Knowledge Construction in the Instrumented Classroom: Supporting Student Investigations of Their Physical Learning Environment

Tom Moher (co-chair), University of Illinois at Chicago, moher@uic.edu
James D. Slotta (co-chair), University of Toronto, jim.slotta@utoronto.ca
Alisa Acosta, University of Toronto, alisa.acosta@utoronto.ca
Rebecca M. Cober, University of Toronto, rebecca.cober@utoronto.ca
Chandan Dasgupta, University of Illinois at Chicago, cdasgu2@uic.edu
Cresencia Fong, University of Toronto, cresencia.fong@utoronto.ca
Alessandro Gnoli, University of Illinois at Chicago, Alessandro Gnoli, agnoli2@uic.edu
Alexandra Silva, University of Illinois at Chicago, amsilva2@uic.edu
Brenda López Silva, University of Illinois at Chicago, brendita@uic.edu
Anthony Perritano, University of Illinois at Chicago, Anthony Perritano, aperri3@uic.edu

Kylie Peppler (discussant), Indiana University, kpeppler@indiana.edu

Abstract: In this symposium we consider the physical space of the classroom in order to understand how location can be used as an input or information source for knowledge-building activities. Five posters encapsulate several projects, addressing the role of *physical or locational elements* within our work, including their role in the pedagogical design, the specific measures collected, and representations employed. The first two projects instrument the classroom with location-specific technologies (e.g., RFID tags), enabling learners to explore location-dependent phenomena (e.g., an earthquake zone, squirrel food patches). The third project maps classroom inquiry discourse (i.e., digital notes) to spatially meaningful locations though out the classroom for collective knowledge mapping. The fourth and fifth projects require learners to consider the physical properties of their learning environment in order to make decisions concerning where they will place motion-activated cameras for wildlife field investigations, allowing learners to instrument the learning environment themselves.

Keywords: physical location, location-tracking technologies, instrumented learning environments

Introduction

There is a long tradition amongst educators to situate learning within a physical orientation in the classroom, through the use of stations (e.g., in elementary classrooms), value lines (i.e., where students are asked to stand in a location that corresponds to their opinion or other value), or even small groups working on specific themes at different table locations. While most classroom instruction remains in the form of lecture (Tapscott, 1998), where location is largely (but not totally!) irrelevant, these longstanding examples have served as a persistent reminder that the physical space of the classroom can be used in pedagogically meaningful ways. A new genre of networked technologies is emerging that can track location and identity, or capture a variety of sensor information. These have opened the doors to new ways of leveraging the physical environment for purposes of learning, creating a new set of interactions with which learners can engage. For example, in BeeSim, students wear a "ForagerBee" glove – a sensor-embedded wearable – to step into the role of a bee and contribute to the health of a "hive" through location-specific actions within the environment (Peppler et al., 2010). Students aim to make optimal foraging choices, such as moving to flowers (fitted with unique resistors) that have the greatest nectar yield and returning to the hive before their "bee" is (virtually) exhausted.

This session will present a set of coherent projects that have pushed the boundaries of such applications, instrumenting students such that the physical environment can tailor its response to their presence at different locations, *or* allowing students to instrument their own physical environment. This set of projects has been conducted across a three-year time span, at several different school settings, with research groups from two universities. It represents a collaboration of theoretical perspectives and technology frameworks to achieve a unique set of curricular interactions. We have instrumented our classrooms to capture and distribute student ideas, to identify and respond to individual students, or to simulate data collection within a scientific community. The emphasis of our work is on science inquiry, with a particular interest in collective forms of progress, where students work autonomously within a larger “whole class” context, aggregating their observations or evidence to advance the understanding or progress within the overall community.

We organize our session as a structured poster set in order to accommodate five projects, giving each project a short presentation, but allowing the audience considerable time to interact with the authors. Each poster will address the role of physical or locational elements within its work, including the role of such elements in the pedagogical design, the specific measures collected, and representations employed. Our discussant Kylie Peppler from Indiana University will serve as discussant, offering comments during the final fifteen minutes of the symposium.

Location matters: The use of classroom space in RoomQuake

Tom Moher, Alessandro Gnoli, and Brenda López Silva

RoomQuake is a multi-week seismology unit designed for enactment in grade 5 and 6 classrooms. The unit problematizes the issue of how scientists are able to determine the properties of remote events—in this case, earthquakes. In RoomQuake, the classroom is imagined to be a miniature version of an earthquake-rich geographic area, and classroom computers situated around the room serve as imitation seismographs (Figure 1, left). During the first few weeks of the unit, earthquakes can be invoked "on demand" as students explore the relationships between the properties of earthquakes (time, location, and magnitude) and the representation of local ground vibration on seismograms. Over the final few weeks of the unit, students apply these understandings to determine the properties of a series of "roomquakes" occurring in their classroom.

In RoomQuake, location matters. When roomquakes occur, they occur at a particular location in the room. The energy transmitted through the ground (the floor of the classroom) travels to the seismographs at a constant speed. Seismograms of the same earthquake will look differently, if they were produced at different distances from the event. Students engage in activities such as (1) estimating the relative distances of different seismographs from an earthquake (based on arrival times or seismogram amplitudes) and using those estimates to qualitatively estimate the epicenter of an earthquake, (2) determining the speed of an earthquake wave front using tape measures and stopwatches, and (3) enacting a room-size version of the mathematical process of trilateration by finding the common point of intersection among multiple circles using tape measures anchored at each seismograph. In each of these, the floor of the classroom becomes a two-dimensional stage for the representation of the phenomenon and the enactment of activities (estimation, measurement, trilateration) common to the practice of seismology.

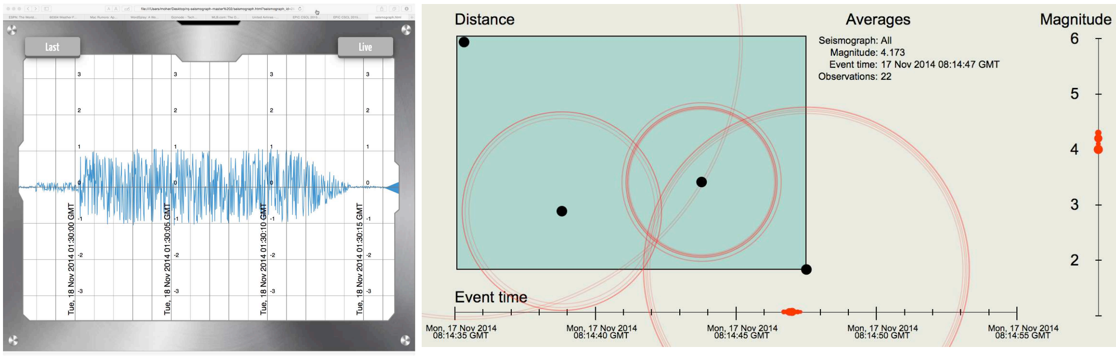

Figure 1. *Left:* Simulated seismograph. *Right:* Aggregate public display of seismogram readings.

In prior quasi-experimental research, we found that students who enacted RoomQuake activities on the classroom floor evidenced more improvement in both practice skills and conceptual understandings than students who performed analogous activities using maps (Moher et al., 2010). We expect that the benefits of physical enactment might derive from a variety of sources, including novelty, increased opportunities for social interaction, greater play value, salience at larger scale, or cognitive benefits associated with pairing action and thought.

Prior versions of RoomQuake included only the latter part of the current unit. Students were taught to interpret seismograms and extract earthquake parameters, but did not develop strong understandings of the capabilities and limitations of seismographs or their dependence on the generation of multiple waves of different constant speeds during an earthquake. The new design introduces a knowledge-building progression in the form of a series of challenges to learners to determine characteristics of earthquakes and waves using a variety of tools: seismographs, tape measures, and stop watches. The classroom floor becomes an experimental space, and "control" of the simulation technology is inverted; in this phase, roomquakes come at the discretion of the teacher (or even student), not according to a schedule, and the earthquake parameters—time, location, and magnitude—are specified by the user, not the goal of inquiry.

We also changed the activity structure of the second phase of the unit. In prior versions, students were typically organized as teams responsible for reporting a consensus reading from specific seismograph. In the new version, students use mobile devices to individually report readings from multiple seismographs, and as the readings are reported in aggregated form on a public display, affording learners an indicator of activity and progress in their spatially distributed work. Included in that visualization is a map of the room showing the distance estimates from each seismogram, reinforcing the "intersection of circles" framing that is difficult to achieve at classroom scale because of the occluding walls (Figure 1, right).

Expanding the pedagogical design space with indoor spatial technologies

Anthony Perritano, Alessandro Gnoli, and Tom Moher

We are interested in expanding the space of pedagogical designs by leveraging current advancements in indoor location tracking technologies such as Radio-Frequency Identification (RFID), inductive and capacitive Near-Field Communication (NFC), and Bluetooth Low Energy (BLE) iBeacons in technology-augmented classroom learning environments. They introduce the notion of a *proxemic interaction*, which is defined by the Human Computer Interaction research community as a way to describe an individual's technology-enhanced, socially-mediated, micro-located actions within a physical space (Marquardt & Greenberg, 2012).

Within learning environments that utilize spatial technologies, location has a meaning, which can become an input or information source for learning activities within an indoor classroom. In our investigations, location becomes an input into a participatory simulation and inquiry-based knowledge building activities (Slotta, 2014).

The affordances that location-tracking technologies add to classroom learning environments can be categorized in three ways: (1) hotspot location tracking—student movement can be detected in and out of discrete activity hotspots or zones; (2) distance tracking—discrete points within the classroom are able to detect, track, and compute distances of students in its proximity, and (3) high resolution tracking— student exact location within the classroom can be tracked continuously in real-time, making student-position an input into new types of learning activity designs. Distance tracking could potentially exchange information with the student or reveal an interaction (Marquardt, Ballendat, Boring, Greenberg, & Hinckley, 2012).

We used indoor location-tracking technologies and concepts within a classroom participatory simulation called Hunger Games (Moher et al., 2013). Hunger Games engages learners as foragers in an environment consisting of several food patches. Students learn the fundamentals of game theory by enacting strategies for survival under optimal game conditions: patch depletion, predation, safety in numbers, etc. Students employed small plush animals or "avatars" with embedded RFID tags to forage, choosing among food patches that were distributed around the room (see Figure 2).

Our choice of indoor location-tracking technology (i.e., RFID tags and readers) had an interesting outcome and created interaction opportunities that we did not anticipate. In our original design, we envisioned that we would track the location of individual students using bracelets or lanyards, with hotspot location tracking. However, this approach proved to be unreliable and technically difficult due to signal overlap from the RFID readers, which produced too much attenuation and false positive detection. To overcome this issue we tuned down the RFID readers' signal to a smaller range (< 30 cm) around the patches. We outfitted each student with an avatar (i.e., a plush toy that that served as an information carrier of his or her accumulated calorie information throughout the simulation) and required that those avatars be placed directly on top of the patches (i.e.., RFID readers). First, students developed affective connections with their avatar (observable by kissing, hugging, etc.; Moher et al., 2011). Two, students had the ability to both participate as an agent in the simulation (by placing their avatar in an optimal food patch) and to be an observer in a meta-role (by walking over to information displays that showed their progress within the game). With this freedom to roam, students moved to displays that showed their score while their avatars were feeding.

We used location as an informational source for students for: (1) *reflection-in-action* during foraging bouts, with the aid of large public ambient displays that provided information about total calorie accumulation for each animal, patch utilization, and a real-time map of each animal's location; and (2) *reflection-on-action* in post-foraging activities supported through community knowledge-building tools.

Figure 2. *Left:* Small plush toys with embedded RFID tags served as avatars for student foragers. *Middle:* Student places her animal on food patch and views foraging scores on iPad. *Right:* Student moving between food patch and large display.

In summary, we described the conceptual and practical use of indoor spatial technologies within a classroom environment. We discussed the affordances that these technologies create, e.g. the notion of micro-locational proxemic interactions, which have the potential to serve as informational inputs into learning activities. Finally, classroom use of these spatial technologies is still at the outset. Our experiences could help inform the educational technology developer community (e.g., the Educoder community; Slotta & Aleahmad, 2009), on the design, implementation, and deployment of location-tracking technologies in educational research contexts.

Spatial mapping of inquiry discourse in the classroom through knowledge visualization

Cresencia Fong, Rebecca M. Cober, Tom Moher, and James D. Slotta

Technology has long been used to support online discussions (Coopey, Schneider, & Danahy, 2013; Peters & Hewitt, 2010; Dougiamas & Taylor, 2003; Linn & Hsi, 2000) and knowledge building (Scardamalia & Bereiter, 1996), where it has served an important role in making student idea advancement dynamically and persistently visible to peers, allowing for collaborative knowledge work on these ideas. However, such environments do not incorporate a phased inquiry discourse progression, and rely instead on the teacher's intuitive sense of inquiry progress. We continue to innovate on the development of Common Knowledge (CK) – a content-agnostic pedagogical and technological note-sharing application for collaborative inquiry. Through tight coupling of an inquiry script and a technology script, CK's third iteration (CK3) scaffolded student knowledge communities through a student-driven phased inquiry progression. It also capitalized on the physical classroom layout as an additional dimension of collaboration scripting and collective knowledge mapping.

Method

We engaged two classes of grade 5/6 students in a nine-week astronomy inquiry progression mediated by CK3. Using tablets, students contributed to a community knowledge base that was publicly visible on the "Common Board", displayed on the classroom's interactive whiteboard (IWB). This interactive display visualized the community's idea flow and enabled learners to sort their ideas by topic. CK3's inquiry script scaffolded the community through phases of science inquiry: *Brainstorm*, *Investigate*, and *Propose*. Students first *brainstormed* questions and theories, by using CK3 to contribute "Brainstorm" notes. They then *proposed* research trajectories and designed experiments to test their theories, by contributing "Proposal" notes. Contributions informed subsequent work in fluid interest-based groups (each group supported by a large-format "Topic Board" interactive display), in which students *investigated* the proposed research in a topic specialty of their choice, sharing findings via "Report" notes, and making inter-group connections. Throughout all inquiry phases, teachers and learners could manipulate visualizations of community ideas (i.e. CK notes) from the IWB, or from a group's Topic Board (during Investigate phase only), clustering ideas by topic relatedness.

Outcomes

Teachers and students used the public displays (i.e., Common Board and Topic Boards) to gain a global awareness of their community's overall state of knowledge, including the relationship between notes and tags/topics (see Figure 3). While students could read and compose notes from their tablets, such knowledge relatedness was not readily apparent on the tablet interface, which simply listed a note's associated tags at the end of the note, and included tag-based color-coding of Proposals. Furthermore, spatially distributing the Topic Boards in the classroom during the Investigative phase facilitated the formation of student-selected interest-based groups that focused students' attention, while also spatially localizing the topics in the classroom. As a means of facilitating inter-group knowledge exchange, students had the option of going on a "knowledge walk" to visit other groups during the Investigate phase, to speak with peers and read their notes.

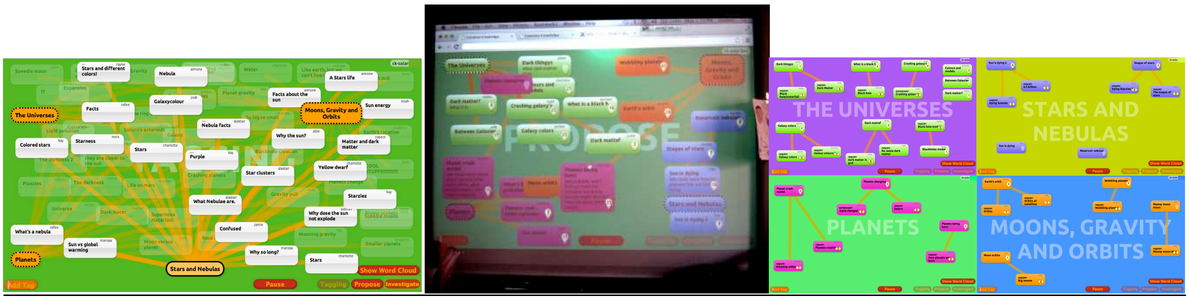

Figure 3. *Left:* One class' Common Board (displayed on the classroom's IWB) during the Brainstorm phase; white Brainstorm notes are visually connected to corresponding tag nodes (which act as filters). *Middle:* Common Board during the Propose phase; Proposals are visually connected and color-coded to align with corresponding topics (tags were elevated to the status of "topics"). *Right:* Topic Board displays (each located at one interest group table) for all four interest groups in the class; all Proposals are visually linked to corresponding Investigate Reports.

Classroom observation data and student feedback indicated that such interest-based co-location enabled students with common inquiry interests to dialogue about their work and offered opportunities for collaboration on investigations. Furthermore, the Topic Boards served as a grounding reference for small-group interactions about the inquiry at hand.

Teachers used students' CK contributions that were visualized on the Common Board to spur oral classroom discussions and guide inquiry. The public displays firmly maintained the goals of inquiry at the foreground; and the final Investigative phase spatially mapped topic specializations to distributed classroom locations, thereby spatially distributing topic-based student collaborations. Thus, CK became a meditational tool between the two learning environments: (1) students' collective inquiry performed in the digital note-sharing environment during student-directed small-group interactions, and (2) teacher-guided classroom discussions.

Using maps to support investigations of animal behavior in our schoolyard

Rebecca M. Cober, Alisa Acosta, Tom Moher, and James D. Slotta

Scientific inquiry can take on many forms, including field investigations; through systematic collection of evidence and communication of results, students can answer their own investigative questions (Windschitl et al., 2007). However, real world environments can be challenging for learners to work in because of their inherent complexity (Kamarainen et al., 2013). One means by which learners can organize and represent descriptive results is through maps, by indexing observed phenomena to physical locations within an environment of interest (Sobel, 1998). Maps can help learners to make sense of an environment, allowing them to explore data (e.g., analyze data and spot trends; Liben, 2001).

Method

We engaged one class (n=22) of Grade 5/6 students in Toronto, Canada in a six-week curricular unit of animal behavior. The goal of the activity was to identify animal species that inhabited the schoolyard, and to understand their behaviors and interactions through the collection and interpretation of photographic evidence. Our interest was to help students to work together as a scientific community and to enable students to create their own visual representations of their results (Ainsworth et al., 2011). We supplied the class with 10 camera traps (i.e., motion-activated cameras) for students to position strategically throughout their schoolyard (i.e., in locations that would likely yield photographs to address their inquiry questions). We provided the class with 10 laminated 36 x 24 maps of their schoolyard and a toolkit to "mark up" the maps, consisting of tokens and stickers with icons (e.g., of animals) and dry-erase markers. In addition, we provided students with iPads (including camera) and a mobile application called Common Knowledge, to allow learners to contribute notes and photographs (e.g., camera trap photos and map photos) to a shared note-space (Figure 4).

Figure 4. *Left:* Camera trap and student placing a camera trap in the schoolyard; *Middle:* Planning map with stickers showing locations of animals sightings; *Right:* Student using iPad to share notes and photos with peers.

What role(s) did maps serve in advancing students' understanding of animal behavior in their schoolyard?

Outcome

Maps were used in three different activity structures throughout the unit: (1) In the initial phase of the unit, students cooperatively constructed aggregate representations of daytime/night-time animal behavior by placing animal tokens on a group map. The tokens corresponded to locations where animals had triggered the camera traps. A whole-class discussion concerning these aggregate maps served to orient students to i) the species that inhabit their schoolyard, ii) location-specific information about species (e.g., raccoons were sighted near garbage cans), and iii) basic temporal patterns of behaviour (e,g., some animals appeared in the daytime only). Students used findings from this preliminary activity to drive their subsequent inquiry questions and activity (i.e., strategic camera trap placement). 2) Throughout all six weeks of the unit, students used iPad cameras to take photographs of maps that were annotated with tokens, markers, etc. and attached these photographs (n=39) to Common Knowledge notes. Maps were used both i) formatively and ii) summatively. Students used maps to plan investigations; for example, students placed camera trap tokens on their map to show where they intended to place a camera, and the accompanying text of their planning note provided a rationale for the placement. Students also used maps to summarize findings; for example, students annotated their map with text and tokens to show results from previous camera trap placements (e.g., depicting a route that raccoons take by synthesizing location-based sightings from multiple camera traps). 3) At the conclusion of the unit, student groups presented their "research stories" to their peers, using PowerPoint. Most of the student groups elected to include photographs of their maps in their presentations. The role of these maps was similar to the role that they played in the second activity structure—to depict a plan for camera trap placement or to show a summary or synthesis of results.

In interviews that were conducted at the conclusion of the unit, one student said that the maps gave him "a bird's eye view [of the schoolyard], as opposed to walking through it." Placing the tokens on the map enabled patterns in the data to emerge; by "connecting the dots" he was able to establish a route that the raccoons took.

Consideration of the physical environment when selecting and instrumenting sites for field investigations

Alexandra Silva, Chandan Dasgupta, Brenda López Silva, and Tom Moher

Field investigations conducted by scientists represent one method of inquiry used to build scientific knowledge that can also be undertaken by students within the classroom (Windschitl et al., 2007). As with general scientific inquiries, field investigations require students to generate research questions, plan investigations, collect data, and report findings (Marx et al., 2004). When planning successful, real-world field investigations, scientists consider the physical environment of a potential field site to determine: 1) if it is amenable to investigation; and 2) how it should be instrumented. The physical environment, or landscape, of an area is an especially important concern in the development of ecological field investigations (Turner, 2001).

Method

Three classrooms of Grade 7 students in Chicago, IL participated in a seven-week instructional unit of animal diversity and behavior. Students worked in small, autonomous groups within the context of the classroom's scientific community to learn from and build upon each other's work as they completed a series of scaffolded, research-based activities. The unit culminated in a succession of autonomously-planned field investigations of animals at sites off school grounds. The five field sites across Chicago represented an extension of the classroom, which learners accessed through landscape- and local-level images (Figure 5), but did not physically visit. As part of the planning process, students selected which field site to investigate and determined how to instrument the selected site with motion-activated camera cameras (i.e., placement and/or positioning of camera traps). The camera traps produced photographic evidence of animals, which students then cataloged and analyzed using a tablet-based application. A separate application, Common Knowledge, allowed students to create and share notes via a shared-note space. Groups produced a *planning note* for each investigation describing the motivation for selecting a given site and instructions of how we (i.e., researchers) should instrument the site. Conclusions drawn from each investigation were shared within the classroom.

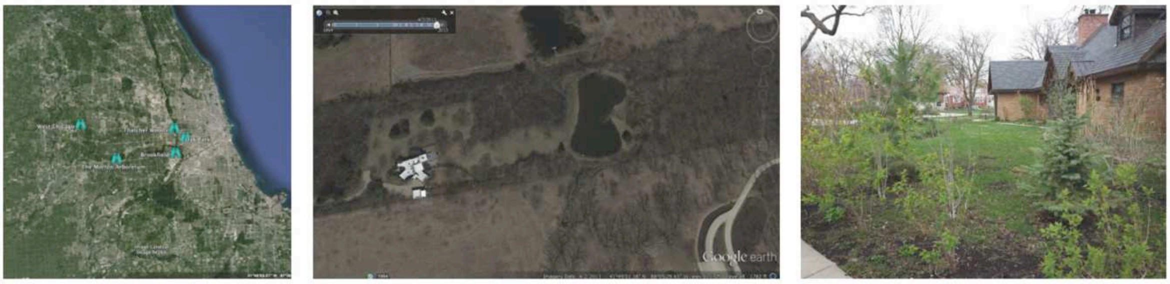

Figure 5. Examples of images provided to students allowing access to the extended classroom. *Left*: Map of available field sites distributed across Chicago; *Middle*: Landscape-level, aerial image of an individual field site; *Right*: Local-level, terrestrial image of a field site.

To what extent did the physical characteristics of students' extended classroom influence 1) the decision of which field site to instrument and 2) the instrumentation of the field site?

Outcome

We coded and evaluated the *planning notes* from each field investigation and found that considerations of the physical environment were incorporated into site selection and instrumentation in the majority of cases. In fifteen of twenty-five cases, students justified their site selections based on physical characteristics of the environment. Despite having access to landscape-level data of the entire extended classroom via an online map application, landscape-level characteristics (i.e. physical composition or configuration on a scale greater than a single site) were only considered in five cases. A comparatively greater number of site selections were motivated by the local-level characteristics of a single site (e.g. presence of a body of water). In thirty-three of the forty plans to instrument field sites, learners explicitly considered some aspect of the physical environment. For example, one group opted to instrument a certain area within a field site "that's not on a trail… so people won't scare the animals away." These learners actively considered the absence of a trail and planned their camera trap placement accordingly. In many cases, students considered the physical environment in conjunction with animal biology or behavior when deciding how to best instrument the field site (e.g., camera height must allow for the capture of larger animals).

The successful planning of real world field investigations requires serious consideration of the physical environment's composition and configuration. In many cases, the physical environment may be an underlying mechanism influencing animal diversity or behavior, and thus essential to consider and understand. During their final presentation, one group effectively alluded to this importance of landscapes within field investigations: "Certain animals like open areas for example, deer, while others like hidden areas like rats… One of our deployment places was Brookfield and we saw many deer there because there was an open space."

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