figure 3). The course instructors and community partner (Governor's Office of California) worked together to identify a project goal and the students had a valuable experience assembling and creating the final product. The students used this project goal as an opportunity to grasp and localize the forces of global change. They engaged with stakeholders to explore how global change is manifested on local scales. In our case, students were aided by the Director of Community Engaged Learning at Stanford, who specializes in preparing students for outreach and community/stakeholder engagement. However, this could also be accomplished at other universities through working with academic personnel specializing in public speaking and interview skills. The Stanford Geospatial Center provided GIS desktop technical expertise and helped the students locate and integrate relevant scientific data for the project. Members of our academic community and our community partner evaluated the prototype product. Their valuable feedback was incorporated into the final release of the class product, the *Story Map*. Throughout the class there were numerous opportunities for students to reflect on their own experiences as well as on the efficacy of the communication product.

<figure 3>

Story Map construction methods

Format

The students and instructors of the course browsed the ArcGIS online *Story Map* gallery and together determined which of the readily available templates would be most effective for meeting the project goal. The Story Map Tabbed template was then used to create the *Story Map*, which is composed of five distinct web maps that have news articles and media as data points overlaid onto different quantitative data layers.

GIS base layers

Students worked in a collaborative environment to discover, collect and implement the data elements into an engaging story. Those with knowledge of biology and environmental science directed the others to the most appropriate base layer for each key problem. For example, students decided that a dataset of precipitation totals for each county would be the best backdrop for drought-related stories found within the climate disruption web map. Using the student-generated list of desired scientific data, the instructors and GIS specialist worked to access published datasets and format them for ArcGIS online. This included datasets downloaded from scientific consortiums, published papers, and government agencies (CDPH 2011; Hansen et al. 2013; Kleeman et al. 2010; MPC 2011; PRISM 2014).

Data points

There were two types of data sources used in the production of each *Story Map*: GIS base layers and geo-referenced data points that represent the human narratives. Students were required to find links to news stories related to global change issues, and enter these data into a database (Table 1). Examples include:

- A news story about how the drought in California is causing job shortages for farm workers.
- A news story about how a certain city may have a high number of people with asthma due to poor air quality.
- A news stories about how rodenticides used in illegal marijuana cultivation are harming native wildlife.

Each data point is a clickable repository of information pertaining to the news story. It includes the article title, author, publication date, a relevant quotation from the article, a photo that illustrates the article's topic, a link to the article, and a note about any multimedia present in the article. Every relevant story also includes all the pertinent geo-referenced data filled out in a standardized tabular format. All of the resulting data were uploaded to create the *Story Map*, which was then published online.

Students were provided many opportunities for discussing data collection and content throughout the term. A mid-term discussion session enabled the students to present their data and highlight their personal stumbling blocks, leading to a productive review of different data collection strategies each student employed. We also hosted data collection events outside of the scheduled course hours, where students could seek advice on data collection strategies and informally talk about trends that they were observing.

Sample Data Points	
Problem	BIODIVERSITY
Region	BayDelta
Entered By:	AMM
County	San Mateo
City	Half Moon Bay
Address	na
ZipCode	na
Topic	Ecosystem Recovery
Group_Stakeholder_1	Commercial Fishermen
Date	6/19/14
Author	Francis, S
Source	KQED Science
URL	http://blogs.kqed.org/science/2014/06/19/a-squid-bloom-in-monterey-bay-is-good-news-for-local-fishermen/
Latitude	37.457424
Longitude	-122.445672
Title	A 'squid bloom' in Monterey Bay is good news for local fishermen
Quote	Half Moon Bay fisherman Michael McHenry says conservation efforts such as closed areas, a ban on weekend fishing and limiting the areas accessible to light boats have allowed the squid population to flourish.
Photo Link	http://blogs.kqed.org/science/files/2014/06/squid-picture-270x162.jpg
Embed file/code	na
Media	Photo
Image Credit	NOAA

Implementation of non-spatial technologies

We employed a number of non-spatial technologies and pedagogies to cement student learning and to assess our progress. Through a combination of active learning strategies, community-engaged learning preparation, and development of a scaffolded learning environment, students were able to tackle the challenge of building a *Story Map*. They learned actively through peer exercises such as role-playing and in “flipped” office hours where students and the teaching team worked side-by-side to explore and collect data. The overarching context for the course was established through the discussion of assigned readings such as *Scientific Consensus on Maintaining Humanity's Life Support Systems in the 21st Century: Information for Policy Makers* (Barnosky et al., 2014) and *Approaching a state-shift in the Biosphere* (Barnosky et al., 2012).

This course was a project-based service-learning class (Heffernan 2001) where knowledge comes from many and varied sources including students, faculty, community, and policy-makers (Heffernan 2001). Because this is not yet a common pedagogical practice at Stanford, students were given special preparation for the outreach component of the class. Through a series of activities, students were introduced to the principles of effective and ethical community and stakeholder engagement. Before speaking with “real” stakeholders, students improved their comfort level and eventual effectiveness through role-play and practice with their peers (Box 1). Additional group discussion directed the students to reflect on how the story map project and its associated activities are connected to overall learning about global change, local impacts, and the role of science in political decision-making.

Box 1. Student reflections on their in-class role-playing experience.

"I learned to ask questions that require more than just a 'yes' or 'no' answer, and to pose questions that could generate narrative, in emphasizing the story-telling aspect of the project."

"I learned that it is important to start off in a friendly, non-obtrusive manner, and to also preface my questions with a respectful introduction. I also believe that it is critical to emphasize how appreciative I am of them taking the time to answer my questions, because creating a sense of value and importance makes for a more meaningful conversation on both ends."

"What was most striking was the fact that I will likely be speaking to people through this project with whose lives and situations I am very unfamiliar."

"Having the opportunity to 'play' such a figure made me aware of the fact that I will need to keep an open mind when speaking to people for this project. There is still a lot I do not know about California and its environment and politics, and so I need to remain sensitive when performing interviews to the real challenges that many people face."

"I need to be careful not to bring my own biases into interviews, as while I may be convinced that one side of an issue is 'right,' performing interviews will give me the opportunity to hear different perspectives, and it will be important to remain open minded and welcoming to all perspectives in order to produce a comprehensive project."

Meeting an educational challenge with geography

As scientists, we have the responsibility to train students in how to effectively communicate complex scientific issues. Yet such a skillset is generally seen as peripheral (at best) to STEM coursework, and even if students do have science communication opportunities, they are largely isolated from actual science courses. Students in communication courses are typically taught general communication strategies for engaging with the public rather than strategies integrated within a science curriculum or directly applied to a real-world policy problem. Traditional GIS courses focus on how to create geospatial data and use specific spatial tools but do not frequently extend these tools outside of the classroom. Our experience with the *Story Map* environment confirmed that a geographic approach to communicating science-based issues can be meaningfully incorporated into an undergraduate course, with a useful final deliverable to a community partner.

In universities, STEM students are put into a pipeline that ends with the production of specialists in very specific fields. This narrowing of scope often prevents students from taking a step back and understanding the broader impacts of their own work and the impacts of STEM research more generally. Even when students are able to identify these impacts, they usually do not have the communication skills necessary to share their findings with non-specialists. Furthermore, students put through this pipeline are often less primed to appreciate the value of non-STEM perspectives. By engaging with a real-world problem, our students made clear connections between the science learned in their courses and the human policy dimensions of the scientific issues. This was made clear in their course evaluations, where for example one student wrote:

> "I only conducted one serious interview about climate change, but all my other 'interviews' (really just conversations) showed me a very human angle to the question: where does my food come from? This question is hard to answer because the answer is obscure for most things I eat, but for that one hour at the farmers' market, I felt an entirely different connection to many of the foods that I otherwise take for granted and don't really give much thought to".

The benefits of GIS and a spatial perspective

Typical approaches to the communication of complex environmental problems are non-intuitive and ineffective. They are often large in scale (thousands of acres of deforestation), abstract (models of future temperature change), and most importantly, difficult for people to relate to their everyday lives. Kearney (1994) lists several facets of effective science communication strategies, in which the strategy must:

- Be interesting
- Present abstract information in a concrete way
- Relate to a reader's knowledge base and experiences
- Describe global issues at a "human scale" (e.g., "act locally, think globally")
- Be extendable and scalable

We believe that the interactive *Story Map* approach to global change accomplished each of these objectives.

Previous studies suggest that students have difficulty understanding that climate change will have different regional impacts (Boyes & Stanisstreet 1993), and that many students do not believe that climate change will have immediate consequences for people, society, or themselves (Pruneau et al 2003). The spatial perspective, facilitated by the *Story Map*, allowed students, policy-makers, and members of the public alike to quickly see how global change manifestations vary throughout California. By incorporating clear, real-life examples from actual community members, users of the map could easily see how these issues impact people living in different parts of the state.

The use of the ArcGIS *Story Map* platform democratized the results of our class by making our communication product free and easily accessible to the public. Compared to the typical static written final assignment, the *Story Map* is highly accessible to the general public. Rather than requiring citizens to read long stretches of text and digest complex issues, our web-based map is visually appealing and organized in an intuitive way that integrates science-based processes with interesting human stories. A vital benefit of the *Story Map* is its interactive environment that encourages users to explore the data in different ways according to their interests. The final class project clearly met the Governor's office's goal: it is currently featured on the Governor's Office of Planning and Research website and has been used K-12 students across the state. In total, it has been viewed more than 6,000 times.

Ultimately, the inherent spatial nature of GIS, coupled with an interactive user interface of the *Story Map*, allowed students to produce a novel communication product and promote their own communication skills as future STEM professionals. Students were able to see the success of this approach and the connections between the course and policy through our communications with policy makers and our community partner. More generally, our students also learned how to design and deliver a product to a client with a specific need. Our students are now equipped with the skills not only to generate scientific data, but also to communicate those data to multiple audiences in meaningful and engaging ways.

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Figure 1. The hierarchical approach to geographic scale of our class and communication efforts.

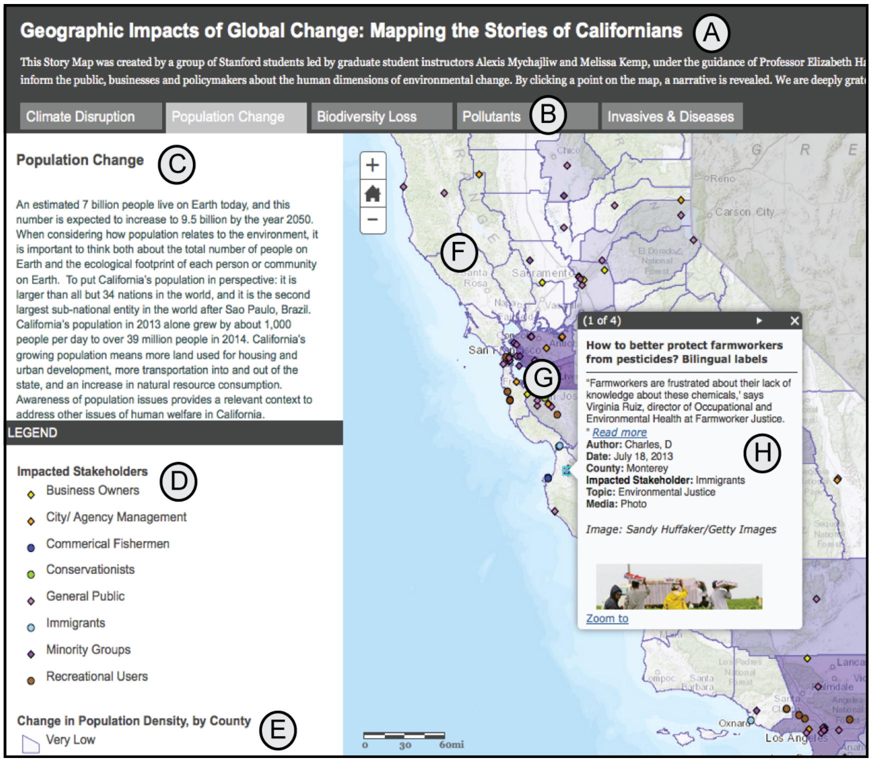

Figure 2. Screenshot of our Story Map, shown here featuring the population change web map. Components A & B are permanent and do not change with web map selection, and components C-H are specific to a web map. A) Map title and link to acknowledgements; B) Tabs that link to each individual web map; C) Scientific blurb about select global change issues; D) Legend depicting impacted stakeholders; E) Legend explaining quantitative data layer; F) Quantitative data layer, here of precipitation values; G) Data points, color and shape coded as stakeholders; H) When clicked, a data point reveals a pop-up window with a quote, image, and link to original article.

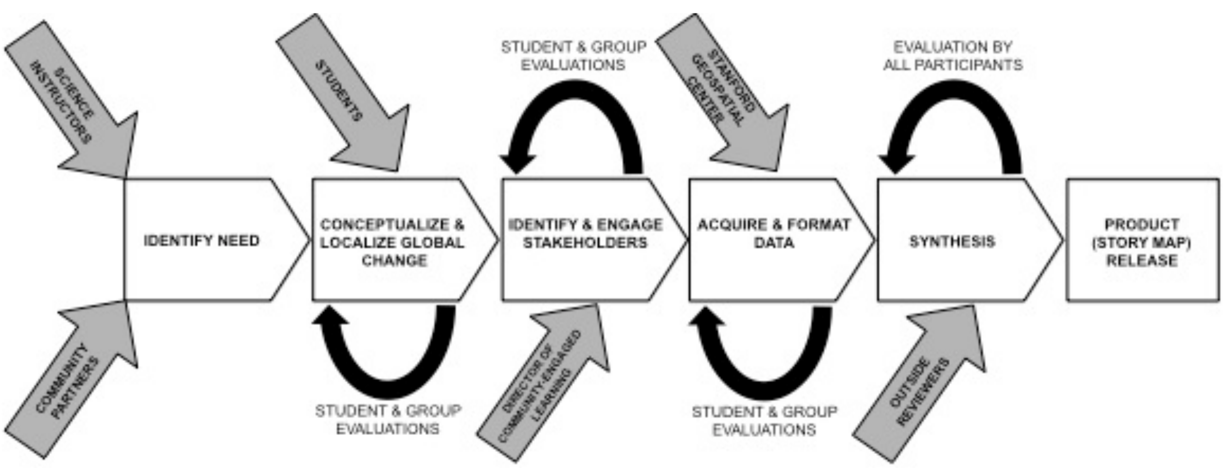

Figure 3. Conceptual flowchart depicting the key components of our class. Figures in white indicate specific steps; gray arrows indicate personnel inputs; and black arrows indicate opportunities for student and class reflections/evaluations.