RoomBugs: Simulating Insect Infestations in Elementary Classrooms

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Abstract
This paper presents research on a collaborative learning environment in an urban elementary science classroom. The application, called *RoomBugs*, simulates a dynamic ecosystem of insects within the physical space of a classroom. Using table-mounted tablet computers as “sand traps” that capture the foot-prints of virtual bugs walking across the screen, participants take on the role of scientists attempting to track and control the imagined insects that exist within their classroom walls. The simulation is designed to create authentic phenomenon without requiring heavy instrumentation.

Keywords
Learning technologies, simulation, embedded phenomena

ACM Classification Keywords
H.5.3 Computer-supported cooperative work, K.3.1 Computer uses in education

Introduction
This paper describes a three week pilot study of an ecology simulation called *RoomBugs*; it is designed for elementary school science classrooms. A foundational goal of the study is to create a convincing simulation within the confines of a given space (in this case a classroom) without requiring heavy instrumentation. In our simulation the classroom is imagined to be infested with hundreds of invisible insects. Student groups are tasked with observing and controlling the insect

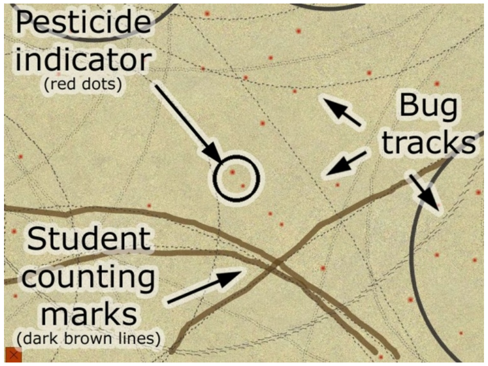
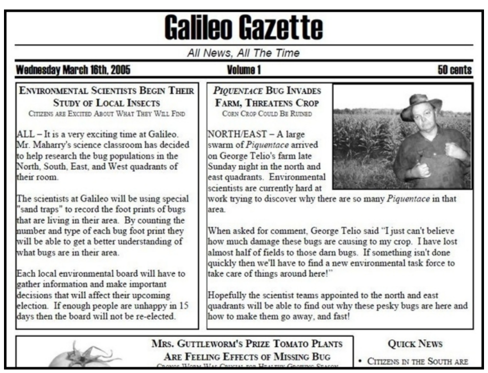


Figure 1: Screen capture of a "sand box" trap showing several bug tracks. The dark brown marks, created by students, identify tracks that have already been counted.



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All News, All The Time

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ENVIRONMENTAL SCIENTISTS BEGIN THEIR STUDY OF LOCAL INSECTS

CITIZENS ARE EXCITED ABOUT WHAT THEY WILL FIND

ALL – It is a very exciting time at Galileo. Mr. Maharry's science classroom has decided to help research the bug populations in the North, South, East, and West quadrants of their room.

The scientists at Galileo will be using special "sand traps" to record the foot prints of bugs that are living in their area. By counting the number and type of each bug foot print they will be able to get a better understanding of what bugs are in their area.

Each local environmental board will have to gather information and make important decisions that will affect their upcoming election. If enough people are unhappy in 15 days then the board will not be re-elected.

***PIQUENTACE* BUG INVADES FARM, THREATENS CROP**

CORN CROP COULD BE RUINED

NORTH/EAST – A large swarm of *Piquentace* arrived on George Telio's farm late Sunday night in the north and east quadrants. Environmental scientists are currently hard at work trying to discover why there are so many *Piquentace* in that area.

When asked for comment, George Telio said "I just can't believe how much damage these bugs are causing to my crop. I have lost almost half of fields to those darn bugs. If something isn't done quickly then we'll have to find a new environmental task force to take care of things around here!"

Hopefully the scientist teams appointed to the north and east quadrants will be able to find out why these pesky bugs are here and how to make them go away, and fast!

MRS. GUTTLEWORM'S PRIZE TOMATO PLANTS ARE FEELING EFFECTS OF MISSING BUG

QUICK NEWS

- CITIZENS IN THE SOUTH ARE

Figure 2: The front page of the newspaper, which provided tangible feedback on changes made in the virtual world

populations, monitoring endangered species, and trying to eradicate pests. Events in the simulation are unscripted; the insects react to student input over the course of several weeks. By mimicking real-world phenomena the simulation attempts to provide an environment where students can perform a more natural form of scientific inquiry and reasoning. In contrast to other mixed reality simulations [7], and to make the deployment of this application plausible across a wide variety of classrooms, the simulation requires minimal fixed position technology affordances and a simplified interface.

A goal of the simulation is to broaden the students' focus beyond the traditional computer screen; we present the tablets as partial representations of a phenomenon and try to integrate the displays into the physical landscape of the classroom [9]. Feedback from student actions is provided through a printed newspaper (Figure 2) and the observable number of tracks left on the tablets. Though it would be trivial to implement, no automatic insect track counts nor identification are provided to aid in data collection. In fact, no text or menus are ever shown on the screens. To avoid breaking the continuity of the simulation the digital pen attached to each tablet acts as a simple stick, capable of drawing lines in the "sand" of the display. New insect tracks are created each day, so a wall-mounted chart is needed to maintain a persistent history for each tablet's populations. To identify tracks a printed field guide is also made available to the students.

There are several reasons why it makes sense to avoid overloading the displays with functionality. Treating the tablets as instruments that simply reflect the state of the phenomenon (the insect populations) reinforces the idea that they are viewing a persistent simulation that continues beyond their observable world (the tablets). A richer graphical representation of the insects, which could be more visually interesting, would also distract students who are enacting the role of data collecting and analyzing scientists (a task sixth graders can easily be distracted from). It is also appropriate to avoid a highly-interactive station requiring extended periods of student attention: this would decrease the number of students that could work at each tablet and also discourage physical movement.

Encouraging movement is desirable in our activity for two reasons: often the solution becomes evident when the students step back and observe the phenomena as a whole, and physical movement between stations is beneficial for reinforcing learning and encouraging student discussion. Incorporating 'physicality' into an activity can capitalize on natural interaction that is already practiced in the real world [6]. It can provide opportunities for discovery and participation that cannot be duplicated in a virtual setting. Using multiple interconnected displays that each contribute to a larger view of the phenomenon is advantageous because it encourages physically active observations by the students, increases student interactions, and we believe enhances the power and scope of the simulation beyond that of a single screen system.

RoomBugs is an extension to a class of simulations called embedded phenomenon. This class of simulation attempts to recreate phenomena using coordinated stations to transform a physical space into a dynamic representation of the phenomenon [4]. Students can observe and interact with the simulation at will,

Figure 3: Students performing their daily inspection of insect tracks using the digital “stick” to mark counted tracks

allowing scientific inquiry-based activities. For *RoomBugs* the entire classroom is imagined to contain several roaming species of bugs. From the student's perspective the areas between displays are simply unobservable regions of a continuous phenomenon. The phenomenon is temporally continuous as well; insects are imagined to be present even when they are not being actively observed by the students.

RoomBugs in the Classroom

This pilot study involved 65 sixth-grade students from two classes in an urban public school who assumed the role of environmental managers tasked to control the insect populations. The teacher's environmental curriculum was timed to coincide with the beginning of our simulation; discussions surrounding the presence of insect populations in the classroom complemented other ecosystem concepts such as predation, migration, competition, invasive organisms, and the diversity of species. While the mechanics of the simulation are not made visible to participants, students used these concepts to hypothesize reasons behind observed fluctuations in the bug populations (predation was of particular interest to some of the boys).

Desktop-mounted tablet computers were placed in different quadrants of the classroom and presented as devices that recorded (simulated) bug tracks. Each tablet displayed what appeared to be “sand boxes” imprinted with the tracks of imaginary insects that walked across the screens (Figure 1). The daily ritual for the student scientists involved classifying tracks, determined local insect population counts, and manipulated environmental variables in an effort to reduce the population of pests and increase the population of desirable insects. Students were provided a (fictional) "field guide" describing the different species of bugs; five species existed during the pilot study.

To enrich the activity with a human perspective we purported that each station represented a distinct area of an imaginary town. The students had to keep the residents of this town happy or their jobs as environmental managers would be at stake. The desires of the residents, made explicit through articles in a printed newspaper, articulated goals for the students to achieve. The newspaper published fictional stories reflecting the tertiary effects that the changes to the insect populations brought to the town, ranging from a farmer losing half his crop to a city council member worried about an endangered species of insect.

Experimental Manipulations

During the three-week unit students had the opportunity to conduct up to eight experimental manipulations involving a change in local moisture levels (wet vs. dry) and pesticide type (for simplicity, red, green, or blue). To request changes in their areas students completed “Environmental Action Forms,” which required them to predict the effects and, if possible, justify these predictions based on previous observations. These action forms were turned in at the end of each day. The effects from the changes were visible on the next day's screen and in the printed newspaper. Small colored dots spread across the “sandbox” display represented the pesticide choice, while the presence of water droplets (and moist dark sand around these droplets) signified the application of moisture.

At the beginning of the activity the classroom teacher established the problem to be solved: each student group needed to find a way to keep residents happy by encouraging desirable insects and at the same time removing unwanted pests. The two moisture levels and three pesticide types provided six possible combinations for the students to apply. To increase this problem search space the temperature at each station (cold or warm) doubled this search space by dividing the five species of insects into two distinct groups: 2 cold-weather insects and 3 warm-weather insects.

Seven of the eight groups took a little over a week to successfully stabilize their local ecosystems. To present a new challenge, and to reflect the reality that observing phenomena sometimes involves adjusting to unanticipated changes, we changed the temperature at all of the stations. The resulting migrations tested student abilities to recognize a changed rule set and to use their previous experience to find a new environmental equilibrium as quickly as possible.

Results

All of the student changes to the virtual world, along with their justifications, were recorded on "Environmental Action Forms" throughout the trial. In addition to this activity data the students were given a customized pre/post-test (administered 3 days before and 3 weeks after the activity), consisting of 4 short answer and 1 multiple-choice questions. The customized test was designed to measure basic skills that we believed necessary for effective scientific inquiry into the simulated ecosystem that was presented to the students. A shortened version of the TOSRA (Test of Science-Related Attitudes), designed to measure student attitudes toward science and scientists, was also administered at the same time. In addition interviews were performed after the activity. Our analysis focuses on changes in their attitude toward and personal use of experimentation, which reflects a growing sense of control and understanding of the simulation.

Data capture was a significant challenge for the students; they had to identify each bug track from a set of 11 species in the field guide and maintain an accurate count within a space of crowded and overlapping trails. Altogether, students accurately captured 94% of 1,524 tracks presented. No a priori counting strategy was prescribed, but three emerged over the course of the unit: (a) using the marker to trace entire track paths, (b) using a single mark on a path to indicate that it had been counted, and (c) in the most sophisticated and efficient approach, counting the number of screen edge crossings for each track type and dividing by two.

Collectively, students had 64 opportunities for experimental changes during the unit; among those instances, students varied two parameters 18 times, one parameter 25 times, and zero parameters 21 times. Two-parameter moves are generally undesirable as it is impossible to ascribe outcomes to a specific variable manipulation. However, six of the two-parameter moves occurred during the first experimental move and six more occurred at the time of the temperature change (and could be attributed to advice garnered from conversations with students in other groups who had prior experience with the new species). Frequency of two-parameter moves decreased over time, with only one of the eight groups persisting in their application over the course of the unit. Zero-(status quo) and one-parameter moves have potentially stronger scientific basis, but students found choosing between them problematic due to confusion between the qualitative feedback provided in newspaper reports (based on adequacy of pest presence) and the quantitative feedback based on track counts (implicitly motivating students to seek "optimal" conditions that would completely eliminate pests). Pre/post-test comparisons of student performance on a transfer test of conceptual understanding multi-variant control showed only insignificant gains.

Pre/post-test comparisons of TOSRA items showed substantial gains in student self-perceptions as legitimized investigators of phenomena. On one pair of items directly addressing this issue we witnessed an 18% decrease in agreement with the statement: “It is better to be told scientific facts than to find them out from experiments” (p-value<0.07), and a complementary 13% increase in agreement with the statement “I would rather find out why something happens by doing an experiment than by being told” (p-value<0.0004). Despite a 24-hour gap between affecting changes and viewing the effects, student propensity to experiment increased.

Based on our observations and those made by the teacher students came into class excited to discover the changes they had enacted in their regions. Lively team discussions indicated to us that there was a genuine interest in finding solutions. Based on interviews conducted after the unit a small percentage of the students actually believed the insects were real during the first few days of the simulation. Though none of them admitted to believing the insects existed within the classroom walls, many thought that the tablets were displaying an actual sandbox that was simply located “somewhere else.” Their high level of activity and belief (for some) in the reality of the virtual environment provides hope that convincing simulations can be created with minimal technical affordances.

Phenomenon Server

The real power of *RoomBugs*, and other embedded phenomena in general, rests in their accessibility to teachers who wish to deploy the applications in their own classrooms. We accomplish a high level of compatibility across computing platforms by only requiring the publicly available Macromedia Flash and an Internet connection for computers participating in the simulation. Our 'Phenomenon Server' (written in Java) acts as a central point of contact, providing each display with the information it needs. The logic behind *RoomBugs* is fairly straight-forward. When the application detects changes made to a tablet's conditions the environmental preferences and current population size for each bug species in the affected area are examined. While the interactions between insect populations can be imagined as fairly complex (there are predator/prey relationships and resource issues to consider), there are only twelve unique environmental states in our simulation. Once the state is known we can simply define the relative effects that state will have on each species and calculate the population changes. After recording the new population counts at a station the 'Phenomenon Server' generates the bug tracks, sending this information out to each station that has subscribed to this phenomenon.

Lessons Learned from *RoomBugs*

Using physical artifacts, such as the action forms and printed newspaper, to enact and reflect changes in the simulation was important to lend credibility to the virtual world. However, the use of these physical artifacts probably complicated understanding of the chronology of the events; it created a disconnect between real-world days and simulations days. Entering data into the simulation from the action forms and creating/printing the newspapers took time. This delay made it possible for the current environment to be different than the conditions used to form the basis for newspaper reports, leading to a disconnect

Future Development

One of the major changes we are making to the *RoomBugs* phenomenon is to transition to a continuous, real-time simulation. The current system simply displays a full day's worth of bug tracks; use of this snapshot does not support our idea that the bugs are constantly present and active. A continuous representation presents interesting challenges for us and the students. An additional station could be used where students could enter environmental changes directly, automating that process and removing the disconnect between real-world and simulation-world time. A continuous representation would also raise questions about how to handle partially visible or newly formed tracks, exploring issues about consistency and error associated with a more realistic simulation.

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