

Online Learning Tools for Middle School Science: Lessons Learned from a Design-Based Research Project

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ABSTRACT

This article reports on how design-based research methodology was used to guide a line of intervention research that developed, implemented, revised, and evaluated online learning science curricula for middle school students, including general education students and English language learners (primarily of Hispanic origin). The iterative, design-based research approach was carried out in two stages with multiple steps per stage: (a) stage 1, or informed exploration, identified and described the problem under investigation; and (b) stage 2, or enactment, redesigned previously developed online science units, implemented each unit in case studies, and completed a feasibility evaluation. The present paper focuses primarily on the second stage, demonstrating the process by which online science units were repeatedly refined with input from stakeholders, and then examined for their feasibility to implement, usefulness for helping teachers engage with students, and potential to effectively deepen science knowledge. Data were drawn from multiple sources, including teacher logs, student and teacher surveys, student notebooks, content assessments, and focus groups. Results indicate that the online science units were feasible to implement, usable, and helpful. The data-driven, design-based research methodology proved to be both practical and efficacious, and underscored the critical importance of involving all stakeholders in the process of curriculum creation and refinement. This work offers a model for the development of constructivist science instructional materials for English learners using online, multimedia technology.

KEYWORDS

Design-based Research, English Learners, Middle School, Multimedia, Online, Science, Technology

INTRODUCTION

Despite large numbers in the U.S. population, females and people of three racial groups (African Americans, Hispanics, and Native Americans) remain underrepresented in science, technology, engineering, and mathematics (STEM) education and careers (NSF, 2015). About 60% of Hispanics qualify for support as English learners (ELs) and they are inherently at higher risk for falling behind; nearly half (49%) are U.S. immigrants and 45% live in high-poverty areas (NCES, 2012). The underrepresentation of Hispanics in STEM fields can be traced to differences in past and current participation in STEM-related higher education and in precollege course achievement (NSF, 2015).

Underrepresented U.S. minority students demonstrate a lower level of proficiency than other groups. On the 2013 National Assessment of Educational Progress (NAEP) eighth-grade math assessment, 45% of Caucasians obtained proficient or advanced scores in math compared to 21% of Hispanics; on the recent NAEP eighth-grade science assessment, the percentages were 43% for Caucasians and 16% for Hispanics (Martin, Mullis, & Stanco, 2012).

Inequities in technology access also exist. In the U.S., Hispanic adults are less likely than Caucasian adults to have access to computers and go online (Lopez, Gonzalez-Barrera, & Patten, 2013). However, the situation is brighter for Hispanic youth. More Hispanic teenagers go on the Internet with their cell phones than Caucasian teenagers (Lenhart, Ling, Campbell, & Purcell, 2010), a trend that should be exploited to provide Hispanic students with digital tools for learning.

Despite optimism that technology advances could be used to improve science achievement and technology proficiency, research suggests that most teachers adopt technology passively as a learn-from medium (Wang, Hsu, Reeves, & Coster, 2014), which has yielded insufficient results in student achievement. This manuscript reports on how design-based research methods were used in the development, implementation, and evaluation of a more active use of technology for learning—specifically, interactive online science instructional materials for general education students and ELs. This paper's focus is on how design-based research methods (Anderson & Shattuck, 2012) were employed to systemically guide intervention development, revision, and evaluation across multiple studies to evidence program effectiveness.

LITERATURE REVIEW

This research is rooted in prior research on technology and science learning among diverse learners. Literature on ELs' science instruction and technology use is reviewed below.

ELs and Science Instruction

Science learning can be especially difficult for ELs due to the years of learning and vocabulary knowledge needed to benefit from science instruction in English (Cummins, 1981; Garcia, 1991). To keep these students from falling behind in science, English language reading, spelling, reading fluency, reading comprehension, and writing must be integrated into science instruction (Lee, 2008). Lee, Quinn, and Valdés (2013) propose that ELs' engagement in science and engineering practices involves both scientific sense-making and language and cultural-relevance (Atwater, Lance, Woodard, & Johnson, 2013), which for Hispanic ELs typically includes Spanish language and traditions of Latin America.

Hands-on, inquiry- and project-based interventions, in which students are encouraged to construct their own knowledge by conducting investigations, are supported by national standards (NGSS, 2013) that promote understanding of science concepts especially among at-risk learners such as ELs (August, Branum-Martin, Hagan, & Francis, 2009). Integrating cultural and linguistic practices with science learning lets ELs use their experiences to benefit and not hinder them (Lee, 2008). Compared to passive learning practices, inquiry-based practices give students a better understanding of concepts (Minner, Levy, & Century, 2010), and have been especially beneficial for ELs' science learning (Lara-Alecio et al., 2012; Lee, 2008).

Inquiry-based methods, or project-based learning (PBL), are based on research in the learning sciences and in the design of learning environments (Slough & Milam, 2013). PBL is guided by the following design principles: making content accessible, making thinking visible, helping students learn from others, and promoting autonomy and life-long learning. To help students learn science content, PBL provides opportunities to engage prior knowledge, skills, concepts, and beliefs—and to expose students' thinking through feedback, revision, and reflection (Slough & Milam, 2013). PBL's hands-on approach strengthens ELs' linguistic skills development and reduces barriers to accessing science content. Teachers should consider that ELs bring to the classroom linguistic (Lee,

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