Maps: A Visual Tool in the STEM Undergraduate Experience

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Abstract

As a visualization tool, maps can illuminate and situate scientific discourse in the academic teaching mission. Ken Foote, noted US geographer and science educator, explains that maps "are the preeminent means of recording and communicating information about the location and spatial characteristics of the natural world and of society and culture" [1]. Scientific primary works are often overlooked as a means to engage STEM (science, technology, engineering, and mathematics) undergraduate students in scientific discovery and advancement. Although many such works are awe-inspiring—works by Galileo or Newton, for example—they also present challenges for undergraduates because it is difficult for students to grasp the scientific notions of the time without additional context. Because maps are primary sources that reflect the context of their creation, they provide a setting for primary scientific works. Maps are caricatures of reality, designed through a process of abstraction [2], and are perhaps more readily understood than primary scientific works. To create this context, and thereby increase student understanding, librarians from the Special Collections and Archives Department (SCA) and the Map Library at the University of Colorado Boulder, use historical maps with primary scientific works, as described by Joel Kovarsky, map specialist from the University of Virginia's Rare Book School [3].

Today's college students are a generation raised in an image-rich information landscape. Using teaching methods that pair a facsimile copy of Copernicus's 1543 work on the heliocentric theory with Gerhard Mercator's Atlas from 1630, or Charles Darwin's 1859 first edition of On the Origin of Species with an 1846 atlas from Elijah Burritt's Geography of the Heavens and Class-Book of Astronomy, our approach locates scientific advancements within their cultural milieu. This paper will focus on research conducted over several semesters that features maps in courses ranging from the history of epidemics and disease, to science writing, to biomedical ethics. Based on collaboration and feedback from STEM faculty, we provide a learning environment that fosters peer-to-peer discussion and a deeper understanding of the relationship between science and society.

Keywords: maps, visual literacy, pedagogy

1. Introduction

Scientific information consists of an expansive array of source materials. This paper specifically focuses on the use of maps, of both land and space, as a visual teaching tool, in conjunction with historic primary source materials, in order to engage STEM undergraduate students. As a means of visualizing data, maps can represent geographic space, or, for example, tell the story of demographic or scientific data—data on population or infectious diseases, for instance. Maps differ from other visual formats in that their credibility is often unquestioned [4]. This is partly because their genesis is grounded in math and science. Timothy Barney notes, "Maps have always struggled between their expected abilities to present simply and precisely scientific information about the world 'as is' and their ability to dramatize perspectives artistically and to reflect ideological and political change" [5]. For STEM students, the problematic authority of maps could be enlightening. Historical maps provide a window to the past through their dual role, simultaneously reflecting and creating the worldview in which they originate [6]. Because "maps are social constructions" [7], incorporating map content invites students to engage in rhetorical discourse. Social learning theory, introduced in 1986 by Vygotsky, posits that most learning is largely an outgrowth of social interactions: we learn through our

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interactions and communications with others [8]. Our approach supports peer-to-peer interactions with the materials, the instructor, and the librarians. By pairing the primary science materials with maps, we contextualize science, thus engaging a diverse community of STEM learners.

2. Methodology

At the University of Colorado Boulder, librarians and teaching faculty use maps and archival materials to complement and contextualize science topics for STEM classes. By inviting the students into the library, we initiate an unconventional learning environment that also serves to expand the students' learning community. In some classes students are organized into small groups of three or four; in others, classroom dynamics support group exploration and discussion. We outline here two different courses wherein maps are used to contextualize historic scientific materials from SCA: 1) A Global State of Mind and 2) Writing on Science and Society. SCA works with two versions of the latter, one focusing on the evolution of medicine over time, taught by Naomi Rachel, and another focusing on the nature of science, taught by Danny Long (one of the authors of this paper).

For A Global State of Mind, a humanities class for engineers, several cartographic items were chosen to illustrate changes in technology—specifically, how the technology of creating maps has evolved. The selection of maps included a detailed aerial view that shows what London looked like in the 1850s, as observed and drawn by an artist in a hot air balloon. Several maps showing exploration routes and surveying results (spanning the next century after the balloon view) added to the story of how the creation of maps evolved technically. We specifically wanted the students to understand that surveying is the basis for most nations' base mapping, before the use of modern methods such as aerial imagery. These images inspired discussion among students about why it was useful to create maps from these vantage points, and how the technology and engineering worked when gathering data needed to create the maps. Librarians and instructors observed that this series of maps sparked much discussion among students, several of whom commented on the accuracy and detailed nature of the early drawings. Students exchanged ideas on how the balloon view might have actually been created. Such small group interactions within the class setting promote peer-to-peer teaching and learning and serve to engage the students in additional conversation about science and technology.

Another example of a successful pairing of maps with rare materials was in Writing on Science and Society. For Naomi Rachel's class, which concentrated on the evolution of medicine over time, SCA displayed a Boulder-Colorado Sanitarium and Hospital brochure from the early 1900s advertising the treatment of tuberculosis patients. The brochure markets the sanitarium as a spa-like vacation setting, providing a strict regimen of diet, exercise, and therapeutic treatments. While the brochure alone was interesting to students, pairing it with detailed 1910 and 1930 Sanborn Fire Insurance maps of Boulder, Colorado, allowed students to place the sanitarium in a geographic context, to visualize where the buildings were located, and to see how the size of the facilities expanded over several decades.

Also in Writing on Science and Society, map librarians displayed a World War II Newsmap created by Theodor Seuss Geisel, more widely known as Dr. Seuss (Fig. 1). This map shows the risks of contracting malaria and discusses how to prevent malaria at a time when the antimalarial drug quinine was being blocked by Germany. Students were fascinated by this map, primarily because it was drawn by a personality that was well known to them. This engagement allowed librarians to teach students more about mapping during World War II, and Geisel's involvement in it, and even prompted several students to further research the map for their subsequent writing assignment. Choosing this particular map to illustrate the theme of medicine in society was successful because of its visual appeal and recognizable author.

Fig. 1: *This is Ann--: she drinks blood!,* illustrated by Dr. Seuss, Special Service Division, Army Service Forces, War Dept. 1943 https://collections.nlm.nih.gov/catalog/nlm:nlmuid-101439358-img

3. Findings

As noted by Bobek and Tversky, visualizations have power [9]. They represent meaning "more directly and naturally than purely symbolic words" [10]. Naomi Rachel asks her class to write review papers on the materials they see in SCA. One student described the impact of leafing through the Mercator Atlas and described how the atlas was both visually appealing and fascinating. For this student the atlas represented the world that early modern Europeans lived in—what they knew about the land and seas and what remained a mystery.

The Mercator Atlas influenced one of Danny Long's students too, inspiring this student to make a total of four maps for his project on the changing universe. In chronological order, these maps show the universe as visualized by Aristotle, Ptolemy, Dante Alighieri, and Galileo. In the first three, the earth sits at the center. Ptolemy's universe includes his famous epicycles, which signify the great lengths to which thinkers are sometimes willing to go to conform to the preconceptions of their age. Dante's universe is conical, with God at the top and the earth, including Hell, at the bottom. This map exemplifies the overlap, during Dante's life, of science and literature. Only in Galileo's universe does the earth leave its central position for the humbler one it occupies to this day. Not only do these maps supply the shape of the universe; they also encourage discussions on humanity's place within it. By engaging with maps, and in some cases creating maps of their own, students think about the nature of science and the role scientists play in society.

Beyond the call for the "marriage" of special collections and cartography, as put forth by Kovarsky, in 2016 authors Widener and Slater Reese outline the integration of archival resources in an introductory geographic information systems course [11]. Currently, the literature on visual learning or spatial ability in the STEM fields indicates that instead of explicitly testing for visual learning or spatial ability, educators should instead "consider how to create meaningful environments that help learners to direct their attention to effective learning processes" [12]. Our success in improving students' map literacy as a skill related to, but not the same as, deciphering texts or deconstructing images will depend on finding ways to teach students to read the presented maps competently [13]. STEM students can also benefit by learning to communicate representations of the intersection of space and ideas, from our teaching about map principles and elements [14].

Our goal to integrate rare and historic scientific works with map materials is an example of what is called for in the current literature. Upon introducing maps to course curricula we have established a baseline expectation whereby instructors now specifically request maps for pairing with SCA materials. Fostering this marriage is a new approach for STEM learning, leading to a better understanding of the complex interaction of science and society.

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