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**EcoMOBILE: Blending Virtual and Augmented Realities  
for Learning Ecosystems Science and Complex Causality**

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Abstract: We are studying whether ecosystems instruction can be more engaging and effective by combining immersive virtual environments and real ecosystems infused with digital resources. In prior research, we developed EcoMUVE, an inquiry-based, four-week curriculum that incorporates student experiences in immersive, simulated virtual ecosystems to enhance student understanding of ecosystems science, the inquiry process, and the complex causality inherent in ecosystems dynamics. Our findings show promising results on its perceived value, usability, and implementation feasibility, along with gains in student learning and motivation. Now, we are developing a series of augmented realities using mobile devices that enable students to collect and share data using probeware, cameras, and microphones; access on-site information about ecosystem components; and visit geo-referenced locations to observe critical components of the ecosystem and to experience virtual simulations related to causality. Our early findings show a variety of ways in which immersive virtual environments and augmented realities complement each other in student motivation and learning.

## **Introduction**

Augmented reality (AR) is an immersive interface utilizing mobile, context-aware technologies (e.g., smartphones, tablets), and software that enables participants to interact with digital information embedded within the physical environment (Dunleavy & Dede, in press). Our research is exploring the unique affordances of AR, as well as the capabilities of data collection probeware, to support setting-enhanced learning in environmental science education (Kamarainen et al., in review). The EcoMOBILE project (<http://ecomobile.gse.harvard.edu>) is funded by the National Science Foundation and by Qualcomm, Inc. and is supported with resources from Texas Instruments, Inc.

The ability to understand ecosystems is enriched by experiences in real environments. Field trips, both real and virtual, lead to increases in science knowledge (Garner & Gallo, 2005); and outdoor experiences can positively influence student attitudes about nature (Ballantyne & Packer, 2002). Yet, the real world can be a difficult learning environment; students may be distracted by the novelty of the social and physical context of the experience, making a focus on appropriate learning tasks difficult (Orion & Hofstein, 1994). Students may be overwhelmed by too much information and may struggle to discern where to direct their attention. As a result of these and other logistical factors, field trips tend to be one-time experiences with limited

connection to what students experience in the classroom curriculum or in their everyday lives.

AR can provide multiple capabilities in support of immersive, context-specific learning during real world experiences (Dede, 2009). AR interfaces can enable contextualized, just-in-time instruction; self-directed collection of real-world data and images; and feedback on student actions and responses. AR's have also been shown to support social interactivity; respond to shifts in context; facilitate cognition distributed among people, tools, and contexts; and provide individualized scaffolding (Klopfer, 2008; Dunleavy and Dede, in press).

Further, research has shown that using data collection probes in science can enhance various aspects of teaching and learning in the classroom and in the field. Using probes in a lab setting coupled with computer-mediated presentation of the results scaffolds critical evaluation of graphs and data (Nicolaou et al. 2007), supports student learning of science concepts (Metcalf and Tinker 2004), and empowers inquiry-based science learning (Rogers and Price 2008). Real-time probeware helps students to see data and related concepts as concretely related to particular phenomena (Vonderwell et al. 2005).

We believe that a combination of both AR and environmental probes may further enhance the field trip experience in ways that neither technology could accomplish on its own. We are studying whether using probes and/or mobile devices equipped with augmented reality experiences can enhance learning by situating data collection activities in a larger, meaningful context that connects to students' activities at the real world setting.

## **Technology**

In our pilot studies, the technology components have included (1) an AR experience running on wireless-enabled mobile devices or (2) water measurement tools using graphing calculators with environmental probes, or both:

Augmented reality experience: The augmented reality experience was created using the FreshAiR augmented reality development platform designed by MoGo Mobile, Inc. The FreshAiR platform allows an author to create augmented reality games and experiences that can be accessed anywhere from an Android mobile device with wireless connectivity and GPS capabilities. "Hotspots" are placed on a map of the physical setting, and these hotspots become accessible to students at the real location in the field. At a hotspot the student can experience augmented reality visualizations overlaid on the real environment, as well as interactive media including text, images, audio, video, 3D models, and multiple-choice or open-ended questions (Figures 1-3).



Figure 1. Students work in teams to explore the pond ecosystem.



Figure 2. Using a visual target to see a 3-D image on the cellphone.



Figure 3. A green hotspot showing the direction and distance to the next location.

Water measurement tools: Students collected water measurements using Texas Instruments (TI) NSpire devices with Vernier environmental probes. The TI NSpire provides graphing calculator capabilities along with a Data Quest data collection mode that allows display of multiple probe readings on a single interface. Probes were provided to measure four variables; dissolved oxygen concentration, turbidity (Figure 4), pH, and water temperature.



Figure 4. In the *Scientific Discoveries* pilot, collecting water quality data on turbidity using digital probes.

Immersive, authentic virtual ecosystems: In some of our pilots, we utilized the pond ecosystem (Figures 5- 7) from our EcoMUVE middle grades curriculum on ecosystems science (<http://ecomuve.gse.harvard.edu>). Students can explore the virtual pond and the surrounding area, even under the water; see realistic organisms in their natural habitats; and collect water, weather, and population data. Students visit the pond over a number of virtual "days," and eventually make the surprising discovery that, on a day in late summer, many fish in the pond have died. Students are challenged to figure out what happened – they work in teams to collect and analyze data, and gather information to solve the mystery and understand the complex causality of the pond ecosystem (Metcalf et al., 2011).



Figure 5: A student using her avatar to explore a virtual ecosystem.

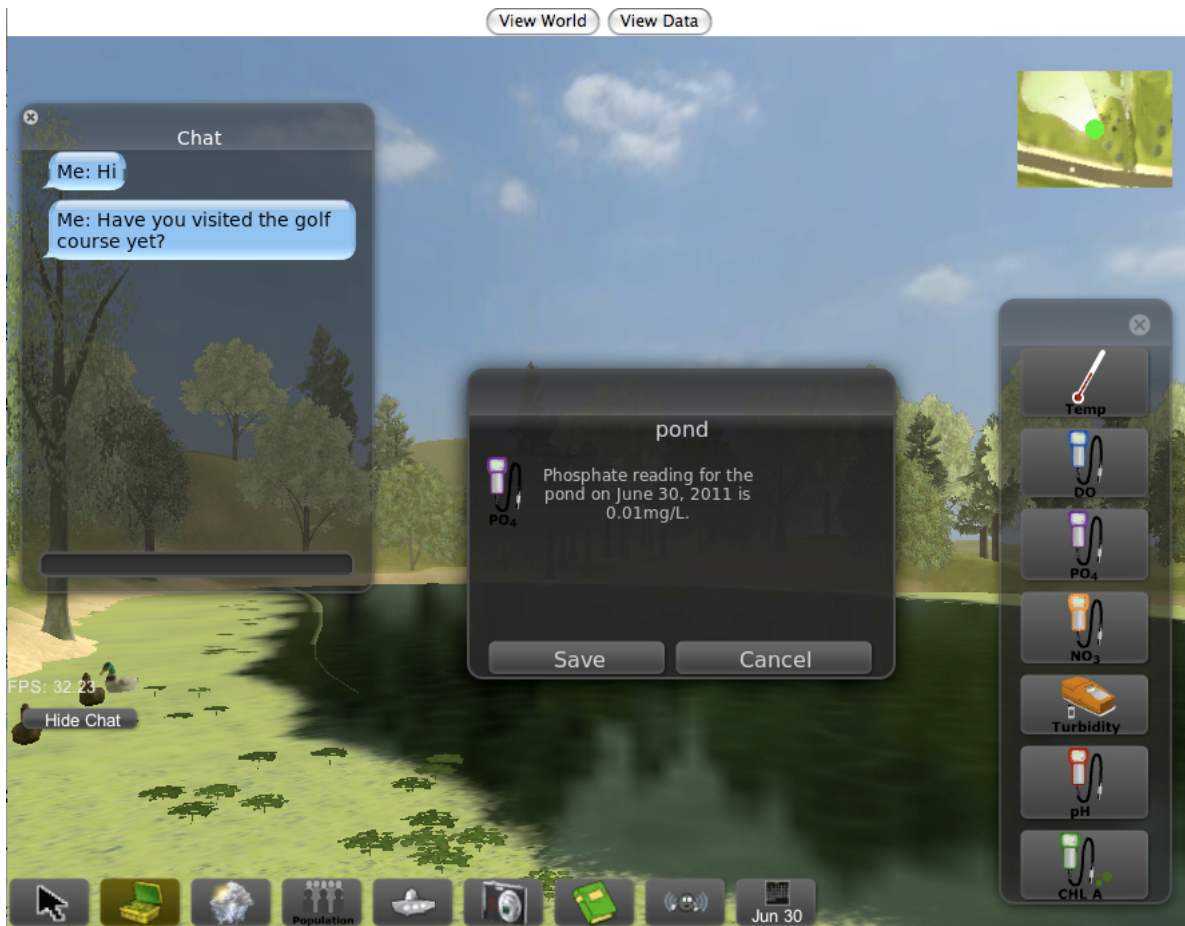


Figure 6: Students can collect water, weather, and population data at the digital pond

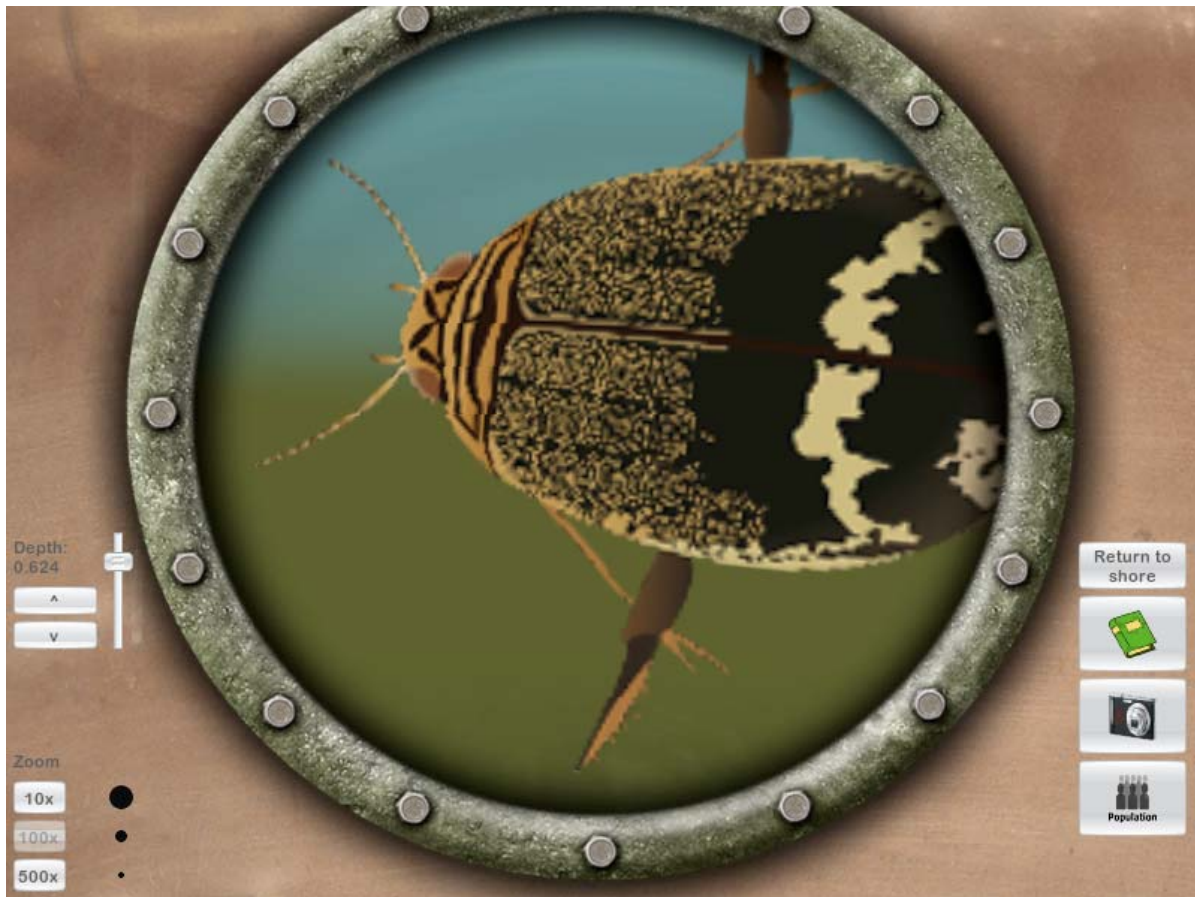


Figure 7: The submarine tool allows students to see and identify microscopic organisms

### Design of Pilot Activities

To help us better understand how to design AR-based curricula, in fall 2011 we developed three distinct environmental science augmented reality experiences as pilot implementations for middle grades students. We provided a variety of content types and process structures to assess which elements are most engaging and powerful.

*EcoMOBILE - Scientific Roles* – Using a jigsaw pedagogy, middle grades students encounter information that builds on the one month EcoMUVE curriculum. Recent research suggests that allowing students to explore high fidelity virtual environments such as the EcoMUVE primes them for exploration and data collection on field trips to similar environments (Harrington, 2010). Following classroom work with EcoMUVE, students use *EcoMOBILE – Scientific Roles* to continue their roles as scientists in the real world. As shown in Figures 1 and 2, students work in teams through an augmented reality learning experience that reinforces learning goals such as understanding the process of decomposition or the definition of a watershed. At the end of the field experience, each student meets with teammates who followed a different path, and they compare their experiences and share results.

*EcoMOBILE - Scientific Discoveries* – Students use *EcoMOBILE – Scientific Discoveries* to combine the power of mobile broadband devices with environmental probes during a field trip to a real pond. Upon arriving at a Fresh AiR hotspot near the pond, students working in pairs may receive more information, answer a question, or be prompted to collect a water measurement. Students use the probes to collect water quality data, and the information provided on the mobile broadband device helps them make sense of the measurements they have collected. When students return to the classroom, they work with their teacher to understand variation in data and the reasons that water quality variables may change. This experience also reinforces students understanding of the interaction between biotic and abiotic factors in an ecosystem.

*EcoMOBILE - Atom Tracker* – Students use *EcoMOBILE – Atom Tracker* to follow a virtual atom around an ecosystem. Students work individually to track an atom, and in the process they learn about ecological transformations like photosynthesis and respiration. Using the mobile broadband devices allows students to “observe” ecological processes as they occur at the molecular level. Students track different atoms and come together at the end to learn from a classmate about the path that another atom has followed. In this experience, students learn about elemental cycles; the processes of photosynthesis, respiration and decomposition; and the principle of conservation of matter. This experience is location-independent, thus may be completed during a field trip, in a schoolyard, or in a large indoor area with access to a wireless signal.

In addition to designing and implementing these three experiences, we created lesson plans for the teachers for each experience, including pre-field trip classroom preparation and post-field trip follow-up activities. We also developed draft assessment materials that we are using during the pilot implementations to gather formative feedback on changes in student attitudes, gains in content knowledge, and summative opinion surveys.

### **Illustrative Research Questions, Interventions, and Findings**

As an illustration, for the *Scientific Discoveries* pilots our research questions centered on characterizing students motivation and learning in combined AR/environmental-probes experiences on the dimensions of:

- 1) Content learning gains related to our specified learning goals (water quality characteristics, relationship between biotic and abiotic factors, data collection and interpretation skills, and the functional roles (producer, consumer, decomposer) of organisms in an ecosystem).
- 2) Student attitudes related to self-efficacy and opinions about the field trip experience (as measured by affective surveys and post opinion surveys)
- 3) Teachers’ experiences with field trip instruction

### *Illustrative Activities*

The EcoMobile Scientific Discoveries pilot included one class period before the field trip, the field trip itself, and one class period after the field trip (Kamarainen et al, in review). The learning goals of the field and classroom activities focused on understanding of the relationship between biotic and abiotic factors, data collection and interpretation skills, and the functional roles (producer, consumer, decomposer) of organisms in an ecosystem. Prior to the field trip, the students had access to “learning quests,” which are online modules providing a 5-10 minute activity that introduces the students to the ideas behind dissolved oxygen, turbidity, and pH.

The field trips lasted approximately 3.5 hours. The activities during the field trip including the following AR experiences, along with more conventional field trip activities:

- Upon arriving at a hotspot near the pond, students working in pairs were prompted to make observations about the organisms around the pond and classify (producer, consumer, decomposer) an organism they observed. Students answered questions about their observations, and received constructive feedback based on their answers.
- At the next hotspot, students were prompted to collect water measurements using the TI Nspire and environmental probes. The AR delivered additional information that helped them make sense of the measurements they had collected. Student recorded their data on a worksheet.
- Students were then prompted to collect water measurements at a second location that they could choose. Students once again recorded their data and were prompted to compare the two measurements.
- At a later hotspot, students were prompted to sketch on paper an organism they had observed near the pond.
- Two more hotspots provided visual overlays, videos, and additional information related to consumers and decomposers, as well as posed questions related to the role of these organisms in the ecosystem.
- As the final activity in the field, students met with another pair of students who had collected the other two water quality variables, and the two pairs compared their measurements before returning to the classroom.

The augmented reality program supported students’ use of the probes by helping them navigate to a location to collect a sample, providing step-by-step instructions for use of the probes, entering the reading in response to a multiple-choice question, and delivering immediate feedback related to the student-collected measurement (Figure 8).

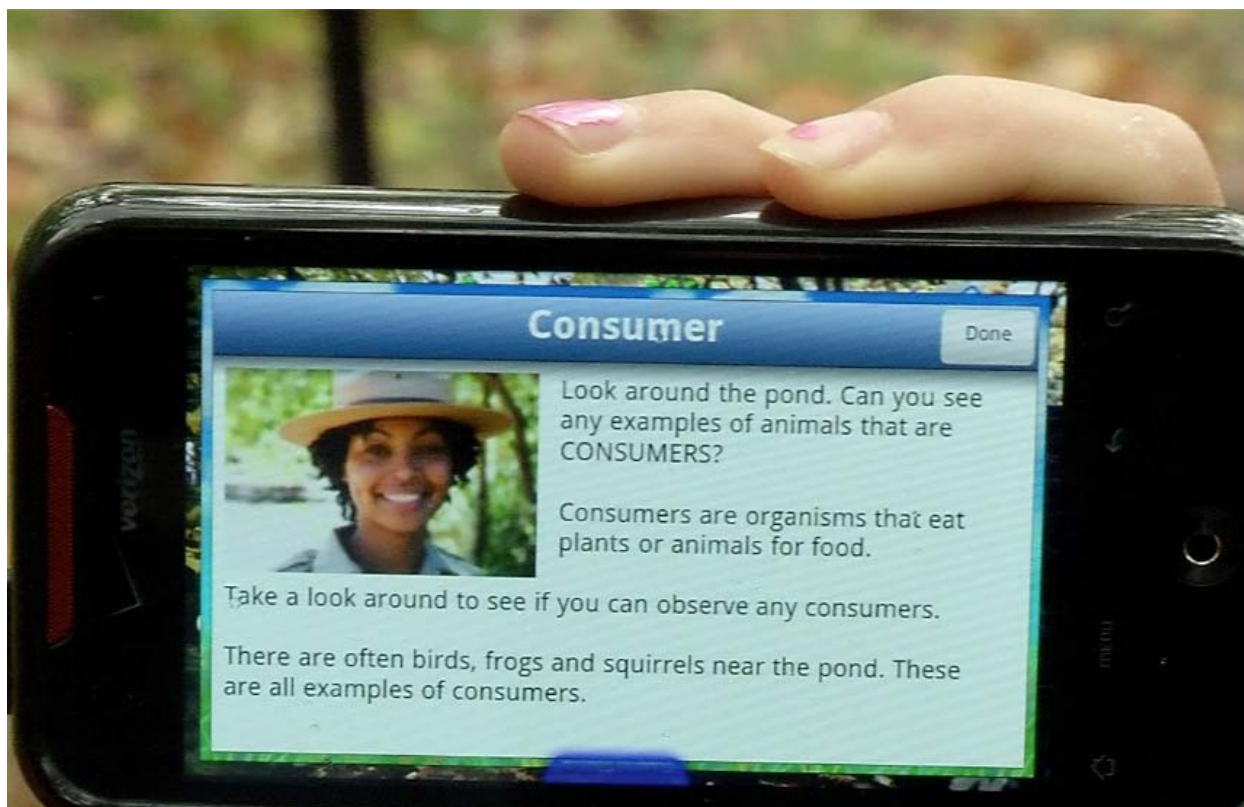


Figure 8. Handheld delivering background information about their research assignment.

On the next school day after the field trip, back in the classroom, students compiled all of the measurements of temperature, dissolved oxygen, pH, and turbidity that had been taken during the field trip. They looked at the range, mean, and variations in the measurements and discussed the implications for whether the pond was healthy for fish and other organisms. They talked about potential reasons why variation may have occurred, how these measurements may have been affected by environmental conditions, and how to explain outliers in the data.

As discussed in detail in Kamarainen et al (in review), our findings from the EcoMOBILE Scientific Discoveries pilots showed that students were highly engaged with the technology and also with science. Teachers were able to use pedagogical approaches that may otherwise be difficult in an outdoor learning environment. Student learning gains on the content survey were significant both from a statistical perspective and from the viewpoint of the teachers, who compared these gains to memories of prior field trips without technological support. These results suggest that combining AR with use of probes inside and outside of the classroom holds potential for helping students to draw connections between what they are learning and new situations. Overall, our findings indicate that there are multiple benefits to using this suite of technology for teaching and for learning.

## Next Steps

This winter, we are analyzing data from our various pilots. Based on the findings, we are designing second generation curricula based on various combinations of AR and probeware. When the weather improves enough in New England to again permit outdoor activities, we will continue small-scale implementations to further improve our design strategies, our understandings of the strengths and limits of these technologies for aiding motivation and learning, and our research methods for these types of immersive, authentic, simulated experiences. Further along, at the conclusion of these design-based research cycles (Dede, 2005), we plan to formally explore student learning through a series of quasi-experimental studies.

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