

# WallCology: Studying Ecology using a Distributed, Persistent Virtual Ecosystem in the Classroom

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**Abstract:** This paper introduces a system for studying ecology that places a virtual ecosystem within the walls of a classroom. WallCology is designed to give students and teachers easy access to affordances which allow them to study ecological phenomena as ecologists would in the field. Using a set of computers as portals into the virtual ecosystem, students study creatures with different morphologies and behaviors moving about on pipes and walls. These portals, called WallScopes, are linked together using a remote server which allows the creatures to move within the larger virtual space based on their own environmental preferences. A two month pilot study of WallCology in an urban middle school classroom comprised of species differentiation and population estimation units demonstrated the feasibility of this approach.

## Objectives

Simulations of mobile populations, whether icon-based (e.g., Korfiatis, 2001; Tisue & Wilensky, 2004; Nevanpää & Law, 2006) or modeled graphics (e.g., Arns, et al., 2006; Fujii, et al., 2006; Lyons, et al., 2006; Mayles, 2006), typically provide learners with access to views of full populations within a closed environment, and approach that does not afford opportunities to problematize the inquiry processes associated with the estimation of population characteristics when observations are limited to samples rather than full populations. Does the sample contain the full range of species present in the larger environment? Is the numerical distribution of species in the sample representative of the distribution within the larger environment? How does sampling at different sites, or at different times, impact population estimates? Questions of this type are important elements of student understandings of the process of observational science for elementary and middle school learners (AAAS, 1993; NRC, 1996).

For the past year, we have been developing and field-testing a simulation platform designed to support authentic science inquiry surrounding life science and population ecology. *WallCology* situates students within a complex virtual ecosystem, where they may conduct empirical investigations. Multiple tablet computers running the simulation are attached to the walls of the classrooms and act as local portals (“WallScopes”) into a larger, imaginary space behind the wall filled with the virtual fauna. The simulation runs continuously, concurrent with regular classroom day-to-day activities, but becomes the center of attention as students engage in collaborative inquiry activities such as the building of field guides based on observations of phenomena or estimating populations.

The goal of this paper is to introduce the rationale behind the design of WallCology, outline its principal interaction affordances, describe the outcomes and design revisions growing out of an eight-week pilot study conducted with seventh grade learners in an urban middle school during Spring 2007. The pilot study focused on two learning goals: the identification of species and the estimation of transient populations from multiple samples. The objective of the pilot study was to gain feedback on the adequacy of application features, the effectiveness of the instructional scaffolding that supported the inquiry activities in support of the learning goals, and the impact of the activity on learners' attitudes toward the investigation process.

## WallCology

Through the WallScopes, students see a set of distinctive local virtual environments of pipes, plaster, lath, and simulated mobile creatures, along with displays of local environmental conditions (temperature and humidity) (Figure 1). The creatures, which vary in their morphologies, behaviors, and environmental preferences (Figure 2), are free to move about the entire virtual ecosystem, and are only seen by students when they wander into an area made visible by a WallScope. Behavior is further impacted by human presence; built-in microphones on the WallScope computers monitor ambient volume levels, and the creatures skitter away when the level becomes too high. In the current version of WallCology, controls are limited to a "tagging" mechanism allowing students to use a stylus to "paint" colored dots on creatures for subsequent tracking and population estimation activities (Figure 3).

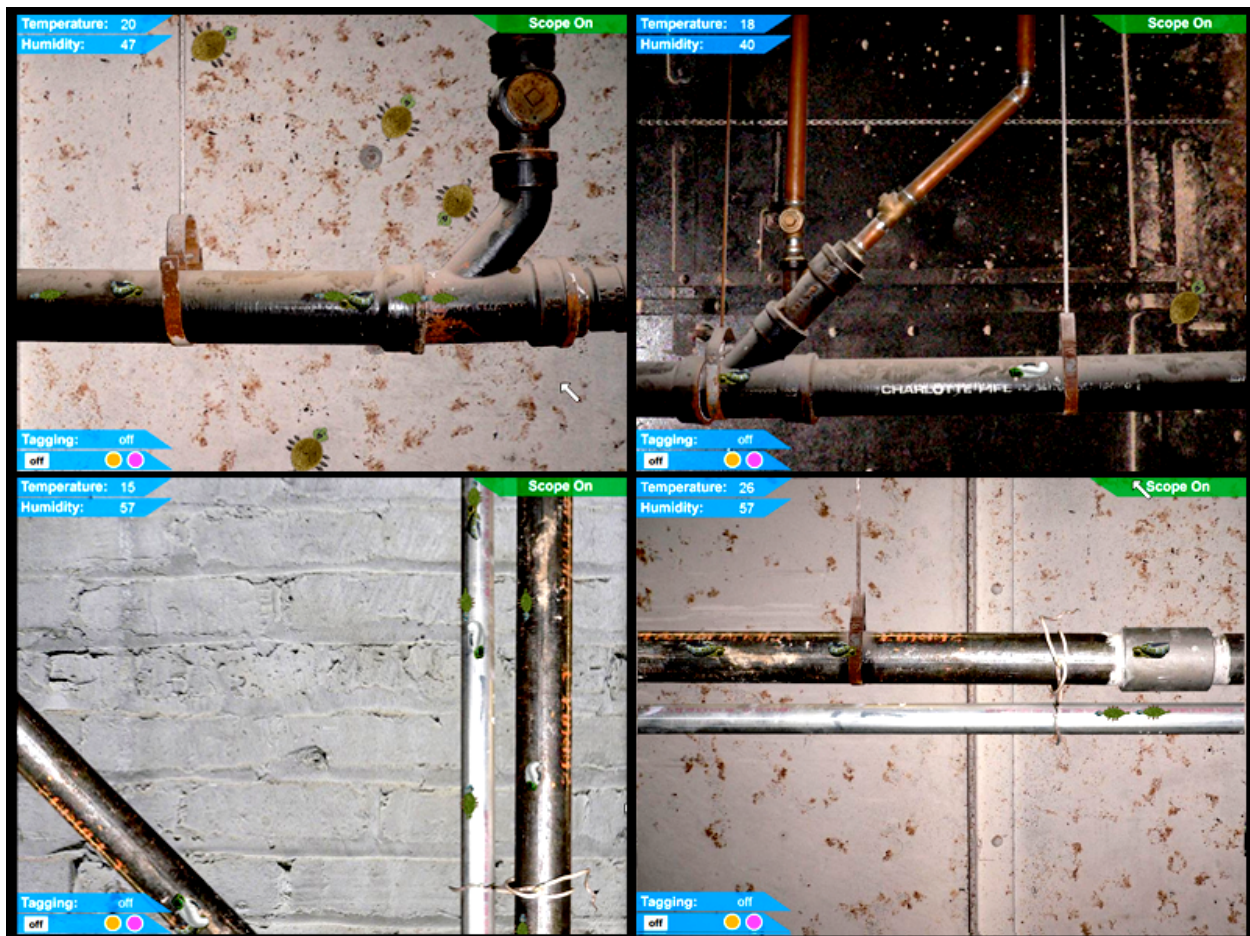


Figure 1: WallCology habitats (screen snapshots from four separate displays)

WallCology employs a client-server architecture. A Java-based application running on a remote server manages the simulation of creature movement among low-resolution “blocks” corresponding to WallScope-sized wall patches; the local client is responsible for animation of local movements within the WallScope blocks. The client application runs on conventional web browsers using the standard Flash plug-in.



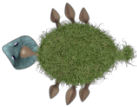
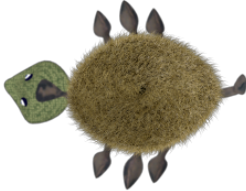
Morphology	Behavior	Habitat preference	Population size
	Move along pipes Jittery motion Respond slowly to noise	Prefers cold; indifferent to humidity	Large
		Prefers heat; indifferent to humidity	Large
	Moves along pipes Linear motion, ordinarily slow Responds rapidly to noise	Prefers humid habitat; indifferent to temperature	Medium
	Moves along walls Rapid, non-linear motion Non-responsive to ambient noise	Prefers dry habitat; indifferent to temperature	Small

Figure 2. Characteristics of WallCology creature populations. Image sizes are scaled proportionally.

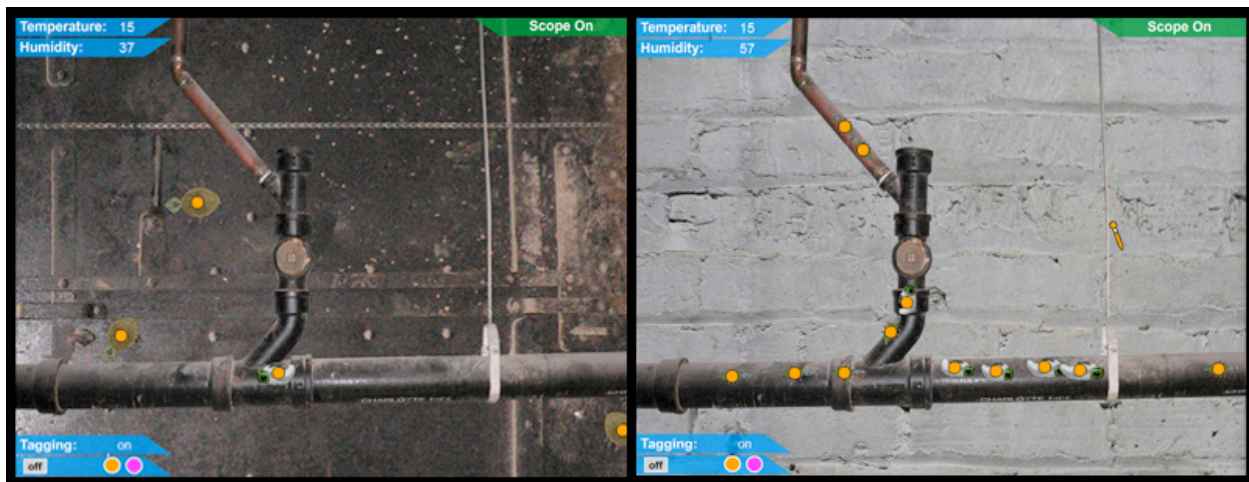


Figure 3: Tagged creatures in WallCology habitats.

## Framework

WallCology extends the “embedded phenomena” representational framework (Moher, 2006; Barron, et al., 2006; Thompson & Moher, 2006; Moher, et al., 2006; Moher & Wiley, 2007) in which dynamic animated simulations are depicted as occurring within a large spatial area within the classroom, rather than within the confines of a single display. A collection of distributed computer displays is used as a shared interface by the entire class, rather than by individual students, and affords only partial views of a presumed larger space of phenomena. Within this framework, inquiry is an embodied, collaborative, whole-class endeavor. The pedagogical basis for the approach derives broadly from theories of situated learning (Brown, et al., 1989; Rogoff, 1990; Greeno, 1998). The embedded phenomena framework situates communities of practice (Wenger, 1998) (in this case, intact self-contained classes) within authentic activity structures (scientific investigations) for the purpose of socially constructing knowledge of both science concepts and the processes of science as a technical and human endeavor (Duschl, 2000). The extended duration characteristic of embedded phenomena learning units seeks to afford time for movement from the periphery of practice to more central roles (Lave & Wenger, 1991) within an apprenticeship context of emerging expertise among peers and teachers (Bandura, 1977; Brown, et al., 1989).

## Method

In the Spring 2007 pilot study, WallCology was used as a component of a two-month population ecology unit in a seventh grade science classroom. Five tablet computers Velcroed to the classroom walls ran the WallScope browser application continuously during the unit.

Four types of creatures were employed in the simulation. In order to problematize species differentiation and encourage learners to consider characteristic beyond morphological features, each of two pairs of creatures was assigned similar (but not identical) morphologies, but with distinctive behavioral patterns and habitat preferences (Figure 2). The objective was not to lead students a normative determination of species membership, but rather to use observational activities as a stimulus for theory articulation and argumentation (Smith & Reiser, 2005). Students worked in small groups to create a “field guide” of WallCology creatures. Each page of the field guide asked students to sketch the creature and provide their observations of the creatures’ morphologies, behaviors, and habitats (Figure 4). Once the field guides were completed, the teacher led whole-class discussions designed to reach a class consensus regarding the identification of distinct species.

Attention turned next to the question of obtaining estimates of population sizes across the entire (visible and hidden) environment. Population estimation focused on two techniques: static sampling and tag-recapture estimation<sup>1</sup>. Students estimated WallCology populations using the static sampling method, observing the screens and noting how many creatures of each kind that they saw, then multiplying by the ratio of the wall size to the WallScope size and averaging across habitats. The process was repeated several times in conjunction with a class discussion on reliability, accuracy, and factors that could lead to inconsistent results. Student were then instructed on the tag-recapture method, and used the Wallscope tagging facility mark creatures that wandered into their WallScopes over a thirty minute period, using the Lincoln-Peterson formula to estimate the creature populations.

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<sup>1</sup> The students used the Lincoln-Peterson (Peterson, 1896; Lincoln, 1930) formula  $\tilde{N} = ct/r$ , where  $\tilde{N}$  is the estimated population,  $c$  is the number of individuals in captured in the second sample,  $t$  is the number of individuals tagged in the first sample, and  $r$  is the number of tagged individuals in the second sample.


<p>Morphology Sketch</p> 	<p><b>Species:</b>          (Latin/Greek) <u>Chloro</u>          (meaning) <u>green</u>          (common) _____</p>
	<p><b>Morphology:</b>          (written description) <u>I has a green body and a greenish blue head. It has six legs. It has a diamond shaped head</u></p>
	<p><b>Behavior:</b>          (normal activity) <u>I move slow until he here a loud clap or any type of noise.</u>          (frightened) <u>It moves very fast when it hears noise or when it feels intimidated</u></p>
	<p><b>Environment:</b>          (habitat) <u>It lives in a dark area in the walls. It likes to be on the rusty pipes. It hangs around its own kind.</u>  <u>High humidity</u></p>

Figure 4: WallCology field guide page

**Data Sources**

*Pre/Post-tests*

The (identical) tests included open-ended items probing understandings of mobile population estimation as well as Likert-scale items selected from the Test of Science-Related Attitudes (TOSRA) (Fraser, 1978).

*Field Guides & Classroom Video*

Five-student groups worked collaboratively to complete the field guides, containing descriptions of observed morphology, behavior, and habitat preference. Video of small-group and whole-class discussion was recorded on selected days during the WallCology Unit.

### *Post Interviews*

Nine students and the teacher were interviewed individually followed by a group classroom discussion to gather additional feedback on the unit.

## **Outcomes**

The attempt to orient students to issues beyond morphology in differentiating species proved partially successful. While students were more strongly oriented toward physical characteristics in class discussions (“when I get to behavior I get kind of confused, I lose my confidence”), their field guides and interviews reflected fairly rich descriptions of behavior, including reactions to noise and speed of travel, and perceived relationships that were not programmed into the simulation (“The sleach [students’ name for the slug/leach-like animal] is scared of the turtle like thing and that’s [why] we think it never comes out [of] the pipes”). Upon the conclusion of the species differentiation activities students participated in a peer review discussion aimed at answering the question, “How many species of creatures are there in WallCology?” Initially students cited morphology to make claims like “the two sleach-like creatures are the same species because they look alike” and “the small turtle and big turtle like creatures might be the same species but the small one could be a baby living on the pipes” (indicating an awareness of life-cycle factors not included in the present implementation). One group then stated agreement with the single sleach theory and added that they have the same behavior. The same group stated that the turtle like creatures had differing behaviors but maybe the turtles do not get scared when they are full grown. The peer review exercise concluded with the drawing of a chart showing similarities or differences between the morphologies, behaviors and environments of the creatures. Based on their data placed in the chart they reached consensus on the view that there are four different types of creatures (sub-species) but that two of the types were from the same species.

While physical characteristics of the habitats were used in the behavioral descriptions, the other environmental variables cued by digital displays—temperature and humidity—were rarely raised during discussions. A likely explanation is that the students were not able to associate qualitative labels (e.g. “hot” or “cold,” “moist” or “dry”) with the quantitative values shown on the displays; the numbers were just numbers, and differences in them may or may not have been meaningful, from the students’ perspectives.

The more concrete goal of learning population estimation techniques proved reasonably successful. On an open-ended item administered before and after the unit, students were asked to describe two methods of estimating populations from samples. Responses were coded on a 10-point scale, assigning credit for factors including the recognition of the inability to access or manipulate the full population, the need for multiple observations over space and/or time, description of qualitative algorithmic method, and articulation of quantitative formulae. Mean scores on the item increase from 4.6/10 (pre-test) to 7.6/10 (post-test),  $t(21) = 6.15$ ,  $p < .001$ . Post-activity interviews with students, however, indicated that while students found the tag-recapture method to have intuitive appeal, and in several cases could describe and apply the Lincoln-Peterson formula, none were able to give a strong characterization of its conceptual motivation.

On the TOSRA (scaled Strongly Disagree = -2 through Strongly Agree = +2), recognition of the need for multiple samples to increase reliability was reinforced by students increased disagreement with the item, “Repeating experiments to check my results is a waste of time” (Pre-test  $M = -.32$ , Post-test  $M = 1.0$ ,  $t(21) = 2.73$ ,  $p < .05$ ). Items relating to students’ stances toward investigation trended in the direction of increased agency, including “Doing experiments is not as good as finding out information from teachers” (Pre-test  $M = -.23$ , Post-test  $M = -.77$ ,  $t(21) = 1.74$ ,  $p = .10$ ) and “I would rather do my own experiments instead of finding something out from a teacher” (Pre-test  $M = .32$ , Post-test  $M = .73$ ,  $t(21) = 1.82$ ,  $p = .08$ ).

## Conclusion

This initial pilot intervention provided tentative support for the feasibility and effectiveness of WallCology-based inquiry activities within a population ecology instructional unit. From a technology perspective, WallCology extended the embedded phenomena framework through the introduction of realistic animation of fauna and the responsiveness of the simulation to student activity (noise). By serving off-site and running on browsers on conventional classroom computers, WallCology promises minimal resource barriers to adoption. Outcome weaknesses in the recognition of environmental variables as cues to species classification, conceptual understandings of tag-recapture methods, and “inadvertent” predatory behavior will contribute to design revisions of the application and instructional plan in future interventions.

We are currently extending WallCology along several dimensions, including the introduction of reproduction and life-cycle stages, predation and food chains, control affordances for an extended set of local environmental parameters and the introduction of new species, theory-driven population growth models, and the ability to share access to the simulation between (actual or virtual) wall-adjointed classrooms. Our long-term goals include extensions to address adaptation and evolution, making WallCology a platform that could be used to support learning progressions in ecology with semester- or year-long curricula.

## References

- American Association for the Advancement of Science. (1993). *Project 2061: Benchmarks for science literacy*. New York: Oxford University Press.
- Arns, L., Brisbin, M., Foldes, D., & Holland, J. (2006). Virtual Reality for Ecosystem Dynamics Education. *Proceedings AMC SIGGRAPH International Conference on Computer Graphics and Interactive Techniques*.
- Bandura, A. (1977). *Social Learning Theory*. New York: General Learning Press.
- Barab, S. A. & Plucker, J. A. (2002). Smart people or smart contexts? Cognition, ability, and talent development in an age of situated approaches to knowing and learning. *Educational Psychologist*, 37(3), 165–182.
- Barron, M., Moher, T., and Maharry, J. (2006). RoomBugs: Simulating Insect Infestations in Elementary School Classrooms. *ACM CHI '06 Extended Abstracts on Human Factors in Computing Systems*. April 24-27, 2006, Montréal, Canada, 315-320.
- Brown, J. S., Collins, A. & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18(1), 32–42.
- Duschl, R. (2000). Making the nature of science explicit. In R. Millar, J. Leech & J. Osborne (Eds.) *Improving Science Education: The contribution of research*. Philadelphia: Open University Press. pp 187-206.
- Fujii, S., Aoyama, H., Sota, M., Iwata, J., & Mizuno, T. (2006) A system for Learning Ecology with 3D graphics and Local Materials Database. *Current Developments in Technology-Assisted Education*. Badajoz, Spain.
- Greeno, J. (1998). The situativity of knowing, learning, and research. *American Psychologist*, 53, 5–26.

- Korfiatis, K., Papatheodorou, E., Stamou, G. P., & Paraskevopoulos, S. (1999). An investigation of the effectiveness of computer simulation programs as tutorial tools for teaching population ecology at university. *International Journal of Science Education*, 21, 12, 1269-1280.
- Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. Cambridge, UK: Cambridge University Press.
- Lyons, L., Lee, J., Quintana, C., & Soloway, E. (2006). MUSHI: A Multi-Device Framework for Collaborative Inquiry Learning. *Proceedings International Conference of the Learning Sciences (ICLS 2006)* (June 2006, Bloomington, IN), 453-459.
- Mayles, G., et al. (2006). *Viva Piñata*. Microsoft Xbox video game. Twycross, Leicestershire, England: Rare, Ltd.
- Moher, T. & Wiley, J. (2007) Classroom Space, Classroom Time, and the Representation of Dynamic Phenomena. Paper to presented at *Annual Conference of the American Educational Research Association*. April 9-13, 2006, Chicago, IL.
- Moher, T. (2006). Embedded Phenomena: Supporting Science Learning with Classroom-sized Distributed Simulations. *Proceedings ACM Conference on Human Factors in Computing Systems (CHI '06)*. April 24-27, 2006, Montréal, Canada, 691-700.
- Moher, T., Hussain, S., Barron, M., and Thompson, M. (2006). RoomQuake: Learning, Self-Concept, and Growth of a Community of Practice in a Persistent Whole-Classroom Simulation. Annual Conference of the American Education Research Association (April 2006, San Francisco, CA).
- National Research Council*. (1996). *National Science Education Standards: observe, interact, change, learn*. Washington, DC: National Academy Press.
- Nevanpää, T. and Law, N. (2006.) Pupil's ecological reasoning with help of modeling tool. Proceeding 2006 Conference on Interaction Design and Children (Tampere, Finland, June, 2006), 41-44.
- Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context*. New York: Oxford University Press.
- Tisue, S., & Wilensky, U. (2004). NetLogo: A Simple Environment for Modeling Complexity. *Paper presented at the International Conference on Complex Systems (ICCS)*, Boston, MA.
- Thompson, M. and Moher, T. (2006). HelioRoom: Problem-solving in a whole class visual simulation. *Proceedings International Conference of the Learning Sciences (ICLS 2006)* (June 2006, Bloomington, IN), 1000-1001.
- Wenger, E. (1998). *Communities of practice*. New York: Cambridge University Press.