Project NEO: Assessing preservice teacher science content knowledge with a video game

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Abstract: The need for STEM majors for our future workforce is growing, yet fewer students are choosing to major in STEM areas, and many are underprepared, in part because elementary school preservice teachers (PSTs) are also underprepared. This NSF-supported project developed and tested the first of several planned modules of a video game based on the Next Generation Science Standards. Results suggest that PSTs who play the video game demonstrate improved science content knowledge. The study also found that PSTs had positive attitudes toward video games as instructional tools. Science content progression and PST education relating to games and science education are discussed.

Introduction

The number of science, technology, education, and mathematics (STEM) majors needed to meet the expected needs of our future workforce will grow, yet fewer students are choosing to major in STEM areas, and those who do may be underprepared (Broussard, S.R., et al., 2007; Langdon, D., et al., 2011). This has led many to suggest that middle school students should be targeted for improving STEM competency and career interest, yet evidence suggests that their teachers are themselves underprepared (Darling-Hammond, L., 2000; Llewellyn, D., 2002). Further, middle school students can only benefit if they have the foundational STEM knowledge from their elementary school years, which is often not the case (Ball, D. L., et al., 2005; Wu, H., 1999). Unlike middle school and high school science teachers, who must meet credentialing requirements to ensure competency in their disciplines, elementary teachers teach all subjects and are not credentialed in any subject. Therefore, interventions planned for the middle school level must be preceded by interventions for elementary teachers (Hill, H., et al. 2005), and they must begin during preservice teacher (PST) education, before teaching habits and philosophies are formed.

Project NEO

The goals of Project NEO were to see if a game built around the next generation science standards (NGSS Lead States, 2013) could A) improve PSTs' attitudes toward science; B) improve science competency for PSTs; C) improve PSTs' attitudes toward games in the classroom, and D) improve PSTs' attitudes toward teaching science. This phase I project, funded by the NSF, designed, developed, and tested a game based on the NGSS to help elementary PSTs learn some of the more challenging content they and their future students will face.

The Project NEO Phase I prototype narrative finds our heroine, Talia, being recruited by a league of scientists to help protect Earth from sudden climate changes created by the villain in order to wipe out certain kinds of plant life. In the process of conducting her tests, Talia (the player) uncovers patterns related to latitude and longitude and to day and night hours that lead to a deeper conceptual understanding of the Earth and its orbit around the sun. Future modules developed in Phase II will expand on this narrative and focus on concepts like angle of inclination, axial tilt, rotation, and the interrelation of these factors as they impact geology, climate, flora, and fauna on the Earth.

Tasks are combined in a full-scale inquiry-based learning game that helps the learner solve a bigger science challenge on the interrelation of day–night, latitude–longitude, axial tilt, rotation of the Earth, and the effects on Earth's flora and fauna and society. A mega-level narrative about a villain attempting to cause catastrophes on Earth in a variety of ways, culminating in the destruction of the Earth by an asteroid (near Earth object, or NEO) that integrates all of the science is introduced at the beginning of the unit and drives all science inquiry and learning across the full game.

Method

A mixed model within-subject pretest–posttest and repeated measurement design was used to test the impact of classroom instruction and game play on science content knowledge and attitudes. PSTs science content knowledge was measured prior to classroom instruction (pretest), again at the end of classroom instruction and before the video game intervention (intermediate), and again at the end of the video game (posttest). Analyses examined within-subject change scores on science content measures from pretest to intermediate (effect of instruction), and from intermediate to posttest (effect of game on attitudes) and pretest to posttest on science content knowledge (long-term recall).

Sample

Twenty-four PST education majors at an Upper Midwest university were invited to participate out of a pool of 400 total PSTs. These students were enrolled in an Earth and Space science class for educators, which covered science material related to the Earth's layers, rocks and the rock cycle, plate tectonics, weather, energy use, astronomy, planets, and the solar system. Of those, 22 (92%) students agreed to allow their coursework to be used for research purposes; all students participated in the game. Of the 22 who signed consent forms, 19 played the game, 17 completed the game in its entirety, and 14 also completed the posttest, yielding a usable data set of 64% of those who consented, which was 58% of the total class. There was one male and thirteen females with an average age of 21. All but one were White, with one non-identified, and all were elementary education majors.

Results

H1: PSTs will demonstrate more positive attitudes toward science after playing the game (intermediate–posttest).

Descriptive statistics and paired T-tests were run to examine this. Attitudes did not go up, which is not surprising given the short-term duration of the intervention. Scores on science inquiry went down by 0.40, however, which is surprising ($t\ (12) = 3.128$, $p = 0.009$).

H2: PSTs will demonstrate better conceptual science understanding after playing the game (pretest–intermediate; intermediate–posttest; pretest–posttest).

Eight science conceptual understanding questions were asked. Scores on Items 1–6 increased from preinstruction (3.46) to postinstruction (4.53) and postgame (4.69). Scores on Items 7–8 increased from preinstruction (2.38) to postinstruction (5.30), but decreased at postgame (4.76). Gains were generally distributed across all items. Paired t-tests showed that changes in all item scores were statistically significant from pre- to postinstruction. Scores on the same tests (totals of Items 1–6 and 7–8) after the game were also higher, although the differences were not statistically significant, with the exception of Items 2 and 7; Items 6 and 8 actually decreased.

Item 2 focuses on the conceptual understanding of the path of the sun and was directly tied to the animations of the sun in different cities within the game. Item 7 is an open-ended question focused on the relationship of day–night hours and latitude and longitude designed to assess conceptual understanding rather than factual knowledge.

Item 6 focuses on how long it takes the Earth to turn on its axis, and Item 8 assesses the strength of the learner's mental model of how and why seasons occur in the first place. Because of modifications to the game during the design process, in which planned content had to be reallocated across future games in order to manage learner cognitive, neither of these concepts was directly represented or tested during gameplay. The NGSS and classroom activities are currently being aligned with the game. This work is subsection in which Hypothesizes C and D were also evaluated, but not here.

References

Ball, D. L., Bass, H., Sleep, L., & Thames, M. (2005). A theory of mathematical knowledge for teaching. Paper presented at *The Fifteenth ICMI Study: The Professional Education and Development of Teachers of Mathematics*, 15-21 May 2005, State University of Sao Paolo at Rio Claro, Brazil. Retrieved January 31, 2014, from http://stwww.weizmann.ac.il/G-math/ICMI/ball_ICMI_prop_oct11.doc

Broussard, S. R., La Lopa, J. M., & Ross-Davis, A. (2007). Synergistic Knowledge Development in Interdisciplinary Teams. *Journal of Natural Resources and Life Sciences Education, 36*, 129-133.

Darling-Hammond, L. (2000). *Teacher quality and student achievement*. Seattle: Center for the Study of Teaching and Policy, University of Washington.

Hill, H., Rowan, B., & Ball, D. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educational Research Journal*, 42(2), 371.

Langdon, D., McKittrick, G., Beede, D., Khan, B., & Doms, M. (2011). *STEM: Good jobs now and for the future*. US Department of Commerce, Economics and Statistics Administration (ESA) Issue Brief #03-11. Retrieved November 3, 2012 at http://www.esa.doc.gov/sites/default/files/reports/documents/stemfinalyjuly14_1.pdf

Llewellyn, D. (2002). *Inquire within: Implementing inquiry-based science standards*. Thousand Oaks, CA: Corwin Press.

NGSS Lead States (2013). *Next generation science standards: For states, by states.* Achieve, Inc., on behalf of the twenty-six states and partners that collaborated on the NGSS. Retreived February 5, 2014, from the World Wide Web at http://www.nextgenscience.org/next-generation-science-standards.

Wu, H. (1999). Preservice professional development of mathematics teachers. (March 1999). Retrieved from http://math.berkeley.edu/~wu/pspd2.pdf