RoomQuake: Learning, self-concept, and growth of a community of practice in a persistent whole-classroom simulation

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Objectives

This paper presents the results of a six-week unit on seismology conducted in a fifth-grade classroom. The unique feature of the unit involved the use of classroom technology, *RoomQuake*, designed to support students' participation in authentic seismological practice: the interpretation of seismograms to determine the epicenter and magnitude of earthquakes. The goals of the empirical study were (1) to gain insight into the impact of the intervention with respect to student mastery of seismological practice skills, development of conceptual understanding of earthquake distributions, and changes in self-conception as investigative agents, and (2) to investigate student participation in an emerging community of practice over an extended time course.

Conceptual framework

RoomQuake is an exemplar of a broader technology paradigm that uses the physical space of the classroom as the locus of imaginary, persistent *Embedded Phenomena* (Moher, et al., 2005; Moher, 2006) that unfold over an extended period of time, and that are investigated (collectively, rather than individually) by using fixed-position computers as "probes" into those phenomena. The embedded phenomenon model is motivated by contemporary understanding of the processes of learning and teaching, including constructivism (Dewey, 1933/1998; Bruner, 1960; Piaget, 1972), the socio-cultural characterization of learning (Vygotsky, 1978) as the development of communities of practice (Lave & Wenger, 1990), the importance of visualization and external representation (van Sommeren et al., 1998; Pea & Gomez, 1992), the role of the teacher as a scaffolding rather than transmissive agent (Pea, 1994), embodied cognition (Clark, 1997; Varela, et al., 1991), and the motivational value of role-playing and simulation (Resnick & Wilensky, 1997). Like these, embedded phenomena seek to situate learning in social and physical contexts that enable and support that learning, and which demand active participation from learners as cognitive and social agents.

Within the specific domain of learning technologies, Embedded Phenomena draws from the traditions of constructivism and inquiry, especially as manifested in the use of technologies which put data capture and manipulation capabilities directly in the hands of learners. Early efforts with stationary "microcomputer-based laboratories" (e.g., Linn et al., 1987; Tinker & Papert, 1989; Krajcik & Layman, 1993) was extended by the mobility of handheld computers through "probeware" (Soloway et al., 1999) that allows students to capture and share data arising from real phenomena. A variety of learning environments have been built by researchers to help students learn subject matter by exploring simulated dynamic representations (e.g., DiSessa, 1977; Papert, 1980; Cockburn & Greenberg, 1996; Horwitz, Neumann, & Schwartz, 1996; Roschelle & Kaput, 1996). Virtual environments (e.g., Dede et al., 1997; Moher et al., 1999; Barab et al., 2000; Windschitl & Winn, 2000) provided learners first-person access to data not directly accessible for reasons of time, space, safety, or scale. Embedded phenomena most directly draw inspiration from pioneering work in the connections between role-playing and nondesktop technologies (Resnick & Wilensky, 1997), especially the concept of *participatory simulations* (Colella et al., 1998; Wilensky & Stroup, 1999; Colella, 2000; Marshall et al., 2003; Klopfer et al., 2002; Facer, et al., 2004; Rogers, et al., 2002), which use computational and display technologies in support of physical activity. Embedded phenomena extend the participatory simulation model by providing continuous, long-term representations of phenomena that run asynchronously ("things happen when they happen") with respect to the regular flow of instruction.

Method

A fifth grade classroom of 23 students received a one-week introduction to earthquakes that included an elementary discussion of plate tectonics and earthquake safety, training on the interpretation of seismograms, and the principles of trilateration. Four networked tablet computers were attached to various locations in the classroom. The tablet PCs were programmed (using Flash applications with a conventional browser) to serve as continuous 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 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. Pulling out the corresponding length of twine, students swept out arcs until they literally collided with one another, physically enacting a mathematical trilateration of the epicenter. 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, and students updated large classroom posters representing location, time, and magnitude distributions. Roomquakes took place both during and outside of school hours; over a six-week period, 21 "roomquakes" were recorded, revealing a "fault line" in the ceiling of the classroom.

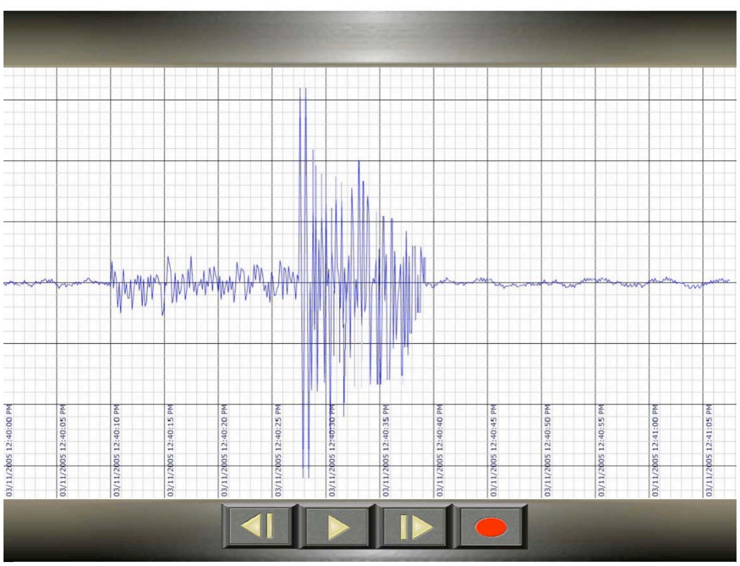

Figure 1: Simulated strip-chart seismograph used in RoomQuake. Bottom buttons scroll through prior events.

Data sources

- *Skill in seismological practice*. Following the unit, students were individually interviewed and asked to demonstrate their ability to read seismograms, determine event magnitudes and distances, and show the loci of potential epicenters. Interviews were videotaped; student mastery was evaluated on five discrete tasks (see Table 1). No pre-test was indicated; none of the students had any prior experience with the interpretation of seismograms.

- *Understanding of earthquake distribution patterns in space, time, and intensity*. Over time, collections of earthquakes follow certain patterns in where they occur (along fault lines), when they occur (after-shocks follow large seismic events), and their magnitude (strong earthquakes are less frequent than mild earthquakes). We probed these understandings through a series of open-ended and multiple-choice prompts using a written instrument that was administered prior to, and two weeks after, the RoomQuake unit. The tests were also administered to another fifth-grade class that did not participate in a science unit on earthquakes or use RoomQuake.

- *Self-conception as investigative agent*. Students were administered selected items from the TOSRA (Test of Science-Related Attitudes) Likert instrument (Fraser, 1981) in tandem with the distribution knowledge pre- and post-tests. The instrument was also applied to the control class.

- *Growth of community of practice*. Six video cameras were mounted on the ceiling of the classroom and oriented to capture detailed activity at the four seismographic stations as well as (wide-angle) activity in the center of the classroom. The cameras were activated for each of the 21 simulated earthquakes, and allowed us to track the activity of each individual student in the classroom.

Results

Skill in seismological practice. Table 1 reflects student mastery of the seismological practice skills of interpreting seismograms to determine event magnitude and the potential loci of event epicenters, as determined during the post-unit interview. Most students mastered the basic skills associated with resolving seismic event parameters; common errors centered on graph interpretation.

Table 1: Student demonstration of seismological practice skill

SEISMOLOGICAL SKILL	DEMONSTRATED MASTERY
Determine time difference in wave arrivals (proportional to event distance)	67%
Pull out dry line to proper length	78%
Demonstrate possible event loci (sweep circle using dry line)	89%
Determine maximum graph amplitude (used in determination of magnitude)	72%
Use chart to determine event magnitude	72%

Conceptual understanding of earthquake distributions. Table 2 shows pre-post differences in treatment and comparison groups' understanding of earthquake distributions in space, intensity, and time. Mastery was determined by consensus scoring on written answers to open-ended prompts and multiple-choice items. Students in the RoomQuake class showed significant improvement from pre- to post-test in understandings of earthquake location and magnitude distributions, but not in temporal distribution.

Table 2: Student demonstration of understandings of earthquake distributions

DISTRIBUTION CATEGORY	% OF STUDENT DEMONSTRATING UNDERSTANDINGS OF EARTHQUAKE DISTRIBUTIONS					
	Treatment Group (RoomQuake)			Non-treatment Group (no RoomQuake)		
	Pre (N=22)	Post (N=24)	Change	Pre (N=22)	Post (N=21)	Change
Location	41	88	+47*	27	43	+16
Magnitude	23	63	+40*	18	24	+6
Time	41	67	+26	32	43	+11

(Location: x^2 (1, N = 46) = 10.98, p < .01. Magnitude: x^2 (1, N = 46) = 7.39, p < .01.)

Self-conception as Empowered Investigators. Table 3 gives pre-post differences for selected items from the modified TOSRA exam. Treatment (RoomQuake) group showed positive trends (though not statistically significant) toward self-conception as legitimized investigators on the four relevant items. In contrast, the non-treatment group trended away from an attitude as investigative agents and toward an authority model.

Table 3: Student attitudes toward science investigation

TOSRA ITEM	LIKERT SCORE: 5-POINT SCALE MEAN RANKINGS (1=STRONGLY DISAGREE, 5=STRONGLY AGREE)					
	Treatment group (RoomQuake)			Non-treatment group (no RoomQuake)		
	Pre (N=22)	Post (N=24)	Change	Pre (N=22)	Post (N=21)	Change
I would rather find out why something happens by doing an experiment than by being told	3.95	4.17	+0.22	4.27	4.22	-0.05
I would rather do my own experiments instead of finding something out from a teacher	3.67	4.13	+0.46	3.91	3.73	-0.18
It is better to be told scientific facts than to find them out from experiments	2.14	2.04	-0.10	2.00	2.00	0.00
Doing experiments is not as good as finding out information from teachers	2.09	1.83	-0.22	1.72	1.91	+0.18
Being a scientist takes too much work	2.36	2.88	+0.52	2.59	2.77	+0.18

Participation in Community of Practice. With each RoomQuake, each student might take on up to 31 discrete roles, including reading and interpreting the seismograph, data entry, physically trilaterating the epicenter, and recording data in public displays (updating poster boards and preparing and hanging Styrofoam balls). By analyzing the videotape records of each event, we were able to identify which roles each individual student assumed for each event in the the RoomQuake series.

The histogram in Figure 2 shows the distribution of participation over the unit. Altogether, students averaged 5.6 roles per event, ranging from 1.3 (the least active student) to 13.6 (the most active student). An analysis of differential participation during the first and second halves of the RoomQuake unit (Figure 3) shows that participation rates by individual remained fairly constant, although the extended time series did afford opportunities for a few initially hesitant participants to becomes substantially involved (the blue region in Figure 3) while at the same time exhausting the interest of some students who had initially been quite active (the red region in Figure 3).

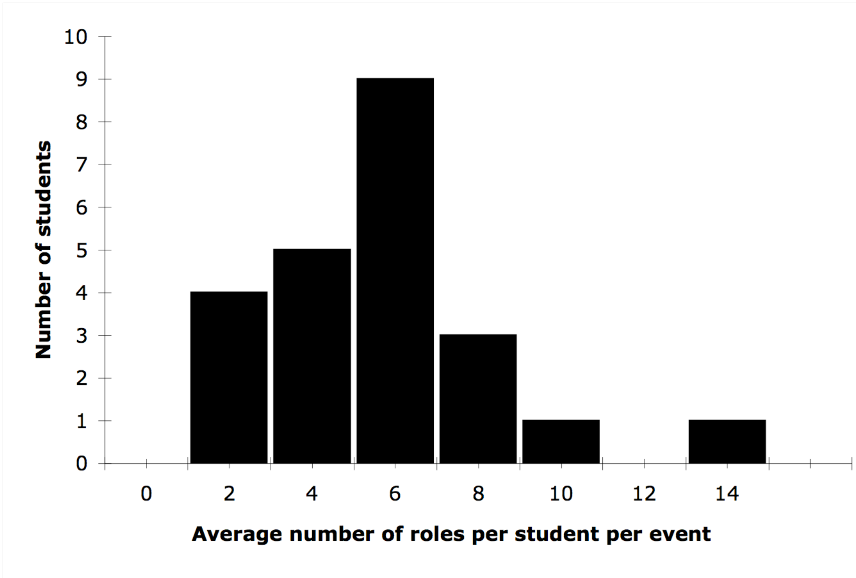

Figure 2: Distribution of participation: average roles per student per event over RoomQuake unit.

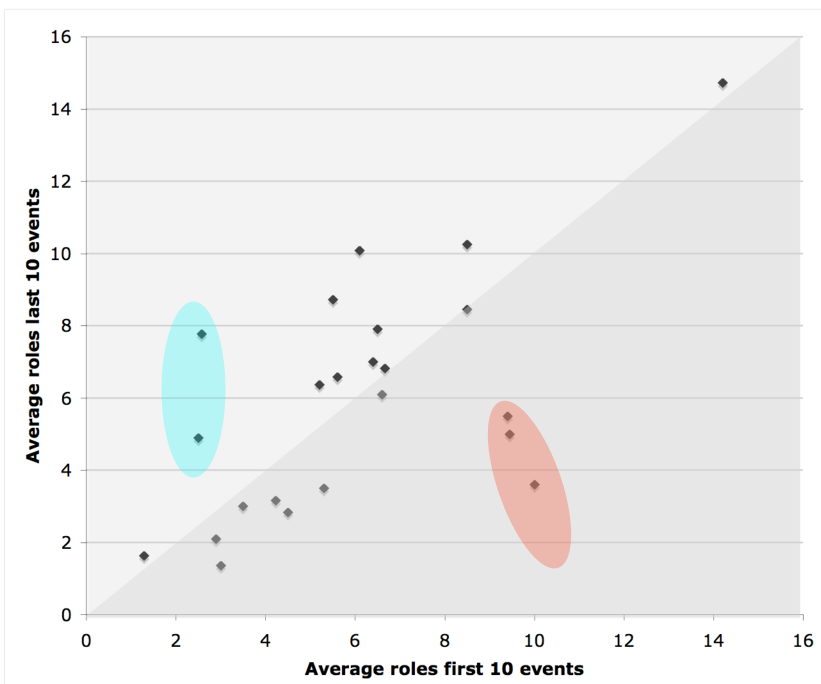

Figure 3. Participation rate in last 10 events as a function of participation rate in first 10 events. Points in the upper-left triangular area represent increased participation in second half of unit. The meanings of the blue and red regions are described in the text.

Beyond participation rate, these data also provide insight into the *breadth* of participation with respect to adoption of different roles during the intervention. On average, students adopted 25.2 of the 31 roles over the course of the unit, ranging from a minimum of 16 to a maximum of 29 distinct roles adopted. Figure 4 shows the distribution of role adoption across the entire class.

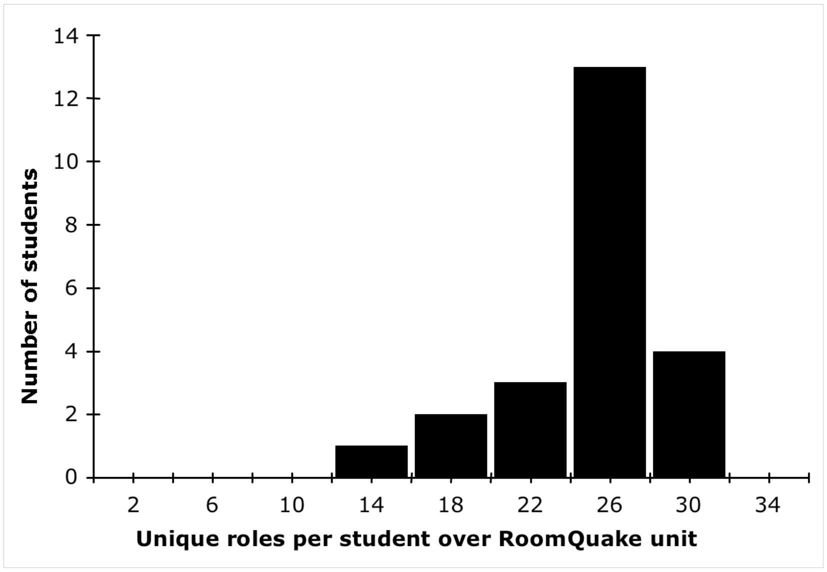

Figure 4: Distribution of student role adoption over Roomquake unit (number of distinct roles assumed per student).

Figure 5 shows a graph of the average cumulative unique roles assumed by students over the course of the 21 simulated seismic events. A logarithmic curve fitted to the time series of averages shows good agreement with the data; the model predicts that an additional 20 simulated events would be required to approach exhaustive assumption of every role by every child in the class.

Summary of results:

- The analysis of student performance in the areas of seismological practice and the understanding of the temporal, spatial, and intensity distributions of earthquakes provides evidence of learning in both domains, albeit with room for improvement. No comparison is yet offered relative to alternative instructional designs with respect to learning; however, with respect to efficiency, it should be noted that responding to an events required an average of 7.55 minutes, for a total cumulative cost in class time of just under two hours and 40 minutes (spread over six weeks).

- The results of the affective (TOSRA) measures provide tentative support for the conjecture that practice can enhance students' self-conceptions as legitimized investigators, but that the recognition of the effort involved can negatively impact the desire to engage in practice.

- Preliminary evidence suggests that the rate of participation is uneven, but that the extended time course provided opportunities for at least some initially hesitant participants to move from the periphery to the center of the community of practice (Lave and Wenger, 1990). The propensity of students to adopt multiple roles over time, rather than specializing in a single role, arguably enriches the learning experience.

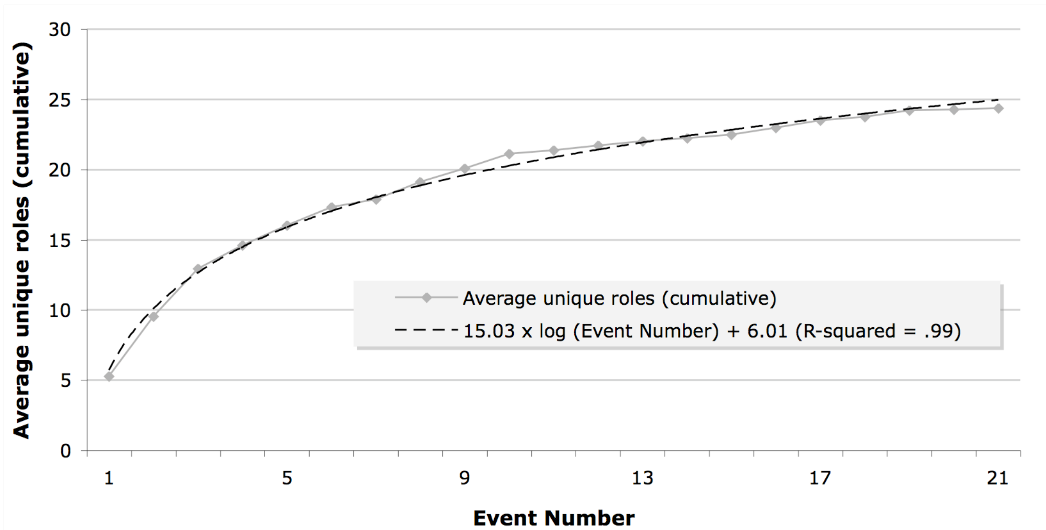

Figure 5: Average cumulative unique roles assumed as a function of event number (time).

Significance

Embedded Phenomena such as RoomQuake physically situate inquiry physically within the simulated phenomena under investigation, and temporally within the regular instructional flow. The adaptations required by practitioners to incorporate such designs are substantial. This report provides tentative evidence that there may be significant learning benefits, to different kinds of learners, from adopting such a paradigm. An additional contribution lies in the analysis of participation, which we believe offers a novel methodological lens for extending empirical descriptions of the growth of communities of practice (Barab et al., 2002).

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