Cartographic Perspectives

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IN THIS ISSUE

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ABOUT THE COVER:

A map of Florida, from Samuel Gridley Howe's 1837 atlas for the blind. See page 46 for more details. Courtesy of the David Rumsey Map Collection.

LETTER FROM THE GUEST EDITOR

Embodying aspects of science, art, and technology, the field of cartography has a corpus of knowledge which is extensive: it interacts and overlaps with other disciplines to an enormous degree; and it is utilised and delivered in a wide range of contexts, from state-directed mass production agencies to personal mapmakers disseminating experimental visualisations over the web; and from knowledge engineers conceptualising database design to social historians interpreting apocryphal sketch maps traced on the Rhodian shore.

This special issue of *Cartographic Perspectives*, addressing issues related to "Education in Cartography," reflects the breadth of study embodied by cartography. The scope of cartographic data handling is immense, and it is no surprise that large numbers of school, college, and mature students have a natural interest in, and commitment to, the subject of cartography. The way in which we teach and inform them of the nature of our discipline is critical: from the beginning of their educational experiences, such scholars can be prudently introduced to a vast range of description, interpretation, and analysis of the elemental tasks of a dynamic and fundamental discipline. The nurturing of societies of knowledgeable and committed citizens through means of education forms an unwritten contract which binds generations together: the rightful expectation of the young is that they will be educated by their elders, to transfer learning, experiences, and skills, along with the intelligence to recognise how they can improve society by enhancing previous knowledge and gaining wisdom.

The subject matter of cartographic education is a three thousand year-old body of accumulated wisdom, which is the core of "what" is to be taught. There is, therefore, a significant amount of material which forms that subject matter. Some is addressed because of curiosity; some addresses the accepted truisms of our discipline; some demonstrates the integral links of cartography to other human endeavours; some contributes to the status of cartographers as "experts" in their craft. Each aspect forms part of a "Body of Knowledge," defining the **content** of our educational curricula. The dynamic nature of contemporary cartographic activity and its potential adaptation to future changes means there is an obligation for cartographic educators to regularly, in the light of advances in the discipline, revise the syllabus they teach; to take advice from industrial advisory panels, professional organisations, and institutional/governmental reports; to maintain contact with alumni who are succeeding in the cartographic profession; and to increase the effectiveness of research-led teaching. In short, the varying experiences of those engaged in the nation's classrooms in delivering education in cartography should be reported, disseminated, and considered. A new regular section within *Cartographic Perspectives*, entitled "Views on Cartographic Education" and edited by Fritz

Kessler, will present such **experiences**, and all are encouraged to submit educational items to *Cartographic Perspectives* for inclusion. Fritz introduces this new section later in this issue.

The new section will join other regular *CP* columns and, to preserve continuity, we have included some of these columns in this special issue, where appropriate. In "Cartographic Collections" (which focuses on map curatorship, **documentation**, and conservation), an account of the outreach work of the Boston Public Library is presented, with an emphasis on educating the public on the importance and value of an accessible municipal map collection. In the "Practical Cartographer's Corner" (presenting tips and experiences from those engaged in map **design**, creation, and production) the educational theme is maintained with an interesting account of production work being done by students in the labs of the University of Nebraska at Omaha. Finally, in "Visual Fields" (which addresses "cartographic aesthetics and design, featuring examples of inspirational, beautiful, and intriguing work"), David Rumsey presents a fascinating artefact of early 19th century school-level education using maps, in the form of an atlas of the United States for blind children.

A number of other aspects of education are exemplified in the main reviewed papers of this special issue of *Cartographic Perspectives*. Pedagogy (the practice of teaching) is addressed in each. The online theme is considered further by Anthony Robinson, who has been at the forefront of promoting the most substantial increase in numbers of students of cartography in recent years, through his leadership of a massive open online course (MOOC) developed by Penn State University and commercial partner Coursera. Anthony's paper addresses, in particular, scalability issues in assessment of students registered for a distance-learning MOOC. In the context of an overview of how MOOCs developed, several detailed aspects of evaluating student work are considered. Peer grading, the role of visual analysis, iterative design, progressive improvement, and detection of plagiarism in submitted material are each explored. A dynamic discipline such as cartography needs dynamic **methods** of educational discourse: MOOCs show one example of how contemporary technology can be used to renew cartographic education, and this paper probes important topics related to their implementation.

The **outcomes** of education are considered in the other main paper in this issue, in which Jeff Howarth reflects on spatial thinking and the pedagogy of GIS. Undertaking some practical testing of students on geography and GIS degree programmes, Jeff has been able to demonstrate the value of spatial thinking in education in many disciplines, how to enhance natural spatial thinking abilities, and how to "teach the teachers" to value spatial thinking in their syllabus development. The importance of Jeff's experiences to the development of cartographic education is in integrating conceptual issues in education, such as cognitive load theory and studies of expert knowledge, with the classroom activities involved in spatial learning.

The generic topics (in bold, above) covered in this special issue of CP are central to the agenda of the International Cartographic Association's newly re-elected (2015–2019) Commission on Education and Training. One of its long-standing Terms of Reference is to monitor the provision of cartographic education around the world: the Commission has noted with concern the decline in cartographic education provision in some countries such as the United Kingdom, the Netherlands, and Germany, but also welcomes the burgeoning of cartographic education in other nations including Spain, Turkey, China, and Brazil. On the strength of its dynamic practitioners (both within the academy and through collaborative commercial/governmental links), their innovation in publication and outreach, the flexibility of curriculum development informed by comprehensive Body of Knowledge and competency model documents, and the vitality of research activity, the United States also falls into the latter category. The initiative for this special issue of *Cartographic Perspectives* came from a realisation that the incisive discussions, debates, and presentations on the topic of education in cartography at the April 2015 meeting of the Association of American Geographers deserved a fuller exploration and broader arena in which to be aired. Along with the regular, stimulating meetings of American cartographers in other forums, through organisations such as NACIS, there is admirable opportunity for cartographic educators in the USA to be innovative, effective, and pro-active in their approach. It is to be hoped that the experiences of American cartographic educators, involved in the range of topics mentioned above, from Body of Knowledge to public outreach, and from web mapping in the classroom to developing a cartographic "mind-set," can continue to be described and disseminated in a way which helps the international community. This issue of *Cartographic Perspectives* is a major step in that direction.

David Fairbairn
Guest Editor

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PEER-REVIEWED ARTICLE

Evaluating Maps in a Massive Open Online Course

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New forms of cartographic education are becoming possible with the synthesis of easy to use web GIS tools and learning platforms that support online education at a massive scale. The internet classroom can now support tens of thousands of learners at a time, and while some common types of assessments scale very easily, others face significant hurdles. A particular concern for the cartographic educator is the extent to which original map designs can be evaluated in a massive open online course *(MOOC). Based on our experiences in teaching one of the first MOOCs on cartography, we explore the ways in which very large collections of original map designs can be assessed. Our methods include analysis of peer grades and qualitative feedback, visual techniques to explore design methods, and quantitative comparison between expert ratings and peer grades. The results of our work suggest key challenges for teaching cartography at a scale where instructors cannot provide individual feedback for every student.*

KEYWORDS: cartographic education; MOOCs; online learning; peer assessment

INTRODUCTION

A new spirit of institutional openness, coincident with the emergence of new forms of education via the internet, has combined to drive the development of learning experiences that reach massive, global audiences. The massive open online course (MOOC) is one such example, growing from an initial pedagogical experiment with two thousand students in 2008 (McAuley et al. 2010) to mature platforms today featuring hundreds of courses from universities around the world for an audience measured in the tens of millions (Pappano 2012). At the same time, mapping technology has proliferated to reach enormous new audiences through location-enabled mobile devices and easy to use web mapping tools. As a result, cartographers have the unique opportunity today to reach massive, global audiences through learning experiences at scale.

The potential to teach cartography to thousands, rather than dozens, has immediate attraction to cartographic educators with an eye on encouraging a broader public understanding of best practices in map reading and design. It also introduces significant new challenges to overcome. We explore one of those challenges here by evaluating the extent to which map design assessment can take place in a massive, distributed global classroom. If we intend to expand the range of students who engage with cartography through increased openness, then we must address the fundamental issue of scale between the relatively few capable cartography educators in the world, compared to the very large potential audience of mapmakers who may be keen to learn.

In the sections to come, we begin by characterizing the state of the art in online teaching at scale. As part of this discussion, we focus on previous attempts to teach massive courses within the discipline of geography. Next we describe the use of peer assessment methods, which are the most common means for supporting evaluation of student-generated projects in massive courses.

Using evidence gathered from teaching a MOOC on cartography, we follow our literature review with a methodological structure we have used to explore the reliability and utility of peer assessment through quantitative and visual analysis. The results of these analyses are then discussed and situated within the broader context of challenges and opportunities for scaling cartographic education to massive audiences. We conclude with ideas for future research to explore emerging dimensions of assessment in a new realm of massive online cartographic education.

TEACHING GEOGRAPHY AT SCALE

This article is written at a time in which distance education methods and mapping technology have become blendable and distributable in radical new ways. This potential has been a long time in the making, however, through decades of previous development in both areas. The rise of e-learning has roots reaching as far back as the 1960s with early experiments fusing computing with education (Nicholson 2007). The science and technology of e-learning saw its renaissance, however, during the 1990s as delivery via the internet became possible for an increasingly large audience of learners.

Distance education today can take many forms, including fully-online and blended models of instruction which employ synchronous as well as asynchronous types of engagement through assignments, discussion, and content delivery (Unwin et al. 2011). The science of online instruction has also seen major developments and has been the subject of significant attention within geography itself (Clark, Monk, and Yool 2007; Terry and Poole 2012). Evidence from hundreds of controlled studies has helped reveal that design guidelines for effective online learning can be developed, and that courses designed with those imperatives in mind perform as well as their in-person counterparts. Furthermore, online classes can offer unique advantages to students in terms of flexibility and access to match a broad range of potential learning styles (Means et al. 2010).

Fully-online geography courses focused on the mapping and geographic information sciences began to appear at universities and colleges in the late 1990s, starting a trend which continues today to emphasize geospatial technology through online certificate and degree programs (McMaster et al. 2007). Classes offered in these programs may use a range of instructional models, including synchronous and asynchronous content delivery, discussion systems, lecture videos, and virtual laboratories (Unwin et al. 2011). While online learning initially seemed to promise the ability to lower costs and support larger cohorts in classes, these myths have largely been debunked by researchers (DiBiase and Rademacher 2005). Instead, the primary advantages of online learning today have to do with access, as there are millions of learners around the world who cannot attend in-person classrooms. This is particularly an issue for adult education, an area where online programs have grown very rapidly in the United States. Few professionals can relocate to attend on-campus experiences, and even when one is located nearby, not many can attend evening and weekend courses for weeks on end without interruption.

In the late 2000s, the first experiments began with a new approach to tackle the scale issue associated with online learning. George Siemens and Stephen Downes at the University of Manitoba launched a new online course in 2008 titled *Connectivism and Connective Knowledge*, which was opened for anyone in the world to participate in for free via the internet. This experimental approach drew in more than two thousand learners from all over the world. *Connectivism and Connective Knowledge* is credited today as the first example of a massive open online course (McAuley et al. 2010). Soon, others began to experiment with developing MOOCs and new platforms for creating and delivering MOOCs. These new platforms included Coursera, launched by Andrew Ng and Daphne Koller from Stanford University, Udacity, created by Sebastian Thrun at Stanford University, and edX, which was co-developed by the Massachusetts Institute of Technology and Harvard University. Today, these platforms and many other new entrants are offering hundreds of classes to millions of learners. Coursera is currently the largest MOOC provider, with more than 10 million students taking courses on its platform by late 2014 (Larson 2014). Generally speaking, MOOC platforms develop partnerships with universities to develop and deliver courses, with the platform providers offering their learning management systems and user base, and the university partners providing content and instruction.

There is no doubt that what encourages learning at a massive scale is the fact that MOOCs are normally free to take. While on the surface offering a free course may seem to benefit neither universities nor the MOOC platform providers, new models for revenue generation are emerging through MOOCs via the provision of microcredentials for a small fee, and via lead generation to encourage MOOC students to enroll in traditional tuition-paid online and residential learning programs. Those who support the evolution of MOOCs have pointed out the potential to reach large and globally diverse audiences that are not typically able to access higher education experiences. Those who are critical of the trend highlight the lack of sustainable revenue generation models, low class retention rates, and pedagogical concerns given the fact that instructors cannot possibly provide individualized instruction and feedback with thousands of students at once.

Since 2013, several MOOCs on geography topics have been developed and taught across a variety of MOOC platforms. The first of these, a course called *Maps and the Geospatial Revolution* (hereafter also referred to as the Maps MOOC), was launched on the Coursera platform in February 2013 (Robinson et al. 2015). Subsequently, several other MOOCs on geospatial science and technology topics have been developed, including *Introduction to GIS using Quantum GIS* (**www.canvas.net/browse/delmarcollege/courses/introduction-to-geospatial-technology-1**), *Geodesign: Change Your World* (**www.coursera.org/course/geodesign**), *From GPS and Google Maps to Spatial Computing* (**www.coursera.org/course/spatialcomputing**), *Geospatial Intelligence and the Geospatial Revolution* (**www.coursera.org/course/geoint**), and *Going Places With Spatial Analysis* (**www.esri.com/landing-pages/training/spatial-analysis**). What these courses have in common is that they are targeting new audiences of geographic learners with free experiences to introduce key geospatial topic areas. *Maps and the Geospatial Revolution* appears so far to be the only MOOC that focuses explicitly on cartographic education, though we anticipate there to be many more options in this area in the near future.

The current state of the art in MOOC platform development supports a limited palette of assessment types. Compared to traditional online learning with small cohorts where individualized grading by an instructor is possible, MOOC assessments are normally limited to autograded quizzes and exams using multiple choice or true/false questions. The key exception to autograded assessments in MOOCs is through the use of peer evaluation frameworks. Many MOOC platforms provide peer assessment tools as the primary means by which individual projects can be evaluated at scale to provide formative feedback.

Peer assessment employs a simple concept at its core: students evaluate the work of their peers (Falchikov and Goldfinch 2000). In a traditional course, peer assessment is frequently employed as a means to generate peer-to-peer discussion on course content or project deliverables. Peer assessment is usually moderated by the instructor in this setting to ensure that feedback is constructive and consistent. Peer assessment has been widely adopted in MOOCs to overcome the problem that MOOC assessment methods are otherwise limited to summative measures that come from autograded quizzes and exams (Suen 2014). In contrast to its application in non-massive courses, peer assessment is not easily moderated by an instructor in a MOOC where there may be thousands of assignments and reviewers at work.

In the sections that follow, we describe the development of a peer assessment intended to support formative feedback for individual cartographic design projects generated in a MOOC. Using data collected from students completing this assignment, we explore several ways in which the resulting grades and assignment can be evaluated to gauge the challenges and opportunities that this framework poses for further explorations in teaching cartography at a massive scale.

PEER ASSESSMENT IN THE MAPS MOOC

To explore the potential for map assessment in courses at scale, we have analyzed map contributions from students enrolled in *Maps and the Geospatial Revolution*. Since 2013, this MOOC has been taught three times by the first author, Anthony Robinson, enrolling more than 100,000 students from over 200 countries and territories.

To evaluate peer assessment reliability and consistency, we use assessments and peer ratings from the first Maps MOOC taught in July, 2013. That session enrolled over 49,000 students, with more than 36,000 participating once the class became active. 3,064 earned a passing grade in the course, with more than 8,000 students active during its final week. High attrition rates are common across MOOCs (Ho et al. 2014), and yet it would take over a hundred sections of a typical cartography course to reach even the relatively small subset who earned a passing grade in the initial offering of the Maps MOOC.

Students in the 2013 session of the Maps MOOC created a total of 2,787 final project submissions. This project represented the culminating effort for the class, and it required students to find spatial data (or create it themselves) and create their own original maps to tell stories about their chosen data sets. Three potential options were presented, from more difficult to less difficult, depending on students' self-assessment of their mapping skill levels. Option 1 suggested the use of Esri's ArcGIS Online tools, which students use in four lab assignments in the course, and therefore the easiest option for those who have made maps of their own only as a result of taking the class. Option 2 suggested the use of Esri's StoryMap templates and tools, which requires technical skill beyond what is explicitly taught in the MOOC. Option 3 encouraged students to use CartoDB, MapBox Studio, or a desktop GIS such as QGIS to complete their projects. This option was intended to push the more experienced students taking the class to build upon their existing knowledge.

Does this map tell a complete story?

- **0** - this map does not appear to tell any story at all.
- **1** - this map begins to tell a story, but falls short of offering a complete narrative.
- **2** - this map tells a good story, but some aspects would benefit from further clarification.
- **3** - this map tells a complete story.

Does this map tell a compelling story?

- **0** - this map does not tell a compelling story at all.
- **1** - this map tells a story that is partially compelling.
- **2** - this map tells a story that is mostly compelling.
- **3** - this map tells a very compelling story.

Is this map designed in a way that reflects the use of best practices in cartographic design and geospatial analysis?

- **0** - this map shows no attention to best practices in cartographic design and geospatial analysis.
- **1** - this map shows only a little attention to best practices in cartographic design and geospatial analysis.
- **2** - this map shows a solid level of attention to best practices in cartographic design and geospatial analysis.
- **3** - this map follows all best practices in cartographic design and geospatial analysis.

Does this map have an aesthetic look and feel that reinforces the objectives of the story it tells?

- **0** - this map has a look and feel that has no evident relation to the story it tells.
- **1** - this map has a look and feel that has only a little relation to the story it tells.
- **2** - this map has a look and feel that has some relation to the story it tells.
- **3** - this map has a look and feel that relates very well to the story it tells.

Figure 1.

RUBRIC AND ASSESSMENT DESIGN

A critical pedagogical component for the design of any peer assessment is its grading rubric. Rubric design deserves special attention in a MOOC given the very wide range of backgrounds and expertise evident in their globally-diverse audiences. In addition, we know that MOOCs typically have more than 50% of their student populations speaking a primary language aside from English, so the language used to describe rubric elements must take this into account to the extent it is possible.

In conjunction with a learning designer, who helped advise on the development of the Maps MOOC content and assignments, we developed a four-part rubric that asks peer graders to evaluate how well each submission presents a complete story, how compelling that story is, whether or not the map design uses best practices in cartographic design, and the extent to which the map has an aesthetic look and feel that reinforces its storytelling objectives. Each of these four elements could be rated from 0 to 3, as shown in the detailed rubric in Figure 1. The maximum possible grade for this assignment is therefore 12 points, and the assignment was weighted to make up 20% of the overall grade for the class.

The Coursera platform allows an instructor to specify how many submissions each student must grade. We chose to require a minimum of three graded submissions for each participant. To our surprise, most students voluntarily graded additional submissions. In fact, a total of 1,825 submissions received at least five peer grades. The Coursera platform allows students to voluntarily grade more than the required number of submissions, and it uses the median rather than the mean of scores to determine the final grade for a peer review assignment.

RESULTS

To evaluate the extent to which map design can be assessed at scale, in this section we explore multiple aspects of peer grading results from the Maps MOOC. We begin by describing the general outcomes seen across three sessions of teaching the course. Next we provide evidence from a quantitative evaluation of the stability and reliability associated with peer grading from the first session of the Maps MOOC. Finally, we show how techniques and tools from image analysis can be used to begin exploring the qualitative dimensions of map designs submitted in a massive course, using the second Maps MOOC project collection as an example.

PEER GRADING ACROSS ALL SESSIONS

One mechanism for comparing peer assessment results across all three sessions of the Maps MOOC is to proportionally summarize grading for each class. Figure 2 shows peer grade distributions across eleven score ranges for each of the three Maps MOOCs taught so far. The average score for each session is also plotted as a line in a corresponding color on this graph.

The 2013 session featured a broader and flatter distribution of score ranges, particularly between 50% and 90%, compared to the subsequent 2014 and 2015 sessions, which have strong peaks in the 80% to 90% range. Although the core course content has remained the same across all three sessions, improvements have been made each time to the instructions provided for the peer assessment activity, as it is one element of the course which appears to be the toughest for students to understand and execute compared to the autograded quizzes, lecture videos, and other materials. We suspect that improvements in how the assignment is presented and explained may help students toward developing higher quality submissions that better fit the rubric imperatives. It is also possible that the size of the cohort plays a significant role, as the first MOOC in 2013 had roughly twice as many participants as the 2014 and 2015 sessions.

On average, scores have increased with each subsequent session by a small, but notable margin. Again, while we cannot be certain of the cause, one potential reason for this would be the constant improvements we have made to the assignment instructions to explain deadlines, the peer grading method itself, and how the rubric should be interpreted/employed. Another potential explanation is that MOOC students in general are becoming more familiar and comfortable with peer grading as a common element of massive courses. We note that more students appeared to struggle with this concept in the 2013 class than in subsequent courses, based on what we have seen students discuss in the forums about this assignment.

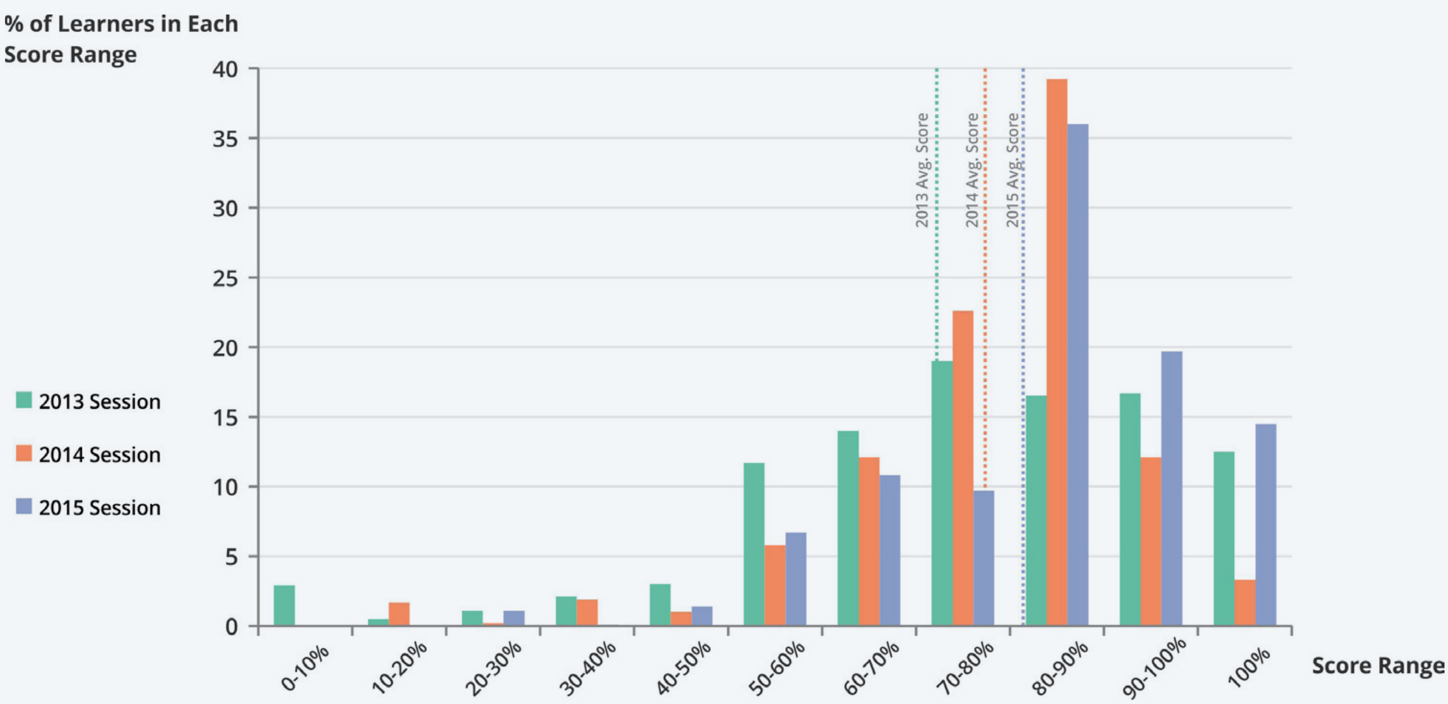

Figure 2.

COMPARISON TO INSTRUCTOR GRADING

To evaluate the extent to which peer grading correlates with expert grading by a qualified instructor, we manually graded a 5% random sample (93) from the set of submissions that had received at least five grades (n=1825) from the first session of the Maps MOOC taught in 2013. The first author reviewed and graded each submission from this subset using the same rubric as used by the students for peer assessment and was blinded to the grades that had already been assigned by students.

Using this manually-graded set of assignments as a sample, we were able to evaluate the reliability and validity of peer grading. We define *reliability* as the tendency for peer graders to agree with each other when rating a given assignment, and we define *validity* here as the agreement between student-provided grades with expert-provided grades.

Reliability evaluation using intraclass correlation coefficient (ICC) analysis reveals that while agreement among individuals is low (ICC = 0.262), taking the averages of five scores provides significant improvements to reliability (ICC = 0.640). Our evaluation of score validity using Pearson's correlation coefficient shows that instructor grades have a strong positive correlation with peer grades provided by students ($r = 0.619$, $p > 0.01$). Further details on our analysis of reliability and validity, including the results of a student survey to evaluate the extent to which students understand and appreciate peer grading, can be found in a recent complementary article (Luo, Robinson, and Park 2014).

VISUAL ANALYSIS

While quantitative evaluation provides insights regarding the overall reliability and utility associated with peer grading in cartography courses at scale, this approach completely obscures the artifacts themselves. What should instructors do if they want to actually see and understand the map designs that students have created in such a large course environment? If thousands of maps are created and submitted, how can cartographic educators make sense of what was made beyond basic measures of overall grades and their reliability?

With this motivation in mind, we set out to explore the visual design of submissions from the second session of the Maps MOOC taught in the spring of 2014. This course generated 1,243 final project submissions from students.

To begin evaluating the look of these maps, first we manually captured screenshots from every map submission and coded them into categories according to the tools used in their creation. Most of the maps (91%) utilized a type of Esri tool (ArcGIS Online, StoryMaps, etc.), while the remaining 9% utilized an alternative mapping platform (CartoDB, Mapbox, Google Maps, etc.). In the context of map design evaluation at scale, this is an important attribute because it highlights the key media used to generate cartographic products across the globe, while it also assesses the extent to which students are applying the tools taught in the MOOC to make maps. This knowledge can help guide future course offerings by suggesting relevant tools to introduce students to. Moreover, the tools used to create maps, their popularity, and their ease of use all have a significant influence on map aesthetics and design processes.

To explore the visual characteristics of these maps, we adopted techniques from image analysis and utilized the ImageJ toolkit (Schneider, Rasband, and Eliceiri 2012), which allows us to combine qualitative categorizations we encode for submissions with automated evaluation of high-level image features extracted from screenshots of the map submissions. Essentially, each map image is represented by four attributes: the tool used to create the map; median saturation value; median brightness value; and median hue value. Given these attributes, we can plot the entire collection of map images in two-dimensional spaces to illuminate visual signatures of map design at both the *global* (entire class) and *local* (individual student) levels.

Figure 3 depicts a montage of the entire collection of student maps, grouped by the different tools used for map creation and sorted darkest to brightest, from left to right, based on median brightness values. This montage conveys the distributions of maps by software type and highlights map types that tend to be brighter or darker overall. At full resolution, one can pan and zoom on the montage to explore and evaluate map designs at the individual level, as a collection, or within/ between mapping software groups.

For example, the most widely used Esri ArcGIS Online maps, shown in the uppermost block of Figure 3, tend to be brighter overall. In contrast, the Esri StoryMap submissions, shown in the fifth block down, are considerably

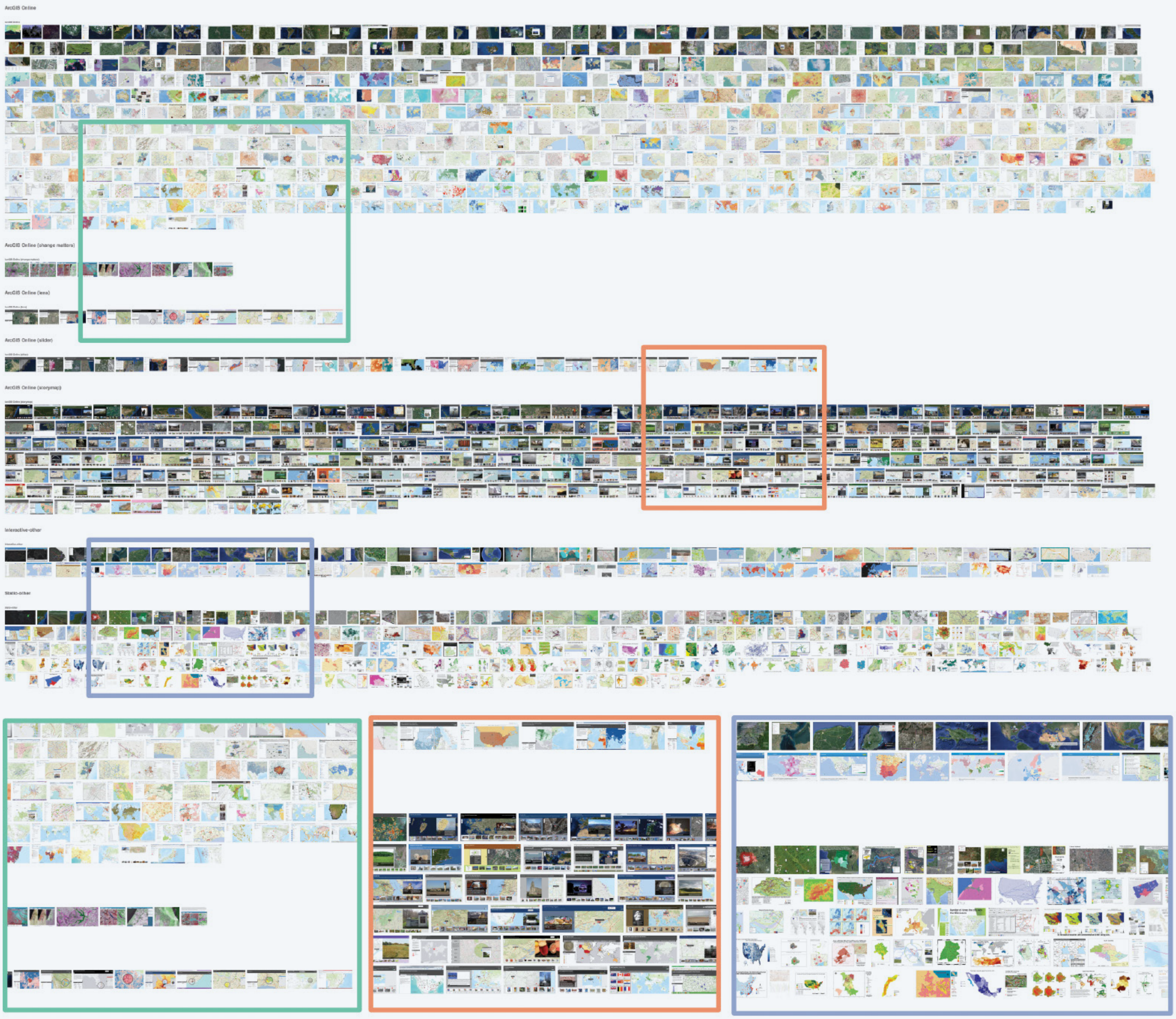

Figure 3.

darker. A closer look at maps in these two categories reveals that students who used Esri ArcGIS Online maps tended to map larger areas, essentially presenting information at smaller map scales, which resulted in more ocean coverage and brighter base map elements. Students who used Esri StoryMaps tended to focus on very specific places, presenting their stories at large map scales and integrating photographs to provide rich context. The lack of ocean and brighter base map elements resulted in overall darker maps. These insights allow cartographic educators to better understand the motivations behind students' individual design choices as well as the role of mapping software in shaping design decisions and overall aesthetics.

Another approach to visualizing map design is to plot map images in a scatterplot using values associated with their visual features. Figure 4 plots map images by median brightness values on the horizontal axis and median saturation values on the vertical axis. The concentration of map images in the bottom right corner of the plot illustrates the strong tendency for students to design bright, unsaturated maps. This trend seems to align with both cartographic theory and with the default map layouts in spatial media authoring software designed with cartographic theory in mind. These maps take visual hierarchy into consideration. The visual characteristics of the base map data which, in most cases, are most influential on the high-level visual features extracted from the map images are subtle and bright. The darker, more saturated colors are used sparingly in these maps to bring primary data to the top of the visual hierarchy.

At the inverse end of the plot, map images are dark, saturated, and typically representative of designs that use satellite imagery as a base map. Maps located more centrally in the plot tend to be vector/raster mashups, Esri ArcGIS Online story maps that integrate photographs into the map design, or large-scale maps composed primarily of landmass. Outliers in the scatterplot may represent map designs that are novel, or that could benefit from constructive critique. From an evaluation perspective, the

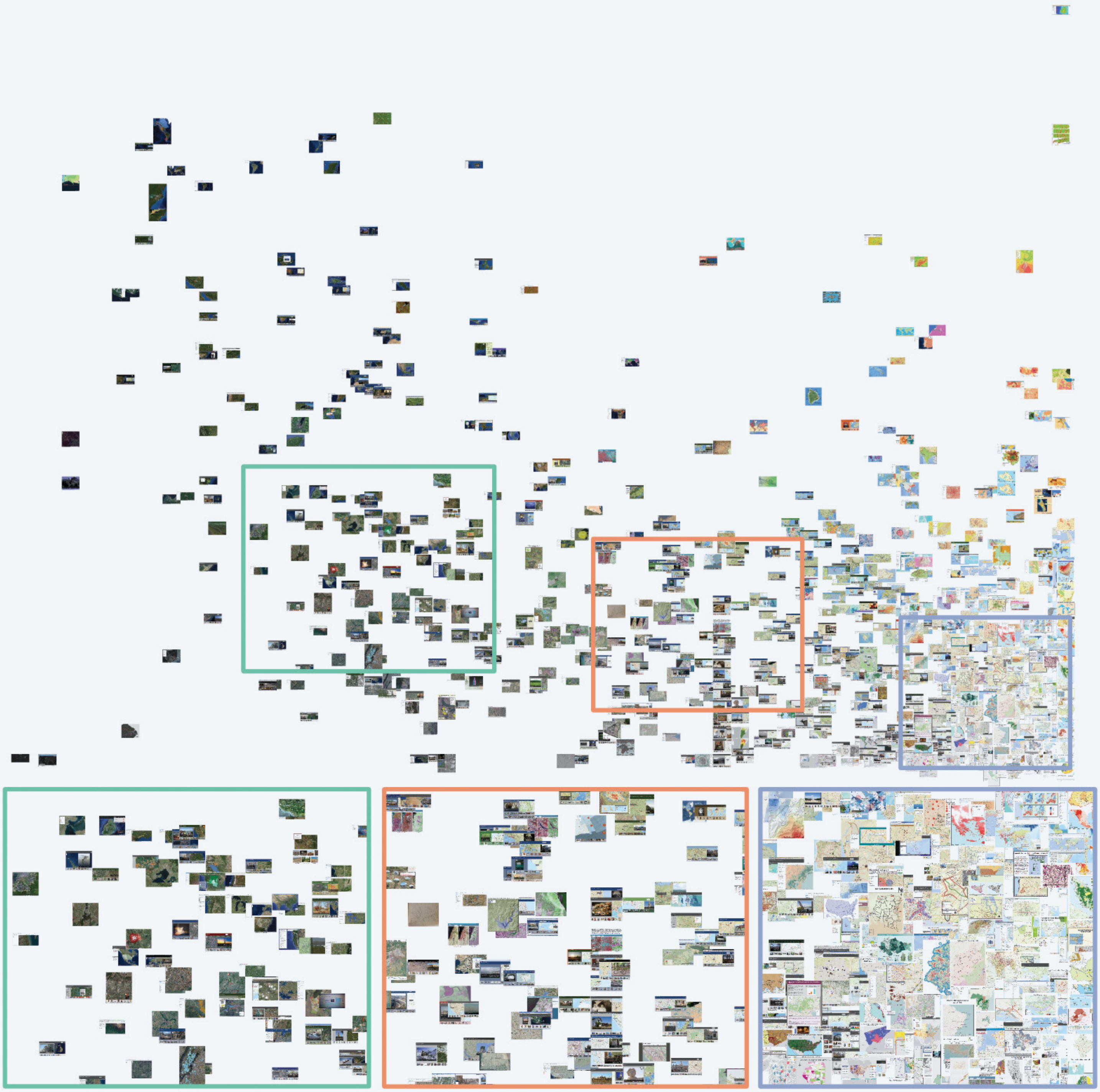

Figure 4.

scatterplot serves as a tool that allows educators to assess students' individual design decisions on visual hierarchy together with software's influence on realizing those decisions. We explore additional methods for visual analysis of peer-assessed map designs in Nelson and Robinson (2015).

CHALLENGES FOR MAP ASSESSMENT AT SCALE

Based on our results from evaluating map designs through quantitative and qualitative means as shown in the previous sections, we propose a series of new research challenges for cartographers to address in order to support map assessment at scale.

WHAT CAN BE DONE TO SUPPORT ITERATIVE MAP DESIGN AND PROGRESSIVE FEEDBACK AT SCALE?

Current peer assessment methods in MOOCs do not support iterative feedback and project development, making it hard to envision a cartographic design course that goes deeper in the way that most cartographic educators would desire. To move beyond single-stage peer assessment in a course at scale would require the development of new platforms that can organize multi-stage reviewing automatically, as well as rubrics that take iteration into account automatically. In a typical cartography class, an instructor will normally assume prior knowledge gains as a class goes from week to week, and penalties for problems may increase over time, while expectations for attention to detail also increase.

While this challenge is a significant one to tackle, it is worth noting that students are already engaging in iterative refinement through informal means in a class like the Maps MOOC. We have observed students posting projects in progress to the discussion forum and soliciting critique for multiple drafts over a period of days or weeks to improve their submissions. This promising sign is tempered by the fact that these students are engaging in ungraded peer review without a standardized rubric. These are two key aspects of peer assessment that would need to be adapted to support iterative progress in a formal assignment.

HOW CAN EDUCATORS SEE AND UNDERSTAND LARGE COLLECTIONS OF MAP SUBMISSIONS?

As we have shown here, it is possible to begin making sense of very large collections of map submissions through the use of image analysis techniques, but these methods are only helpful in providing broad observations. These methods could be made more useful if there were interactive interfaces that provided not only for the overviews that are currently afforded, but also for more detailed drill down to review individual submissions that appear interesting. Another technical hurdle to overcome is the need for instructors to capture thousands of submissions in some form that can be analyzed by these systems. Our experiment required significant manual effort that no instructor would be able to execute under normal circumstances.

Dynamic maps present further challenges for computationally-assisted analysis. Here we have focused on simply exploring map designs via analysis of single screen captures. The vast majority of our submissions are actually from interactive digital maps which cannot be completely summarized by a single screen capture. Therefore we see the need for new techniques to help capture and compare dynamic map projects, potentially leveraging click-stream data to assess the synthesis of map design and interaction primitives as outlined by Roth (2013).

WHAT CAN BE DONE TO AUTOMATE THE PROCESS OF DISCOVERING FRAUDULENT SUBMISSIONS?

Academic integrity issues are certainly not unique to distance learning or MOOCs, but we note here the need for better ways of discovering fraudulent submissions when faced with a massive collection of assignments to review. There is a wide range of tools available today that allow instructors to submit collections of written works to check for academic integrity violations, but to our knowledge there remains a gap in technology and services when it comes to supporting instructors who want to know whether or not a given image has been previously published. Manual searching is of course possible, but automated techniques are essential in the context of a massive course.

This problem becomes even more difficult if one considers submissions that feature interactivity, where it can be trivially easy for students to claim another's work as their own and where similarities may not be readily detectable using image analysis methods alone.

HOW CAN QUALIFIED CARTOGRAPHIC EXPERTS BE EASILY IDENTIFIED AND ENCOURAGED TO ASSIST STUDENTS IN NEED?

Perhaps the greatest challenge we see in the further development of peer assessment techniques for cartographic education at scale is the need for map design expertise to become more scalable. While we have shown here that a relatively simple assignment with an easily understood rubric can generate consistent and reliable results, we expect grading reliability and utility to decrease as the need for detailed cartographic expertise increases for a given assignment. For example, it may be easy for students to identify the need to normalize data on a choropleth map, but far harder to identify the incorrect use of a given projection, or the need to carefully align and distribute layout elements.

We do not, however, expect that such expertise may only reside with an instructor. Our experiences with the Maps MOOC have shown that there are significant groups of professional cartographers and geospatial analysts who take the class, even though it would seem to be far too basic for those audiences. Such students tend to be interested in trying the MOOC platform itself, and some are clearly present in order to help novices get started in cartography. It would be ideal if students with expertise were more readily identifiable such that they could be then directed by an instructor to make interventions and help solve the scalability issue when it comes to providing expert feedback.

CONCLUSIONS AND FUTURE RESEARCH

Our work here has contributed lessons learned from the development and evaluation of peer assessment at a massive scale through experiences in teaching a MOOC on mapping. We have shown how such an assignment can be structured, what happens when students grade each other, how those grades compare to instructor grading, and how techniques from image analysis can help instructors see large collections of maps designed for a MOOC assignment. Based on these evaluations of peer assessment, we have outlined several key research challenges that require further research in order to develop mature mechanisms for evaluating map designs in massive cohorts. Our analysis of students' final map projects offers a unique evaluative approach to large map collections, assesses the extent to which students integrate theoretical concepts with current mapping tools and platforms, and can help guide future course offerings in designing content relevant to global cartographic aesthetics and demand.

As a next step in this research, we are focusing attention on the other types of feedback that we have collected from peer reviews in the Maps MOOC. In addition to numerical scores from rubric-based evaluation, most peer assessment frameworks provide for unstructured text feedback for reviewers to explain their ratings. In the context of the Maps MOOC, these data include thousands of qualitative descriptions from peer graders, and anecdotal reports from students indicate that these explanations are critically important sources of feedback in addition to the numerical ratings. To date we have not conducted a structured analysis of these data, and we anticipate that there are more lessons to be learned from what is contained therein. Text responses on peer assessment assignments introduce another potential scale issue for educators to solve. If there are thousands of written responses, how can one instructor make sense of this feedback and use that knowledge to improve or refine a given assignment? We believe there is the potential to leverage topic-modeling tools, including methods like latent Dirichlet allocation (Blei, Ng, and Jordan 2003), to computationally extract and summarize key topics in large collections of text. These techniques are in use today for a wide range of contexts where making sense of a large corpus requires some degree of automated summarization, and initial experiments have already been conducted to explore their potential utility for analyzing the massive conversations that take place in MOOC forums (Robinson 2015).

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PEER-REVIEWED ARTICLE

Learning by Solving Problems: Cognitive Load Theory and the Re-Design of an Introductory GIS Course

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This article presents a teaching model to support learning by solving problems with geographic information technology. Using the case study of a re-designed introductory course in geographic information systems, I present research from studies of expertise and Cognitive Load Theory that identify learning objectives and methods for problem-based instruction. I illustrate a general template for learning geographic technology by solving a problem based on a process of understanding the problem, developing a plan, and implementing the plan. This template also reinforces learning during practice and exam problems. The article aims to encourage future research on problem-based instruction of geographic information technologies that integrate cognitive studies of learning, spatial thinking, and problem solving.

INTRODUCTION

There are good instructional resources for those who ask the question, "How can I develop a GIS&T curriculum that works?" (Prager 2011, 64). But as a junior member of a department, the question I needed answered was slightly more modest: "How can I re-design components of a course that I have inherited from a colleague in a way that preserves what works while improving what could work better?"

In spring 1987, Bob Churchill began offering a course titled "Cartography/Graphics" in the Geography Department at Middlebury College. Churchill viewed computer-based cartography as a "profitable pedagogical tool," one that "can be used to illustrate many basic spatial and cartographic concepts far more emphatically and convincingly than conventional classroom approaches" (Churchill and Frankland 1981, 69). In 1990, Churchill renamed his course "Geographic Information Systems" after the pedagogical tool that he used. He designed his course to introduce students to spatial analysis and cartographic design by showing them how to use GIS tools to solve authentic problems. He presented these tutorials live, during a three-hour laboratory meeting. At the end of each lab, he gave a homework assignment that required students to solve a problem that was analogous to the in-class tutorial in many ways, but also presented some small twist where the solution he showed in class wouldn't work and the students had to trouble-shoot independently. By 1999, his course had been made a requirement for all majors in both the Department of Geography and the Program in Environmental Studies. Then in late October 2004, Bob called a colleague in the department to tell him he wasn't feeling well enough to make it to class that day. On November 14, 2004, nine weeks into the fall semester, Bob Churchill passed away.

In 2007, I arrived at Middlebury, fresh from graduate school, to teach Bob's class. I received eight labs that descended from Bob's course, but no other teaching materials. There were no lab notes, no explanations for the content, and no lecture materials to accompany the laboratory tutorials. So I studied the labs like rare artifacts. Why did he spend the whole lab period demonstrating how to solve one long problem before students worked independently? How could he have presented the tutorials in ways that would help the students digest the depth of content that they contained? What made a problem different from the tutorial in a way that gave it a good twist?

This article shares answers to some of these questions and aims to help instructors who are engaged in the design of instructional materials that support learning while solving problems with geographic information technologies. In the next section, I review research in expertise and cognitive load theory that point to learning objectives and strategies for problem-based instruction. Next, I present my revisions to Bob's teaching model to support problem-based learning in an introductory GIS course. The discussion section connects the framework to (1) general kinds of knowledge that characterize expertise, and (2) evidence-based methods for instructional design from cognitive load theory. The discussion concludes by connecting the framework to future research questions in cartographic education, including applications for teaching cartographic design.

LEARNING BY SOLVING PROBLEMS

"The Strawman Report" (2003, 13) posits problem solving as a core component of learning GIS, arguing that it is "essential for academic programs to emphasize the practical aspects of the GIS&T domain along with the theoretical ones… Central to all paths is the development of problem identification and problem solving capabilities." But the report does not offer instructors much specific guidance for doing this. Similarly, the Body of Knowledge for Geographic Information Science and Technology (DiBiase et al. 2006) that followed the Strawman Report provides a rich list of desideratum to define levels of competency with geographic information technologies, but doesn't offer prescriptive advice to help teachers support this learning.

So as I began to redesign Bob's course, I started with a basic question: what do students do when they solve problems? Duncker (1945) defines a problem as a situation that arises when an agent "has a goal but does not know how this goal is to be reached."

> Whenever one cannot go from a given situation to the desired situation simply by action, then there has to be recourse to thinking. (By action we here understand the performance of obvious operations). Such thinking has the task of devising some action which may mediate between the existing and desired situations.

This suggests that problem solving is the thinking that students must learn to do when they don't know what to do. It also suggests that when students can do something without thinking about it, then the thing that they are doing is no longer a problem for them. Applied to the technology we teach, the latter point is presumably a basic learning objective for most GIS instructors: we'd like our students to be able to do things with geographic information technology without having to think a lot about the software itself. In Marble's (1998) pyramid of competency, this constitutes the first operational level ("if an operation is accessible from the interface tool bar, then the individual should be able to handle—*and understand*—it without too great an effort").

But the first point is more challenging. How can instruction help students learn to think through a problem with a GIS? As an instructor, the issue is two-fold. First, what are meaningful learning objectives for "problem identification and problem solving capabilities" that transcend skills that are specific to software? Second, how can instruction support learning and not make learning more difficult?

THINKING THROUGH PROBLEMS

To get at the first question, I began by asking: how do experts differ from novices when solving problems? This question can be approached in at least two different ways and each reflects a different metaphor of learning (Sfard 1998). One way is to identify kinds of knowledge that experts seem to possess and that novices do not possess. This frames learning with an *acquisition* metaphor, as something that learners can acquire, construct, and transfer. An alternative approach is to compare what experts seem to be able to do while solving problems that novices cannot do. This frames learning with a *participation* metaphor, as something that experts *do* rather than *have*, and as something embedded in practice. Below, I briefly follow both routes to outline learning objectives that can be drawn from each.

The first path considers expertise as domain-specific knowledge that experts acquire over years of experience. In an insightful review of research in physics, computer programming, and medicine, Mayer (1992) identifies four key differences between experts and novices. First, experts seem to understand *facts* differently than novices, where facts are basic knowledge of a domain. Experts seem to store this basic knowledge in larger units and can access it more rapidly than novices. Second, experts seem to understand the *semantics* of tasks differently than novices. They are more likely to recognize conceptual underpinnings of problems, while novices are more likely to focus on surface features. Third, experts seem to understand the *schematic* structure of a problem differently than novices. This can be observed be comparing how experts and novices sort problems. Experts are more likely to discriminate problem types with categories that reflect a principle-based plan for solving problems, while novices are more likely to sort based on surface features of problems. Fourth, experts seem to understand *strategies* for generating and monitoring solutions differently than a novice. Experts tend to employ large chunks of knowledge to plan solutions, while novices are less likely to work forward through a solution with a plan while considering alternatives.

Dana Tomlin's (1990) textbook on cartographic modeling neatly illustrates each kind of knowledge in the domain of problem solving with a GIS. Factual knowledge is illustrated by his description of "Cartographic Models" (2–23). A cartographic model consists of map layers, which have a title, resolution, orientation, and zones; zones have a label, value, and locations, and so on. For Tomlin (an expert), a map layer consists of all these lower-level facts. A student who uses this textbook (novice) will likely learn each lower-level fact individually and slowly associate them into larger chunks. Semantic knowledge is illustrated by Tomlin's description of "Relationships Between Cartographic and Geographic Space" (24–45). Here, he begins to explain reasons for measuring distances between the center points of cells and reasons for measuring length based on relationships of a location to its eight neighbors. The semantics of these tasks are revealed by Tomlin's explanations that are based on relationships between spatial concepts and cartographic models. Schematic knowledge is illustrated by Tomlin's taxonomy of local, focal, and zonal operations (64–165). He sorts GIS operations into groups based on underlying spatial principles. Strategic knowledge is illustrated by his discussion of "more sophisticated techniques" that involve "combining selected operations into procedures that are tailored to the needs of particular applications." These are similar to routines in computer programming and evidence a means of organizing knowledge about solutions in larger chunks organized around higher-level goals.

Another way of framing expertise is to examine what experts seem to be able to do rather than focus on the kinds of knowledge that experts seem to possess. For Schön (1983, 53–55), expert practitioners are often able to do things without thinking about them, without being aware of having learned how to do these things, and without even the ability to describe what it is that they know that allows them to act. This tacit knowledge he calls "knowing-in-action" and, importantly, it is something learned through practice and not through the conscious application of principles. In addition, he describes the ability of expert practitioners to think on their feet, to learn by doing, or to think while acting, which he categorizes as "reflecting-in-action." This again emphasizes what experts know to do, rather than what knowledge they have, and also situates this active knowing in a particular problem context.

As Sfard (1998) notes, the importance of recognizing two different frames for learning from or through experience is not to choose one as superior over the other, but rather to encourage instructors to incorporate the ideas of both in their design of learning environments. For me, the two together help shape objectives for both acquiring knowledge and learning by doing. For the former, objectives include helping students organize facts, explain how and why operations work, compare and contrast different problems, and develop plans for solving them. For the latter, objectives include helping students learn to do things without thinking about them, enable incidental learning through action, and encourage reflection while problem solving.

A final issue common to both frames of learning concerns how to guide students through the process of solving problems. Pólya (1971) recognized that learning to solve mathematical problems requires some thoughtful guidance by teachers, and he provides a useful template to support learning by problem solving. He suggests teachers should guide students through four phases of problem solving. First, help students understand the problem. This includes recognizing the goal, the initial states, and the conditions. Second, help students devise a plan by looking for analogies between the current problem and ones that have been solved previously. Third, help students carry out the plan and monitor each step to check if it is correct or as they expected it. Fourth, help students reflect on their result and the solution that obtained it, examining if there may be alternative ways to derive the result and whether there are parts of their solution that they might be able to use elsewhere.

COGNITIVE LOAD THEORY

While I developed these learning objectives, I also sought a framework to help understand learning as a cognitive process and how instruction may influence this process. I could sense that there were at least two components of Bob's teaching model that students found difficult. First, students struggled to connect lecture content to the labs. Second, students struggled to keep up with the live tutorials. It was difficult for them to click along with the tutorial, take notes, and connect software tools with deeper aspects of problem solving all at the same time. I wanted to understand if the difficulty lay in the material itself or if it instead had to do with the way that I presented the material to students, or perhaps in some combination of the two. I found Cognitive Load Theory (Plass, Moreno, and Brünken 2010) to be particularly useful because it considers ways in which the intrinsic content of material, the way an instructor presents this content, and the way that novices solve problems all interact to influence learning. In this section, I briefly outline the theoretical framework and the strategies it offers instructors for supporting learning while problem solving.

At first glance, Cognitive Load Theory (CLT) appears firmly embedded in the acquisition metaphor of learning. CLT views learning as an active process, involving the integration of new information with previous knowledge and the construction rather than the replication of knowledge (Bartlett 1932). Sweller (2010) calls this the "borrowing and reorganizing principle" of learning: we borrow information from other people's memory and then reorganize it by assimilating this new information with things we already know. CLT posits that learning involves the construction of general knowledge structures called "schemas" that we construct in working memory and then store in long-term memory (Figure 1). While the capacity of long-term memory appears to be quite vast, the capacity of working memory is limited. CLT largely concerns how the limited capacity of working memory, as well as the previous knowledge stored in long-term memory, can affect how we use and acquire knowledge.

With respect to how we use knowledge, CLT posits that schemas held in long term memory can be processed in two ways. The first is unconscious processing,

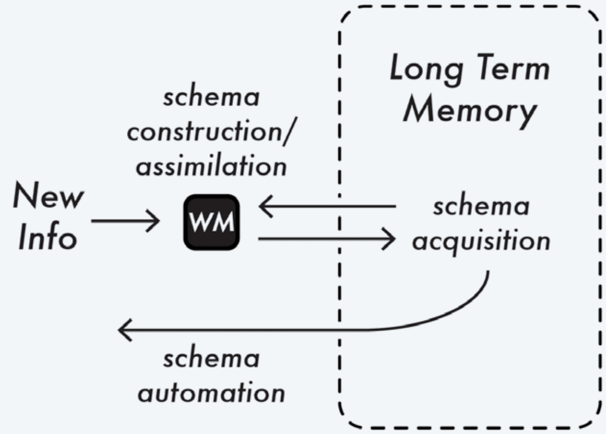

Figure 1. Cognitive Load Theory assumes a model of learning based on schema construction in Working Memory (WM), schema acquisition in Long Term Memory, and schema automation from Long Term Memory.

or something done without thinking and without placing load on working memory. In CLT, this process is called "schema automation" or "automatic processing." This is distinct from "controlled processing," which occurs in working memory and is characteristically slow, conscious, and limited (Schneider and Shiffrin 1977). Thus, although the jargon used to describe learning within a CLT framework fits easily with the acquisition metaphor of learning, it does not necessarily exclude the participation metaphor, or at least the kinds of knowing described by Schön (1983). Automatic processing bears similarity to knowing-in-action, as both involve knowing without thinking. Additionally, controlled processing seems similar to reflecting-in-action.

With respect to how we acquire knowledge, CLT distinguishes three basic types of demands that learning places on cognitive processing systems (Moreno and Park 2010). *Intrinsic load* results from the process of representing the content that needs to be learned and deals largely with the inherent complexity, or the number of elements and their interactions or relationships between them that must be held in working memory at the same time during schema construction. *Extraneous load* results from elements that occupy a learner's working memory which are independent of (and not essential to) the content to be learned and are instead attributed to the presentation of the information. Whatever capacity of working memory that is not occupied with intrinsic or extraneous load then has the potential to be germane to the goal of schema acquisition and automation. This *germane load* results from the active work of constructing and acquiring schemas.

A common goal of research guided by CLT is to identify instructional strategies that minimize extraneous load on problem solvers in order to better enable the processing demands of intrinsic and germane loads. In CLT, these strategies are called "effects" because they have been empirically verified to affect learning outcomes.

The *worked-example effect* describes a decrease in extraneous load that can result when novices study a complete description of a solution (Sweller and Cooper 1985; Ward and Sweller 1990; Renkl and Atkinson 2010). Worked examples do not simply show students the answer. Rather, they share with students the process of thought entailed to solve the problem. Comparisons of learners who studied conventional problems and worked-examples have found that those who study worked-examples have better learning outcomes with respect to transfer performance, or higher performance reached with less time studying problems and with less mental effort (Paas and Van Merriënboer 1994). Worked examples are not common in GIS education, but have been studied extensively in other domains, including statistics (Paas 1992; Quilici and Mayer 1996), algebra (Sweller and Cooper 1985; Carroll 1994), geometry (Paas and Van Merriënboer 1994), databases (Tuovinen and Sweller 1999), and design (Rourke and Sweller 2009).

Worked examples are most successful when they employ additional methods for presenting instruction that reduce extraneous load. One method is to present elements in integrated formats rather than in isolation. This is most important if the learner needs to hold the elements together in working memory in order to construct and acquire a schema. This is called the *split attention effect* (Chandler and Sweller 1991; Sweller and Chandler 1994; Sweller et al. 1990). Another method is to replace multiple instances of information that present the same content and can be understood in isolation with a single source. This is called the *redundancy effect* (Chandler and Sweller 1991; Sweller and Chandler 1994).

There is also some evidence that the germane load of worked examples can be improved with additional methods. One method is to present worked examples that contain task variability. This helps foster comparison of problem types and is called the *variability effect* (Paas and Van Merriënboer 1994). Another method encourages students to imagine a procedure or task after studying a worked example presentation. This is called the *imagination effect.* It appears to helps learners automate previously constructed schemas when compared to methods that require learners to study a worked example without requiring them to close their eyes and imagine it (Cooper et al. 2001; Ginns, Chandler, and Sweller 2003; Leahy and Sweller 2004).

Another key insight from CLT concerns the limitations of the worked example and other associated effects that arise due to the previous knowledge a learner may bring to the classroom. The *expertise reversal effect* occurs when strategies that decrease extraneous load for novices have the opposite effect on learners with more domain expertise (Kalyuga et al. 2001; Kalyuga et al. 2003). It appears that the worked example effect is strongest for novices. As learners develop domain expertise, providing them detailed descriptions of solutions can be extraneous and increase working memory load. It requires them to process additional information that is not germane to schema construction and acquisition. As a result, *guidance fading* strategies aim to minimize negative effects by sequencing instruction from worked examples to independent problem solving (Renkl et al. 2002; Renkl and Atkinson 2003). Often guidance fading strategies wean learners from worked examples by asking them to complete one or more missing steps in an otherwise worked-out solution, called the *completion effect* (Paas and Van Merriënboer 1994).

A common goal for all of these strategies is to enable *explanation* activities as part of the solution process (Chi et al. 1989). Renkl (2010, 233) identifies several general strategies for eliciting explanations that connect to three kinds of knowledge that characterize expertise (Mayer 1992, 387–414). In *principle-based explanations*, a learner explains an underlying domain principle for an operation or set of operations (semantic). In *goal-operator explanations*, a learner identifies goals achieved by operators and recognizes relationships between goal structures and operator sequences (strategic). In *example comparisons*, a learner compares and contrasts the deep or functional structure of different examples (schematic).

At this point, we've discussed the following components to guide the design of problem-based instruction with geographic information technologies:

1. Frame learning objectives with types of expertise drawn from both acquisition and participation metaphors of learning

2. Guide students through stages of problem solving

3. Present information with methods that manage cognitive load

The next section illustrates how I implemented these components in my redesign of Bob's course.

A TEACHING MODEL TO SUPPORT LEARNING BY SOLVING PROBLEMS WITH GIS

The teaching model I currently use maintains two central components of Bob Churchill's original model: (1) a worked-example method to introduce GIS tools to students in the context of solving geographic problems, and (2) task variability by presenting students nearly analogous practice problems following the introductory tutorial problem. The two major changes I made to this teaching model are (1) to present the worked example as three stages of problem solving, and (2) to present the software tutorial as a pre-lab assignment. Figure 2 illustrates the main components of the teaching model. The vertical axis shows the three types of problems presented to students (tutorial, practice, exam). The horizontal axis represents three phases of problem solving (understand, plan, implement). The tone of each shape represents fading in a social dimension from instructor-led (black) to collaborative (hatched) to independent (hollow). The orientation of each shape represents sequencing in a transfer dimension, or the degree to which the problem is analogous to the first problem, from nearly analogous with a slight twist (only a slight rotation) to a problem that involves a situation that is not analogous to a tutorial problem (a large rotation).

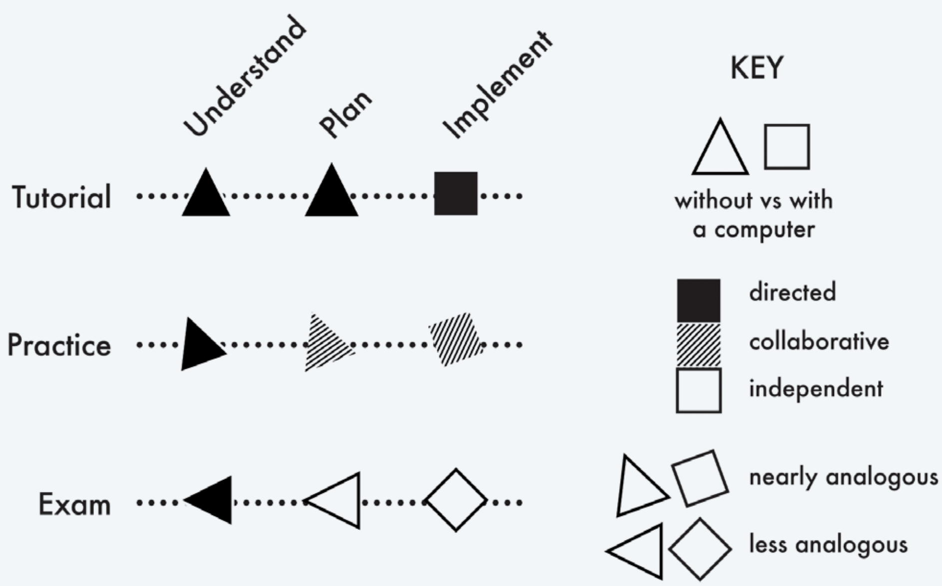

Figure 2. Teaching model for learning to solve problems with GIS.

Over the duration of the semester, instruction transitions from Tutorial to Practice at a weekly interval (each week, students solve both types of problems), repeating this pattern for several weeks before students attempt Exam problems during a staged take-home format.

Below, I illustrate the teaching model with an example drawn from the second week of instruction that used a version of IDRISI by Clark Labs.

UNDERSTANDING THE TUTORIAL PROBLEM

The week begins in lecture when students first receive a verbal description of a problem on a sheet of paper. There are at least two learning objectives for the phase of understanding the problem:

1. To recognize functional components of a problem

2. To develop complementary verbal and pictorial models of the goal

Both objectives aim to focus attention away from surface features of the problem and towards the problem's deeper structure. For the first, I try to help students identify descriptions of the goal state, the initial state, and the conditions. To do this, I mark up the problem with different colors to distinguish different components and encourage students to do the same. Using an overhead projector or a digital tablet, I use different colors to underline or highlight the goal state, the initial states that are given to them, and the conditions or constraints that are given to them (Figure 3).

GOAL	On college campuses, planners often use parking lot designations to discourage first year students from bringing personal vehicles to campus. This aims to encourage students to spend more time on or near campus, and also to encourage ridesharing with friends or with public transportation when exploring the region. Your task is to identify parking lots on college-owned land that could be used for parking by the 225 students in the freshman dormitory.
CONDITIONS	The parking lots should be large enough to accommodate one car per dorm resident, but they should require the students to walk at least ¼ mile from the dorm to access their vehicles. In your model, use the American Planning Association's recommendation that parking lots should allocate 300 square feet of space per car (this includes space to park the car and also for the lanes to access the parking spot).
INITIAL STATES	We provide you with two raster layers to use in this analysis. One represents locations that can be used for student parking on campus with Boolean values (1 if students can park at that location, 0 if they cannot). The other represents the location of the single college dormitory that houses first year students, also with Boolean values.

Figure 3. Help students recognize functional components of a problem's verbal description.

For the second learning objective, I draw schematic diagrams of the spatial relationships that define the problem's key conditions (Figure 4). I tend to draw the pictures in front of the students, rather than just flash pre-made graphics on a screen, as I find that this helps encourage students to draw along with me. Thus the graphics in Figure 4 are a bit more crisp-looking than what students would see on the blackboard.

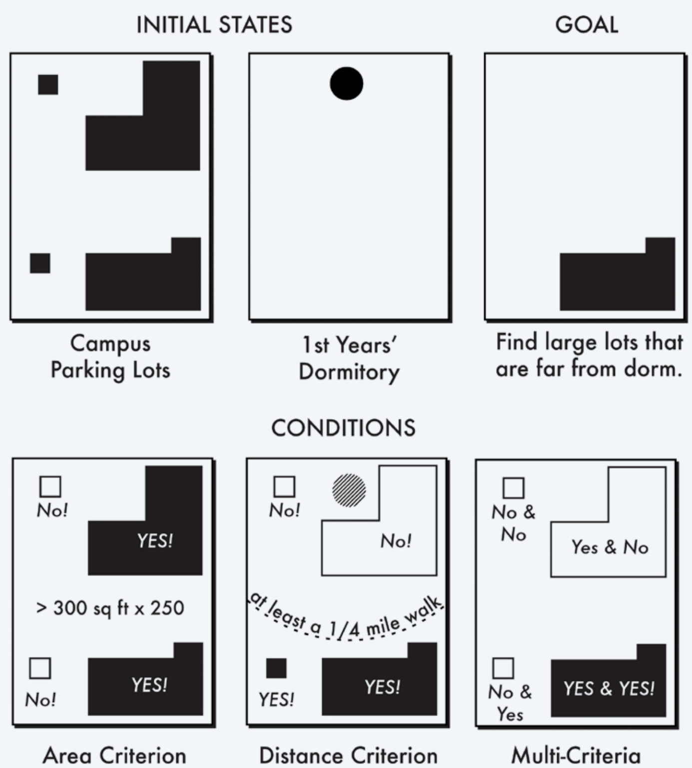

Figure 4. Helping students develop pictorial representations of a problem's functional components.

PLAN TUTORIAL SOLUTION

The next stage involves developing an initial plan for solving the problem. We continue this discussion in lecture. The four learning objectives are to:

1. Decompose a problem into a hierarchy of sub-tasks
2. Map general functions to specific operations
3. Develop good representations of each sub-goal
4. Organize tasks into a sequence of moves to be implemented

For the first objective, I first show students how to decompose the goal into a series of sub-tasks by focusing on telic ("in order to") relations of goals (Figure 5a). For example, I ask, "In order to find lots that meet both area and distance conditions, what two things must we know first?" That should lead to two sub-tasks: find lots that satisfy area condition and find lots that satisfy distance condition. We continue this decomposition activity until we bottom at the initial states that were given to us. At this point, we reflect on the structure of the task hierarchy in order to recognize how sets of tasks suggest larger chunks of the procedure. In this example, we can connect three chunks of tasks to the three conditions visualized during problem representation.

Next, we focus on mapping specific tasks to general functions that can be described with key terms (Figure 5b). To do this, I have students compare a task to related subtasks and ask students, "What seems to be the key term that appears in the goal description but not in the related sub-goals?" This should encourage students to identify vernacular terms for the function of each goal. For example, "and" is the key term in the first goal as it doesn't appear in the two related sub-tasks. This activity creates a list of vernacular words that identify the function of each task that we can then map to technical terms for each tool (Figure 5c)

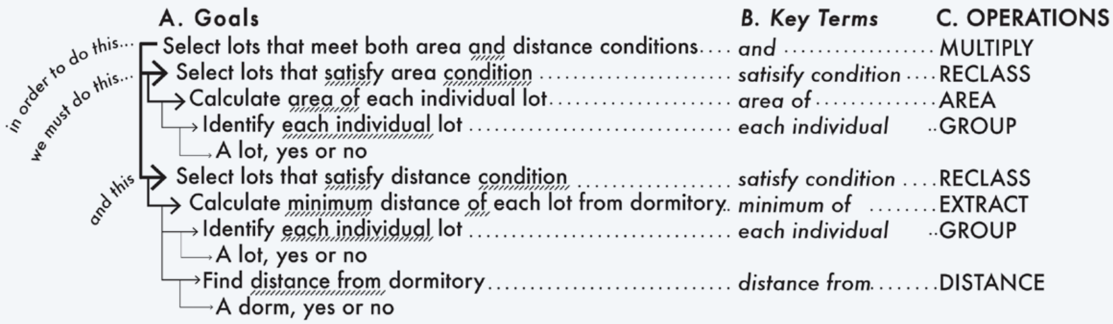

Figure 5. *A verbal task hierarchy that maps vernacular key terms to technical operations.*

This sets up a return visit to the phase of understanding problems. Essentially, we've broken one problem into many little problems. Students may again need help understanding the components of each new little problem and help developing pictorial models to complement their verbal descriptions. To do this, I draw schematic diagrams of each sub-problem that aim to help students understand principles for solving them. Figure 6 provides an example for the sub-problem "to identify each individual." We return to the idea of transforming an initial state to a goal state under certain conditions. To help students associate the abstract concept with things they already know, I transition drawings from everyday objects to technical implementations (Figure 6).

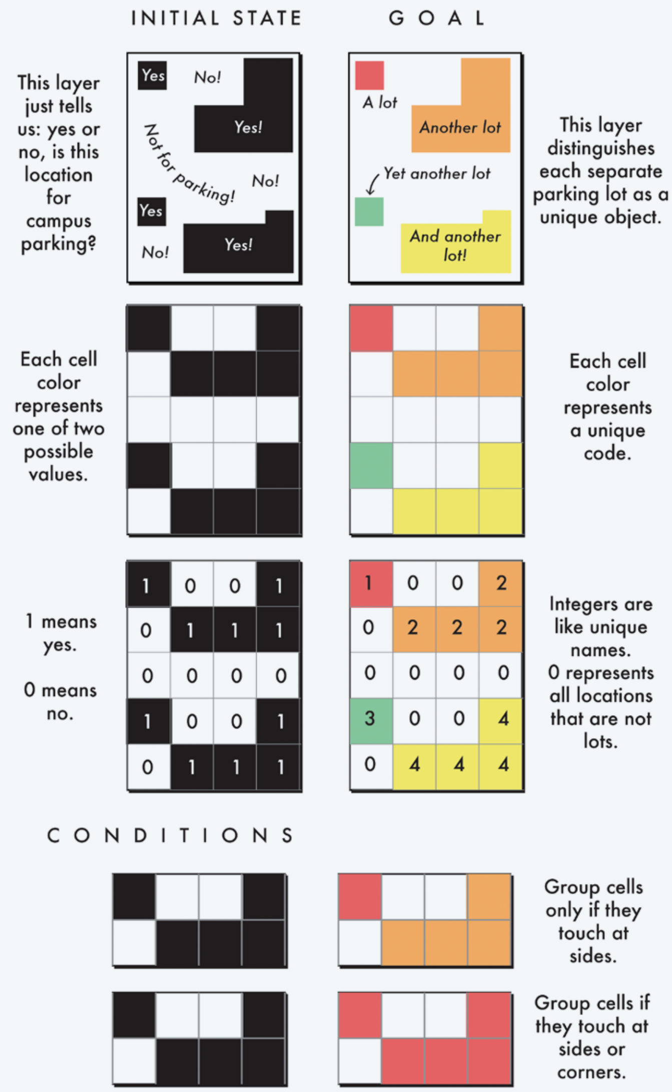

Figure 6. *Help students understand sub-tasks by thinking from everyday objects to technical concepts.*

After helping students understand each subtask, we then resume the planning phase and discuss efficient ways to arrange the tasks in a workflow. Students may need help thinking about how task hierarchies can influence sequencing strategies. There are at least three components to planning solutions: (1) identify connections between tasks, (2) make the solution efficient by removing steps, and (3) determine a sequence. (The busy-looking Figure 7 shows these three components all at once, though I tend to draw them for students in a sequence.) I encourage students to think about planning a workflow as something akin to writing: first focus on making an initial draft and then consider how this might be improved through revisions. As a first draft, we draw a workflow diagram that transcribes each task and shows relationships between them. Figure 7 shows this with black ink. In our revision, we focus on ways to make the solution more efficient by eliminating steps that will not affect the answer. Figure 7 illustrates this with red ink. Third, we explore principles for ordering actions in a workflow by considering how the structure of the solution may exert some control over the sequence of operations. Looking at the work flow diagram, whenever two branches join to make a larger stem, we can tell that no step after a confluence can begin until

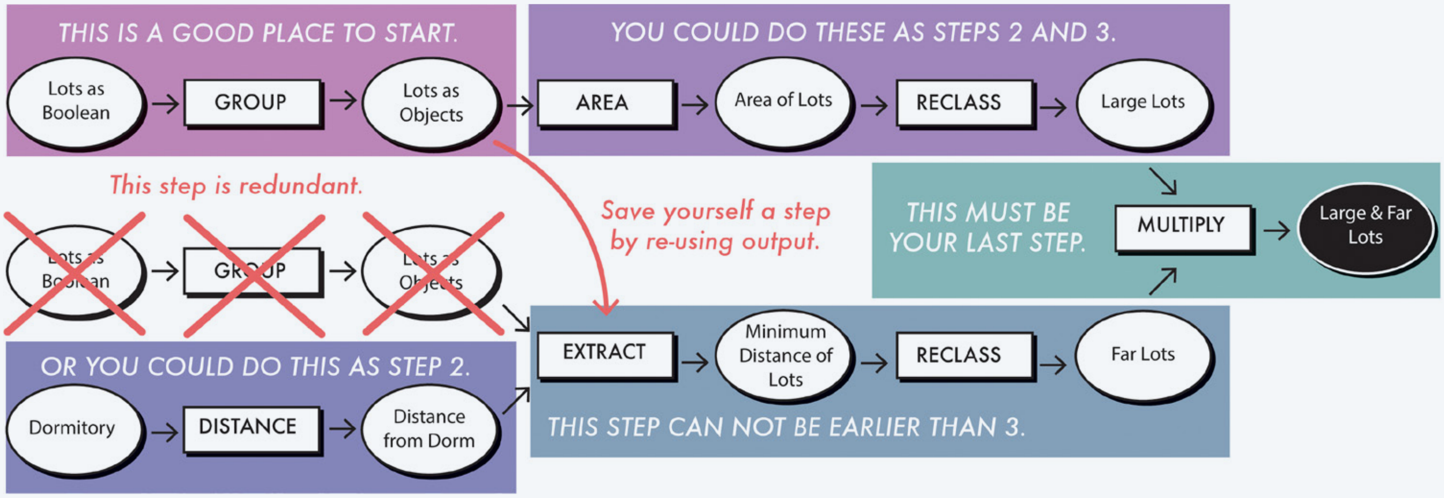

Figure 7. *Help students think through three phases of workflow planning: initial draft in black, revisions for efficiency in red, sequencing in twilights.*

all steps in each branch have been completed. We can also see that nothing about the problem's structure controls which of these two branches gets taken up first.

OPERATION	key terms	GOAL
(1) GROUP	individuals	To identify individual lots
(2) AREA	area of	To calculate area of each lot
(3) RECLASS	satisfy condition	To select lots that satisfy area condition
(4) DISTANCE	distance from	To calculate distance from dormitory
(5) EXTRACT	minimum of each	To calculate minimum distance of each lot from dormitory
(6)		To select lots that satisfy distance condition
(7) MULTIPLY	and	To select lots that meet both area and distance conditions

Figure 8. *The task hierarchy segments implementation lessons.*

IMPLEMENT TUTORIAL SOLUTION

The next stage involves implementing the plan to solve the problem. Students study these learning materials as homework in preparation for our laboratory meeting. The two learning objectives are:

1. To learn routine tasks of navigating the GUI and of operating tools

2. To monitor the solution implemented with respect to the plan

To implement solutions, I make video tutorials that combine a spoken narration with a screen capture of my interaction with the software to help guide students through the graphic user interface of the software and help them connect these actions back to the plan for solving the problem. This allows students to study the tutorial at their own pace and gives them time to take notes while they follow along. Students are required to study these materials before coming to our lab meeting. To help students connect these actions with the plan, I use the task hierarchy to segment these software tutorials (Figure 8). Each video provides a worked example for how to execute one step in the plan. The playlist does not show how to use a tool twice. When students can produce correct answers by implementing the plan with computer software, they are required to take a short quiz. This also provides incentive to study the plan and implementation materials.

PRACTICE PROBLEM

With the practice problem, instruction fades from directed, or instructor lead, to collaborative problem solving. The understand, plan, and implementat phases of the practice problem all occur in the computer laboratory. I encourage students to work in pairs or small groups of not more than three. The learning objectives of this stage are to:

1. Support learning through task variation

2. Foster self-explanations during each stage of problem solving

The means to these ends consists of a new problem that in most parts has an analogous structure to the initial training problem. The surface features differ and there is at least one part of the problem that is not analogous with the tutorial problem. For example, I often use a variant of this island biogeography problem following the first-year student parking lot problem.

> In 1967, Robert MacArthur and Edward Wilson published a monograph titled *The Theory of Island Biogeography*. The theory posited that certain biological characteristics of islands, such as the number of resident species, could be predicted based on the island's area and distance from the mainland. The "area effect" posited that the rate of extinction would be inversely related to the island's area: extinction rates would be higher on smaller islands than on larger islands. The "distance effect" posited that the rate of immigration would be inversely related to the island's distance from the mainland: immigration rates would be higher on islands near the mainland than on islands far from the mainland. Jared Diamond (1969) tested the theory, using bird species lists from California's Channel Islands. Using the raster layer named "CA_borderland," please make a single map layer that codes each Channel Island based on both distance and area. Classify the islands with 20km increments for distance (<20, 20–40, etc) and a log scale for area ($1km^2$, $10km^2$, $100km^2$, etc). The final layout should show the mainland and show each island with a single code that represents both the distance class and area class.

What makes this problem different than the tutorial problem? First, the surface features are different. We're dealing with islands and the mainland rather than parking lots and dorms. We're also concerned with the movement of critters rather than first year college students. Second, the initial condition and the goal state are both different. Students will need to separate the mainland and islands as separate layers in this problem and they will need to figure out how to develop a coding scheme that uses one value to represent two attributes. But the key spatial relationships that define the problem's conditions do not differ from the practice problem. The mainland and islands are all disjoint, as were the dorm and parking lots. Because of this, the middle part of the solution is directly analogous to the tutorial problem.

In the laboratory meeting, students are required to complete each task in the three-phase workflow presented in the tutorial. They are required to check in with an instructor after they have completed their plan and then again after they have completed their implementation. Through these interviews, the instructor aims to elicit explanations from students. Questions may include:

- **Example comparisons:** *Q*. Why does your plan differ from the plan for the tutorial problem? *A*. We need to separate the mainland from the islands because you didn't provide them on separate layers like last time. And we need to use addition here to combine the area and distance classes rather than multiply them.

- **Goal-operator explanations:** *Q*. What would happen if you had calculated the area of islands without first doing the GROUP step? *A*. I would calculate the area of the entire archipelago rather than each individual island.

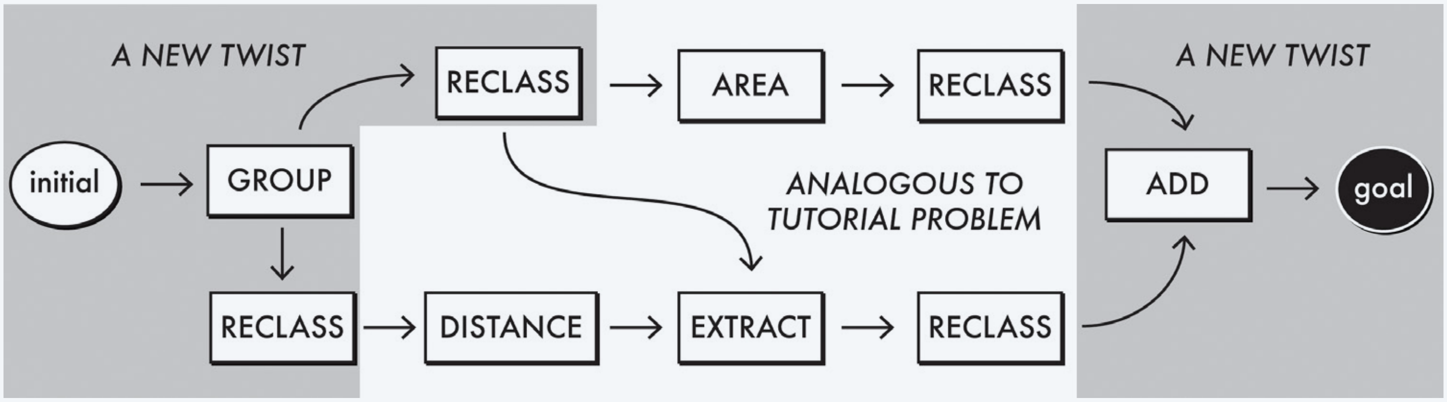

Figure 9. *Plan for practice problem. Conditions are analogous to tutorial problem. Initial states and goal present new twists.*

- **Principle-based explanations:** *Q.* Will you be able to see any of the small islets that surround these islands in your final answer? *A.* If they are smaller than the square of the cell size, then probably not.

After implementing their plans, the students are then required to show their answers to an instructor and correct any mistakes if necessary. When they have arrived at the correct answers, the instructor again engages the students in the final reflection stage of problem solving.

- **Example comparisons:** *Q.* How does this workflow differ from the tutorial? *A.* It's pretty similar, we just used addition rather than multiply at the end. And we defined classes differently in the steps before that.

- **Goal-operator explanations:** *Q.* Why are the cells immediately adjacent to the mainland feature never less than 100m distance? *A.* The minimum distance from the target is the cell size of the raster layer.

- **Principle-based explanations:** *Q.* Do you think the area that you calculated might overestimate or underestimate the area of the islands? *A.* Well, on one hand you could say it underestimates it because it calculates planimetric area rather than surface area. But on the other hand, it basically adds together chunks of 10,000 square meters, so maybe that overestimates things?

When students have arrived at the correct answer, presented the answer in the requested layout, and provided satisfactory answers to the prompts, they have completed this part of the instruction.

EXAM PROBLEM

After three or more weeks of cycling through tutorial and practice problems, I give students an exam that aims to both assess their learning in the course up to this point while also proving an opportunity for them to continue to learn. Exam problems (I generally give two) have some analogies with tutorial and practice problems. One exam problem will also involve a twist that results from a novel spatial relationship in the problem conditions. For example, consider this problem:

> When driving on a road, your cell phone call will likely be dropped when you drive across a coverage zone boundary (or at the first pixel on the road that is immediately adjacent and outside of a coverage zone). Given a layer that shows the number of cell towers that can be "viewed" from every location in the state and another layer that shows state highways, make a table that reports the number of pixels on each road where your call would likely get dropped. Don't worry about the direction you may be driving, just report the total number of pixels on each road that are immediately adjacent to and outside of a coverage zone. Assume that if at least one tower is visible at a pixel, then that pixel is in a coverage zone.

This problem can be solved in five steps or fewer with tools that the students learned in the tutorial and practice problems described above, but many students struggle mightily with the problem. To solve it, they must work out a new spatial relationship in the problem conditions that differs from those they have previously encountered (Figure 10). In CLT language, they have not acquired schemas for solving all parts of this problem and must engage in the construction of a new schema without guidance.

As Figure 2 indicates, the exam is again structured around three phases. The exam begins with a presentation of each problem by the instructor. I tend to draw schematic pictures of the problem's conditions, helping students with this one part of understanding the problem in order to draw their attention to the key condition of the problem. I also provide students with pictures of the real datasets, including pictures of the metadata (cells size, extent, reference system, data schema, etc.). Students then have a period of time to develop plans for solving the problems. They are asked to complete a detailed workflow (input-operation-output diagrams) and detail all parameters for each operation that may affect the outputs. They are permitted to experiment with their plan using any of the data from the tutorials and practice problems from previous weeks, but do not have access to the exam datasets during this planning phase.

After several days, we meet again and students submit the original materials from the planning phase (workflow descriptions). They have been instructed to save a copy of these materials for the next phase. I then make the datasets available and students have a window of time to implement their plans. Ideally, they can implement their

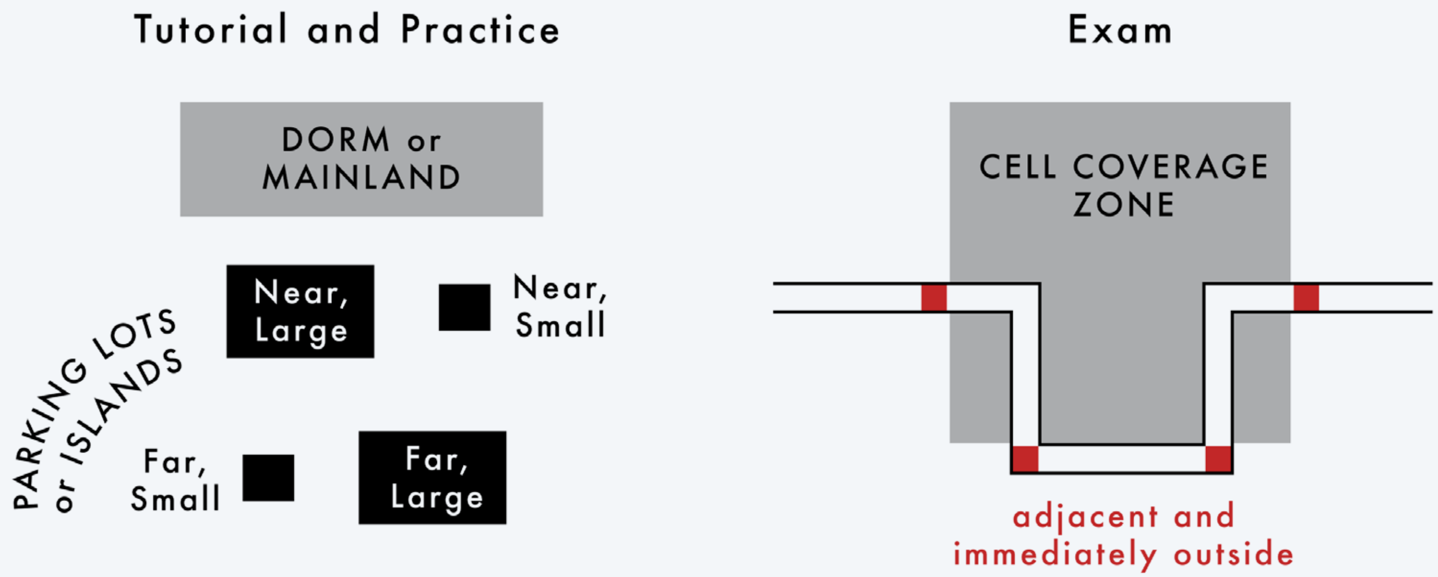

Figure 10. Conditions for one exam problem present a twist from conditions learned in tutorial and practice problems.

plans without any changes and arrive at the correct answer, but this case is usually quite rare. If their plan needs some adjustments, they are required to make the necessary corrections on their copy of the original workflow or, if the corrections are quite extensive, on a new worksheet.

After a couple days, we meet again and students submit the answers to the problem along with their corrections to their plans, if necessary. I then share with students the correct answers to the problems and discuss possible solutions and common errors. If students did not submit the correct answers in their implementation materials, then they are required to write a verbal description of each error that remained in their implemented plans and to demonstrate to an instructor that they understand how to produce the correct answers to both problems. When they have submitted these final corrections, they have finished the exam.

Thus at the end of the exam, we have sampled each student's understanding of GIS at three different moments during the process of solving the problems. This establishes a simple assessment framework. Figure 11 shows four general groups of learners. The top group develops a correct solution during the planning phase. The lower group submits plans with some errors, but can correct these errors independently once they are able to interact with the problem datasets. The answers and plans they submit at the implementation phase are both correct. The next group submits implementation materials with incorrect answers and errors in workflow, but once they can discuss the problem with an instructor, they are able to explain their

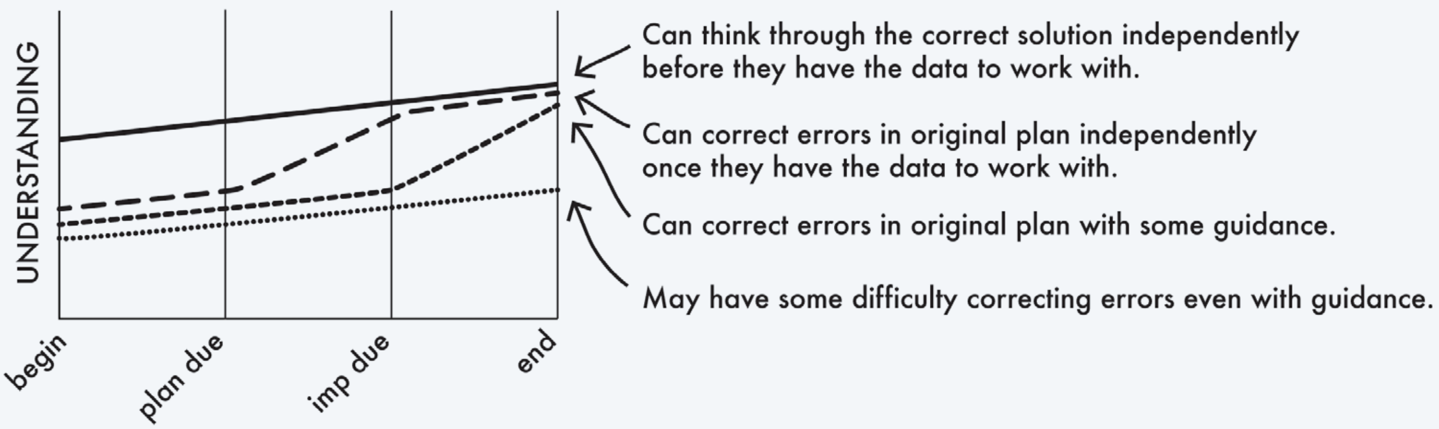

Figure 11. Assessment framework for exams.

errors and demonstrate that they can implement solutions that produce the correct answers. The final group may still have difficulty with this final part of the exam, struggling to correct errors and perhaps failing to ever produce the correct answers.

DISCUSSION

I preserved two main components of Bob Churchill's original course: presenting a tutorial that showed students how to solve a problem with a GIS and providing analogous problems with some twists in practice and exam problems. Both of these components are, in theory, supported by principles from cognitive load theory. In theory, the tutorial as a worked example should help students devote cognitive resources to learning factual, semantic, strategic and schematic knowledge associated with the problem. This is because the students won't have to devote cognitive resources to naïve problem solving strategies, like means-ends analysis, that focus attention on minimizing differences between the present state and the goal state. In theory, presenting students with analogous problems that contain different twists (or non-analogous components) should also help schema construction based on the variability effect.

One substantive change to the teaching model involved expanding the worked example into three stages (and creating moments of reflection) in tutorial, practice, and exam problems. This represents my attempt to establish a general template for a worked example that involves GIS but transcends the use of the tools themselves. Table 1 outlines the main learning objectives of each stage and connects them to different kinds of knowledge and knowing that they aim to support. Hopefully, this helps distinguish the worked example method from the practice of teaching "cookbook" labs. In the latter, the instructor merely provides students with click-by-click instructions for solving a problem given the specific software the instructor has chosen to teach. As I use the term, a worked example aims to support learning factual, semantic, schematic, and strategic knowledge, while also providing opportunities to learn tacit knowledge during the implementation phase, and conveys all of this as kinds of thinking that guide the clicking of a solution.

The second change to the teaching model did not alter the substance of the course but rather changed the mode of presentation. The video tutorials re-package content that Bob had formerly presented as a live demonstration into a format that students can study at their own pace. Video provides viewing controls (pause, rewind, forward, and variable playback speed) that allow students to cater instruction more to their individual needs. Students can pause to take notes, rewind if they miss a step, and stop when they are tired and want a break. In theory, allowing students to self-segment the instruction into small, reviewable chunks lowers the intrinsic load of the instruction. Furthermore, students can also watch on double-time if the content seems familiar or they can choose to skip entire sections. In theory, this provides a means to lower the extraneous load of instruction that may arise from expertise reversal for advanced students.

Videos present words as spoken narration and pictures as animations. This differs from the more traditional strategy of providing lab instructions as printed text and static images. Future research on how the presentation of words

Understand Problem	
Recognize functional components	*Strategic*
Develop complementary verbal & pictorial models	*Semantic, Schematic*
Plan Solution	
Decompose hierarchy sub-tasks	*Strategic*
Map general functions to specific operations	*Factual, Semantic*
Develop good representations of sub-goals	*Factual, Semantic, Schematic*
Organize tasks in sequence	*Strategic*
Implement	
Learn routine tasks and data structures	*Factual, Strategic, Knowing-in-action*
Monitor solutions	*Strategic, Reflecting-in-action*

Table 1. *Learning objectives of worked examples and different kinds of expertise that they support.*

and pictures influence learning can be informed by multimedia learning theory (Mayer 2009; Mayer 2014), which bears some similarities to CLT. Furthermore, the teaching model presented here may be useful for instructors who are considering teaching models that blend online with more traditional instruction by helping identify when instructor-student interaction may be most beneficial versus when a synchronous learning environments may be more beneficial because they allow students to self-pace the instruction.

Other principles from Cognitive Load Theory helped guide the design of teaching opportunities that resulted from expanding the worked example across lecture, prelab, and in-lab instruction (Table 2). For example, the split attention effect is a familiar plague of lecture-lab format classrooms (DiBiase 1996), where instruction presents concepts and tools separately. The problem, however, is that it's not particularly easy to present concepts and tools at the same time, or at least in a way that students can hold both in working memory at the same time. The examples of a task hierarchy (Figure 5), sub-task representation (Figure 6), and workflow plan (Figure 7) are attempts to present lecture content that help students develop schemas that integrate kinds of knowledge (strategic and semantic) that are employed when solving problems. Similarly, my decision to not create a video module for any task more than once (Figure 8) connects to both the redundancy effect and the completion effect. The imagination effect supports my strategy of drawing pictures of a problem's functional components (Figure 4) on the blackboard in front of students, rather than showing them prepared slides. It also motivates the strategy of having students plan solutions as a workflow before they interact with the computer to implement the plan. Finally, the strategy of social fading from instructor lead, to collaborative, to independent problem solving reflects the principle of guidance fading and also fosters a participatory learning environment.

Presentation Strategy	Cognitive Load Effect
Lessons integrate different kinds of knowledge	*Split-attention effect*
Video playlist does not teach same tool twice	*Redundancy effect*
Presentations of concepts with words and pictures unfold in front of students	*Imagination effect*
Social fading from instructor-lead to collaborative to independent problem-solving	*Guidance fading*
Video playlist omits some steps	*Completion effect*

Table 2. *Connecting presentation strategies to cognitive load effects.*

The example provided in this article deals with a problem of spatial analysis with GIS tools. Future research can examine the generalizability of this framework to other domains of cartographic education, including cartographic design, and other tools of cartographic practice, including print-based and web-based technology. This connects to several recent research programs on map design. Discourse analysis of map-making strategies by students (Wiegand 2002) illustrates one method to investigate how students are thinking about making maps. Research on multi-objective decision-making in map design (Xiao and Armstrong 2012) similarly aims to "help novice map makers understand the design process and make cartographic principles more relevant to an expanding community of non-geographers." Expert systems research can help identify if-then rules of cartographic decision making (Buttenfield and Mark 1991; Brus, Dobešová, and Kaňok 2009) that aim to explain reasons for particular actions in a solution. Similarly, a pattern language framework for teaching mapmaking explicitly aims to help students plan and understand reasons for actions in creative design workflows (Howarth 2015).

CONCLUSION

This article presented a teaching model for problem-based learning with GIS that incorporates findings from studies of expertise and cognitive load theory. I developed a general template for a worked-example that guides learners through three stages of problem solving and apply strategies for managing cognitive load while learning. CLT helped guide my redesign of a teaching model inherited from a senior colleague, providing a basis to keep the parts that should (in theory) work, while also identifying other parts that might make learning more difficult. CLT also raises important questions of the current model that may lead to revisions in the future. For example, do the learning goals in my strategy of presenting the worked example in stages add extraneous load? Does the presentation of tools in the context of a problem's solution complicate the transfer of knowledge, creating an *Einstellung* effect, where the learner is more likely to apply previously constructed schema than create novel solutions? This article aimed to present the process by which a current teaching model evolved with the hope of encouraging future research that tests strategies for presenting information to learners at the intersection of cognitive theories of learning, spatial thinking, and problem solving.

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The Norman B. Leventhal Map Center at the Boston Public Library: The First Ten Years of Public Outreach and Educational Programming Using Historic Maps

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The Norman B. Leventhal Map Center at the Boston Public Library (LMC/BPL) was launched in July 2004 as a partnership between Norman B. Leventhal and the Boston Public Library. In 2007, it became a separately incorporated 501(c)3 non-profit organization governed by an independent Board of Directors. Created to promote the use of maps as an important educational tool to understand history, geography, civilization, and the world today, the LMC seeks to preserve, catalog, study, and exhibit the Boston Public Library's rare and historically significant collection of over 200,000 maps and 5,000 atlases dating from 1482 to the present. Approximately 10 percent of the maps (20,000) and 20 percent of the atlases (1,000) date from before 1900.

Founded in 1848, the Boston Public Library was the first free publicly supported municipal library in the United States. It was the first to lend a book, open a branch library, and create a dedicated children's room. It is the second largest library in the United States by number of volumes and is one of only two public libraries that is a member of the Association of Research Libraries. Today, the BPL and its 24 branches serve almost 3.5 million people annually.

ACCESSIBILITY TO SCHOLARS, GENERAL RESEARCHERS, AND CASUAL VISITORS

In 2011, the LMC moved from its temporary library location to a newly renovated space in the 1896 McKim Building of the Boston Public Library's Central Branch, located at Copley Square in downtown Boston. Upon entering, LMC visitors are greeted with a map gallery, which features rotating exhibitions of about thirty objects every four months. The new LMC space also includes a learning center where patrons can browse over 1000 reference titles, a securely equipped research room that invites patrons to conduct research in a comfortable environment, and a state-of-the-art storage vault to house the historically significant collection. The LMC is staffed with eight full-time positions.

In-depth reference services are provided at the Map Center, Monday through Friday. On average, the LMC assists between 20 and 25 researchers per month in the research room, while staff answer nearly 120 additional map-related inquiries in person per month. While appointments are suggested, the LMC often accommodates casual researchers who have serendipitously become

***Figure 1.** Visitors enjoy the Norman B. Leventhal Map Center Gallery.*

interested in the collection as a result of viewing exhibitions in the map gallery. The free accessibility of the collection allows these casual visitors an opportunity to experience a research library's collections first-hand.

WORLDWIDE ACCESSIBILITY THROUGH THE WEBSITE

The LMC website, **maps.bpl.org**, was launched in 2006 and continues to be the central location for the Map Center's web presence as well as the main access point to the freely available digital collection. As the map collection is cataloged, conserved, and digitized, the maps are added to the site. Currently more than 7,000 digital map images are now accessible through the website where users can download, zoom, pan, and buy a reproduction of each of LMC's digital items. The LMC's website receives over 11,000 views on average per month, a number that has grown steadily since its launch.

In addition to the LMC's collection, agreements have been made with other institutions such as the American Antiquarian Society, Boston Athenaeum, British Library, Harvard Map Collection, Library of Congress, New York Public Library, and Newberry Library, as well as private collectors, to include American Revolution Era primary source material from their map collections within the LMC's website. This has been done in an effort to promote digital philanthropy, diversify the digital collections, and provide an access hub for historical maps. So far, the number of these types of items included in the LMC's digital collections is over 1,050 maps.

Figure 2. *Screenshot of the Norman B. Leventhal Map Center's website.*

ACCESSIBILITY TO THE PUBLIC THROUGH EXHIBITIONS

The LMC has mounted multiple gallery exhibitions since occupying its new space. Each was curated to include roughly 30 maps or cartographic items, and exhibitions have included physical tours, gallery guides, lecture programs, and outreach programs. More recent gallery exhibitions have also been formatted for the web as a virtual tour. They can be viewed at the Boston Public Library's exhibitions webpage: **www.bpl.org/exhibitions**. One recent exhibition, *City of Neighborhoods: The Changing Face of Boston*, featured current and historical maps and photographs portraying changes in Boston's neighborhood demographics over the past 100 years. Over 48,000 people visited the exhibition, which was also translated into Spanish, Haitian Creole, and Chinese to accommodate the city's most common non-English speakers.

Since the LMC moved into its new space, the staff has also completed two major exhibitions featuring about 90 objects each. The first, *Torn in Two: 150th Anniversary of the Civil War*, hosted in the BPL's Main Exhibition Hall from May to December 2011, celebrated the American Civil War's sesquicentennial by featuring 50 historic maps and 40 photographs, prints, and related materials. In 2012 and 2013, the exhibition toured to the Grolier Club in New York City, Ford's Theater in Washington, DC, and the Osher Map Library in Portland, Maine, where additional audiences could view the collection.

The second major exhibition, titled *We Are One: Mapping America's Road from Revolution to Independence*, opened in May 2015 in the BPL's Main Exhibition Hall. The exhibition commemorates the 250th anniversary of Britain's 1765 Stamp Act by displaying 60 maps and 40 related graphic documents, paintings, and three-dimensional objects. The exhibition closed at the end of November 2015, but will travel to Colonial Williamsburg in 2016 and to the New York Historical Society in 2017.

ACCESSIBILITY TO TEACHERS AND SCHOOL CHILDREN THROUGH EDUCATIONAL OUTREACH

Educational programming for K–12 students is at the core of the Map Center's mission to spark young people's curiosity about the world. Educational activities range from intensive programs where students are introduced to how to think about and engage with historic maps, to teacher training workshops that expand educators' views of the ways in which they can teach with maps. Over 2,500 students and teachers participate annually in education programs both in the Map Center and at schools. The students range from second graders learning about the elements of maps, to high school students researching the history of their Boston neighborhoods. Approximately 50% of the students are from Boston Public Schools.

Additionally, over 200 teachers annually participate in professional development workshops ranging from half-day workshops to one-week institutes. The LMC continues to expand partnerships for offering workshops, including the Museum of Fine Arts in Boston, Boston National Historical Park, and the Library of Congress's Teaching with Primary Sources program.

The Center's website serves as the main access point for map resources, lesson plans and activities for younger students. The website includes the *Maps in the Classroom* section, where downloadable map reproductions can be searched by location and curriculum topic. Additionally, the *Teacher Resources* section of the website includes lesson plans, curriculum units, and map activities searchable by grade level, location, time period, and topic.

In connection with the *We Are One* exhibition, the Map Center has made the American Revolution the main focus of its educational programming for students and teachers in 2015–2016. Funding for these initiatives has come largely from the Library of Congress's Teaching with Primary Sources Program (Eastern Region), and the Massachusetts Foundation for the Humanities. This initiative has created resources and opportunities for students and teachers to take advantage of the rich American Revolution era resources available at the Leventhal Map Center and Boston Public Library. Components of this project include:

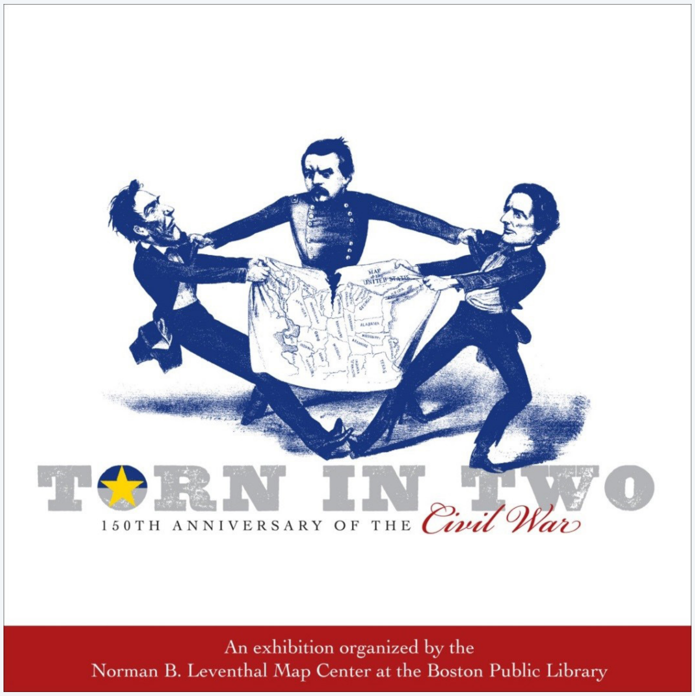

Figure 3. *Exhibition catalog cover for* Torn in Two.

- **Teacher Fellowship Program**

  Through a competitive application process, the LMC selected two teachers who spent 10 days during the summer of 2015 doing extensive research in the Map Center, BPL, and Library of Congress collections. Fellows produced lessons and resources focused around teaching the American Revolution with maps.

- **Summer Teacher Institute — *Mapping Boston's Role in the American Revolution***

  In partnership with: Boston National Historical Park, Massachusetts Historical Society, Bostonian Society/Old State House, Old South Meeting House, Paul Revere House, Old North Church, and the National Archives and Records Administration. Twenty-seven teachers spent a week investigating the Revolution with a geographical focus. Teachers received three graduate credits from Framingham State University.

- **American Revolution Map Sets & Teaching Materials**

  Working with a teacher advisory group, the Map Center has produced the first in a series of map sets connected to the collections of the LMC and Library of Congress. These sets will be presented at teacher workshops and available for any teacher from the LMC website.

FUTURE PLANS

The LMC has recently been awarded grants from the National Endowment for the Humanities and the Institute of Museum and Library Services to improve access and use of its digital collections, starting with items that pertain to the American Revolutionary War Era and including collections from numerous partner institutions. Among the many enhancements being developed, users will be enabled to georeference maps and create digital overlays, and educators will be able to access, utilize, and create digital lesson plans related to the maps for classroom teaching. All of the resulting developments will be available in an open source repository for use by other cultural institutions. A 5-year plan for Map Center gallery exhibitions includes such titles as *Women in Cartography*, *Shakespeare's World*, and *Under Your Feet*; each one exploring different cartographic and historic topics. Each exhibition will eventually become available online and accessed through the LMC's website, as will upcoming news regarding events or developments within the collection.

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Understanding the Heat Map

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INTRODUCTION

Popularized in the mashup era, heat maps show the density of point features with a yellow-orange-red color continuum. Figure 1 shows an example of a heat map depicting the prevalence of tornadoes. Google's *Geo Developers Blog* describes these maps as a representation of "geospatial data on a map by using different colors to represent areas with different concentrations of points — showing overall shape and concentration trends" (Yeap and Uy 2014).

The term "heat map" is not universally used within the GIS world. Yeap and Uy (2014) mention that they are generally known as "intensity maps." Esri's (2012) ArcGIS documentation refers to this type of map as a "point density interpolation" that is useful for purposes such as "finding density of houses, crime reports, or roads or utility lines influencing a town or wildlife habitat." While "point density interpolation" is a valid term for this method, "heat map" is more frequently used and understood. For example, QGIS, an open source GIS program, has a module for the production of "heatmaps."

Heat maps take noncontiguous point data and display them as being continuous. This method is not appropriate

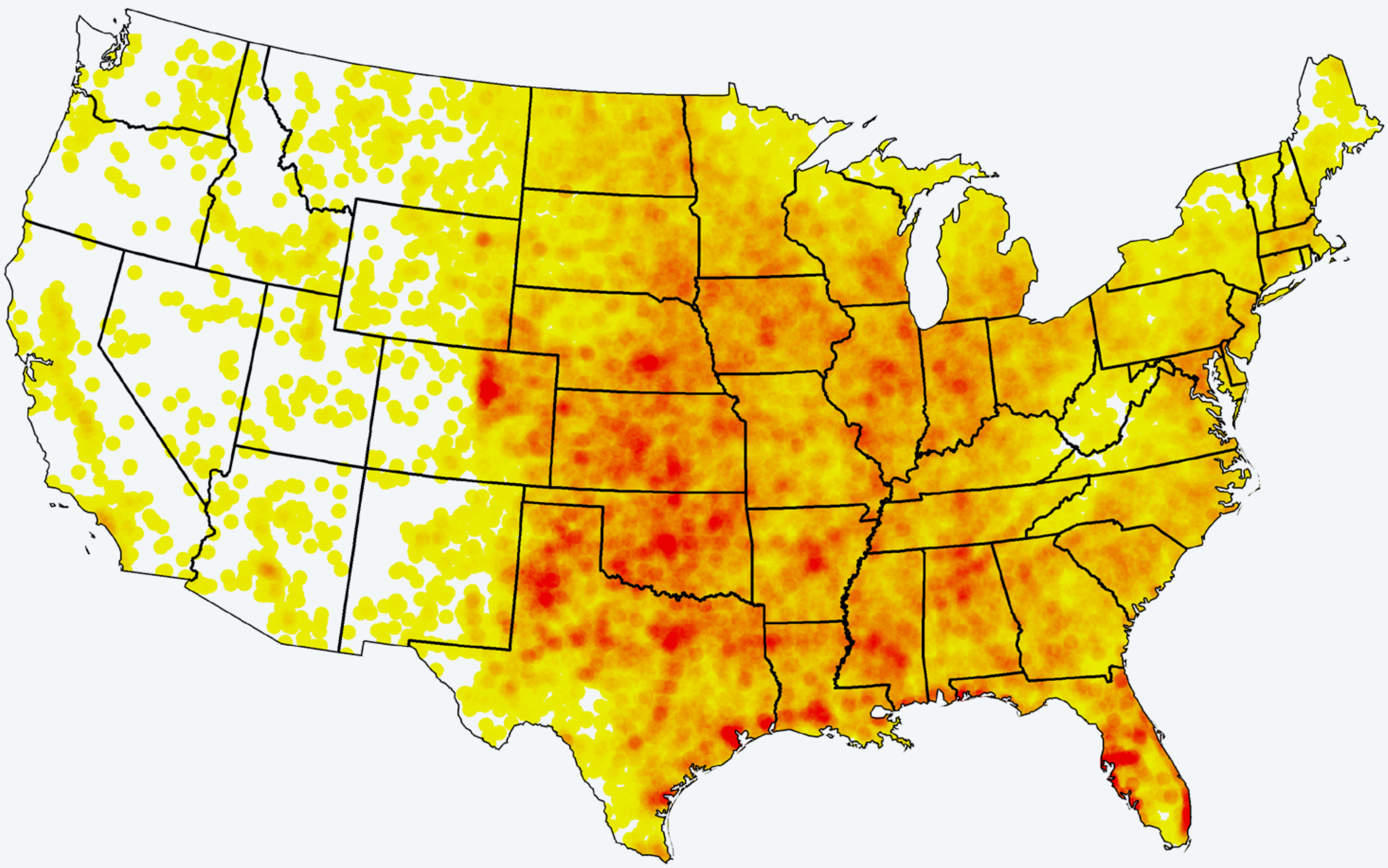

Figure 1. *A heat map of tornado locations from 1950 to the present.*

for all data. While mapping elevation or temperature as a continuous surface would make sense, mapping data that do not vary continuously over space may not. Additionally, having too few points upon which to base the surface will typically lead to larger errors.

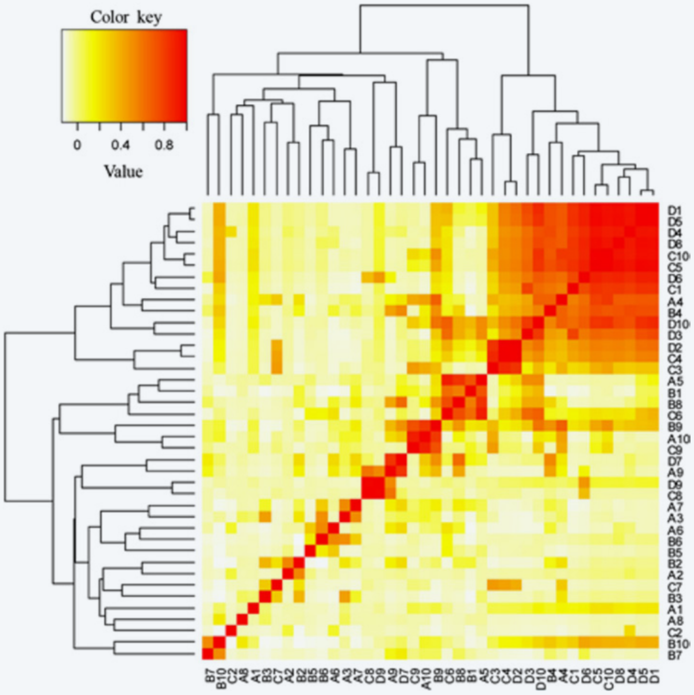

Figure 2. A statistical cluster heat map. From Benucci et al. (2011).

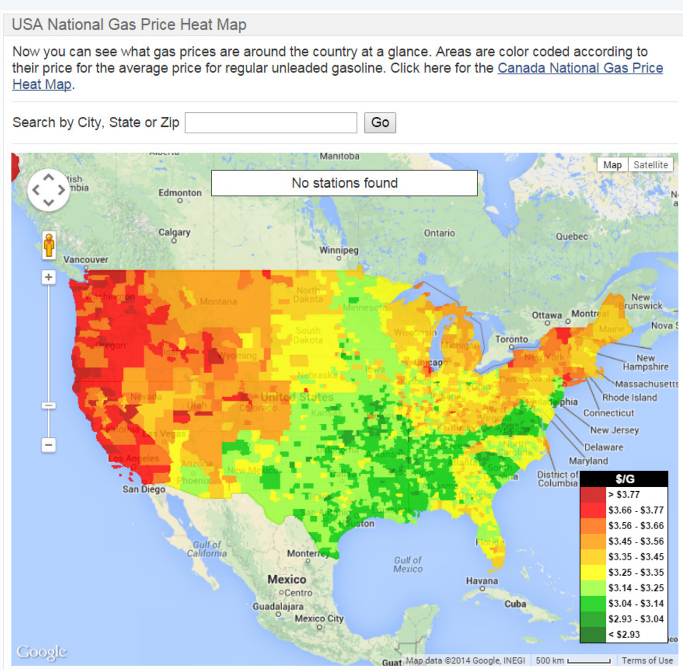

Figure 3. The labeling of a choropleth map as a "Heat Map." From www.gasbuddy.com.

The term "heat map" has been used in statistical analysis for many years. Figure 2 shows a "cluster heat map," a statistical matrix used to show correlation between different variables. Dziuda (2010) defines this method of visualization as "a graphical representation of data where the individual values contained in a matrix are represented as colors." Wilkinson (2009) finds "the earliest sources of this display in late 19th century publications," and calls them the "most widely used of all bioinformatics displays." Eventually, this form of statistical analysis transitioned into the creation of cartographic heat maps.

Heat maps were so named because of their color schemes, which move from yellow, to orange, then to red as values increase, giving the appearance of getting "hotter." The term heat map is sometimes erroneously applied to other types of maps, particularly choropleth maps (see Figure 3), which could be mistaken for heat maps due to their frequent use of similar colors.

MAKING HEAT MAPS

Heat maps show the density of points in an area as a raster. They are formed by creating a distance buffer around each point in a data set. Once the radius distance has been chosen, the circles are placed on the map; the raster shows the number of overlapping circles in each cell (Figure 4).

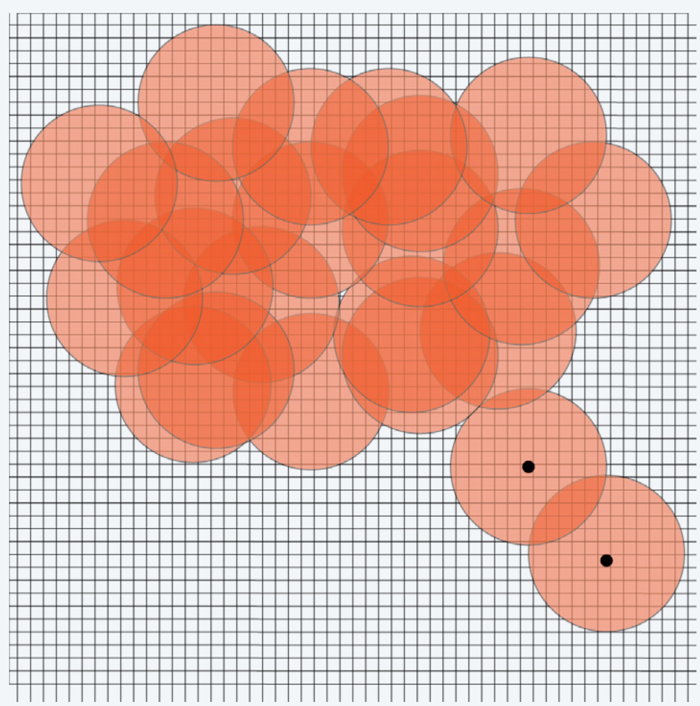

Figure 4. How buffers overlap within the heat map.

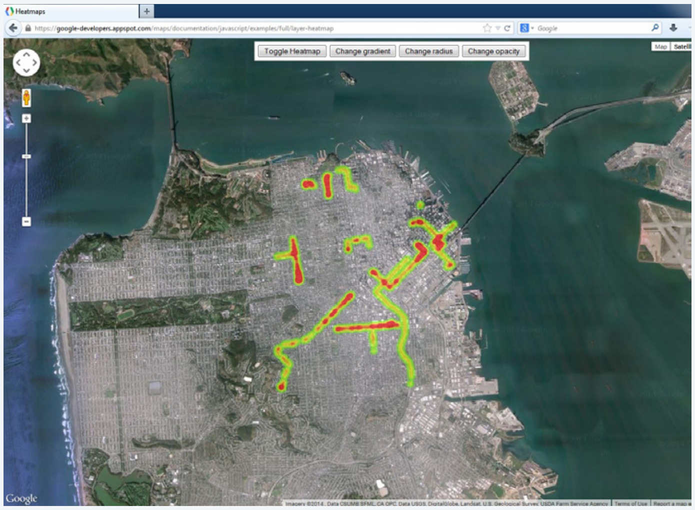

***Figure 5.** The Google Maps API Heat Map from the Google Developers Page.*

Increases in the number of overlapping of circles will return a higher density and color the map accordingly. In an interactive map, the buffer can be defined by the user and manipulated to show more or less overlap.

The Google Maps developer's page (**www.developers.google.com/maps**) includes code to create a heat map from point data. In Figure 5, the example map shows taxi pick-up locations in San Francisco. The pick-up locations have been geocoded from street addresses to determine their latitude and longitude. These points are then given a radius defined within the code (see Example 1). The overlapping radii create the higher density and give each area a color value. The user changes the radius within the map by choosing one of the buttons on the top of the map. The code that produces this map is shown in Example 1.

HEAT MAP VARIABLES

Examining the Google Maps API code, you can see the function `changeRadius` that defines the radius of the matrix is 20 units. However, when zooming in and out within the Google heat map, the actual unit of measure changes with the zoom level. Figure 6 shows the same San Francisco taxi pick-up locations at three different zoom levels. One can clearly see how the changing unit creates different representations of the same data at each map scale.

MISLEADING OVERLAPS

A possible problem of using overlapping circles is that a high density may be indicated where there are actually few points, as seen in Figure 7.

Figure 8 shows an example heat map of golf courses the state of South Carolina. We see that the method does not accurately represent the density of points. Notice that there are areas where the heat map indicates a high concentration of golf courses, but there are no data points. This area has received a higher value because of the overlap of the circles centered on nearby points. This problem is particularly common when non-continuous data are being used to create a heat map.

Identifying this problem is difficult without seeing the points, and so placing the point data on a layer above the heat map helps prevent misleading the map user. Reducing the circle radius also reduces the frequency of this problem.

***Figure 6.** Google heat maps of San Francisco taxi pick-up locations at three different zoom levels.*

```
// Adding 500 Data Points
var map, pointarray, heatmap;

var taxiData=[                                                    // setting the points using LatLng
       new google.maps.LatLng(37.761344,-122.406215),
       new google.maps.LatLng(37.760556,-122.406495),
       new google.maps.LatLng(37.759732,-122.406484),
       new google.maps.LatLng(37.758910,-122.406228),
       new google.maps.LatLng(37.758182,-122.405695),
       new google.maps.LatLng(37.757676,-122.405118),
       new google.maps.LatLng(37.757039,-122.404346),     // lat/long points
       new google.maps.LatLng(37.756335,-122.403719),
       new google.maps.LatLng(37.755503,-122.403406),
       new google.maps.LatLng(37.754665,-122.403172),
       new google.maps.LatLng(37.759732,-122.403112),
       new google.maps.LatLng(37.751266,-122.403355),
];
function initialize(){                                            // defining options for the map
       var mapOptions={
       zoom: 13,                                                  // setting zoom for the map
       center: new google.maps.latlng(37.774546, -122.433523),   // creating a center for the map
       maptypeid:google.maps.maptypeid.SATELLITE                  // defining the type of map (satellite)

       };
map = new google.maps.Map(document.getElementById('map-canvas'), // calling google map
      mapOptions);

var pointArray = new google.maps.MVCArray(taxiData);      // calling the taxiData to create the points

heatmap = new google.maps.visualization.HeatmapLayer({
       data:pointArray                                            // turning the array into the heat map layer
       });
heatmap.setMap(map);                                              // setting the heat map on the map
}
function toggleHeatmap(){
       heatmap.setMap(heatmap.getMap() ? null:map);
}
function changeGradient(){                                        // sets the colors for the heat map
       var gradient = [                                           // rgba colors for the gradient
       'rgba(0,255,255,0)','rgba(0,255,255,1)','rgba(0,191,255,1)','rgba(0,127,255,1)',
       'rgba(0,63,255,1)','rgba(0,0,223,1)','rgba(0,0,191,1)','rgba(0,0,159,1)',
       'rgba(0,0,127,1)','rgba(63,0,91,1)','rgba(191,0,31,1)','rgba(255,0,0,1)',
       ]
       heatmap.set('gradient',heatmap.get('gradient')?null:gradient;
}
function changeRadius(){                                                 // defines the radius of the points
       heatmap.set('radius',heatmap.get('radius')?null:20;       // setting the radius at 20 units
}
function changeOpacity(){                                                // setting the opacity of radii
       heatmap.set('opacity',heatmap.get('opacity')?null:0.2;    // setting opacity to 20%
}
google.maps.event.addDomListener(window,'load',initialize);
```

Example 1. *Google Maps API heat map code.*

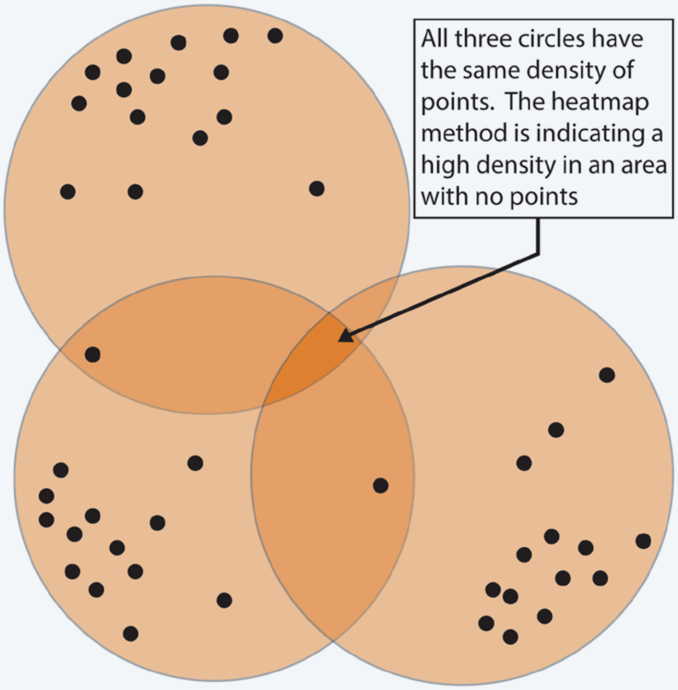

Figure 7. *The heat map method can create a high density for an area that has very few, if any, points.*

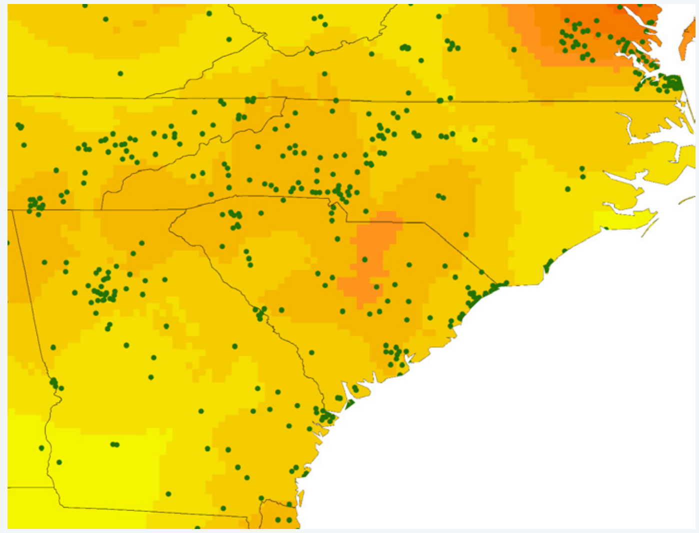

Figure 8. *Golf courses in South Carolina and nearby states. The darker area in the middle is a result of a combination of a high number of golf courses along the coast and inland.*

CONCLUSION

This article highlights the practical uses as well as the disadvantages of heat mapping. Along with desktop GIS software, there are also online methods for creating heat maps. The advantage of heat maps is that the mapped distribution is easily interpreted. These maps can be visually stimulating and users are able to make quick comparisons. As a visual tool, heat maps can be very powerful but the mapping method can be problematic. Although these maps show valuable information, there is often no indication of how the values are determined, and the method of determining values may create high values in areas that have no points. While heat maps may be visually stimulating, the representation may be incorrect and misleading. The technique should be used with caution, and only when the underlying points can also be displayed.

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Introducing *Views on Cartographic Education*

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INTRODUCTION

The mapmaking process has evolved from hand-drawn linework on vellum to an interwoven, digitally and technologically rich fabric. This evolution has permeated the entirety of the cartographic process, including data collection, which software and applications are used to make maps, and how maps are disseminated. Cartographic instructors and, in fact, anyone who has participated in mapmaking for any length of time, have witnessed continuous technological advances that have enabled, for example, web, mobile, and cloud mapping. These are truly interesting times to be a cartographer.

In spite of the attractiveness of where cartography presently is situated, one should remain vigilant as to the promise of where it may venture. For the professional, keeping pace with the constantly changing technologies can be quite challenging. While often promising, new technologies do not necessarily retain their original luster as newer versions quickly supersede previous ones. More specifically, cartography instructors often must pick and choose which technologies are most appropriate to integrate into their curriculum. Although technological evolution has been a factor throughout the history of mapmaking, the present pace of technological change is particularly rapid, and shows no signs of slowing. It is this changing cartographic landscape, and questions over how to deliver a current and relevant curriculum, that form the scope of this special issue of Cartographic Perspectives. This special issue on cartographic education is also the platform for launching a new section titled Views on Cartographic Education.

RATIONALE FOR NEW SECTION

When developing content for a cartography course, many instructors probably tap into material they experienced during their own college classes. Others modify those previous lessons by integrating new content from various outside resources focused on teaching specific ideas. Still others create fresh approaches to instructing students how to make maps. *Views on Cartographic Education* is designed to provide a forum for cartography instructors to share ideas on what worked in the classroom and what didn't. This new section will allow the sharing of teaching experiences (both good and bad aspects) with other instructors, promote the development of a standard content for cartography courses, and act as a resource for current professional cartographers seeking to learn the new skills and knowledge needed for a rapidly changing career field.

TARGET READERSHIP

This new section is not intended to be an outlet for academics pursuing original peer-reviewed research or controlled experimentation dealing with cartographic education (although *CP*'s Editor would welcome these kinds of submissions!). Rather, this section is intended to be a forum where pedagogical experiences in cartographic instruction in the classroom or the lab environment, and beyond, are shared. Of particular interest to readers are novel approaches instructors take to teaching cartography. In addition to the more traditional academic classroom environment, this section will appeal to a larger non-academic group. For instance, cartography lab employees can seek out information from this section to help with their workflow efficiency, secondary school teachers can see an activity that could be incorporated into their classroom as an exercise on map design, programmers can find new code samples that they can include in software, and casual mappers can learn how to use newly developed open source mapping software. In other words, topics found in this section are not intended to only appeal to those teaching in a traditional academic classroom environment, but to the larger cartographic community.

POSSIBLE CONTENT IDEAS

Below are a few possible ideas on content for this new section:

- Share lab exercises where clear learning goals are stated and outcomes can be assessed
- Debate as to what constitutes the range of appropriate content in cartography courses
- What pedagogical approaches have been successful when teaching content that is challenging?
- Discuss successes and failures resulting from an experiential teaching/learning process
- Introduce novel ways of teaching cartographic content
- Discuss the use of multimedia such as YouTube videos, to teach cartographic topics
- Report on new technology and how this technology could be integrated into the classroom
- Details of interesting or challenging classroom experiences
- Results of or ideas on engaging students with projects outside the lab environment (e.g., community outreach)

THIS SECTION NEEDS YOU!

Content for this new section is welcomed from around the cartographic community: instructors at institutions of higher education, mapping software developers, professionals in private industry, freelancers, government employees, and more. All are encouraged to share their teaching experiences and/or their practical "how-to" knowledge. The pool of potential contributors is vast, and you are encouraged to be a part of it!

THE SUBMISSION AND REVIEW PROCESS

The submission process is handled through *CP*'s journal management system. To submit your article for consideration, please visit **cartographicperspectives.org** for specific guidance on the submission process. Articles submitted for publication consideration to this new section will undergo a modified review process. All articles will be vetted by the Section Editor and two reviewers, who will comment on the article's clarity, currency, and degree of interest to *CP*'s readership. The publication decision will mirror that which is used for articles appearing in *CP*'s peer-reviewed sections.

SUGGESTIONS TO AUTHORS

In writing an article for this new section the following three points should be kept in mind. First, authors should explain the rationale and motivation for the article. In other words, there should be some discussion as to why this article was penned (e.g., experimentation with a novel teaching approach) and why the reader would be interested in this information. Second, the author should reflect on the outcomes of the experience. These reflections should include results that were deemed both good and bad. Third, illustrations, screen captures, and images are especially encouraged to be submitted as part of the article. Evidence of instructional outcomes through finished map examples is particularly encouraged.

Articles submitted to this section should be between 1,000 and 2,500 words. Depending on content, longer or shorter submissions will also be considered.

Fritz Kessler,
Section Editor

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Atlas for the Blind, 1837

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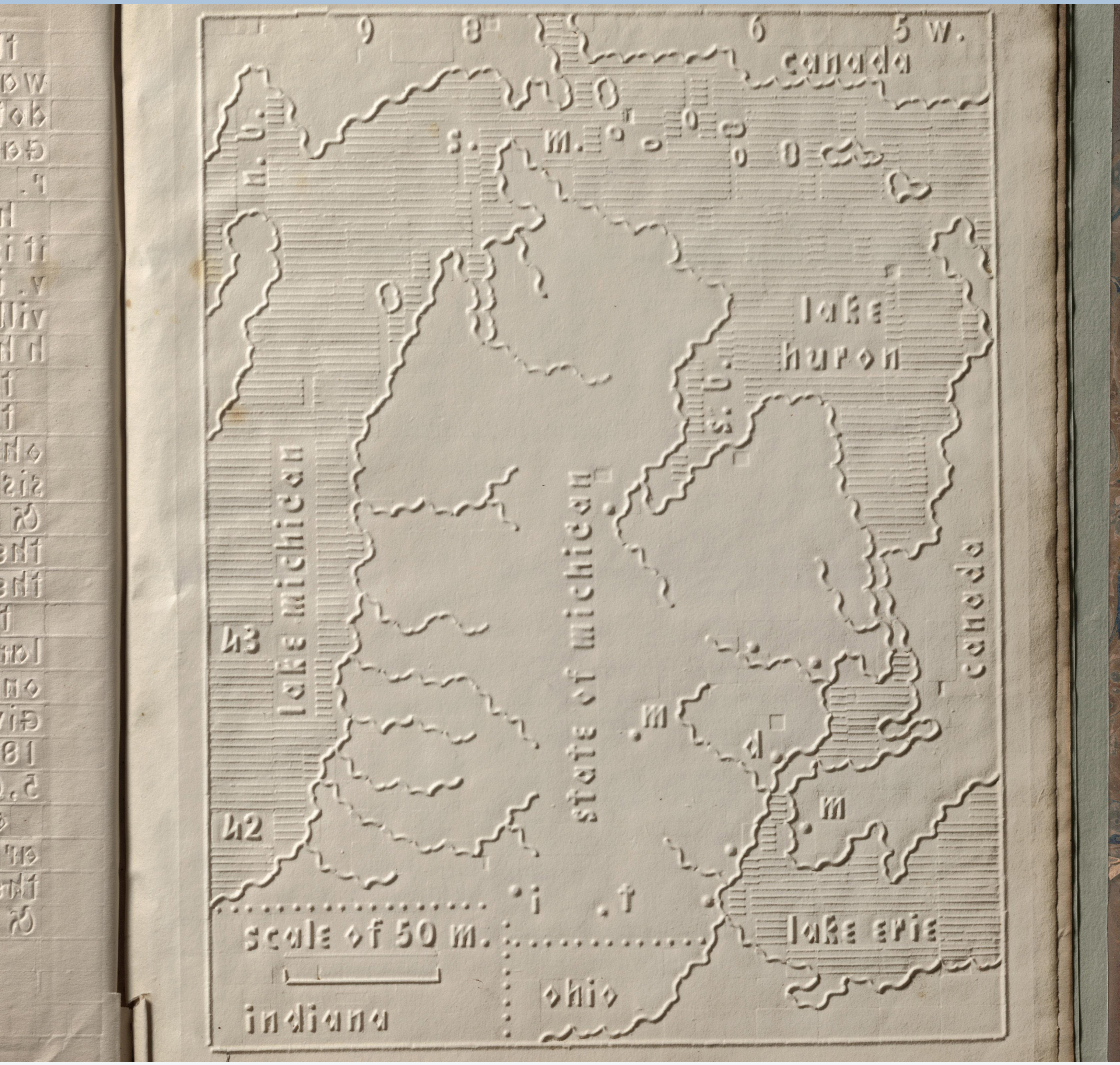
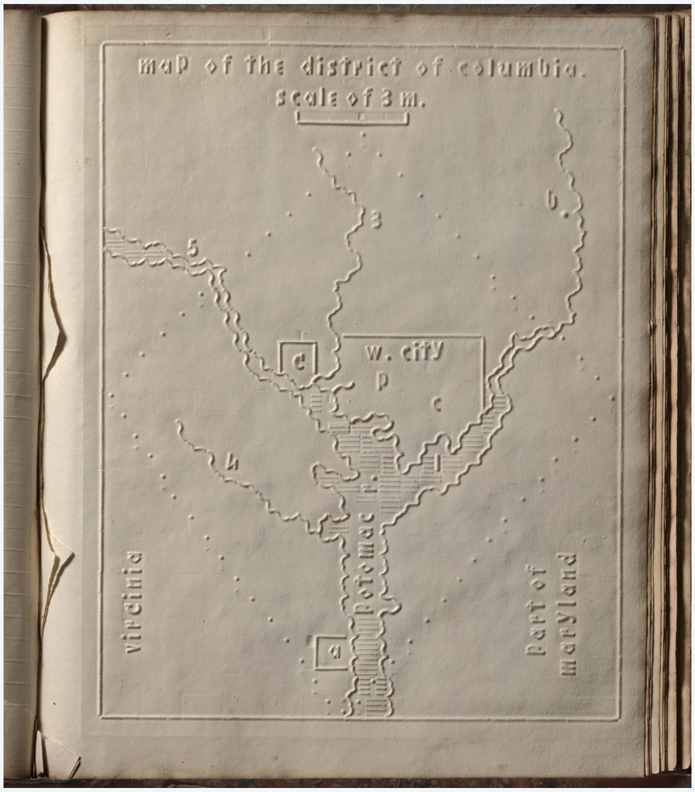
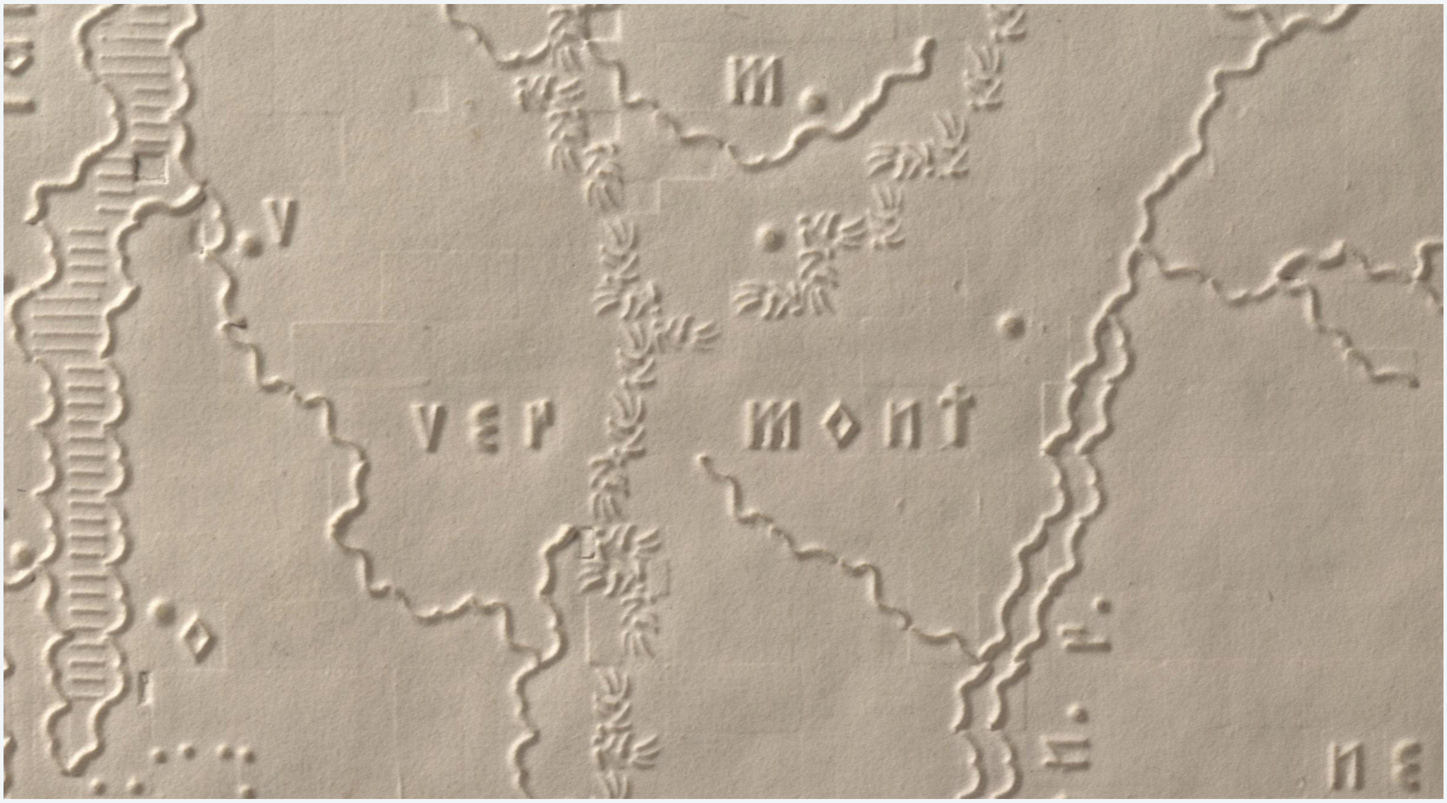


The *Atlas of the United States Printed for the Use of the Blind* was published in 1837 for children at the New England Institute for the Education of the Blind in Boston. Without a drop of ink in the book, the text and maps in this extraordinary atlas were heavy paper embossed with letters, lines, and symbols. To the best of our knowledge, this is the first atlas produced for the blind to read without the assistance of a sighted person. Braille had been invented by 1825, but was not widely used until later. It represented letters well, but could not represent shapes and cartographic features.



This map of the District of Columbia shows Washington (w. city), Georgetown (g), and Alexandria (a) as well as the President's house (p) and the Capital (c).

Samuel Gridley Howe (1801–1876) was the founder and president of the New England Institute (later known as the Perkins Institute) and produced the atlas with the assistance of John C. Cray and Samuel P. Ruggles. Howe was the husband of Julia Ward Howe, the American abolitionist and author of the US Civil War song "The Battle Hymn of the Republic." He was a champion of people with disabilities and believed that blind youth could be taught geography through maps created with his special paper embossing process. In his introduction to the atlas, Howe notes that crude attempts had been made to create maps for the blind, but they used primitive methods of creating



This enlarged view of the Vermont map shows the various symbols used as well as the impressions of the underlying blocks used in the embossing method. Mountains are shown as a series of short lines in this detail of the Green Mountains.


st. J. r.
maine
47
46
45
44
lower
canada
new hamp shire
new
brunswick
atlantic ocean
scale of 50 miles.

Map of Maine.

relief and required the assistance of a sighted person. He claimed that his new embossing method was superior in all respects. Today, it is difficult to know how successful the atlas was, although there can be little doubt that these maps helped Howe's blind students visualize geography. We do know that 50 copies were made and five survive today, including one available in the David Rumsey online map collection. The atlas includes 24 state maps with a page of text describing each state and the symbols used on the maps. In our scans, we have lit the maps and text pages from one side to create shadows that reveal the embossing.

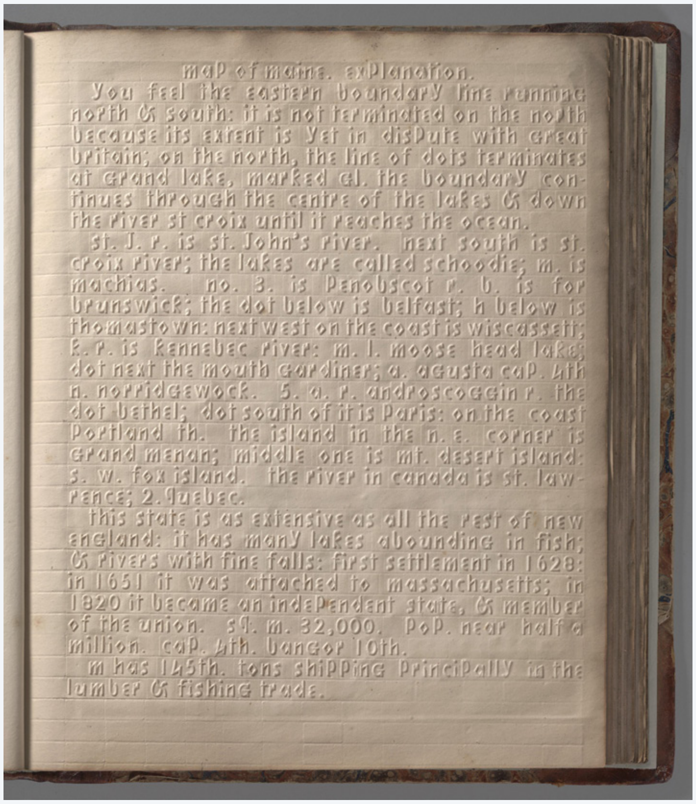
The first map in the atlas is of Maine, with dotted lines showing the border with Canada and New Hampshire. Numbers and letters indicate towns, rivers and lakes, and numbers 6 through 9 and 44 through 47 show longitude from Washington DC and latitude. The map shows a scale of 50 miles. All of this and more is explained in the text page for Maine, which follows the map.

Howe wrote about the success of his method of raised relief to teach geography to blind children: "They soon understood that sheets of stiff pasteboard, marked by certain crooked lines, represented the boundaries of countries; rough raised dots represented mountains; pin heads sticking out here and there, showed the locations of towns; or, on a smaller scale, the boundaries of their own town, the location of the meeting-house, of their own and of the neighboring houses, and the like; and they were delighted and eager to go on with tireless curiosity. And they did go on until they matured in years, and became themselves teachers, first in our school, afterwards in a private school opened by themselves in their own town."

Eventually Braille proved more effective than Howe's method of embossed letters, but his maps remain today as wonderful examples of teaching the basic elements of geography and spatial relationships to blind students, enabling them to create the idea of maps as visualizations in their memories. And the Perkins Institute he led continues to teach blind students today, comprising a long and successful record of blind education, including the teaching of Helen Keller.

You can view the entire atlas at **davidrumsey.com**.

David Rumsey is President of Cartography Associates, a digital publishing company based in San Francisco, and is Chairman of Luna Imaging, a provider of enterprise software for online



map of maine. explanation.

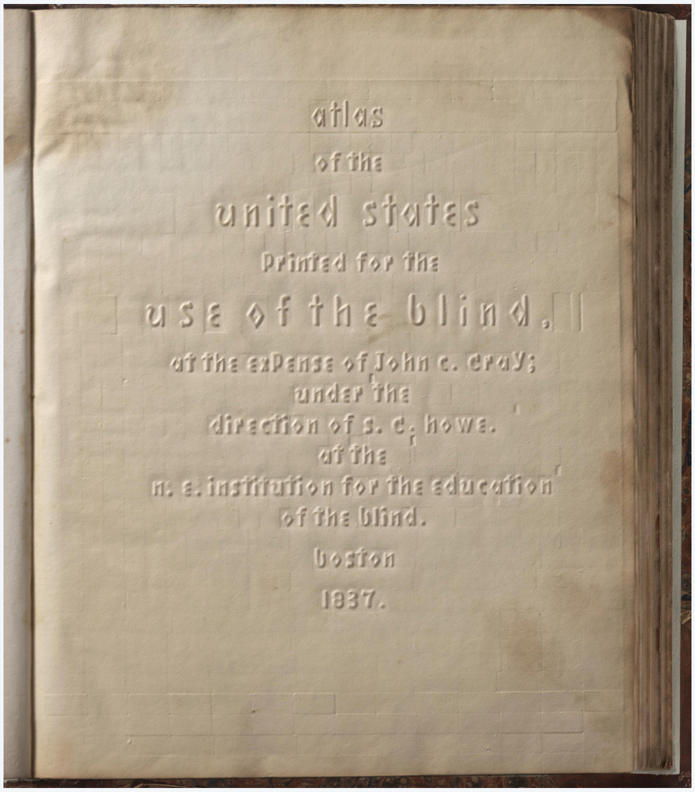
You feel the eastern boundary line running north & south: it is not terminated on the north because its extent is yet in dispute with great britain; on the north, the line of dots terminates at grand lake, marked gl. the boundary continues through the centre of the lakes & down the river st croix until it reaches the ocean.

st. J. r. is st. John's river. next south is st. croix river; the lakes are called schoodic; m. is machias. no. 3. is Penobscot r. b. is for brunswick; the dot below is belfast; h below is thomastown: next west on the coast is wiscassett; k. r. is kennebec river: m. l. moose head lake; dot next the mouth gardiner; a. agusta cap. 4th n. norridgewock. 5. a. r. androscoggin r. the dot bethel; dot south of it is Paris: on the coast Portland th. the island in the n. e. corner is grand menan; middle one is mt. desert island: s. w. fox island. the river in canada is st. lawrence; 2. quebec.

this state is as extensive as all the rest of new england: it has many lakes abounding in fish; & rivers with fine falls: first settlement in 1628: in 1651 it was attached to massachusetts; in 1820 it became an independent state, & member of the union. sq. m. 32,000. pop. near half a million. cap. 4th. bangor 10th.

m has 145th. tons shipping principally in the lumber & fishing trade.

The text page titled "map of maine, explanation" that follows the Maine map.



atlas
of the
united states
printed for the
use of the blind.
at the expense of John c. gray;
under the
direction of s. g. howe.
at the
n. e. institution for the education
of the blind.
boston
1837.

The title page of the atlas.

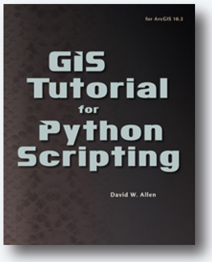
image collections. He was a founding member of Yale Research Associates in the Arts, also known as PULSA, a group of artists working with electronic technologies. He subsequently became Associate Director of the American Society for Eastern Arts in San Francisco. Later, he entered a 20 year career in real estate development and finance. Rumsey retired from real estate in 1995 and founded Cartography Associates, beginning a third career as a digital publisher, online library builder, and software entrepreneur.

Rumsey began building a collection of North and South American historical maps and related cartographic materials in 1980. His collection, with more than 150,000 maps, is one of the largest private map collections in the United States. In 1995, Rumsey began the task of making his collection public by building the online David Rumsey Historical Map Collection, www.davidrumsey.com. Currently the online web site has over 64,000 high resolution images of maps from his collection. The site is free to the public and is updated monthly. Recently, Rumsey has been creating historical map projects both in Google Earth, Google Maps and the virtual world of Second Life.

The covers of the atlas. Even the title label on the spine is raised and embossed, saying "Atlas of The United States."

Visual Fields focuses on the appreciation of cartographic aesthetics and design, featuring examples of inspirational, beautiful, and intriguing work. Suggestions of works that will help enhance the appreciation and understanding of the cartographic arts are welcomed, and should be directed to the section editor, Laura McCormick: laura@terracarta.com.

GIS TUTORIAL FOR PYTHON SCRIPTING



By David W. Allen.

Esri Press, 2014.

276 pages. $70.00, softcover.

ISBN: 978-1589483569

Review by: Adam P. Dixon, World Wildlife Fund & University of Maryland, Baltimore County

The newest book from Esri Press on Python scripting, *GIS Tutorial for Python Scripting*, is a hands-on walk-through of the many capabilities available within ArcGIS for Desktop which can be programmed using Python. Esri has recognized since the beginning that the world of geographic analysis cannot be contained within a GUI interface and has made some laudable strides in combining the graphical with scripting to allow analysts optimal utility of their software. The purpose of the book is to showcase the integration of Python within the ArcGIS desktop interface and to teach Python from this perspective. It is pleasantly written, with a can-do attitude that relentlessly implores the reader to apply his or her problem-solving skills through twenty-three tutorials ranging from basic manipulation of attribute tables to creating custom tools. Tutorials, exercises, and sample data are all based on theoretical needs of a municipal GIS manager. The author, David Allen, is the GIS manager for the city of Euless, Texas, part of the megalopolis of Dallas-Fort Worth.

The book's five chapters total 255 pages in length, followed by 21 pages of appendices. Chapters are divided into tutorials that address overarching concepts of Python in ArcGIS. The chapters begin with using Python in labeling and field calculations, move through stand-alone Python scripting (covering cursors and loops allowing advanced access to data), then on to the mapping module (convenient for map automation), and end with creating ArcGIS toolboxes and Python add-ins. The stand-alone scripting chapter—arguably the most useful—contains nine tutorials, while the mode of the other four chapters is three tutorials. Each tutorial begins with a short explanation of the topic at hand (formatting labels, loops, cursors, *while* statements, etc.) and then dives right in to typical challenges at a suburban municipal GIS office. One tutorial covers the calculation of the flow rate of wastewater through the city's sewer system, where the variety of underground pipe sizes and pipe materials necessitates a set of *if-else* statements within the field calculator of the ArcGIS attribute table. Another tutorial takes the reader through the steps needed to create lists of all the single-family and multi-family structures within the fire department's response zones and to use the list to output a set of PDF maps for the fire department manager. Following each tutorial is an exercise based uponin which the user practices the concept with a similar but different question. Most of the code from the tutorials can be applied within the exercises as the new concepts are reinforced through repetition and referencing the previous tutorial steps.

GIS Tutorial for Python Scripting was copyrighted in 2014, and written for ArcGIS 10.2. The current version of ArcGIS at the time of this writing is 10.3. You will absolutely need an ArcGIS license to use the book to learn Python. I actually used 10.2.2 throughout my read of the book, and found that it generally worked, but did run into some problems that could not be resolved. Since basic principles of Python and the desktop environment generally stay more constant, I would advise readers up to five years in the future just to downgrade to ArcGIS 10.2 to complete the tutorials, and then to upgrade back to the current version upon completion. I imagine after five years from now, this book will be obsolete.

GIS Tutorial for Python Scripting is well written. The author's pedagogical theory is that hands-on problem solving leads to thorough absorption of the information. This is generally true, but he wasn't completely successful at giving all the tools and information needed to complete the exercises, thus eliciting unnecessary frustration. Which brings me to my next complaint: the book felt cheap. Esri Press books as a rule do not have the best printing or paper quality. It is no doubt a little silly to spend resources on books about ArcGIS 10.2 when ArcGIS 10.3 and so on will be available soon thus casting the information into obsolescence in a frighteningly short amount of time. Regardless, the cheapness of the book, and more importantly the lack of attention to detail in the formatting lead to further frustrating moments, especially if you are unaware that a literal reading of the book is not always advised. It is hard to advise against character-for-character literalism when Python programing syntax is case and character sensitive; an errant space or apostrophe can take a frustratingly long time to discover. But that is indeed the case. The user of the book must do the best he or she can to get through it and leave it at that.

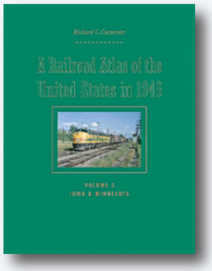
Using the book to teach Python programming to a group of students might really make this book shine. Minor errors in the book could be quickly discovered by a Python expert teacher and immediately resolved. Further, the content matter and pace of the exercises are perfectly suited for the brief and concentrated sessions that make up a semester. Frustration must be the greatest barrier to entry to programming. If the user cannot find a solution within the programming syntax, he or she is doomed, and thus a person like a lab assistant to ask questions is a godsend. Without assistance, determined persistence is the only resolver of intractable programming errors. One of the unspoken lessons of the book (and learning to program in general) is that with practice, identifying and resolving errors becomes easier, but begins as a seemingly wide river with a strong current to swim. Which brings us back to the qualities of this book. It could use a touch of mercy, especially for the solo practitioner. The independent Python tutee, with only the book as his or her guide, will have problems. Each tutorial walks the reader through the steps in a concisely explanatory manner. There were multiple times however, the tutorial was precisely followed and the final script refused to function as warranted by the recipe, due to formatting errors or typos wreaking havoc on Python's exacting syntax. A flawlessly formatted programming book might not exist. But the design of each tutorial could be vastly improved by including the full code employed during the session at the end for reference (or at least put it in an appendix or online). As it is, the code is chopped into pieces throughout the tutorial and piecing it together can be confusing. The can-do attitude and problem solving virtues of the book begin to seem foolish and bring only misery when one spends hours on a tutorial only to give up because no solutions appear possible.

No mention is made of non-Esri applications where Python programming may be useful. Quantum GIS has a Python interface for instance, and it would have been good to know how these interact. GDAL utilities are also accessible with Python. A new Python library called Pygeoprocessing has been developed by developers at the Natural Capital Project (**goo.gl/4Obalz**). I am just touching the surface of all the geographic Python tools out in the world. It is not surprising that an Esri book does not contain these concepts but a nod in the name of collegiality would have been nice.

GIS Tutorial for Python Scripting is sold throughby Esri for $70.00 and comes with all the sample data required. If you use ArcGIS at your workplace and are in the market for Python tutorial material, this is a good buy. You'll have a guided tour of the use of Python and understand the full set of the impressive capabilities available to you in ArcGIS. You should expect to spend quite of bit of time to complete the book. I was slightly beyond a newbie in Python prior to undergoing this exercise and spent at least fifty hours getting through all of the materials. Some of the tutorials take longer than the others, but in general they take about two hours or more when you include the exercise.

The book is thus at best a wonderful curated tour of Python use in the proprietary GIS software package, and at worst a plodding and frustrating exercise in teaching oneself how to program. The spectrum of your experience navigating through the book will certainly touch these highs and lows, although the exercise in totality did seem worth it. Having completed the tutorials I'll be able to approach Python in a much more creative and constructive manner in my daily work, and I'm now able to get started with more confidence on a programming project I've had on the back burner. I felt like the first three chapters were much more important than the final two, which dealt with ArcGIS toolbox and toolbar creation. These felt more like an ArcGIS tutorial than a Python one. If you are a teacher, you might find this set of tutorials a great walk through the many typical activities your students will encounter as GIS professionals. The self-study aspects of the book (especially the first three chapters) would complement a larger syllabus covering the Python universe.

A RAILROAD ATLAS OF THE UNITED STATES IN 1946, VOLUME 5: IOWA AND MINNESOTA



By Richard C. Carpenter.

The Johns Hopkins University Press, 2013.

232 pages, 170 color maps. $70.00, hardcover.

ISBN: 978-1-4214-1035-7

Review by: Jed Marti, Artis LLC

The *A Railroad Atlas of the United States in 1946* series captures the extent and geographic organization of railroads near the height of their influence on the American landscape. Volume 5 details Iowa and Minnesota; the previous 4 volumes cover the northeastern states.

In 1946, railroads employed 1.3 million people maintaining tracks and equipment with a military-like organization. Any town of importance had one or more railroads servicing its industry and transportation needs. In these times, before the arrival of the daily train, "the day was glorious with expectancy; after them, the day was a dead and empty thing" (Twain 2009). Railroads were very much at the forefront of life as they are now in the background.

Following a short introduction are maps of Minnesota and Iowa followed by some short notes on each. Two important pages list railroad company abbreviations, many of which are no longer obvious to us (e.g., MILW: Chicago, Milwaukee, St. Paul, and Pacific Railroad).

The maps are hand drawn and labeled and are taken from a variety of sources both modern and historical. Except for some details, they are based on USGS 1:250,000 and 7.5 minute quadrangles, or historical atlases. Important population centers have more detailed maps. There is considerable railroad detail but little other content than bodies of water, political boundaries, and place names. The author has hand drawn railroad features from a selection of 10 colored pens. Railroad markings mostly concern operational details: round houses, control towers, train order offices, switch controllers, bridges, crossings, viaducts, stations, coaling stations, telegraph call letters, and milepost markers. Somewhat wider markings delineate multiple tracks on the same grade and dashed lines indicate abandoned lines.

An appendix for each map provides railroad operational details such as dates for construction of switching mechanisms, towers and abandonment. Much of this is dry detail but a few nuggets of colorful history scattered throughout make for delightful reading. An index of place names completes the volume.

Why would a cartographer want a historical atlas and is this the one they should purchase? This is an attractive volume and the maps are more appealing than the modern black and white *SPV's Comprehensive Railroad Atlas of North America* series. The color coding helps separate the railroad features from political and water features. The inclusion of notes on each map is also welcome; I'm unable to find any similar comprehensive attempts. Could we wish for more? Modern GIS could generate historical maps, with the 3rd dimension being compressed time. Color and animation could bring out the salient features against the changing historical background.

Can this volume be useful to the modern transportation planner? We are experiencing a minor change in attitudes about public transportation. Light rail, trolleys, and interurban services are available or being constructed in most large cities and have increasing ridership. Many such existed in the past but were destroyed by the ubiquitous automobile. The late 1800's saw a massive increase in these systems, many constructed with little thought to who would use them. It behooves us to study both the successes and failures. Much of the infrastructure lies buried beneath us—grades and routes constructed earlier can be reused if their locations are known.

Would you use this atlas as a guide for some fieldwork or railroad tourism? As suggested in the introduction, probably only in conjunction with some other atlas that is also at 1:250000 scale; the lack of modern roads and features on the maps makes it a difficult activity using this atlas alone. This would be exacerbated in unpopulated areas where few such features exist and railroad remnants may be more interesting to find. An open question is whether or not all the features shown are from 1946. If a Midwestern river changes course (as they are wont to do) are we seeing the 1946 river or the 2013 river? An atlas with 2013 features and 1946 rails might be confusing and consequently be limited to just this purpose. Finally, the hardback format might be a problem on a field trip, what with spilled coffee and lunch.

Is this a collection of maps a cartographer would enjoy perusing for their artistic qualities? Certainly, this work is a major undertaking for a single person. The patience necessary to draw the maps and the steady hand for filling in the details on hundreds of them (this is the 5th volume after all) is unlikely to be found again, killed by the very technology we wish might have been used. That being said, there is much more one could wish for in details and references.

As a railroad nut (the polite term is "railfan"), I randomly examined some of the voluminous literature of railroad history and there is nothing of this scope even at the state level. Individual volumes may present more history (Carr 1989; Whitehouse 1988) but the maps are of secondary importance or non-existent. Most are in black and white and not particularly easy to decipher. Authors tend to concentrate on specific railroads or locales. Internet collections are not comprehensive and have only short histories, perhaps one or two photographs, and uncertain scholarship.

Mr. Carpenter has begun a vast undertaking—more than three fourths of our land mass remains to be serviced. This 5th volume is part of the Johns Hopkins University Press series *Creating the North American Landscape* which covers such esoteric topics as alley houses, the development of public courthouses, and the evolution of the mobile home. I look forward to further volumes that encompass the West—a vast railroad landscape for mining and public transportation, the remains of which are still visible to those that will look.

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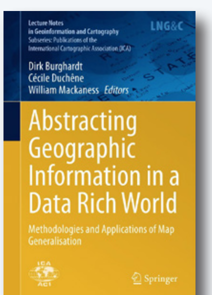
ABSTRACTING GEOGRAPHIC INFORMATION IN A DATA RICH WORLD: METHODOLOGIES AND APPLICATIONS OF MAP GENERALISATION



Edited by Dirk Burghardt, Cécile Duchene, and William Mackaness.

Springer International Publishing, 2014.

407 pages, maps, diagrams, illustrations. $139.00, eBook.

ISBN: 978-3-319-00203-3

Review by: Timofey Samsonov, Lomonosov Moscow State University

Abstracting Geographic Information in a Data Rich World is an ambitious work that presents cutting edge achievements in one of the most complicated areas of professional cartography: map generalization. The ten hot research topics that comprise this 400-page volume are tightly fitted into a synoptic observation format that makes you feel the variety, depth, and breadth of contemporary map generalization research. While the fundamental work edited by Buttenfield and McMaster (1991; glorified by Dr. Anne Ruas as a "generalization bible" in its preface) [1] concentrated on generalization rules and knowledge engineering, this book follows the direction established by the 2007 ICA volume *Generalisation of geographic information: Cartographic modeling and applications* (Mackaness et al. 2007). It discussed the possibilities of on-demand mapping, real-time generalization, and agent-based systems that allow simultaneous generalization of a set of objects from different themes. The current volume is significantly more user-centric, wider in scope, and primarily addresses solving complex high-level methodological and technological problems, while leaving the many technical implementation details to the bibliography list that is available to inquisitive readers.

The main body of the book stretches from Chapters 2 to 11. Each chapter consists of two parts: the first part states the problem and reviews current approaches to solving it, the second part consists of three case studies (except Chapter 11, which includes results from seven national mapping agencies and the INSPIRE program). This format allows the reader to quickly assess the significance of the problem and the effectiveness of its particular solutions. As the authors of Chapter 5 "Generalisation operators" state, they did not make an exhaustive review of generalization operators, concentrating instead on network generalization aspects in the "case studies" part. However the brief synoptic overview of operators is still here in the theoretical part of the chapter. This principle is true for every part of the book. The focus is on current problems, and historical overview is kept to a minimum. It gives the reader quick access to current achievements of map generalization research instead of a long slog through a boring textbook that mentions all previous contributions to the problem and its surroundings.

The concept of *data enrichment* is woven through almost every chapter of the book and seems to be one of the most important generalization tools. The editors emphasize the necessity of a very rich geographical model for a high level of automation in Chapter 1. Enrichment is a key to extraction of high-level structural properties of geographical distributions, which is important for *generalization of object groups* and systems. Data enrichment shows its usefulness both in tasks of generalization itself and in *evaluation* of generalization results. This is illustrated by case studies concerning hydrography networks and building patterns generalization in Chapters 6 and 9 respectively.

The book largely avoids digging into the innards of particular generalization operators and relationship measures between features, while concentrating on *generalization process modeling* (Chapter 7) and *spatial relationship ontologies* (Chapter 3) instead. These help users to formalize the knowledge about execution sequences of generalization operators and underlying spatial reasoning that is based on data analysis. Introduction of fuzzy relationships (Chapter 3) is important for effective data enrichment, because it allows for detecting patterns in not-ideally-arranged object groups. These patterns are then harmonized during generalization.

Evaluation is important for the description of spatial relationships and characteristics of objects that are altered by the generalization process. The book stresses the necessity of automated evaluation of generalization due to requirements of contemporary map production environments and on-demand mapping. Coupled with increasing demand for a user-centric approach, this points to a need for methods that estimate map quality from the point of view of an abstract reader. Map readability formulas presented in Chapter 9 are an example of one possible approach to this task. Overall, the eligibility of every generalization solution depends on the *user requirements* that result in *map specifications*, which can be discovered through knowledge-based systems and wizards in case of on-demand mapping systems. This task is investigated in Chapter 2.

Chapters 4 and partly 7 are more concerned with the technological base of generalization. In Chapter 4 a variety of *topological data structures* including tGAP and SSC (Space-Scale cube) are presented. These technological means are supposed to be effective in progressive data transfer and continuous zooming. The concept of 5D space-scale is vividly illustrated here and it possibly has a big potential not only in generalization but in multiscale data analysis too. A significant part of Chapter 7 is dedicated to usage of *web services* to provide generalization *geoprocessing tools*—another technological advancement that will cover requirements of web-based generalization systems in the near future.

Four application topics are singled out in separate chapters—integrating and visualizing volunteered geographic information (VGI; Chapter 5), terrain generalization (Chapter 8), generalization in context of schematized maps (Chapter 10), and generalization in practice within national mapping agencies (Chapter 11).

It is not a surprise that VGI received a great deal of attention in the book—2014 celebrated ten years of the OpenStreetMap (OSM) project, which has shown fantastic results providing an overwhelming amount of detailed and useful spatial data. However research in OSM generalization is still in its infancy, a fact emphasized in Chapter 5, which shows the simplicity of applied operators. Geosensor networks and popular social media also produce a large amount of spatial information that should be integrated with existing data for their usage in exploratory research. Some experiments in this area are also presented here. Overall, this chapter leaves the feeling that it more states problems than solves them, and I am sure that the topic of VGI generalization will be one of the hottest in the forthcoming decade.

Three interesting issues of *terrain generalization* mentioned in Chapter 8 are worth drawing attention to. The first is *visualization-oriented DEM generalization*, in which terrain models are generated for a specific method of representation: hypsometric coloring and hillshading. The second is the possibility of including terrain in multi-agent models to make adjustments to surface geometry during generalizations to preserve topology and avoid conflicts. The third aspect is *security* of maps derived after generalization—specifically for generalization of isobathic maps. All these contexts are well illustrated by case studies.

Schematized maps represent the highest level of abstraction and are interesting both as a quintessence of generalization and as a vivid representation of main structural features. Some specific approaches to their creation and applications as well are presented in Chapter 9.

The final chapter "Generalisation in practice within *national mapping agencies*" is quite impressive. It demonstrates the variety of approaches to automated map production workflows in seven different countries (six European and USA) and international activity (INSPIRE). The difference between digital cartographic model (DCM) and digital landscape model (DLM) is shown here even more prominently than in the previous methodological chapters, being illustrated by real production examples. In this chapter the reader will find fully automated production workflows proudly presented by the Ordnance Survey, IGN France, and Kadaster NL—probably the most exciting result contained in this book. If you have read the book straight through from the beginning, at this point you will be satisfied to read these examples of real-world applications that prove that the previous investigations now have practical output, and the dream of automated generalization is becoming a reality. However, much is to be done in the world of abstracting of geographic information. Every chapter of the book states its own problems that are also summarized in the concluding chapter of the book.

This volume is probably not for all cartographers; it is deeply focused and is particularly oriented toward specialists in generalization problems. This focus makes it unsuitable for a novice reader who is unfamiliar with the technological and methodological complexities around abstraction of geographic information. All topics of the current generalization agenda are discussed, which makes this book invaluable for those who want to remain up to date in this area. The questions raised here are not the kind that can be quickly implemented from description. They concern high-level architecture of generalization systems and will take time to reconstruct. The authors of the book assume that the reader will be familiar with a variety of functions, such as line simplification, measuring distances, constructing triangulations etc., which are just atomic components in the presented methodologies.

Though it comes close, the book does not quite feel like a fully integrated monograph. It is still more like a compilation of topics, sometimes written independently of one another—little nuances betray it. For example, the design of schemes is dissimilar across chapters (compare, for example, Figures 3.19, 10.15, and 11.11—three completely different points of view to design!). In Chapter 5, the authors use the term "Dimensional change" (p130), whereas the term "Collapse" is almost universally recognized and is used to denote this operation in Chapter 6, which provides the observation of generalization operators. Information redundancy is not completely avoided, either. When you approach Chapter 8 in the second part of the book, you may note Figure 8.1, which illustrates the difference between model and cartographic generalization, despite the fact that this dichotomy was discussed more than once earlier.

There are also a few methodological aspects in the book that I found to be insufficiently developed or missing important conditions. In Chapter 4 the authors explain advantages of smooth tGAP/SSC structure while not mentioning that it can result in too narrow polygonal features. This is unacceptable in map generalization and can be clearly seen in Figure 4.7d (middle gray polygon). Some constraints in feature width should be introduced here and maybe a combination of classic and smooth structure should be tested. There are also real cases in which aggregation of polygons and their removal is invalid (administrative units, or countries, for example).

The Quadtree-based point generalization case study (Chapter 6), while being very interesting overall, misses analysis of the artificial regularity of some results. It also provides a strange explanation of priority between displacement in horizontal/vertical directions vs. diagonal—as if it is not known how the algorithm works and its influence has been discovered just from results of data processing. But possibly, this explanation is a consequence of the limited text space available for explanation. In Chapter 9, the authors discuss schematized maps and mention cartographic line frequency (OLLpA), then suggest the new Bertin (Bt) unit for its measurement. It seems strained and artificial to me, since by definition the OLLpA (as it is given in the book) is simply *line density* measure in *cm* per cm^2 for example (see equation in Chapter 10.4.1).

In the introduction chapter the authors, trying to describe the full scope of problems in a limited text frame, sometimes become inaccurate in their statements. For example, they mention Hausdorff distance as a shape characteristic (6), but Hausdorff distance is more likely a measure that can be applied to estimate the proximity relationship (Chapter 3) between two groups of points or between two lines or two polygons, but is not a direct shape characteristic. In some places, more details would be better for understanding the material. The procedure of harmonizing requirements in the EuroSDR case study (Chapter 1) remains a black box; how it was performed in particular is unclear. An explanation of the algorithm for matching GPS trajectories with incomplete user-generated road data (Case 3 in Chapter 5) is too short and difficult to understand. The same concern comes up again in Chapter 9, in which map readability formulas are discussed but ironically not one formula is provided.

However that may be, these issues are inconsequential and very few in number. Overall this book provides a really critical contribution to summarizing, conceptualizing, and discussing the main problems and solutions in map generalization to date. Many questions that arise during the reading of the book can be cleared up via detailed inspection of the bibliography lists at the end of each chapter. I recommend this book to everyone who works with map generalization and wants to be productive in solving his or her tasks, as well as those who are interested in understanding short- and mid-term perspectives in map generalization developments.

Fifteen years passed between the founding of the ICA working group and the appearance of their 2007 book. This follow-up volume required only half as long to be published. This is a clear indication of increased activity in the field and of the necessity of spreading knowledge, noting problems, and initiating new discussions in the map generalization community. I hope that this accelerating rate of publications means that we will see the next book in a few years with even more impressive results.

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Robinson, A. H., J. L. Morrison, P. C. Muehrcke, A. J. Kimerling, and S. C. Guptill. 1995. *Elements of Cartography, 6th Edition.* New York: John Wiley & Sons.

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Peterson, M. 2008. "Choropleth Google Maps." *Cartographic Perspectives* 60: 80–83. doi: 10.14714/CP60.237.

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Danzer, Gerald. 1990. "Bird's-Eye Views of Towns and Cities." In *From Sea Charts to Satellite Images: Interpreting North American History through Maps*, edited by David Buisseret, 143–163. Chicago: University of Chicago Press.

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