Co-present distributed simulations of science phenomena for K-8 learners: A technology designers' round-robin symposium

Participants

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Focus and organization of the symposium

While the personal computer (and by implication the individual learner) continues to be the target platform for most educational software, the affordances of distributed computing and communications have received considerable attention within both the learning and technology worlds for their potential in supporting the development of communities of science learning. These capabilities have been manifested in two complementary but distinct frameworks. On the one hand, researchers are exploring the affordances of technologies, particularly the Internet, that link physically separated users (e.g., Pea, 1993; Edwards et al., 2001; Dede, 1995). At the same time, inspired by the Participatory Simulation framework emanating from MIT (e.g., Resnick & Wilensky, 1997; Colella, 2000), designers are actively exploring the potential for using distributed collections of computation devices within physically shared ("co-present") spaces.

In this session, we spotlight four recent designs that have adopted this paradigm in support of K-8 learners' first-person investigations of simulated phenomena: *Hunting of the Snark, RoomQuake, Savannah, and MUSHI-Life*. Unlike PC-based simulations where the phenomena under investigation are accessible via a single physical source, these simulations situate the representation of phenomena in a physical space of (indoor and/or outdoor) activity, and require learners to move around, access multiple heterogeneous data sources, and work with peers as integral components of their inquiry. Because the form factor is no longer prescribed, there is a great deal of design freedom—but precious few guidelines to help constrain design. In crafting such environments, developers face design challenges in three central and interconnected areas: (1) the representation of phenomena, (2) the design of activity structures for investigating those phenomena, and, (3) beyond the phenomena themselves, incorporation of technological and instructional scaffolds to support learning within those structures.

This symposium will include of the co-designers of the learning technologies: Yvonne Rogers (Snark), Tom Moher (RoomQuake), Danaë Stanton Fraser (Savannah), and Chris Quintana (MUSHI-Life), along with Louis Gomez, who will serve as moderator and discussant for the session. (Gomez is the Coordinator the Learning Science PhD program at Northwestern University; his research focuses on school and classroom organization support through technology and the application of computing and networking technology to teaching and learning.) In order to benefit from fresh perspectives on these technologies, we will employ a "round-robin" format in which each panelist will present a critical discussion of one of the other designer's learning environments. Each panelist will be given ten minutes to provide a brief introduction to their "assigned" environment, followed by a presentation of their interpretation of the work through each of three common thematic lenses: representation, activity, and scaffolding. Following each presentation, the original designer will be given five minutes to respond to the analysis or engage the presenter in dialogue. The discussant will follow with a ten-minute synthesis of emergent themes and research questions raised during the session. Finally, the discussion will be opened to the audience for the final 15-20 minutes of the session.

Thematic lenses

Representation. The importance of representation in learning has been a dominant theme in the learning sciences (e.g., Kozma, et al., 1996; Greeno & Hall, 1997). In each of these environments, the representation of phenomena is distributed in space; in some, it is also distributed in representational form and across extended time courses. The representations used here are, for the most part, considerably more abstract than the high fidelity graphic representations leveraged in many emerging learning technologies. How does each of these environments address the integrative and interpretive cognitive demands inherent in their designs?

Activity. The activity structures associated with each of these projects impose new demands on space, time, and instructional (including computation and display) resources, and upon teachers who would manage those resources. Moreover, each requires learners to engage in systematic observation for the purpose of discovery and/or problem solving, leading to a concern that the emphasis on practice might come at the expense of conceptual learning. How does each of these environments address the institutional, resource, and attentional challenges implicit in these new activity designs?

Scaffolding. Phenomena alone do not constitute an inquiry-learning environment; situated learning requires scaffolding from the teachers, peers, and semiotic artifacts that occupy that environment. Embedding explicit scaffolds within the technological affordance, however, has the potential to inhibit the sense of immersion within the simulated phenomena. How does each of these environments embed, or through, the scaffolding necessary to support student learning?

Presentations

Hunting of the Snark (presenter: Quintana; developer: Rogers)

Inspired by Lewis Carroll's book of the same name, in *Hunting of the Snark*, pairs of children explore a rich mixed-reality environment for the purpose of discovering characteristics of the Snark, a mythical creature who appears in various shapes and forms in multiple media space (Rogers, et al., 2002; Luckin, et al., 2002; Price, et al., 2003). In the "well," students use RFID-encoded physical tokens representing different kinds of food to "feed" the Snark, for the purpose of determining its dietary preferences; abstract visualizations of the Snark's mouth provide feedback (appreciation or disgust). In the "cave," children explore the Snark's auditory preferences by stepping on pressure-sensitive pads that generated different sounds at different volumes; auditory (vocalizations of nonchalance, excitement, or fear) and visual glimpses of the Snark are generated in response. In the "flying space," children don jackets instrumented with accelerometers that measure arm movement; their gestures (e.g., flapping their arms) are represented on a projected display along with an abstract image representing the Snark, which responds to the gestures with visual and auditory expressions of sadness, joy, or boredom. A specially designed "Snarkcam" is used during interaction in the media spaces to capture Snark behavior, morphology, and personality expressions.

Snark is designed as an environment within which children can engage in reflective discovery. In an exploratory study involving ten pairs of children ages 7-10, subjects were asked to find out "as much as they could" about the Snark—its appearance, likes, and dislikes—by exploring the media spaces, and to capture as much of their experience as possible using the Snarkcam. Following the activity, students were prompted with open-ended questions during paired interviews. Data sources included video (with audio) records of students' actions, interactions, gestures, and spoken dialogue. Videos were analyzed along for evidence of effectiveness along five dimensions: engagement, exploration through interaction, creativity, reflection, and collaboration.

Results of the analysis showed a high level of engagement (reflected in physical and verbal expressions of interest). Differences in exploratory interaction were related to prior experience in real-world settings; affordances in the "well" were more transparent, for example, than those in the "cave," where the connection between learner actions and the Snark's responses (foot placement to generate sound) had no direct analogue. Learners constructed rich intentional descriptions of the Snark (e.g., "cheeky," "mischievous"), and offered analogical comparisons (e.g., a spider) as they used the Snarkcam data to reflect on and construct meaning from their experience. The need for physical collaboration during the activity translated into children's mutual scaffolding of recall during the post-activity interviews.

RoomQuake (presenter: Rogers; designer: Moher)

In *RoomQuake,* an entire class serves as a team of seismologists tasked with finding the location of a seismic fault line presumed to exist within the physical space of their classroom. Computer displays situated in fixed locations within the room serve as simulated seismographs, continuously displaying seismic activity (usually background vibration) at that specific location. Seismic events, aurally signaled by the rumble of a subwoofer, cause the seismographs to trace out the characteristic waveform (seismogram) corresponding to each seismographic station's position. Students read the waveforms to determine the Richter magnitude of the event and its distance from each station. Using calibrated strings anchored at multiple (at least three) seismographs, students sweep out arcs reflecting the loci of possible epicenters from each recording station; their point of mutual collision represents a physically realized trilateration[1] of the epicenter's location. Styrofoam balls are hung from the ceiling to represent the position and (via color coding) magnitude of each event. The emergent historical record of events reveals the shape and location of the fault line.

RoomQuake is designed for use within an instructional context centering on plate tectonics and seismology. In a pair of pilot studies (Moher, et al., 2005; Moher, et al., in preparation) RoomQuake was used in two fifth grade classrooms with the same teacher in consecutive school years. In each study, students experienced more than 20 "roomquakes" over a period of about six weeks. Learning goals focused on three areas: (a) development of skill in seismological practice, (b) conceptual understanding of seismic event distributions in space, time, and intensity, and (c) ability to enact and explain mathematical trilateration. Data sources included written pre/post assessments of event distribution characteristics and trilateration, formative assessment of distribution characteristics in the form of periodic student event "predications," and post-activity demonstrations of practice skill. Additionally, in the second pilot, the room was instrumented with video cameras to capture student process activity and discourse.

In both studies, students demonstrated strong mastery of the seismological practices of interpreting seismograms and determining event characteristics (epicenter and magnitude). An instructional design revision between the two studies—maintenance of large public posters of accumulating data—resulted in substantial improvement in students understanding of event distribution characteristics. A software design revision intended to enhance the sense of realistic professional practice—requiring student on-line data entry—was counter-productive as a motivating element. Students' strong ability to demonstrate trilateration did *not* translate well into paper-and-pencil media. An analysis of video protocols to characterize individual participation and role adoption in the second study is currently in process.

Savannah (presenter: Moher; designer: Fraser)

In *Savannah*, a group of students assumes the role of a pride of African lions intent on survival. In an outdoor setting, equipped with GPS-augmented wireless-networked PDAs, they roam the environment looking for food and water sources, safe resting places, and predators that threaten their existence. The PDAs provide visual and aural representations of the phenomena present in the imagined savannah: lion and elephant calls, still images of the environment, and paw prints of wildlife, based on the users' dynamic locations. Coordination with pride members is required to kill larger prey, which can serve as a food source for multiple lions. Periodically, lions return to a "den," where they can use an interactive whiteboard to review their traversal paths and imagery they had encountered during their sojourn through the savannah, reflect on their survival strategies, and replenish themselves with food for another round of activity.

Savannah seeks to support children's conceptual understanding of animal behavior through an engaging role-playing activity. In a pilot study (Facer et al., 2004), students were introduced to the savannah in a "non-competitive" mode, where they were allowed to freely explore the space and prompted to reflect on potential resources and dangers. Active exploration segments were alternated with reflective sessions in the den, where a teacher facilitated group discussions of strategy. Following the exploration phase, students were told that they now had to survive in the

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[1] *Trilateration* is often confused with *triangulation*. The former determines target locations based solely on distances; the latter employs displacement angles to achieve the same goal.

hostile environment, and participated in several "live" sessions where they could kill and be killed. The data source for the characterization of student engagement, game identity, and learning included transcriptions of process discourse and post-activity interviews and field observations.

Affective response to the simulated environment was strong; students spoke of themselves as lions, demonstrated fear of predators by madly scrambling away from their locations, and expressed jubilation over kills. They negotiated multiple roles as lions and as reflective learners, though engagement sometimes suffered when placed in the latter roles. The students noted the affordance limitations relative to both reality and to high-fidelity video games, but continued to express general satisfaction with the realism imposed by the games challenges. Evidence of learning focused on the "lion power" needed to kill different kinds of prey, and predators to avoid at all costs. In some cases, however, affordance limitations in the activity caused students to adopt behavior inconsistent with an understanding of lion behavior, over-representing killing activity to the exclusion of strategic stalking and resting characteristic of real lion prides.

MUSHI-Life (presenter: Fraser; designer: Quintana)

In MUSHI (multi-user simulation with integrated handheld devices)-Life (Vath et al., 2005), groups of students assume roles as environmental entomologists. A tablet computer shows a simulation that includes different insect-like “bugs” with different physical characteristics (e.g., mandible or limb types, etc.). A set of rules describes how the bugs reproduce, feed, and interact with other bugs in the environment. The survival ability of a given bug is governed by its phenotype, different characteristics of the environment, and characteristics of other bugs it may encounter in the simulation. Students can view the overall simulation (i.e., the global view of the simulation environment) on the tablet computer, and then use individual PDAs to "capture" and "release" individual bugs, or to view magnified, detailed portions of the global environment, such as the interaction of a given set of bugs or the characteristics of a given bug.

MUSHI-Life is designed to support students' explorations of questions surrounding natural selection and adaptability. It may be used in an observational investigation to identify behavioral patterns related to survival within native contexts (e.g., are the bugs moving in systematic or random ways) or to directly observe the effects of moving a bug to a non-native environment (e.g., moving a bug from a desert to an arctic setting). Alternatively, users may explicitly manipulate bug characteristics (e.g., giving the bug different mandible or limb types) to experimentally determine their relationship to adaptation and survival.

By using an integrated suite of public and private devices, MUSHI-Life seeks to provide a framework to give learners multiple linked representations of a simulation so learners can explore and manipulate a scientific simulation by seeing different aspects of the simulation at different levels of granularity. This can help learners see that there are different levels to understand in complex simulations, such as understanding how local interactions can impact the global behavior of the simulation. Furthermore, a MUSHI system provides different opportunities for learners to engage in both group discussions and individual work within the same project. This can give learners the opportunities to engage in more reflective thinking while also engaging in the types of social interactions that can positively impact learning.

The first prototype of MUSHI-Life was completed in June 2005. Initial focus group testing with students ranging from sixth to eight grade will begin in the late 2005, with classroom-based research studies scheduled for early 2006.

Importance

The emergence of distributed and mobile technologies dramatically broadens the design space available to designers of learning environments. A critical examination of that design space in the areas of representation, activity, and scaffolds, in the context of a conversation with learning researchers and practitioners, can help provide designers with systematic lenses to inform their work.

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