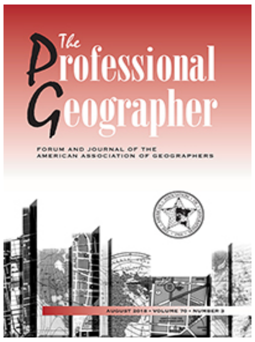

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This article reports on the design and evaluation of Global Madison, a mobile map designed to support teaching and learning about globalization using Madison, Wisconsin, as a situated classroom. Our experience of place increasingly is mediated by mobile devices, opening new opportunities and challenges for research, industry, and education. Despite this rising popularity, few guidelines exist for creating and using mobile maps. Following tenets of user-centered design studies, we conducted two mixed-method evaluations of Global Madison to improve the tool and generate design insights that are potentially transferable to similar mobile mapping contexts: 244 students participated in an online survey after completing the tour and eighteen students were observed in the field. The evaluations generated new design considerations for mobile maps supporting situated learning, include: focus on critical issues that might leave students stranded, append location-based services with traditional mapping, enforce cognitive association between map and landscape, supply a consistent feed of information for new learners, encourage collaborative learning in the landscape, and promote student safety above all else. **Key Words: adaptive cartography, geographic education, globalization, mobile maps, situated learning.**

本文报导“全球麦迪逊”这个利用威斯康辛麦迪逊作为情境化教室，设计用来支持教学和学习全球化的行动地图。我们的地方经验，逐渐受到行动装置所中介，开启了研究、产业与教育的崭新机会与挑战。尽管行动地图日益盛行，却鲜少有设计与运用该地图的指南。我们追随以使用者为中心的设计研究原则，设计“全球麦迪逊”的混合方法评估，以改进该项工具，并提出具有转移至类似行动地图脉络潜力的设计洞见：在完成该旅程后，有两百四十四位学生参与网上调查，并对十八位学生进行田野观察。这些评估生产了支援情境化学习的行动地图的崭新设计考量，包含：聚焦有可能让学生束手无策的关键议题，

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在传统製图上附加根据区位的服务，执行地图与地景间的认知连结，对新学习者支援持续的信息供给，鼓励地景中的合作学习，此外亦提倡学生安全。**关键词：调适地图学，地理教育，全球化，行动地图，情境化学习。**

Este artículo informa sobre el diseño y evaluación de Global Madison, un mapa móvil creado para ayudar a la enseñanza y aprendizaje de la globalización, usando a Madison, Wisconsin, como salón de clase situado. Crecientemente nuestra experiencia de lugar está siendo mediada con aparatos móviles que abren nuevas oportunidades y retos a la investigación, la industria y la educación. A pesar de esta creciente popularidad, existen pocas guías sobre cómo crear y usar mapas móviles. Siguiendo los principios de estudios de diseño centrados en usuario, hemos hecho dos evaluaciones de método mixto a Global Madison para mejorar la herramienta y generar perspectivas de diseño potencialmente transferibles a contextos similares de mapeo móvil: 244 estudiantes participaron en un estudio en línea después de completar el tour y 18 estudiantes fueron observados en el campo. Las evaluaciones generaron nuevas consideraciones de diseño de mapas móviles adecuadas para aprendizaje situado, que incluyen: enfocar asuntos críticos que podrían dejar varados a los estudiantes, adjuntar servicios basados en localización con mapeo tradicional, reforzar la asociación cognitiva entre mapa y paisaje, proveer un consistente suministro de información para los nuevos aprendices, estimular el aprendizaje colaborativo en el paisaje, y promover por encima de lo demás la seguridad del estudiante. **Palabras clave: cartografía adaptable, educación geográfica, globalización, mapas móviles, aprendizaje situado.**

In this article, we report on the design and evaluation of Global Madison (see www.geography.wisc.edu/globalmadison/), a mobile map supporting teaching and learning about globalization using Madison, Wisconsin, as a situated classroom. The possibility of mobile maps has resulted in a fundamental shift in the relationship between cartography and geography. Maps today are more than an abstraction of the landscape interpreted from afar; they are interactive information repositories that contextualize and enrich place. In the following, we refer to a *mobile map* as any cartographic representation or mapping application explicitly designed for viewing and use on a movable, handheld computing device, such as a smartphone or tablet (Muehlenhaus 2013). Global Madison imagines the landscape as a mobile classroom for thinking critically about globalization, first using a location-based service to guide students to historic landmarks within Madison and then using the mobile platform to deliver narration, maps, and images that contextualize these places in relation to broader processes of economic restructuring. Following tenets of user-centered design studies (Seidlmair et al. 2012), we completed two mixed-method evaluations of Global Madison with students in a realistic setting to improve the mobile map and generate design insights that are potentially transferable to similar mobile mapping contexts.

Evaluation of Global Madison identified new design considerations for mobile maps supporting geographic learning and thinking. Considerations include: focus on critical issues that might leave students stranded, append location-based services with traditional mapping, enforce cognitive association between map and landscape, supply a consistent feed of information for new learners, encourage collaborative learning in the landscape, and promote student safety above all else.

Geographic Education and Mobile Map Design

Maps long have been recognized as important tools for promoting spatial thinking, providing learners with concrete representations of complex geographic phenomena and processes (Downs et al. 2006; Lee and Bednarz 2009). With the rise of personal computing, multiple scholars have advocated for the use of desktop geographic information systems (GIS) and web-based maps to support classroom geography education (e.g., Sui 1995; Kerski 2003; Baker 2005; Fuhrmann et al. 2005; Sitton and Lund 2007). Today, advances in mobile maps offer new ways to integrate situated learning into critical geographic pedagogy, or lessons that take place in a realistic setting and require students to engage with the subject of study under cultural, logistical, and technological conditions that are different from a traditional classroom (Anderson et al. 1996). For optimal situated learning, students are given essential (but not comprehensive) background on a given topic and subsequent prompts to encourage critical reflection (Griffin 1995). The proliferation of mobile devices means that these prompts can be provided remotely at intervals throughout the learning experience (Armstrong and Bennett 2005; Table 1). Zurita and Baloian (2012) reviewed existing mobile maps supporting situated learning, which we do not repeat here.

Table 1 *A summary and update of Armstrong and Bennett's (2005) ten principles of designing mobile maps for geographic education. The design and evaluation of Global Madison addressed the importance of many of these principles*

No.	Principle
1	Make the abstract concrete through *in situ* learning experiences (i.e., situated learning)
2	Define flexible locational triggers
3	Accommodate multiple learning styles
4	Make learning interactive, dynamic, and student-centered
5	Teach about spatial relationships and their digital representation
6	Instruct about safe editing practices and metadata when the mobile map supports VGI
7	Instruct about privacy and ethical use when sharing VGI
8	Promote personal safety
9	Practice safe communication both in a collaborative environment and across a network
10	Do not write bloated code for mobile devices

Note: VGI = volunteered geographic information.

There is an emerging body of research on the technological limitations of the mobile platform and associated constraints on map design and use (Meng et al. 2005; Roth 2013). Mobile devices generally have smaller screens, reduced processing power and memory capacity, less reliable data connectivity, reduced network bandwidth, a limited battery life, and post-WIMP (windows, icons, menus, pointers) multi-touch input devices limited to finger-based interactions (Chittaro 2006; Muehlenhaus 2011; Nagi 2014). Although the mobile barrier on map design will lessen as technology improves (Looije et al. 2007), the possibility of physical mobility through the landscape remains an essential consideration in mobile map design (Clarke 2004; Goodchild et al. 2004). Sunlight, extreme temperatures, precipitation, wind, noise, congestion, and safety all act as environmental constraints on mobile map design and use (Reichenbacher 2001).

Beyond technological constraints, mobile mapping often is discussed in relation to three research topics within cartography and GIScience: (1) location-based services, (2) adaptive cartography, and (3) volunteered geographic information. *Location-based services* (LBSs) describe programs and scripts for the processing, delivery, and presentation of information that is tailored to the user's current location (Tsou 2004). Wayfinding applications using LBSs are among the most commonly used maps today (e.g., Apple Maps, Google Maps) and have affected mobile map design in at least two important ways. First, LBSs support *egocentric* design, where the map remains centered on the user's location while moving through the landscape to provide spatial context (Klippel et al. 2010). Second, LBSs support precise turn-by-turn directions, calling into question the appropriate level of detail on mobile maps. Research suggests that mobile maps should have generalized base information (Meilinger et al. 2007) with directions anchored to a small set of *salient landmarks* with distinctive properties, such as a unique façade, shape, color, visibility, or cultural importance (Raubal and Winter 2002). Finally, egocentric wayfinding applications often allow users to reorient the map so that forward and not north is up, making it easier to relate map symbols to salient landmarks as they are experienced when moving through the landscape (van Elzakker et al. 2009).

Location is only one way to adapt a mobile map to the user's context. Popular availability of Global Positioning System (GPS) enabled mobile devices in the early 2000s coincided with an initial interest in *adaptive cartography*, or algorithmic approaches for customizing map design to the use and user context (Zipf 2002; Reichenbacher 2004). Adaptive cartography aligns with the practice of *responsive web design*, an approach to design with open web standards (HTML, CSS, JavaScript) that applies contingent style rules to modify page content based on the display device (Marcotte 2014; Roth et al. 2014). Whereas the primary emphasis thus far has been on responding to the device or browser, adaptive cartography also must consider the abilities and preferences of the users, the information delivered through the map, and the tasks the users are attempting to accomplish (Reichenbacher 2003).

Finally, mobile maps can support the production of *volunteered geographic information* (VGI), or spatially explicit, crowdsourced information about the landscape (Goodchild 2007). The possibility of mobile-derived VGI is exciting for citizen science but has opened new ethical questions about the risks to individuals who contribute private geographic information (Wilson 2012). Further, mobile technology has been criticized for exacerbating the digital divide, reinforcing power structures across gender, race, and socioeconomic status, and acting to further silence marginalized voices (Stephens 2013). Additional research is needed to understand the intersection of mobile map design, VGI, and ethics (Ricker et al. 2014).

Taken together, these different strands of debate suggest that mobile maps offer a rich site for new research on critical geographic pedagogy and cartographic practice. Empirical work is needed to evaluate the emerging conventions of mobile map design broadly (see Table 2) and also to articulate specific design strategies for mobile maps supporting situated learning of geographic concepts.

Case Study: The Global Madison Mobile Map

We created the Global Madison mobile map as a case study to better understand the benefits and limitations of mobile mapping for situated learning about globalization. Global Madison supports International Studies 101 (IS101), an introductory, fifteen-week course at the University of Wisconsin–Madison (UW–Madison) that explores global interdependencies and inequalities related to trade, labor, finance, governance, health, and the environment (see Sparke 2013). One of the challenges when teaching such a course is that students come to think about globalization as an abstract, monolithic process that happens somewhere "out there" (Massey 2005). Instead, IS101 tries to ground uneven processes of globalization in specific sites. In this way, students learn how the local and global are always coconstitutive of one another (Mountz and Hyndman 2006).

In previous years, local examples were integrated into lectures to literally "bring home" key points. Students also were encouraged to relate regional news stories to broader political issues in their discussion sections. Nevertheless, based on classroom conversations and responses to exam questions, it was difficult for students to develop relational thinking skills through lectures, readings, and classroom discussion alone. Global Madison was designed to give students a more concrete, situated experience within their local environment that they could draw on for the remainder of the course. The mobile map aims to make the otherwise "familiar" landscape of Madison "strange" to students, enabling critical engagement with the interconnection between the global and the local.

Table 2 *Some emerging conventions for adapting map design to mobile devices*

Convention	Constraint	Reference	GM
Map composition and layout			
Maximize the screen real-estate used for the map view	Screen size	Muehlenhaus (2013)	Y
Use full-screen dialog windows for text and interface menus	Screen size	Muehlenhaus (2013)	Y
Respond to vertical and horizontal aspect ratios	Handheld	Chittaro (2006)	Y
Scale/generalization			
Present only task-relevant information	Bandwidth; screen size	Meng (2005)	Y
Generalize base map	Bandwidth; screen size	Meilinger et al. (2007)	Y
Include salient landmarks for orientation	Mobility	Raubal and Winter (2002)	P
Increase default map scale (i.e., zoom in)	Screen size	Tonder and Wesson (2009)	Y
Constrain smallest map scale (i.e., max zoom out)	Mobility	Davidson (2014)	Y
Provide visual affordance for off-screen content	Screen size	Chittaro (2006)	Y
Load map progressively, using tiles	Bandwidth	Muehlenhaus (2013)	Y
Cache essential information on load	*Bandwidth*	*Roth et al. (2018)*	*Y*
Use vector tilesets	Bandwidth	Buttenfield (2002)	N
Projection			
Center map on user's location	Mobility	Meng (2005)	P
Update user's position on the map	Mobility	Peterson (2014)	P
Reorient view so that forward is up	Mobility	van Elzakker et al. (2009)	N
Symbolization			
Emphasize reference over thematic mapping	Mobility	Muehlenhaus (2013)	Y
Increase contrast within visual hierarchy	Viewing conditions	van Tonder and Wesson (2009)	Y
Increase brightness and saturation of map features	*Viewing conditions*	*Roth et al. (2018)*	Y
Increase size of interactive point symbols	Multi-touchscreen	Stevens et al. (2013)	Y
Include road map and aerial imagery base map options	Mobility	Davidson (2014)	N
Symbolize unsafe crossings or other hazards	*Divided attention; mobility*	*Roth et al. (2018)*	*Y*
Typography			
Use sans serif fonts	Screen size	Muehlenhaus (2013)	Y
Increase text size and tracking	Screen size	Muehlenhaus (2013)	Y
Divide long sections of text into multiwindow blocks	Screen size	Muehlenhaus (2013)	Y
Keep text upright as user rotates map	Handheld	Muehlenhaus (2013)	Y
Map elements			
Use loading screen for map title	Screen size	Muehlenhaus (2013)	Y
Hide legend, help, and supplementary info by default	Screen size	Muehlenhaus (2013)	Y
Include persistent north arrow for egocentric view	Mobility	Muehlenhaus (2013)	N
Allow text and audio options for descriptions/directions	Screen size	Davidson (2014)	Y
Interaction			
Include post-WIMP widgets only	Multi-touchscreen	Muehlenhaus (2013)	Y
Provide visual affordances for interactive widgets	Multi-touchscreen	Stevens et al. (2013)	Y
Support double-tap and pinch for zoom	Multi-touchscreen	Muehlenhaus (2013)	Y
Support grab-and-drag for pan	Multi-touchscreen	Muehlenhaus (2013)	Y
Support two-finger twist for rotate	Multi-touchscreen	Muehlenhaus (2013)	N
Eliminate pan arrows and large zoom bar	Multi-touchscreen	Muehlenhaus (2013)	Y
Include +/– zoom buttons to zoom with one hand	Multi-touchscreen	Muehlenhaus (2013)	Y
Enable voice recognition for keying interactions	Multi-touchscreen	Muehlenhaus (2013)	N
Use sound and vibration for interaction feedback	Handheld	Muehlenhaus (2013)	N
Allow the user to tap anywhere to close pop-ups	Multi-touchscreen	Muehlenhaus (2013)	Y
Support tap and hold for advanced options	Multi-touchscreen	Muehlenhaus (2013)	N
Include search for user's current location	*Battery; mobility*	*Roth et al. (2018)*	*Y*
Include feature to calculate routes	Mobility	Davidson (2014)	Y
Support an offline or (for responsive) printable version	*Bandwidth; battery*	*Roth et al. (2018)*	*Y*

Note: The GM column marks those recommendations followed in the mobile version of Global Madison after improvement from the student evaluations: Y = yes; N = no; P = partial). WIMP = windows, icons, menus, pointers. Entries in italics indicate design insights reported in this article.

We scheduled the guided tour for the third week of the semester, just as students are introduced to the course themes, and used Massey's (1991) essay "A Global Sense of Place" as the companion reading.

Global Madison supports situated learning through two features: (1) an LBS that leads students along major paths, through city nodes, and to historic landmarks (following Lynch 1960), converting Madison into a situated classroom, and (2) delivery of narration, maps, and images at each landmark that serve as essential background and critical thinking prompts (after Bennett et al. 2007). We implemented Global Madison as a mobile website using open web standards and the Leaflet.js web mapping library (http://leafletjs.com/), rather than a native app installed on a mobile device, to avoid cross-platform issues (e.g., Apple vs. Android platforms) and allow students to review the tour on their desktop devices after completion. We selected Leaflet.js over other web mapping alternatives because of its minimal code base, core functionality for mobile, and open source licensing, enabling extensions of the code and avoiding pay structures that might limit access beyond UW–Madison (Roth et al. 2014). Although the decision to develop on the open web carried important advantages, content is not downloaded to the device on installation of the app and instead needs to be served over a network connection while on the guided tour. To ensure that students without a mobile device or data plan can complete the assignment, ten handheld tablets are kept on library reserve for checkout during the week Global Madison is assigned.

When students open Global Madison (Figure 1), they are presented with the options to begin using the mobile map assuming a starting location of the UW–Madison campus or to use the Google Maps LBS to determine their initial route when off campus. On entering the map itself, students are given the route to the first landmark and a six-minute audio narration providing essential background on the relationship between Madison and economic globalization for review while navigating to the first landmark. This narration also can be viewed as a sequence of text segments (after Muehlenhaus 2013). Each landmark is consistently represented by an iconic point symbol, colored red to indicate that it is interactive and sized as a 36-pixel × 36-pixel square for accurate touch interaction (Stevens et al. 2013). Students can identify

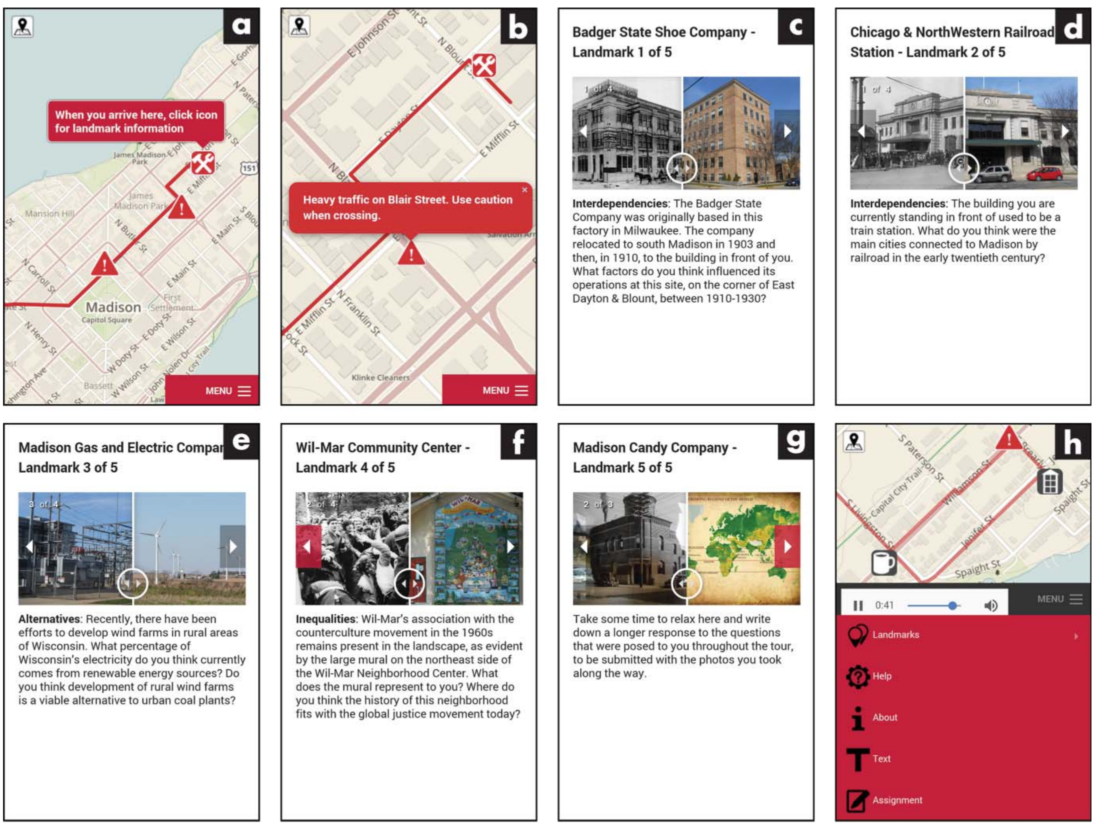

Figure 1 *The Global Madison mobile map as viewed on a mobile device. (A) Routing to the first landmark, with a prompt to click on the landmark to activate background and critical thinking prompts. (B) Warning messages about unsafe crossings and other potential navigation issues. (C) A critical thinking prompt at the Badger State Shoe Factory with swipable historic and modern images. (D) A critical thinking prompt at the Chicago & Northwestern Railroad Station with swipable historic and modern images. (E) A critical thinking prompt at the Madison Gas and Electric Company with visual comparison to alternative sites. (F) A critical thinking prompt at the Wil-Mar Community Center with historical photography that influenced current artwork. (G) Critical reflection for the visual essay at the Madison Candy Company. (H) A menu allowing students to retrospectively review information from the mobile map while compiling their visual essay on campus or at home. Global Madison is available at http://www.geography.wisc.edu/GlobalMadison/. (Color figure available online.)*

Table 3 *The Global Madison guided tour includes five landmarks selected to explore global interdependencies, inequalities, and alternatives through the lenses of commodity chains, transportation, energy, labor, and fair trade*

Landmark	Description
1. Commodity Chains and the former Badger State Shoe Company (Figure 1C)	The six-story brick building is the former site of the Badger State Shoe Company, which employed 250 laborers at its peak in the 1920s. The landmark, now condominiums, and nearby Old City Market provide students an opportunity to contrast Fordist, assembly-line production with post-Fordist commodity chains, represented in this case by a map of Nike's global network of subcontractors.
2. Transportation Networks and the former Chicago & Northwestern Railroad Station (Figure 1D)	The decorative façade marks the former location of one of Madison's six now-defunct intercity passenger rail stations, the primary transportation nodes connecting Madison to the regional economic hub of Chicago. The façade abuts what is one of Madison's busiest thoroughfares for downtown automobile travel and its busiest commuter bicycle path (part of the former rail bed), providing students with a juxtaposition of the way in which people and goods once moved through the landscape to their transportation today.
3. Energy Consumption and the Madison Gas and Electric Company (Figure 1E)	Among Madison's most iconic skyline features are the four smokestacks that rise from the Madison Gas and Electric power plant, established in 1902 and converted from coal to natural gas in 2011. Students are able to consider local and global alternatives to fossil fuels while having a multisensory experience walking among the buzzing, vibrating electrical transformers.
4. Labor Politics and the Wil-Mar Community Center (Figure 1F)	Housing in Madison's Williamson-Marquette neighborhood originally was built at the turn of the twentieth century for middle-class families working in nearby businesses and factories. In the 1960s, this area became well known as a regional hub for the counterculture movement and was the site of many protests to end the wars in Southeast Asia and promote the empowerment of women and people of color. The mural painted on the Wil-Mar Community Center gives students a chance to reflect on the intersection of labor and human rights worldwide.
5. Fair Trade and the former Madison Candy Company/present-day Ground Zero Coffee (Figure 1G)	The final landmark is the former site of the Madison Candy Company, whose faded lettering still marks the side of the brick building. The site is now home to Ground Zero Coffee, offering a concrete example for subsequent classroom discussion about the international coffee market and the politics of fair versus free trade.

their current location using the Leaflet.js LBS geolocate feature (Peterson 2014), but the location is not updated in real time, as preliminary tests revealed a substantial impact on battery life when triggered continuously (after Armstrong and Bennett 2005).

Once students reach a landmark, they are presented with a one-minute audio narrative providing a historical introduction to the landmark and a series of critical thinking prompts about global interdependencies, inequalities, and alternatives regarding the landmark in present day. The critical thinking prompts provide context for the otherwise unseen aspects of the physical landmarks, helping students to reflect on the spatial relationships between those sites and other places around the globe. The prompts include a mixture of text, audio, and visuals to accommodate multiple learning styles (after Armstrong and Bennett 2005). Five landmarks in Madison were selected as examples of core course themes (Table 3).

To make learning interactive, dynamic, and student centered (following Armstrong and Bennett 2005), students submit a visual essay of their experience on the guided tour. The objective of the visual essay assignment is for students to demonstrate their understanding of globalization by extending and enriching Global Madison content with pictures and descriptions of their own reading of the landscape. We did not implement functionality for students to contribute their visual essays as VGI given the ethical concerns around VGI discussed earlier. Instead, we created a menu allowing students to retrospectively review information from the mobile map while compiling their visual essay on campus or at home. Therefore, the Global Madison mobile map needed to be responsive to mobile and nonmobile devices. It is responsive in three ways: (1) the map and interface layouts switch from full-screen content blocks to a fluid layout between mobile and nonmobile, (2) the narration default switches from audio to text between mobile and nonmobile, and (3) the LBS geolocate feature is not available in the nonmobile version (Figure 2).

A beta version of Global Madison was assigned during the third week (15–21 September) of the Fall 2014 semester to an IS101 course of 400 students. Students had the option of completing the guided tour by themselves or collaboratively during one of five instructor-led sessions throughout the week. The complete route is approximately three miles (~5 km; Figure 3), with an expectation that students can complete the guided tour by foot within three hours in lieu of classroom contact time for the week.

Evaluation

Our evaluation of Global Madison followed recommendations for user-centered design studies established in information visualization and usability engineering (Robinson et al. 2005; Munzner 2009). In contrast to traditional quantitative experiments that simplify the map designs and control the geographic setting to produce generalizable insights,

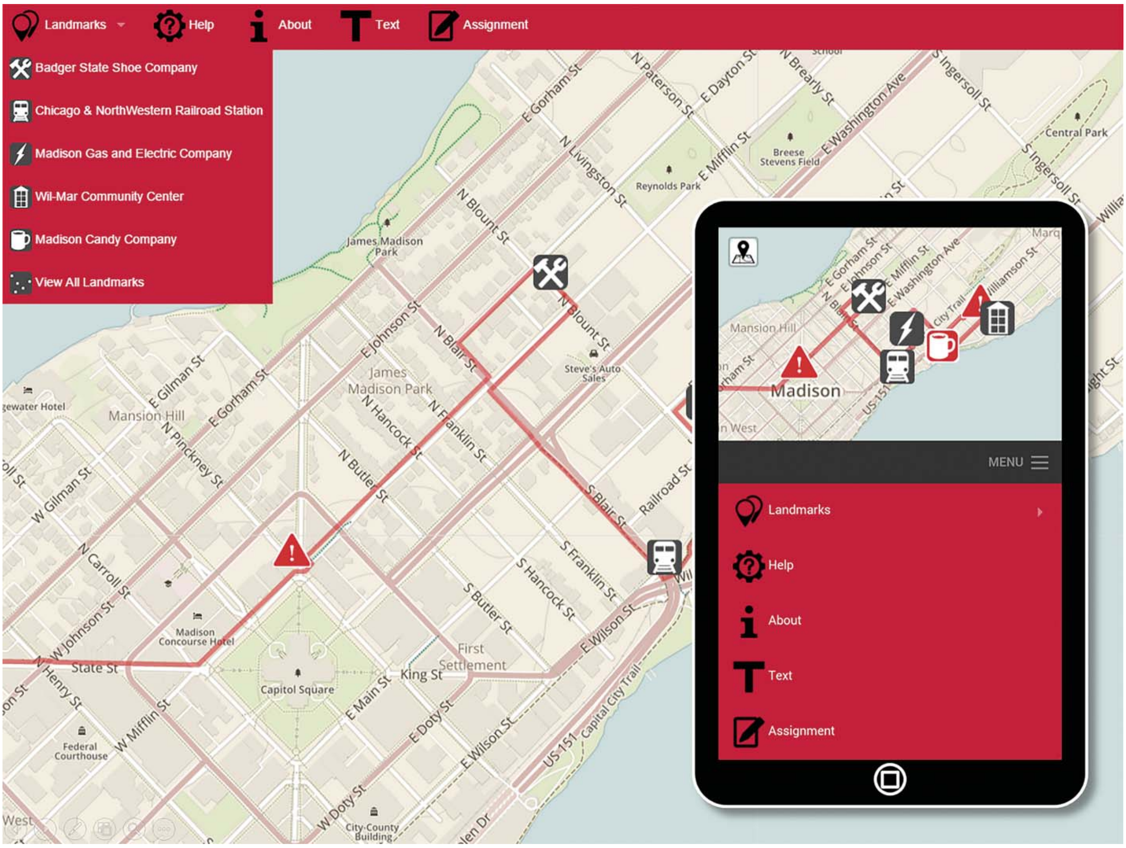

Figure 2 *The responsive web design strategy used for Global Madison. (Color figure available online.)*

design studies recruit target users (here, students) and test in a realistic setting to find insights that are potentially transferable to other design contexts (Seidlmair et al. 2012). Design studies have the dual goal of improving the evaluated tool and identifying new design considerations for future projects.

We conducted two evaluations of Global Madison using a mixed-methods approach that paired a broad online survey with the entire IS101 class with a deep field observation with a small set of students to assist in our interpretation of patterns in the survey. A subset of 244 of 400 students completed an online survey after the guided tour. Because we tested in a realistic setting, we did not vary the design or assignment (i.e., separate students into controlled conditions) to avoid giving some students potentially suboptimal situated learning materials. The survey included sixteen multiple-choice questions, Likert-scale ratings, and open-ended qualitative reflections aimed at understanding the student experience with Global Madison. The online survey also included retention questions covering content from the guided tour and background questions on student demographics, prior knowledge, and interests related to Global Madison. Individual student differences were analyzed quantitatively using inferential statistics: t tests were used for differences by gender (no students identified their gender as "other"), language, and viewing device; analysis of variance was used for differences by nationality and academic standing; Pearson's correlation test was used for variation by age; and Spearman's correlation tests were used for variation by prior knowledge and interests. Differences across landmarks included in the guided tour were analyzed using a chi-square test, with Mann–Whitney tests used to compare specific pairs of landmarks. The Bonferroni correction was applied to account for multiple comparisons. The open-ended qualitative feedback and subsequent field study (details later) were used to inform the interpretation of inferential statistics and identify necessary design revisions. The online survey took approximately fifteen minutes to complete and students were awarded 1 percent course extra credit for participating.

We also observed eighteen IS101 students in the field while completing the guided tour to capture critical incidents during their situated learning experience. Participants in the field observation completed the guided tour in groups of two (nine groups in total) to mimic the potential collaborative component of the exercise. We collected the navigated route and critical incidents observed either directly from use of the map or verbalized by one or

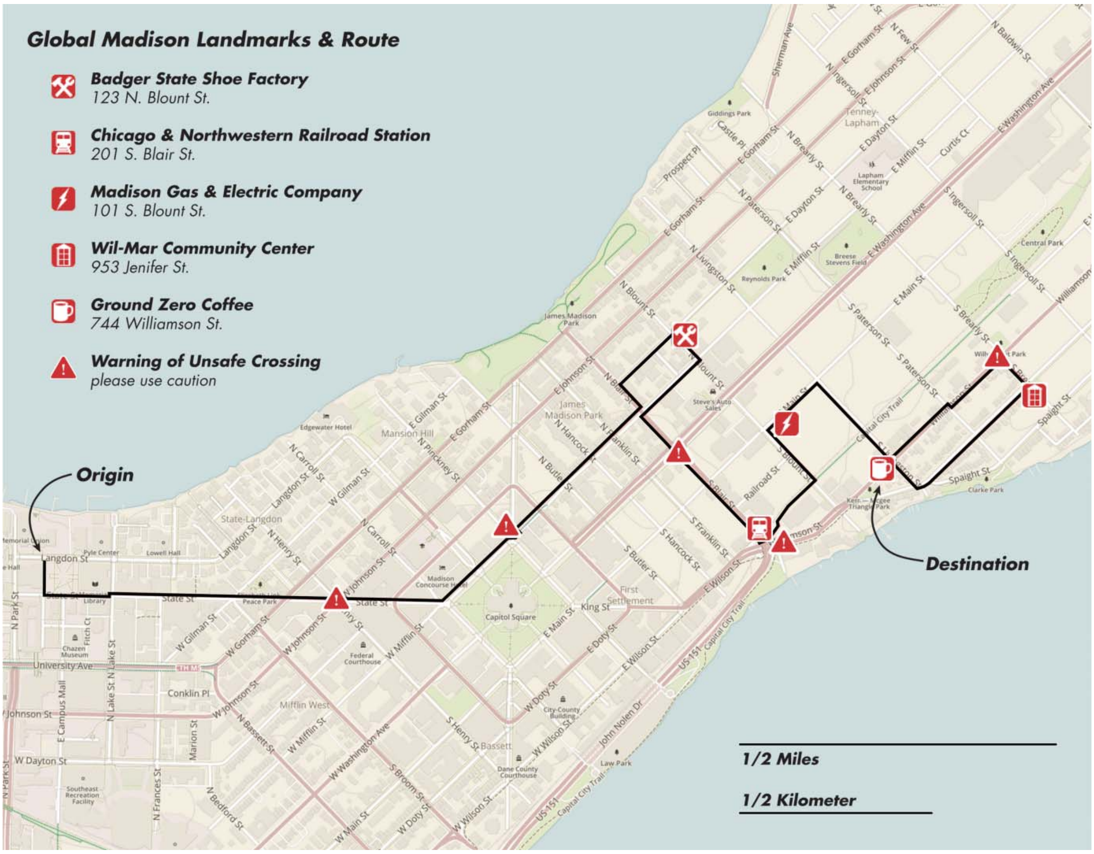

Figure 3 *The complete guided tour route with five landmarks. (Color figure available online.)*

Table 4 *The coding scheme used to identify and organize critical incidents during the field observation*

Critical incidents		**Frequency**
Hardware		55
H1	Observed issue with data connectivity and caching	23
H2	Observed issue with GPS and LBS	1
H3	Observed issue with battery life	2
H4	Observed issue with audio	27
H5	Observed issue with brightness and viewing conditions	2
Software		30
S1	Observed confusion over where to click	13
S2	Observed misclick or user errors	9
S3	Observed issue with switching between programs	6
S4	Observed issue with responsive design	2
Navigation		50
N1	Observed unsafe crossing	3
N2	Statement of being confusion about the route	17
N3	Statement about the length of the route	7
N4	Statement about difficulty with landmark salience	23
Weather		4
W1	Statement about rain or other forms of precipitation	1
W2	Statement about the wind	2
W3	Statement about being hot	1

Note: GPS = Global Positioning System; LBS = location-based service.

Table 5 *A comparison of student demographics for both evaluations of Global Madison*

Characteristic	Online survey	Field observation
Gender		
Female	173	9
Male	71	9
Other	0	0
Nationality		
U.S.	202	8
Other	34	7
U.S. and other	8	3
Language		
English first	206	7
English second	38	11
Standing		
Freshman	155	11
Sophomore	48	3
Junior	27	3
Senior	12	1
Other	2	0
Device used		
Smartphone	219	0
Tablet	25	18 (all dept. tablets)
Total	244	18

both participants. We intervened only when concerned about participant safety. We coded the frequency of observed critical incidents into four categories: (1) hardware issues, (2) software usability issues, (3) navigation issues, and (4) weather issues (Table 4). Students were given $10 for participating in the field observation. Table 5 provides a comparison of student demographics for both studies.

Results

Feedback from Online Survey

The online survey provided positive evidence that Global Madison supported situated learning about globalization, as students successfully retained information from the guided tour and generally found the learning experience stimulating. Students answered 75.9 percent (SD = 19.5 percent) of the retention questions about the landmarks correctly, an acceptable performance given that students were not expecting to be quizzed on content and that responses were ungraded. We found no significant differences in retention by gender ($t = 1.085$, $p = 0.280$), device used ($t = 0.424$, $p = 0.672$), or academic standing ($F = 1.357$, $p = 0.250$), and there was no significant correlation between retention and age ($r = -0.060$, $p = 0.350$). The similarity in retention by device suggests that our responsive design strategy offered a consistent experience across devices. Further, the retention similarity across academic standing suggests that Global Madison was pitched correctly for an introductory audience.

We did find significant differences at alpha = 0.05 in retention by nationality ($F = 3.895$, $p = 0.021$) and language ($t = -2.426$, $p = 0.019$), with international students and students whose first language is not English retaining relatively less information about the landmarks. This finding led us to review the embedded translate functionality in

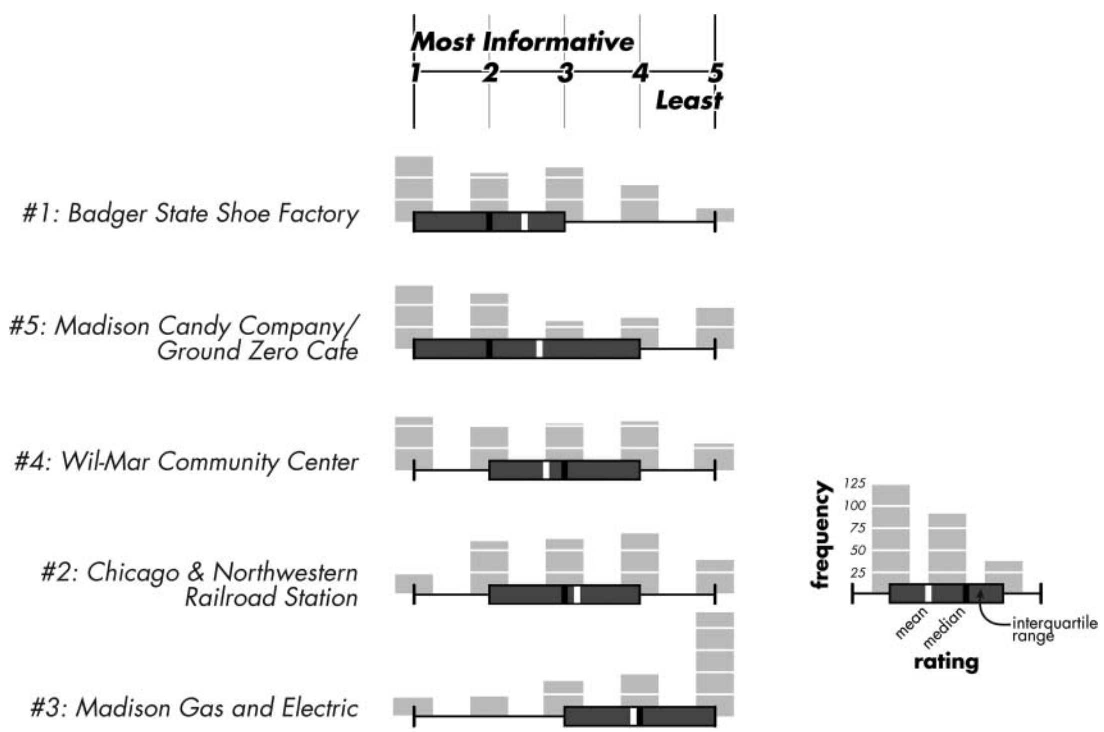

Figure 4 *Ranking the five Global Madison landmarks in the online survey. The complete Likert-scale distributions of responses are provided as supplemental materials.*

mobile browsers during class, given the large international audience for the IS101 globalization course (Table 5). The ability to flexibly translate languages was an important, unforeseen advantage of using open web standards for Global Madison rather than native mobile apps, adding to the advantages of cross-platform support and responsive mobile and nonmobile designs.

Students did not find each of the landmarks on the guided tour equally illustrative of globalization ($H = 156.170$; $p = 0.000$; Figure 4). Correlation analysis showed no significant influence on landmark rankings by demographics, prior knowledge, or interests, suggesting a consistent experience of the landmarks across participants and that variation in the landmarks themselves led to the observed differences in intuitiveness rankings. Students ranked the first landmark as most informative, noting in the qualitative feedback that the narration, maps, and images were particularly rich for this site. The surrounding environment also provided opportunities to capture photos for the visual essay, as several additional historic buildings and signage about the neighborhood's history are on the same block as the former Badger State Shoe Factory. Several students noted that the landmark was easy to find given its height and dedication plaque and that its location away from busy streets made the experience less stressful and more enjoyable.

In contrast, students ranked the third landmark as least informative. From pairwise comparisons between landmark rankings, we found significant differences at $\alpha = 0.001$ between the third landmark and every other landmark on the guided tour, strong evidence that the Madison Gas and Electric Company was less successful than other landmarks at supporting situated learning about globalization. We expected students to have a multisensory experience while walking among the power transformers of the Madison Gas and Electric Company. In the qualitative feedback, many students reported difficulty confirming that they were in the correct location because the destination was an entire city block and not a salient building. Several students also reported in the qualitative feedback that they felt unsafe at this landmark given its location within the remaining industrial blocks of the Madison isthmus, illustrating the interplay of Armstrong and Bennett's (2005) principles for mobile map design (e.g., define flexible locational triggers; make learning interactive, dynamic, and student centered; promote personal safety) on the ultimate learning of students.

Finally, an important theme across students was a request for additional landmarks on the guided tour and for greater background about each landmark. Although restricting the background content and critical thinking prompts is a core tenet of situated learning and important for keeping mobile maps lightweight on network connections, the correct balance of content appears to be a function of the amount of student experience with the topic and the length of the guided tour. A consistent feed of background narration (text or audio), maps, and images is needed for new learners and for longer tours. As a result, we now spend one fifty-minute lecture period prior to the assignment to give requisite background on Madison and the landmarks included in the guided tour. We also are exploring ways for students to contribute additional landmarks and background content to Global Madison (i.e., VGI), viewable only within the class.

Regarding feasibility, responses to the online survey suggested that Global Madison was an appropriate replacement for one week of class contact and thus matched our anticipated difficulty and length for IS101. Students reported an average completion time of 123.0 minutes from start to finish, well under the budgeted three hours. It is worth noting, however, that the average reported temperature was 20.4°C (68.7°F) given the September assignment date. The sequencing for a spring semester offering needs to be rethought for a place like Madison that experiences extreme seasonal temperature differences. Students who completed the tour collaboratively generally reported an easier time navigating the route, as they were able to quickly correct mistakes in wayfinding and overcome design and usability issues with help from instructors or peers. Students with the shortest completion times reported traveling the path individually on their bicycle or in a car, potentially limiting their engagement with the landscape. Finally, three students described walking the tour as "difficult," "exhausting," or "strenuous," an important reminder that accommodations need to be made for any situated learning assignment requiring physical activity.

Likert scale questions on the design of Global Madison suggested several cartographic revisions to Global Madison and informed discussions on mobile map design broadly (Figure 5). Participants responded positively to the route and landmark symbolization and legibility of the map labels, and had no opinion on point symbol design, initial zoom scale, and interface design. Participants, however, did report wanting more detail and labels on the map, an opinion consistent with the request for more landmarks and information about these landmarks. As a result, we swapped the original, simple base map with a more complex base map tileset containing additional context information and labels drawn from OpenStreetMap (Haklay 2010).

Participant response was more negative or varied for two key design features of the mobile map. Although participants were neutral on the length of audio snippets, they were split on their preference for listening to audio versus reading text. Such a finding reflects Armstrong and Bennett's (2005) principle to accommodate multiple learning styles. Participants also were varied in their ease in navigating the route and especially in their confidence that they were headed in the correct direction. In open-ended comments, many participants reported a learned helplessness around spatial navigation and map reading, stating that they were "bad with directions" or that they have trouble "reading maps." Because spatial navigation and map

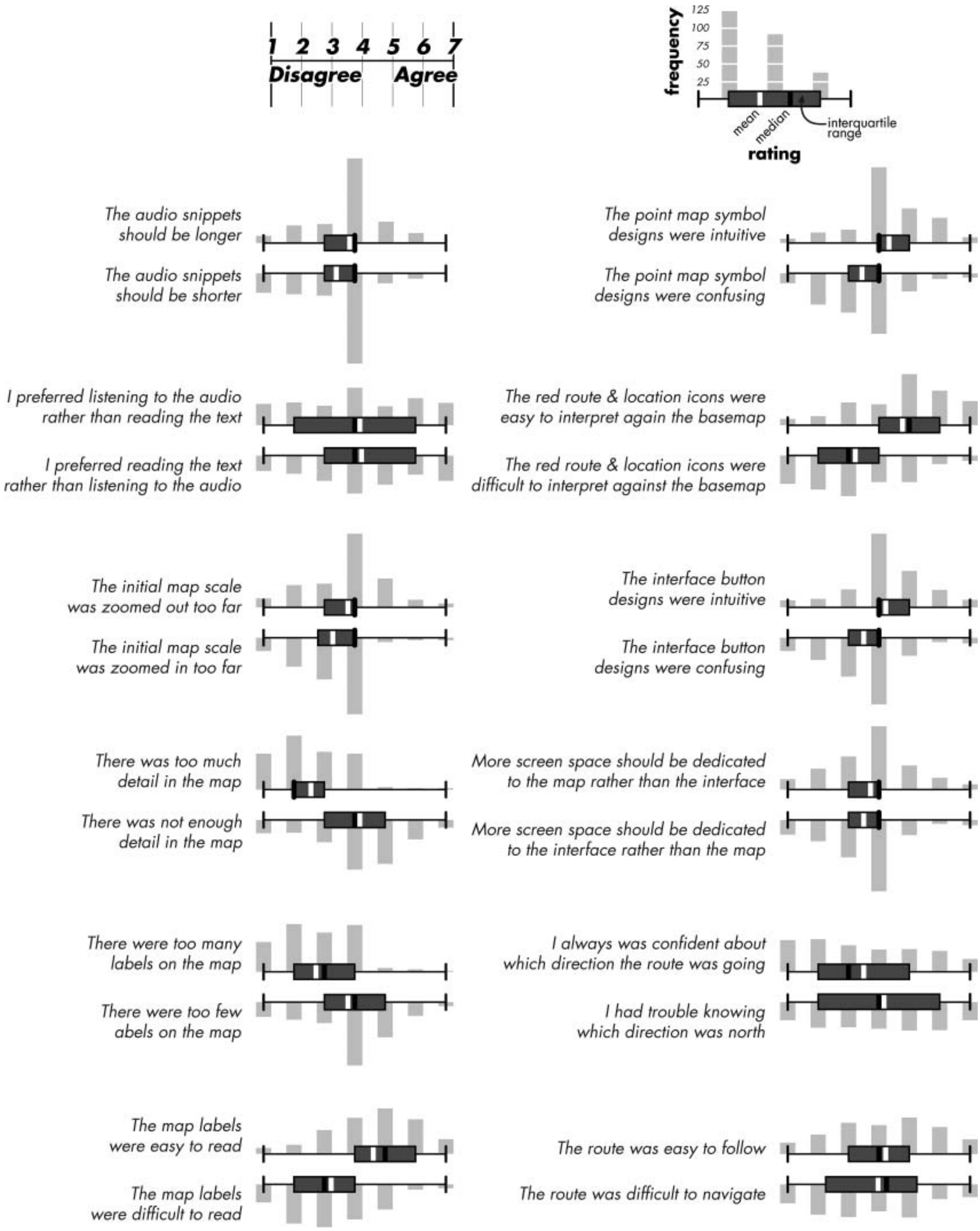

Figure 5 *Feedback on the map design of Global Madison. The complete Likert-scale distributions of responses are provided as supplemental materials.*

reading are learned skills, a situated learning exercise must be designed to confront misconceptions and work to build confidence, improving navigation and map reading skills along the way. Because the mobile and digital context is an additional encumbrance on students uncomfortable with navigation and mapping, we also now provide a printed map of the route in the class period that Global Madison is assigned to give students added flexibility when planning for the guided tour and navigating on the guided tour.

Likert scale questions on usability captured feedback on a range of issues or constraints of the mobile context for mapping (Figure 6). Surprisingly, environmental conditions (rain, cold, wind) were not

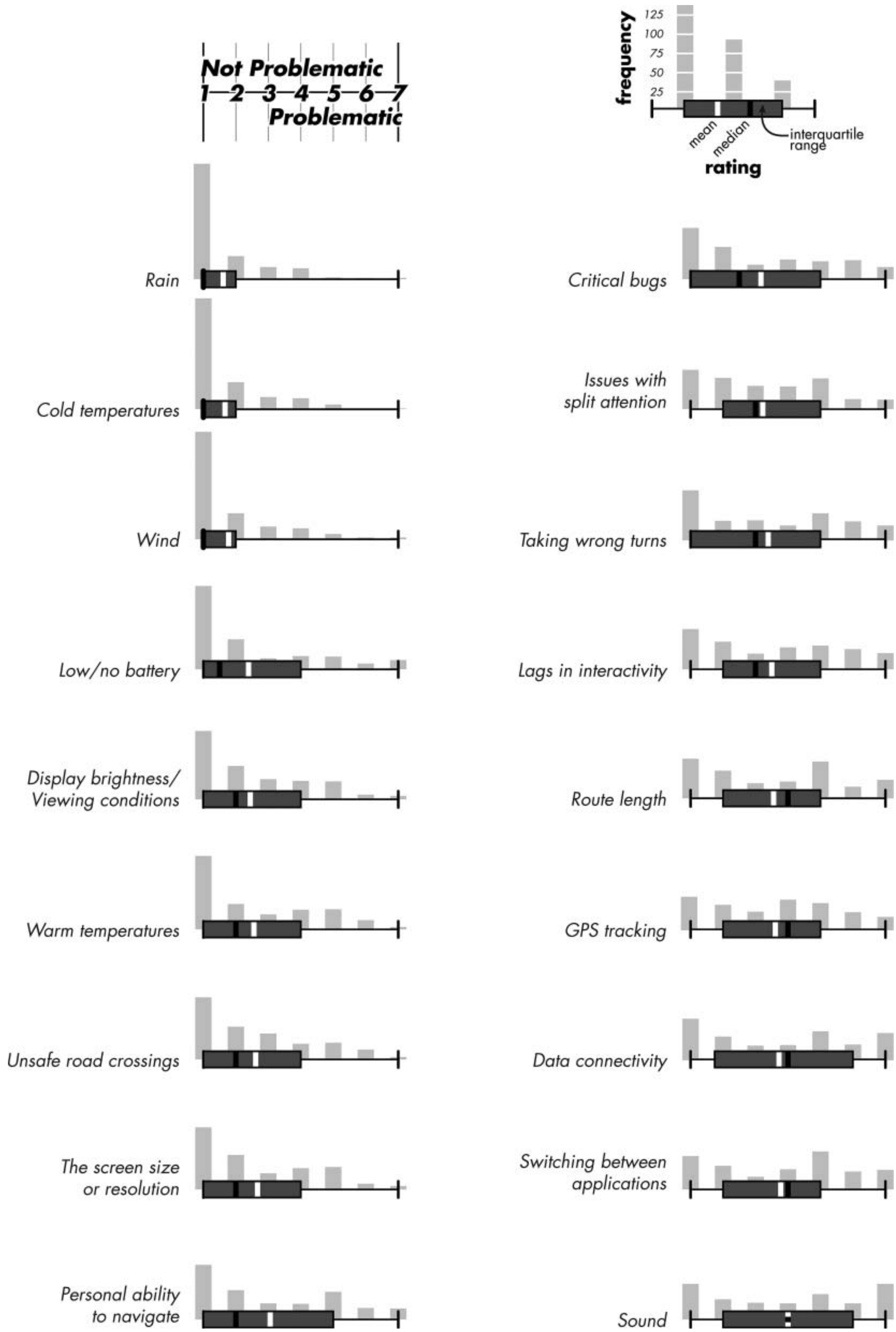

Figure 6 *Usability issues with Global Madison. The complete Likert-scale distributions of responses are provided as supplemental materials. Note: GPS = Global Positioning System.*

problematic and only three participants encountered rain during the guided tour. Although the fortuitous weather is a combination of the September assignment date and luck, opening the assignment for a full week allows students to avoid bad weather when not procrastinating. Other mobile constraints that Global Madison met well included battery life, viewing conditions, and screen size and resolution.

Several of the more problematic issues related to the two concerns in the map design described earlier: audio prompts and navigation. Audio was reported as the biggest issue with Global Madison, and interruptions or complete failures in audio playback were the most commonly mentioned frustrations in the open-ended reflections. The GPS tracking and route length also were seen by many as problematic, as we did not continuously update the user's position but instead required students to use a discrete geolocate feature. Based on student feedback, we now provide addresses for each landmark on the print map so that they can route themselves using other mapping applications when lost. Finally, participants reported data connectivity and switching between applications as problematic, specifically for capturing pictures for the visual essay assignment.

In open-ended reflections, many students balanced the challenges of the assignment with a deeper understanding of their local landscape. One student candidly offered, "There were times during the tour when I thought to myself, 'I would rather be doing something else right now,' but with that said, I learned about places in Madison that I never knew existed and witnessed firsthand the effects of globalization, so I am glad I did the tour." A second student remarked on the novelty of the assignment: "Overall, I liked and enjoyed the guided tour. I think the idea of this tour was creative and fun! I think it was a nice way to relate the issues in class to the city around us. I've never done something like this in class before, so that is pretty cool." Many students described a greater appreciation for Madison and its global connections in their closing reflections. One student wrote, "I enjoyed this tour! I definitely learned more about Madison's history. At times, we neglect the rich history that a place like Madison can have." Another wrote, "I've lived in Madison my whole life and I had yet to know about the history of the city. I really enjoyed the walking tour." In their photo essays, many students recalled experiences living or traveling in other parts of the world and drew connections between the landscapes they encountered there and the sites they visited in Madison. In this way, Global Madison was successful in making a familiar landscape strange to promote new ways of critically thinking about globalization.

Critical Incidents during Field Observation

The field observation explained many patterns in the online survey responses and identified additional issues with Global Madison. We collected 139 critical incidents during the field observation: fifty-five about hardware, thirty about software, fifty about navigation, and only four about weather (Table 5).

The field observation confirmed from the online survey that audio (twenty-seven incidents) and data connectivity (twenty-three incidents) were significant hardware constraints on Global Madison but also showed that they were interrelated, as all audio incidents resulted from interruptions in data connectivity. To combat this issue, we implemented a caching solution that downloads all audio files at the start of the guided tour near campus wireless to avoid interruptions in connectivity. Audio remains problematic in mobile web browsers, though, as the cache can take a substantial amount of time to load on poor wireless connections and is lost if the student closes or refreshes his or her browser while on the guided tour. For now, heavy reliance on audio requires developing natively mobile apps installed on the device (with all audio downloaded and stored with it), restricting interoperability across devices. Students experiencing audio problems were able to switch to the text version, however, indicating that audio failures related to data connectivity did not prevent students from completing the guided tour.

Although battery life only was an issue twice during the field observation, it was a disastrous issue when it did occur in that students were forced either to rely entirely on their partner for the remainder of the tour, pause the tour to recharge, or complete the tour at a later time. Students relied on their partner in both cases observed in the field observation, although several students reported either pausing the tour or returning at a later date in the online survey. In the latter two scenarios, students potentially become stranded, as the device is needed to complete the tour as well as navigate home. The importance of battery life for completing the assignment and personal safety (see later) further justified our decision to exclude a continuous, battery-draining LBS feature. Relatedly, we observed only one incident with the discrete LBS geolocate feature, a problem frequently reported in the online survey. We did, however, observe several students discovering this feature well after starting the guided tour, suggesting that the feature worked well but was not noticeable in the mobile map. As a result, we have made the geolocate feature more prominent in the top-left corner of the display. Both incidents with brightness and viewing conditions were quickly corrected by standing in a shaded area or holding the mobile device differently and thus were not considered impactful on the experience.

Our software was relatively stable during the field observation. The most common software issues were confusions over where to click (thirteen incidents) or misclicks on the wrong interface buttons (nine incidents), with these usability issues primarily occurring when first opening Global Madison. To combat this issue, we now include a startup tip that opens atop the first landmark on load with the prompt, "When you arrive here, click icon for landmark information"

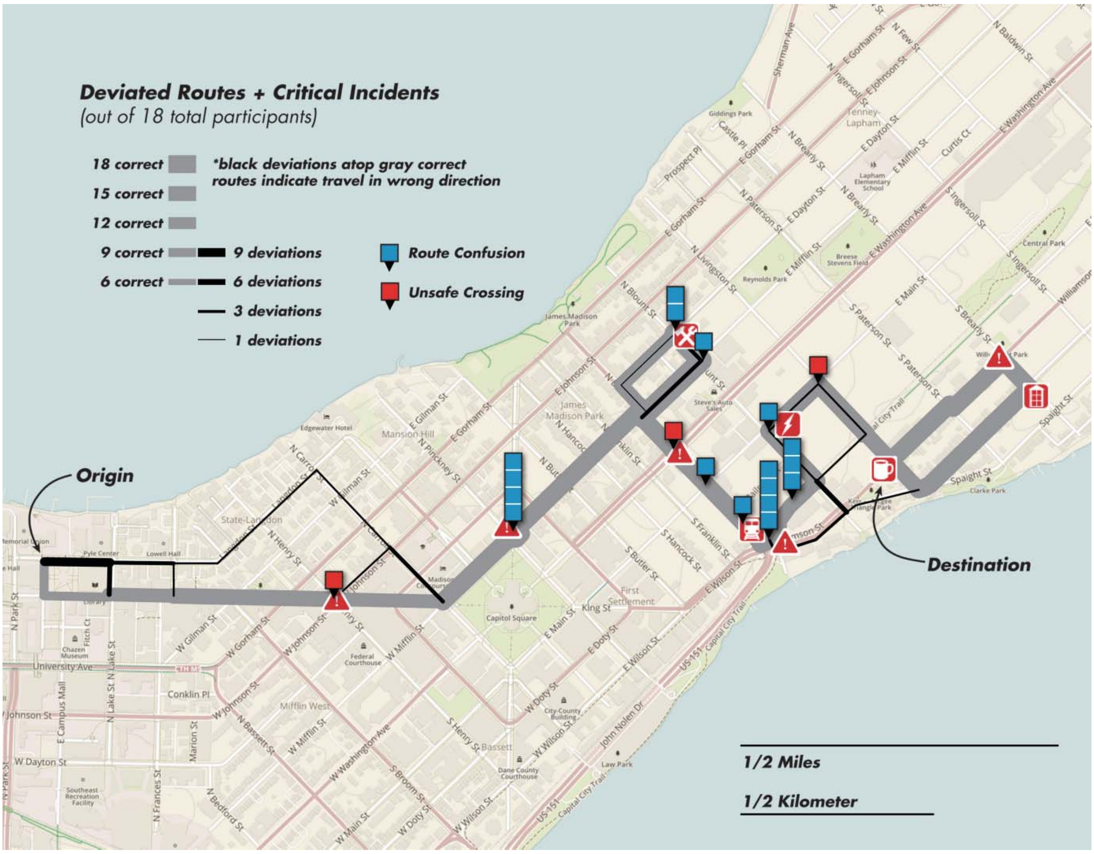

Figure 7 *Wayfinding during the guided tour. The map depicts the navigated routes as a flow map, scaling the thickness of the path segment according to the number of students following the given route. Correct navigation is shown in gray and deviated routes are shown in black. The frequency of incidents in wayfinding is overlaid as point markers, identifying chief locations of concern with navigation and split attention. (Color figure available online.)*

(following Mead 2014). We also expanded the help documentation available through the mobile map and now provide an in-class demonstration of the complete assignment before students leave for the guided tour. Students again had issues switching between applications to collect pictures, although less so than what was reported in the online survey (only six incidents), suggesting that use of multiple programs was inconvenient but not a major issue. Finally, we identified the same small bug in our responsive design solution twice, which we have since corrected.

We captured the most critical incidents on student navigation. As with qualitative feedback from the online survey, students had difficulty confirming that they were at the correct location for the Energy Consumption module during the field observation. Beyond this landmark, however, students at times had difficulty in cognitively associating the narration, maps, and text to features in the landscape (twenty-three incidents), an issue that has to do as much with spatial orientation as navigation. As a result, we contributed several dozen paths and building footprints in OpenStreetMap to ensure that there are a sufficient number of reliable and salient landmarks in the base map to relate the critical thinking prompts to the students' surroundings. As with the online survey results, there were several negative comments made about the length of the route, although these seven incidents did not impede completion of the guided tour within the allotted time.

Most students deviated from the intended route at least once during the guided tour (Figure 7). Several lengthy deviations occurred early in the route, when students were still near campus and thus were more familiar with the area. Deviations away from campus were more problematic, due to both lack of familiarity and stress over finding the landmark to complete the assignment. We observed seventeen incidents clustering at eight different intersections where students were confused about the route, with two intersections standing out as particularly unclear. In addition, we observed three unsafe crossings where a student ignored crossing signals and walked in front of oncoming traffic. Each time, the student's attention was divided by his or her mobile device. Although infrequent, an unsafe crossing is the most critical kind of incident that can occur when using a mobile map, and the observed incidents gave us pause about assigning Global Madison at all. As a result, we now take three strategies to promote safety during the assignment: (1) We deactivate audio between landmarks, with audio only available when near the landmark; (2) we mark the map with a number of cautionary, triangular symbols that identify unsafe crossings or confusing pathways; and (3) we assign students into groups of three to complete the guided tour and visual essay as a team. The shift to a group assignment has the added benefits of collaborative learning, efficient navigation, and technology backup, making the learning experience more reliable and engaging.

Conclusion

In this article, we described the design and evaluation of Global Madison, a mobile map supporting situated learning about globalization. Global Madison served as a useful case study to critically examine opportunities in geography for situated learning as well as discussions in cartography and GIScience at the intersection of LBSs, adaptive cartography, and VGI. In the following, we summarize new design considerations for mobile maps supporting situated learning identified through the Global Madison case study.

- *Focus on critical issues that might leave students stranded*. The mobile platform imposes a number of hardware constraints on mobile map design. During development, critical issues that occur infrequently (e.g., battery life) need to be given more attention than common issues that do not impede the learning experience (e.g., switching between apps, poor environmental and viewing conditions).
- *Append LBS with traditional mapping*. Despite the ubiquity of mobile devices and location-based services, wayfinding with mobile maps remains challenging in a new environment. For situated learning, append LBSs with traditional maps and other textual descriptions to confront misconceptions and build confidence, improving navigation and map reading skills along the way.
- *Enforce cognitive association between map and landscape*. Retention and engagement drops markedly when students are unsure how the mobile map and surrounding environment are connected. For instance, inclusion of a city block (the Madison Gas and Electric Company) as a landmark among other salient buildings made it difficult for participants to confirm that they were in the correct location when reaching the third landmark. To enforce cognitive association, select landmarks that are salient in the landscape and supply critical think prompts that clearly relate to the landscape.
- *Supply a consistent feed of information for new learners*. Tenets of situated learning limit background information to the essential only, instead relying on carefully placed critical thinking prompts (Griffin 1995). The appropriate density of information delivered through a mobile map, however, is a function of the amount of student experience with the topic and the length of the guided tour, with more information needed for new learners and long routes to produce an engaging, complete experience.
- *Encourage collaborative learning in the landscape*. Generally, students find situated learning and guided tours more engaging when they work in groups, as they can use the time and space between landmarks to discover, discuss, and think critically together. Working collaboratively also simplifies route navigation, overcomes fatal errors in the mobile map, and promotes safety, the final design consideration.
- *Promote student safety above all else*. Above everything else, focus on student safety by identifying all unsafe crossings in the mobile map. Require students to complete the guided tour together and restrict use of the mobile map to daylight or business hours.

Our experience of place increasingly is mediated by mobile devices, and mobile maps offer a rich site for research on critical pedagogy and cartographic practice. Yet our understanding of the design of mobile maps for situated learning remains in its infancy. Since the Fall 2014 evaluation, we have assigned Global Madison three additional semesters, reaching more than 1,400 students. We are excited to integrate new concepts and technology as research, industry, and education unlock the potential of mobile mapping and situated learning. ■

Supplemental Materials

The source code and guided tour script, online survey protocol, and data analysis are available on the publisher's website as supplemental materials to this article and can be reused and extended following a Creative Commons Attribution-NonCommercial 3.0 license.

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