Mobile City Science: Technology-Supported Collaborative Learning at Community Scale

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Abstract: In a new era of digital media and democracy, there is widespread concern that technologies have incapacitated us from learning and teaching across diverse communities and perspectives. While this notion may ring true in certain contexts, this paper describes a study, "Mobile City Science," that designed a novel learning experience in which educators and young people used mobile and place-based technologies to document and analyze the diverse perspectives of community members living in rapidly changing urban areas. The objective of this work was to teach young people digital literacies associated with "city science," an emerging interdisciplinary field that creates data-driven approaches to complicated community issues. Participants were videotaped as they collected and analyzed information about a specific neighborhood using wearable cameras, GPS devices, heart rate monitors, and a GIS software. Early findings show that Mobile City Science uses technology to engage people with diverse perspectives around a community scale problem.

Major issues addressed

Technology has changed the nature of political engagement. For every "success" story of increased government transparency and youth mobilization, there is an instance of political balkanization and divisiveness (e.g., Manjoo, 2016). In this new era of digital media and technology, many have argued that the sheer ubiquity of our technological interactions have incapacitated us from learning and teaching across diverse communities and perspectives. In an article titled, "How We Broke Democracy," Rose-Stockwell wrote, "If we cannot build the tools of our media to encourage empathy and consensus, we will retract further into toxic divisions that have come to define us today" (2016). This study, "Mobile City Science," represents one such attempt to use technology and digital media as a means of encouraging empathy and building consensus around a "live" community problem. Importantly (and in contrast to Facebook and Twitter), technologies in Mobile City Science engage young people and youth educators *in neighborhoods,* in face-to-face interactions, to generate new information and representations of diverse perspectives.

Before the most recent presidential election, social science was promoting the idea that "big data," produced by our multiple devices and technologies, would make cities and their citizens "smarter," or work better together. After the results of the election came through on November 8, 2016, several fundamental questions are now being asked about the promise of big data. Whose lives do these data actually represent? Who learns what from these data? What is the origin of data, and who has legitimacy to make interpretations and arguments from it? How did communities become so balkanized and bifurcated, bolstered by "data?"

While these questions remain problematic issues for political engagement at large, *they also open-up novel teaching and learning opportunities for underrepresented young people to create and engage with vast amounts of data across stakeholders that may have divergent perspectives on community issues.* Creating insights and data-driven approaches to community issues, or "city science," is an interdisciplinary field that is emerging alongside ubiquitous computing (MIT Media Lab, n.d.). Geospatial applications and mobile devices are especially conducive to this kind of data-driven inquiry process; these tools support and promote moving around the community and interfacing with shopkeepers, residents, and visitors *in place*. The mapping capabilities of geospatial apps and tools support a spatio-temporal way of recording, interpreting, arguing from the data collected around the neighborhood. These technological affordances have been shown to differently engage people in community-based issues, in ways that leverage physical mobility, be it walking, bussing, or bicycling around a geographic area (e.g., Nold, 2009; Taylor, 2013).

Potential significance of the work

As a whole, this research takes seriously the role of underrepresented young people using technology in Jane Jacobs' (1961) provocation that "…cities have the capability of providing something for everybody, only because, and only when, they are created by everybody" (p. 238). Mobile City Science (MCS) provides four key contributions to the learning sciences and other fields concerned with new ways of engaging underrepresented youth in community-level issues and dialogue through technology. First, MCS informs and contributes to theories of embodied learning (e.g., Alibali & Nathan, 2012; Farnell, 1999; Glenberg, Gutierrez, Levin, Japuntich, & Kaschak, 2004; Goldin-Meadow, Cook, & Mitchell, 2009) by analyzing how and what young people, and the people that educate them, learn about complex community issues from being on-the-move through their neighborhoods with mobile and location aware technologies. Second, MCS formalizes innovative ways of teaching community engagement to young people living in underserved areas of the city; MCS is a set of on-the-move teaching and learning experiences that support young people in collecting, analyzing, and arguing from spatial and other forms of data (e.g., GPS tracks, geo-referenced video files, density plots, place-elicited interviews). Again, these data represent the diversity of lived experiences within the geographic area. Third, MCS provides accessible, technologically enhanced ways for youth-serving organizations, community developers, urban planners, and/or social science educators to engage young people in civic processes and conversations happening at the scale of the city. Finally, MCS will contribute to a new theory of social change where technologies potentially democratize (rather than balkanize) learning and participation (e.g., Bilkstein, 2013; Papert, 1991; Resnick, et al., 2000; Wilensky & Papert, 2010) in processes of community development to include young people's data-driven perspectives in planning and policy implementation.

Approaches

The past decade has seen rapid growth in development and distribution of location-aware technologies (e.g., GPS in mobile devices), digital mapping tools (e.g., Google Maps, Open Maps), and tools for spatial analysis and modeling (e.g., QGIS, MapBox, mobile augmented reality). These technologies create new opportunities for linking data on personal mobility with a growing variety of spatially organized, open, and large-scale data sets (Busch, 2014; Kahn & Hall, 2016). In the hands of consumers, including school-aged youth, these tools and diverse sources of information are increasingly taken up in emerging practices of "neo-geography" (Goodchild, 2009; Graham, 2009; Liu & Palen, 2010). Some of these practices involve substantive learning opportunities in overlapping conceptual domains for STEM disciplines (e.g., Enyedy & Mukhopadhyay, 2007; Radinsky, 2008) and the humanities (e.g., Farman, 2013, 2015; Van Wart, Tsai, & Parikh, 2010).

Theoretical approaches

Engaging young people and adult stakeholders in mobile experiences through the city exemplifies a blurring of physical experience and representation that is so central to theories of embodiment. Blurring the disconnect between the physical and the represented is the basis for embodied learning, and is arguably a more authentic means for teaching and learning irrespective of content domain (e.g., Alibali & Nathan, 2012; Farnell, 1999; Glenberg et al., 2004; Goldin-Meadow, Cook, & Mitchell, 2009). Embodied learning theorizes learning as a process that is distributed across all of the sense-making modes of the body. This multimodality of sense-making is fundamental to not just learning *in situ*, but to how we organize "perceptual symbol systems" (Barsalou, 1999) individually and socially. For instance, Lakoff & Johnson (1980) demonstrated how seemingly abstracted metaphors are grounded in, or harken back to, some fundamental embodied experience that makes them almost universally understood in interactions.

Importantly for this work, researchers pursuing questions with an embodied learning lens carefully consider how all of these meaning-making modes are mediated by the various technologies that permeate daily life (e.g., Hall, Ma & Nemirovsky, 2015; Lee & Thomas, 2011; Keating & Sunakawa, 2011). An aim of MCS is to contribute to a more robust theory of embodied learning by providing descriptive and comparative analyses of how young people and adult professionals make "body sense" (Cajete, 2000) of the urban spaces in which they are engaging with technology. In a special issue of the Journal of the Learning Sciences, researchers provided arguments for the centrality of the body for learning mathematics (Hall & Nemirovsky, 2012). While that work has most recently promoted embodied cognition as a viable theory of learning, educators and educational researchers still struggle against the tendency to fetishize abstracted, "pure knowledge" over the ways in which our moving, feeling bodies make sense of the world. Additionally, and as Stevens (2012) pointed out in his commentary to the "Modalities of Body Engagement in Mathematical Activity and Learning" JLS Special Issue, attempting to build a broad understanding of how the body and learning relate via solely classroom-based studies is a major limitation to robust theory-building. Thus, MCS provides a (literally) grounded account of embodiment that problematizes the absence of space and place in previous accounts of learning.

Cognitive and learning scientists agree that "the original function of any brain is to control motion – only mobile organisms have brains" (Streek, Goodwin, & LeBaron, 2011, p. 7). However, leveraging physical mobility as a learning resource is still undervalued and underutilized in more traditional learning arrangements. Some researchers have pushed the possibilities of learning on-the-move with location aware and wearable technologies for creating place-based, mobile experiences (e.g., Hall, Ma, & Nemirovsky, 2014; Rosner, et al., 2015; Ryokai & Agogino, 2013; Taylor & Hall, 2013; Taylor, accepted). One early example of using mobility as a means for learning about and showing an experience of a place is the art of Jeremy Wood, an artist working at the intersection of cartography, visual arts, and geometry (Lauriault & Wood, 2009). Wood made visible his own embodied experiences through the landscape by re-appropriating GPS, a tool historically used by the US Military to precisely locate and track its missile submarines (Sample, 2014). Wood's "GPS drawings" represented a coordinating effort of walking (or driving or biking or swimming) and technology to tell a story about a place. These stories, in the form of geospatial representations, taught viewers about a practiced, lived landscape that an overhead satellite map makes invisible. In this way, physical mobility (mediated by geospatial technology) not only allowed the maker to see a place differently through first walking it and then viewing the GPS tracks, but also taught an audience about a different experience of that place.

This novel way of using mobile mapping technologies highlights how walking especially remains an act of civic and political agency (Rosner, 2015; Ingold, 2007; Suchman, 1995). Silent marches, migrations, and "memory walks" (Bonilla, 2011) are acts of dissatisfaction with the status quo; these walks also represent a process of teaching and learning where diverse publics inform more powerful others of inequitable lived experiences. This notion of mobility was a launching point for Mobile City Science; this designed experience supports youth to produce maps that are representative of their lived experiences of being a young person in a rapidly shifting urban setting, and the experiences of others. Moreover, MCS is intended to bridge the world of mapping and quantification familiar to urban planners and cartographers to the world of place-based story-telling and affect to produce a new opportunity space for teaching and learning at the interface of diverse publics (e.g., young people, shopkeepers, residents, urban planners, neighborhood school educators, parents).

Methodological approaches

Mobile City Science is a community-based design research project (e.g., Bang, Faber, Gurneau, Marin, & Soto, 2016) to understand and create new forms of techno-civic engagement for young people with mobile and location-based tools. We are asking these top-level research questions that guide the design study: (1) How do participants (i.e., young people and youth educators) use the designed MCS activities (e.g., historic neighborhood geocache, GPS drawing) to engage diverse perspectives on a community issue? (2) What kinds of data do participants collect and produce about their communities using these tools? (3) Whose lived experiences and perspectives do these data represent? (4) How are young people using data, and these tools, to make informed arguments and representations about changes to their communities?

We are working closely with three youth-serving organizations, Oasis Center, Digital Youth Network, and New York Hall of Science. These three organizations are highly respected for their technologically rich versions of "citizen science" they already do with young people and adult community members in Nashville, Chicago, and Queens, New York. We held, and are still holding, co-design meetings that are audio recorded and analyzed thematically. We held a training for youth educators from these organizations to implement the Mobile City Science curriculum in their respective communities. The four-day training was audio and video recorded.

The MCSC we create builds upon the current on-the-move citizen science programs that these youth-serving institutions already deliver. Importantly, MCS activities leverage mobile and location aware technologies for youth to collect, analyze, and argue from spatial and other forms of data. Some of the following teaching activities, and corresponding learning objectives, are included in past and ongoing MCS implementations (see Figures a, b, c, and d below for examples):

MCS designed activities

- *Pre/Post Assessment:* On the first and last days of the MCSC, young people are asked to draw their neighborhood on paper (i.e., "free recall maps," Hart, 1977) and asked open protocol questions as they draw. The changes between the free recall maps drawn on the first day of the study and the final day help us understand how young people's perceptions of their neighborhoods, and maps as a particular way of representing their neighborhoods, have changed over the course of the curriculum.
- *Youth Neighborhood Data Collection* supports young people to understand the *current* state of their neighborhood. Two examples of collecting neighborhood data are below:
    - Youth conduct **walking and biking audits** of the neighborhood with maps in hand. As they move through the neighborhood, they annotate the map with the routes they take, things that are missing on the map, map inaccuracies, and conventions that would be helpful for this way-finding exercise. Young people also take geo-tagged digital photos, and collect heart rate data (dramatic elevation changes are a real barrier for pedestrians and cyclists, especially in Seattle). They add this data, including the photos and heart rate information, into an open source GIS software (i.e., Google Earth). There are two important learning objectives

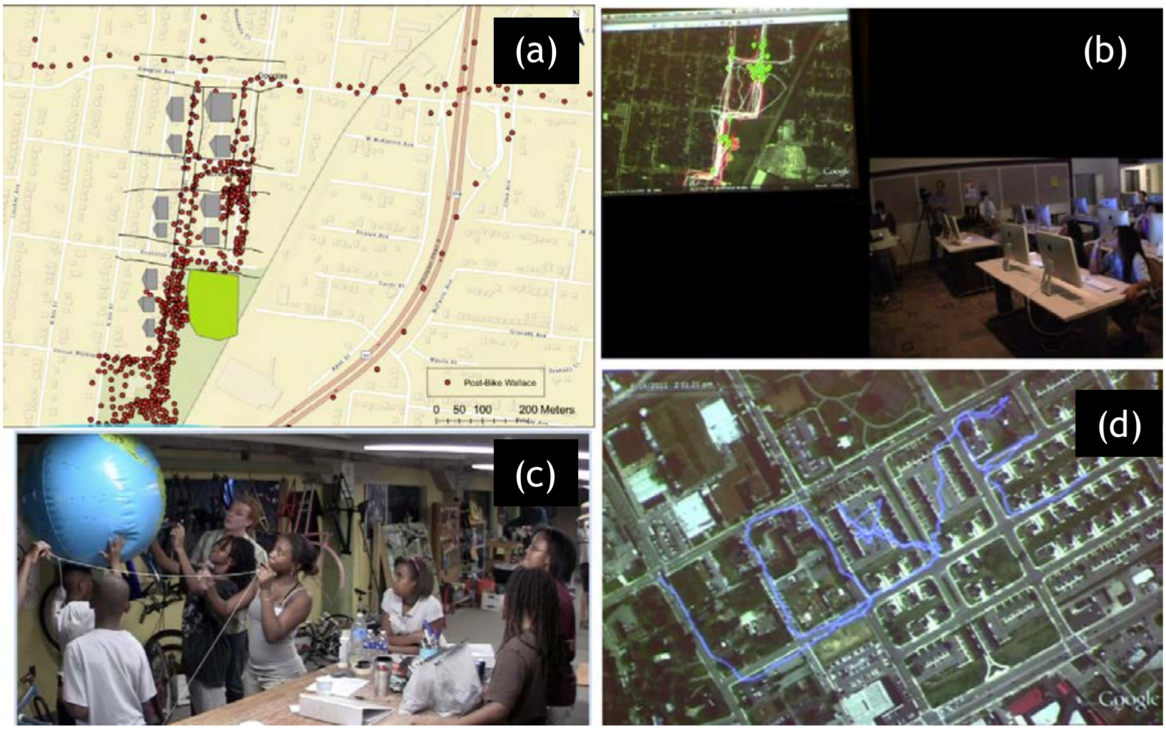
associated with this activity. The first learning objective is to learn about maps and spatial data through different representations (i.e., a paper map and a digital map) of a familiar place. The second related objective is for young people to learn about what different types of maps show, ignore, and highlight and how these different portrayals achieve a different purpose and can convey very different messages regarding the same place.

  - Youth conduct an **historic geocache** of the neighborhood with GPS devices in hand to collect historic data about the place in which they live (e.g., famous residents, important institutions, urban development decisions). At each cache, they have to produce some form of data (e.g., geo-tagged photo, geo-referenced video, GPS tracks, interview). Participating youth add this data as another map layer into an open source GIS software. The learning objectives for this activity are threefold. First, young people learn how different spatial phenomena are connected and impact people differently, over time. Secondly, young people gain facility with GPS devices and open source GIS software through recording and representing their own data. Related to this second objective, youth will begin to understand the affordances and limitations of these technologies based on one's purpose for using them. Third, young people are encountering notions of difference and multiple experiences of the same place.

- *Youth Data Analysis* supports young people to interrogate data as a different way of *seeing* one's neighborhood. Two examples of analyzing data are below:
  - Participating youth collect and analyze their **personal time geography** with GPS track data that show "typical" routes and locations that young people use and frequent (Hagerstrand, 1979). They analyze this data in a GIS to learn how to look for patterns, problems, and possibilities from spatial data. For example, patterns might be in relation to the grid network. Problems might be about the interstate system cutting through the neighborhood. And possibilities could be about additional bus routes for youth to access a library.
  - Thinking closely about the data they have collected, young people create **asset maps** of the neighborhood and greater community. Asset maps show the things that are working well about the geographic area, the deficits that exist, and the assets young people are imaging for the future of this place. As an instructional activity, asset mapping will support youth to think about places as developing over time and that this development is, in part, planned and mapped first.

- *New Neighborhood Maps* support young people to show and say something new about their neighborhoods from the multiple perspectives they have encountered and considered. Two examples of creating new neighborhood maps are below:
  - In the neighborhood, participating youth produce **GPS drawings** with GPS devices in hand (e.g., Lauriault & Wood, 2009). GPS drawings are novel messages or images written or drawn at the scale of the neighborhood chosen and produced by youth. After walking or biking these new messages or images, the GPS tracks are loaded into a GIS and shared with the group. As a neo-geography practice, young people learn about the emerging affordances of these mapping tools for showing affective responses to the places in which they live.
  - Young people build geospatial simulations, or **mobile augmented reality** (MAR; Heinrich et al., 2008; Rothfarb, 2011; Ryokai & Agogino, 2013) experiences using *Aris* (an open source platform for building map-based, mobile tours and interactive stories). These MAR experiences allow others to experience potential changes to the neighborhood and community from the perspective of the young person making it. In other words, as a person walks through a young person's community with Aris open on her phone, that young person's suggested changes to the built environment *in that place* will populate the smartphone screen (think Pokemon Go without the monsters). Building MAR experiences is a chance for young people to consider ways of building persuasive spatial arguments around *their own experience of living in an underserved area* of the city.

- *Youth Data-Driven Arguments* support young people to recommend evidence-based changes for their neighborhoods through maps. Participating youth create **counter-maps** of their neighborhoods, using all of the data collection and analysis they have done over the course of the study, and share these with their peers, adult educators, and researchers. This part of the curriculum allows young people to practice making claims to space and resources from spatial data. Young people share counter-maps with the community stakeholders with whom they came into contact during the above on-the-move activities, and also interested professionals (e.g., planners, transportation engineers, public school administrators and educators).



Figures 1a, 1b, 1c, 1d. These images show snapshots of some of the teaching activities involved in MCS. Image (a) shows a participant's free recall map geo-referenced to track data he collected and a base layer map of his neighborhood using a GIS. Image (b) shows participants examining and talking about their GPS track data during the personal time geography activity. Image (c) shows participants learning about GPS technology before doing the historic neighborhood geocache. Image (d) shows what one group wrote/walked through their neighborhood during the GPS drawing activity.

Data collection and analysis

For each MCS implementation, we are collecting video recordings of youth engagement, including their own wearable camera footage. We also collect artifacts that young people (and educators in the training) create as analyzable materials. These artifacts include free recall maps, GPS tracks, geo-tagged photos, digital maps, mobile augmented reality (MAR) experiences, and interviews with community members. These artifacts are treated as evidence of learning, or youth changing their perspectives over time, since their technical and community engagement practices become more sophisticated over the course of their participation in MCS. We also conducted ongoing and retrospective analyses of the design experiment as a "paradigm case" (Cobb et al., 2003, p. 13; Brown, 1992) of on-the-move embodied learning throughout and about the city. As we run and analyze implementations, we refine the design of MCS to address youth-relevant issues that are specific to each community, and to better address our design objectives. Implementations also provide comparative material from which to see differences in youth participation and learning based on the specific context and the refined design of the "experience."

Major findings

While iterations of Mobile City Science are still underway in Chicago and New York, we can report some major findings from the first rounds of youth participation (Nashville) and educator trainings (Seattle). Also, some findings come from facilitated design charrettes where youth participants shared their findings and arguments with urban planners, directors of the non-profits serving the youth of that community, cartographers, and parents.

The first major finding of this work is that moving between daily, lived experience (at the embodied, mobile, and practiced scale) and the representation of that experience (at the abstracted, static, and mapped scale) provides young people, and adult educators, with new insights about the technological and data infrastructures that support community level decisions. Because MCS participants are generating *original* data of a familiar neighborhood or community, they see how and what gets distilled from lived experience to a "data point" so that it can be mapped. Participants often find this distillation process (e.g., Bowker & Star, 2000) unnerving or frustrating. In the GPS drawing activity, for instance, a group of young women expressed concern about their track data not showing how difficult it was to walk up and down steep hills and the overall physical effort that task required. After talking with a local merchant during the geocache, a participant struggled to find a way to *show*, through maps, the shopkeeper's anxieties about a quickly gentrifying neighborhood

The second major finding is that re-mediating the daily mobility of young people with old and new technologies (e.g., bicycles, GPS devices) provided youth with powerful comparative leverage when ground-truthing maps and arguing for "on the ground" changes. On-the-move activities leveraged all of the sense-making modes of the body so that learning/problem-solving experiences were vividly recounted and used as evidence in conversations with (adult) stakeholders. During a final community design charrette, several youth argued for a protected bicycle path along a high traffic corridor. To make their point, several young people animatedly recounted, and then showed their maps of, being "buzzed" by a city bus while they were on bicycles along a designated bike route. The MCS facilitators also showed the head camera footage of that event. The adult stakeholders that attended were visibly moved by this data-driven argument.

Finally, the familiar context of the neighborhood and/or school community provided participants with a biographically relevant setting and authentic motivation for imagining a better future for that place. The familiar context of the neighborhood and/or school community allowed young people to leverage a variety of learning resources – neighbors, favorite locations, memories – that are often absent in de-contextualized, stationary mapping exercises or citizen science more generally. The adult residents, professionals, and stakeholders with whom youth came into contact during the on-the-move activities often fueled this interest and motivation for youth as they provided previously unknown stories and concerns about the community. In another example from the historic neighborhood geocache activity, a group of MCS participants spoke with a local shopkeeper who had been operating her store in the same location for more than twenty years. The shopkeeper alerted the MCS participants that the neighboring university was advocating for a dramatic change to the "character" of the neighborhood to include high-rise buildings; she was afraid that this shift would force her out of her building, unable to afford the higher rents. While the MCS participants were familiar with the argument to increase density in urban areas for several reasons, they were not aware of the consequences this could have on longtime residents and shopkeepers in older, rent stabilized buildings.

Conclusions and implications

While technologies continue to emerge, the demands they make on us change, but so do the opportunities they give us. Rather than thinking only of digital media and technology as keeping us apart (cf., Turkle, 2011), isolating us from the range of lived experiences and perspectives that exist within even a single community (or home), Mobile City Science follows the tradition of computer-supported collaborative learning. Mobile City Science represents an attempt to use technology and digital media as a means of learning through empathy and consensus building around a "live" community problem. The technologies in Mobile City Science engage young people and youth educators *in neighborhoods,* in face-to-face interactions, to generate new information (data) and representations of diverse perspectives. MCS as a learning experience supports young people to identify important local issues, understand multiple perspectives on those issues, and synthesize across these data to produce a cogent recommendation for neighborhood change. Similar to the intended outcomes of work by Gordon, Elwood, and Mitchell, (2016), MCS "expands adult-centric notions of civic agency and develops participatory mapping practices that elicit young people's knowledge on their own terms" (p. 2). Creating and arguing from data produced with geospatial technologies is an emerging techno-civic literacy that young people must learn for influencing change in their communities.

After the latest presidential election, President Obama stated that our current media ecosystem "means everything is true and nothing is true" (Remnick, 2016). By this statement, he meant that "non-truths" are easily circulated through digital media and people cannot only become misinformed but also bolstered by misinformation that agrees with their existing worldview. This issue is a national teaching and learning crisis; people can use technology to roadblock consensus building from a shared set of data treated as "truth." In such a context, we argue that the learning sciences must focus its efforts on creating not just tools, but complete teaching and learning experiences, that encourage empathy and consensus across a *diverse* range of stakeholders and community members. Otherwise, we may continue to "retract further into toxic divisions that have come to define us today." We hope Mobile City Science is one such teaching and learning experience for young people and the adults that educate them in youth-serving organizations.

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