Roomquake: Embedding Dynamic Phenomena within the Physical Space of an Elementary School Classroom

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ABSTRACT
Authentic practice in science requires access to phenomena. In this paper, we introduce RoomQuake, an application designed to foster the growth of a community of learning around scientific practice in seismology. Rather than treating seismic activity as remote events, RoomQuake seeks to enhance salience by situating those phenomena directly in the classroom. Using fixed-position PDAs as simulated seismographs, students determine the magnitude and distance of a series of "randomly" timed events by reading characteristic waveforms and using calibrated tape measures to sweep out arcs from multiple stations until they literally collide, physically enacting mathematical trilateration. We describe our experience in a six-week unit in a fifth-grade classroom.

Author Keywords
Learning technologies, simulation, embedded phenomena

ACM Classification Keywords

H.5.3 Group and Organization Interfaces; K.3.1 Computer Uses in Education

INTRODUCTION
For many adults, the most evocative memories of elementary school recall times when the physical classroom was transformed—partly through imagination, partly through artwork, props, and tools—into a rainforest, a grocery, or the U.S. entry point at Ellis Island, where we could play the role of explorer, merchant, or immigrant. This tradition of enacting scenarios within "decorated classrooms" anticipated many of the contemporary themes in learning and teaching, including constructivism [1,3,8], the socio-cultural characterization of learning [13], the development of communities of practice [5], the value of visualization and representation [6,12], teachers as scaffolding rather than transmissive agents [7], and the motivational value of role-playing and simulation [10].

However, the tools that teachers employ to scaffold this practice have not changed much over the years. Artwork, physical models, dioramas, mobiles and the like help to establish presence, but are, for the most part, static, non-responsive artifacts. Only recently have researchers begun to explore ways in which emerging technologies (under such rubrics as ambient displays, augmented reality, mixed reality, participatory simulations, etc.) might be able to augment traditional tools with dynamic representation and control affordances.

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This paper describes an effort to augment a classroom, using a "thin layer of computation" [2], for the purpose of allowing students to gain experience in the seismological skill of locating the epicenter and magnitude of earthquakes. Over a period six weeks, a fifth grade class experienced a series of 22 *roomquakes*—simulated earthquakes. Rather than treating the earthquakes as remote events, we adopted the conceit that the phenomena were occurring directly in the room, as if the room were a scaled-down version of a large geographic region. With each seismic event, students used simulated instrumentation, simple tools, and physical movement to determine epicenter and magnitude, and recorded the sequence of event by hanging Styrofoam balls from the classroom ceiling; over time, the classroom "fault line" emerged.

RoomQuake is presented as an example of a class of simulations that we call *Embedded Phenomena*. Applications in this class embed imaginary dynamic phenomena—scientific or otherwise—into the physical space of classrooms. These phenomena are "made visible" through a (usually small) number of computational affordances scattered around the room, representing visual or instrumented observations of the state of the phenomena, as well as controls (for experimentation). Teachers design instruction that includes student observation and investigation of those phenomena.

The concept of embedded phenomena owes much to the notion of participatory simulations [e.g., 2,4,9], which places learners as first-person participants in simulations of dynamic phenomena. Embedded phenomena differ from participatory simulations, however, in that they associate computational affordances with fixed positions within the environment rather than with individual agents, akin to ambient displays [14]. This approach has significant practical value in school settings, as fewer devices are required and the devices don't leave the premises.

The canonical example of an embedded phenomenon is the Equator Project's "Hunting of the Snark" [11] in which an imaginary creature is purported to be roaming around a classroom, and young children gather evidence about the nature of that creature via a collection of tangible and movement-based affordances.

Roomquake extends that work to simulate real phenomena: earthquakes. We conjectured that (1) using the whole classroom as the locus of both the phenomena and interpretive semiotic artifacts reflecting the investigation of that phenomena, (2) scheduling simulated "seminal events" asynchronously with respect to the conventional flow of classroom instruction, and (3) scheduling activity over an extended time period, together would promote student interest and participation in the activity, and finally, enhance learning.

ROOMQUAKE IN THE CLASSROOM

A fifth grade classroom of 19 students received a one-week introduction to earthquakes that included an elementary discussion of plate tectonics and earthquake safety, student construction of a primitive seismograph, and an introduction to mathematical trilateration[1]. Four synchronized PocketPCs were literally attached to various locations in the classroom. The PocketPCs were programmed to serve as real-time strip-chart recorders of seismic activity, presenting simulated low-level random noise until a database of clock-driven "seismic events" triggered the generation of parameter-driven characteristic waveforms specific to the location of each seismograph (Figure 1).

A dry-line (calibrated reel of twine) was anchored at each of the seismographic stations. As each seismic event occurred (accompanied by a sustained rumble from a PocketPC-driven subwoofer located in the corner of the classroom), student teams read and interpreted the seismogram waveforms and determined the roomquake magnitude and (unique) distance (in meters) of the epicenter of the quake from each of the stations (Figure 2). Pulling out the corresponding length of twine (Figure 3), students swept out arcs until they literally collide with one another, physically enacting a mathematical trilateration of the epicenter (Figure 4). At the students' direction, the teacher then hung (color-coded) Styrofoam balls from the ceiling of diameter proportional to the magnitude at the calculated epicenter (Figure 5). Roomquakes took place both during and outside of school hours ("things happen when they happen"); the seismographic stations retained "snapshots" of prior events. (Students could also check for earthquakes occurring outside school hours by consulting a web site on which seismograms are posted.)

Student learning was assessed in three areas: science content knowledge, knowledge of seismological practice,

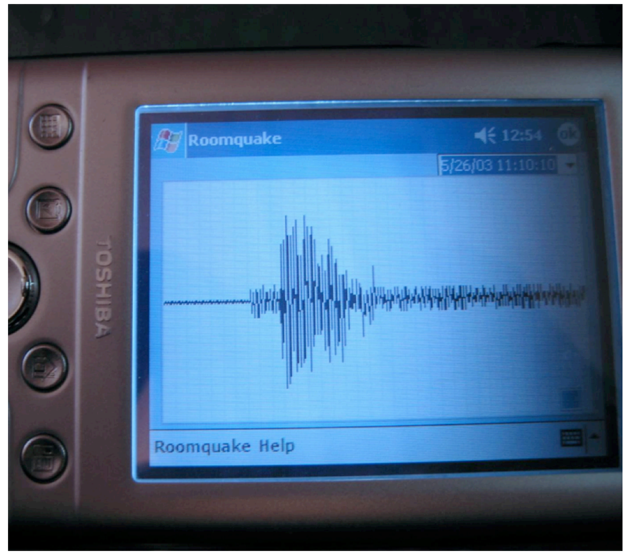

Figure 1. PocketPC serves as simulated seismograph.

Figure 2. Determining event distance and magnitude.

Figure 3. Sweeping arcs representing potential event loci.

[1] Trilateration is often mischaracterized as *triangulation*.

and the mathematical technique of trilateration. Pre-unit interviews with the class established that the students had no significant knowledge in any of the three areas.

Distribution of earthquake epicenters and magnitudes

Students were periodically given a questionnaire asking, "where will the next roomquake occur?" (the form of response was not specified) and "how strong will it be?" Over time, student responses moved from random predictions and uniform distribution theories—usually designated by point predictions of the event location—to the regional and curvilinear predictions consistent with plate boundaries (82% by the end of the unit). Students were considerably less successful at demonstrating an understanding of the Gutenberg-Richter relationship—a ten-fold (in our case, two-fold) reduction in frequency with increasing magnitude—although almost all recognized the inverse relationship between magnitude and frequency.

Seismological practice

At the end of the unit, students were interviewed individually and asked to demonstrate the suite of skills necessary to determine the roomquake properties. In general, students demonstrated a high degree of proficiency on all of the sub-tasks. The most common error was the interpretation of magnitude as the absolute difference between the highest and lowest points of the graph, rather than the height of the curve relative to the time axis. Students were especially strong when the milieu turned to physical demonstration, with only one student unable to draw out the dry line to proper length, and only two students failing to demonstrate that the potential locus of events defined a circle.

Seismological practice skill	Proficiency
Determine time difference in wave arrivals (proportional to event distance)	88%
Determine maximum graph amplitude (used in determination of magnitude)	69%
Use chart to determine event magnitude	81%
Pull out dry line to proper length	94%
Demonstrate possible event loci (sweep circle using dry line)	88%

Table 1: Individual student mastery of seismological practice skills upon completion of RoomQuake unit (N=16).

Trilateration

We determined at the outset of the unit that the students were unfamiliar with the technique of trilateration. We used a conventional blackboard presentation and discussion to introduce the notion of how distance from a point defines a circle, how two overlapping circles can contain two points of intersection, and how a third circle is required to find which of those two points is the actual epicenter. After the discussion, students were given a paper-and-pencil quiz that asked them to explain why three seismographs were required to trilaterate an earthquake epicenter. The results were coded, and 42% of the students were able to provide a competent explanation of the need for three seismographs immediately following the classroom discussion. Following the RoomQuake unit, the same test was given; in the post-test, 63% of students were able to provide a competent explanation of the need for three seismographs.

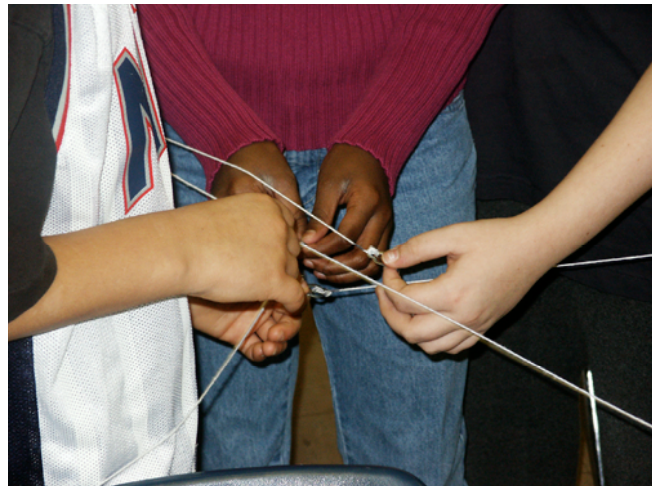

Figure 4. Finding epicenter through physical trilateration.

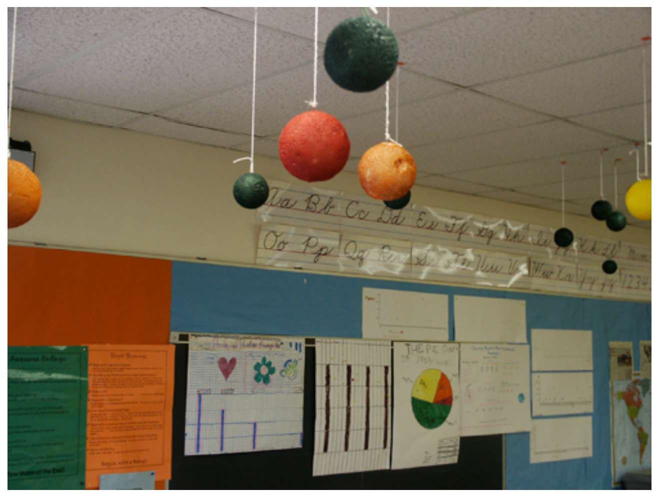

Figure 5. Styrofoam balls reflect seismic event history.

DISCUSSION

Perhaps the most striking aspect of the RoomQuake unit was how readily the students adapted to the activity. While at first hesitant about procedures and full of questions, over time the students developed genuine mastery of the seismological practice; what took 30 minutes to complete for the earliest roomquakes required only five minutes at the end of the unit. While we lack a formal measure, the development of a "community of practice" [5] seemed strongly in place, as students moved easily from role to role, explained procedures to others, and demonstrated procedures to classroom visitors. We believe strongly that the extended duration of the activity was central to the development of that community, and the spread of understanding to students who needed time to work their way into full membership.

Science content learning, we believe, might be improved in two ways. First, our intentional introduction of noise into a smooth roomquake location curve combined with student measurement error to blur the nominal plate boundary; student error is (more than) sufficient to ensure an imperfect curve. Second, student understanding of the Guttenberg-Richter relationship might be enhanced by maintaining a public record of magnitudes organized to scaffold that learning, much as the geographic representation on the ceiling reinforced understanding of location distribution.

From a user perspective, RoomQuake was largely successful. While the number of electronic affordances was less than the number of students, the additional roles (twine puller, magnitude computer, supervisor, etc.) were sufficient to occupy a class of 19 students. In the next version of RoomQuake, the PocketPCs are being replaced with tablet computers in order to provide greater resolution (and, hopefully, reduce error).

CONCLUSION

RoomQuake introduces a new activity structure in classrooms: temporarily suspending regular instruction to attend to an event-driven scientific task. Participation in the activity, which is voluntary, requires physical movement. From the outside, it looks like chaos. Needless to say, it is not for every teacher and every classroom. But we believe that RoomQuake, and embedded phenomena more broadly, are particularly well suited to school organizations where students remain in one room most of the day, allowing time for the simulation to "take hold" in their imaginations.

We were pleasantly surprised that the level of engagement remained high and that nearly all of the students were able to make significant progress toward achieving the learning goals. In our view, what was important was not the specific skill learned, but rather the development of capacity to learn such skills, and to employ them effectively within a community of practice. The relatively "lightweight" technology employed, combined with the students' active imaginations, proved sufficient to support that development.

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