Understanding Data Variability in Ecosystems: Blending MUVE and Mobile Technologies to Support Reasoning with Real World Data

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Abstract: Inquiry-based instruction is a focal point of recent research and Next Generation Science Standards, but students have difficulty connecting evidence to claims, especially when data are highly variable. We explore a blended curriculum that supports inquiry activities in a virtual world, followed by inquiry activities in the real world with first-hand collection of authentic, variable data supported by mobile devices. This study characterizes how students use and interpret data across these two instructional contexts.

Introduction

Both research findings and the Next Generation Science Standards advocate for using inquiry-based instruction to reach learning goals related to science content, practices and understanding the nature of science (Wilson, Taylor, Kowalski, and Carlson, 2010; Achieve, 2013). At the same time, it is recognized that careful scaffolding of inquiry activities (Quintana et al., 2004; Hmelo-Silver et al., 2007) and reflection upon scientific practices (White & Frederiksen, 1998) are necessary to reach these learning objectives. Here we report on a pilot project in which we use a multi-user virtual environment (MUVE) in the classroom and augmented reality experiences during a field trip to scaffold student engagement in inquiry activities and to promote reflection on the role of variability in data collection, synthesis, and interpretation.

Across domains, students have difficulty relating evidence to claims (e.g., Krajcik et al., 1998), and this problem can impede students' attempts to meaningfully connect inquiry activities and science concepts. This is a particular challenge in the field of ecosystem science, because (1) the temporal and spatial scale of observable patterns in ecosystems are difficult to represent within the bounds of classroom instruction, and (2) environmental data tend to be inherently "messy" – meaning that it may be difficult to detect the ecologically-relevant signal among the noise, or variability, in the data. While first-hand data collection has been shown to promote student motivation (Hug & McNeill, 2008), students struggle to reason using data in which variability from both measurement error and meaningful natural processes plays an important role (Kanari & Millar, 2004). Thus, evidence of ecosystem phenomena is difficult for students to apply for scientific reasoning.

In this study, we explore a blended approach in which students begin with a structured classroom experience conducting inquiry activities with a fixed and simplified data set (EcoMUVE), followed by mobile broadband device supported inquiry activities in the real world with first-hand collection of highly variable data (EcoMOBILE). Augmented realities (AR) for learning utilize mobile, context-aware technologies (e.g., smartphones) that enable participants to interact with digital information embedded within the physical environment. The AR technology supports extending student learning by allowing field data to be more easily shared and analyzed back in the classroom. We show how students' experiences across these instructional contexts enhance their ability to make sense of messy real world data.

Methods

EcoMUVE and EcoMOBILE provide complementary exposure to data and variability in the context of a larger inquiry problem. EcoMUVE (http://ecomuve.gse.harvard.edu) is a two-week immersive virtual ecosystem representing a pond and its surroundings. Students explore the pond via avatars, traveling in time over a virtual summer, and discovering a fish kill. Working in teams to solve this mystery, students collect data on water measurements such as temperature, dissolved oxygen, phosphates, pH, and turbidity, explore at microscopic and even atomic levels, and use tables and graphs to view and analyze data over time.

EcoMOBILE (http://ecomobile.gse.harvard.edu) provides a complementary experience to the use of EcoMUVE in the classroom because students have an opportunity to apply their ideas about pond ecosystems during a field trip to a local pond. EcoMOBILE employs two technologies: MBDs (mobile broadband devices) running augmented reality software and note-taking applications, and probeware to collect measurement data.

The pilot study included one teacher and four classes (N=90) of seventh grade students from a suburban school district in the northeastern U.S. Students worked with the EcoMUVE curriculum during a two-week period, followed by one week of experiences associated with EcoMOBILE, including the pond field trip. Research data collected for this study included video and audio recordings of students, worksheets, and pre-post surveys around the EcoMOBILE portion of the activity. Students worked in pairs to collect data measurements – temperature, dissolved oxygen (DO), or turbidity. They chose measurement locations around the pond, documenting the spots using Evernote. Map and number line visualizations prompted students to compare and reflect on reasons for different measurement results. During post-field trip class discussion of data, notes and photos, students shared hypotheses about the variations they had observed.

Findings

Pre-post survey: The pre-post survey, pre-administered after EcoMUVE but before EcoMOBILE, and post-administered after EcoMOBILE, included questions related to interpretation of variability. Students were presented with two similar questions involving hypothetical variable dissolved oxygen (D.O.) data from a pond. Within EcoMUVE, students observed D.O. measurements between 4mg/L to 10.2 mg/L. The survey items contained three data sets with measurements in this range (between 7.2 to 8.8 mg/L) and a fourth data set that ranged from 22.9 to 23.1 mg/L, values that are far outside the normal range. After selecting a closed-response option, students were asked to explain their reason for choosing that option. When considering small differences between two data sets, students' written explanations shifted to include significantly more ecological mechanisms (paired t-test, $p = 0.032$) that could contribute to the observed differences, like decomposition, plants, and water depth. When considering a data set with large differences, a marginally significant number of students (paired t-test, $p=0.06$) used personal experiences to help explain the observed differences.

Field trip experiences: Brief field interviews indicated that students had many ideas about the reasons for variation they observed in the field, identifying factors like sunny or shady spots, depth of the probe, and muddiness of the water. They also made distinctions between slight or insignificant variations, compared to larger, significant differences. For example, one student described a cluster of shady-location temperature measurements ranging from 14-16°C as "all pretty much the same," then pointed at the map to show a higher measurement of 20°C "over here where I think there's more sunlight."

Post-field trip discussion: Looking at the combined class data in the classroom, students commented on clusters and outliers in the number line, and groupings on the maps. Students recalled and felt connected to their experience, sharing details of their collection experience. Students' photos and notes were highly useful in contextualizing the data; for instance, students noticed in temperature photos whether the location was sunny or shady, or whether the spot was insulated by fallen autumn leaves.

Prior EcoMUVE experience: In post-discussions, students' hypotheses frequently referred to concepts highlighted in EcoMUVE, which grounded their understanding of processes such as photosynthesis and decomposition. One student said that "photosynthesis can produce oxygen in the water and I got the 12.5 right on the bottom right corner there and that was a more plant filled area." Another student suggested that "all the leaves blew over to there, so that means they will decompose and bacteria and cellular respiration."

These initial findings suggest that students were applying ideas about variability to the data they had collected and were able to connect their claims about the cause of variability with reasoning that included knowledge they had gained through using the EcoMUVE curriculum in the classroom. This study offers initial support for the idea that using a blended curriculum that scaffolds inquiry activities, situates variability in personalized, real-world contexts, and offers structured exposure to increasingly variable data can aid student ability to connect evidence to claims.

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