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Abstract

This study utilized student construction of Lego™ WeDo robots and shared language experiences in 3rd and 4th grade Learning Communities to examine how English Language Learners and students with language/literacy disabilities can be supported in acquiring content-specific language along with the scientific concepts. Paired sample *t* tests reported statistically significant gains using a pre-test/post-test design for all learners regardless of identified disability or language proficiency level. Similarly, one-way ANOVAs revealed no statistical differences in gain scores or post-test scores for native speakers with no identified disabilities, students identified with disabilities, and English language learners, evidencing equal-access for all learners to the simple machine science curriculum provided by WeDo.

Introduction

An increasing population of school-aged English language learners (ELL) in the United States presents a number of challenges for schools, families, and the individual children. The Urban Institute (2010) reported that one in five children, under the age of 18, is a child of immigrants, making this the fastest growing segment of the U. S. population. Many children with limited English proficiency (LEP) face academic and social challenges in school. In second language acquisition, Cummins developed the theory of Basic Interpersonal Communication Skills (BICS) and Cognitive Academic Language Proficiency (CALP) wherein a child may become proficient in social language but do not develop competency in receptive or expressive academic language or CALP (Cummins, 2003). According to Cummins, children may appear to have a high degree of fluency while interacting with peers and teachers in social situations, but they may not have mastered the specialized academic language of the classroom. They may comprehend and express understanding for concepts in the home language, but lack the language skills to express these concepts in the academic register of the second language. Teachers may misinterpret their struggle as learning delays and recommend them for special education testing. Additionally, low scores on a variety of academic tasks and developmental assessments, ELLs are often misdiagnosed and misrepresented in Special Education programs. In a study of Californian schools, Artiles et al. (2005) analyzed the placement of ELL students in special education programs and found that the elementary grades reported 53% of the students in special education classes were ELL. Specifically, rates of placement in Learning Disabled (LD) and Language and Speech Impairments (LAS) classes, revealed that ELLs were consistently overrepresented. Similarly, native-English speaking students identified with disabilities also continue to struggle with academic concepts, particularly when acquisition of technological or scientific language is required (Basham & Marino, 2013). Moreover, Dalton et al., (1997) noted in their seminal study that students with disabilities in STEM learning activities frequently: (a) have limited prior knowledge, (b) are reluctant to pose questions, (c) are less likely to have a plan for solving problems, (d) struggle to implement teacher recommendations, (e) have difficulty with inductive and deductive reasoning, and (f) seldom transfer knowledge to other contexts. Thus, as purported by Samonov et al. (2006), both ELLs and students with disabilities often require a great deal of scaffolding to manage the vast amount of information necessary to solve complex inquiries such as those included in STEM curricula. Therefore, it is imperative that teachers design engaging curricular materials that offer a wide range of metacognitive and content-specific language supports.

With the increased emphasis on reading and math, science has become completely absent from many classrooms across the United States (Bautista & Peters, 2010). Yet, science can extend across content areas (math, language arts, art/design, etc.) by encouraging students to develop solutions that incorporate a variety of disciplines (Basham, Israel, & Maynard, 2010). Additionally, science has often been noted as an ideal subject through which to engage at-risk learners (Palincsar, Magnusson, Collins, & Cutter, 2001). It can provide the perfect context for cross-curricular studies because it can be drawn, read, written, spoken, and demonstrated and use of science notebooks to support successful inquiry-based projects in order to enhance science content and processing, while acquiring scientific and/or technical language, particularly for ELLs and students with language/literacy disabilities (Amaral, Garrison, & Klentschy, 2002). In their dual function as recorders of science and language reinforcement, science notebooks help student acquire science content-specific language and strengthen written skills (Nelson, 2010).

Similarly, a curricular design framework, *Universal Design for Learning* (UDL), is increasingly being recognized as an ideal way to operationalize accessible curriculum (CAST, 2011). From a UDL perspective, a curriculum encompasses everything that a learner encounters within a learning experience including standards and goals, instructional materials and tools, and instruction, as well as the means by which outcomes are assessed. As a framework for instruction, UDL uses both instructional practices and modern instructional materials and tools (e.g. technology) to provide an engaging learning environment for all learners, particularly those at-risk. A measurable focus of UDL is to enable each learner to actively and cognitively engage in targeted learning, with a specific focus on making all learners "expert learners." This is accomplished through use of multiple means of representation, expression and action, and engagement to plan curriculum for presumed and known levels of learner variability (CAST 2011). UDL stipulates that curriculum, instruction, and related materials should provide multiple representations of key concepts, principles, and vocabulary. In a technology-enhanced learning experience, such as WeDo to teach simple machines, this can be accomplished via support for visual literacy (making meaning from and with graphics, diagrams, pictures, and images), simulation, video, and sound (McDonald & Howell, 2011).

Methods

Setting

Recent studies suggest that the most powerful teacher education programs require teacher candidates to spend extensive time in schools throughout the program, examining and applying the concepts and strategies they are simultaneously learning about in their courses (Darling-Hammond, 2006). To this end, Indiana University Purdue University Columbus (IUPUC), has initiated partnerships with K-6 schools to establish professional development schools (PDS) to provide a consistent and strategically integrated program of high-quality clinical work, informed by a vision and philosophy shared by university faculty and K-6 practitioners that focuses on providing equitable access to high-quality curriculum and state-of-the-art instructional practice for diverse learners.

IUPUC has adopted Science as one of the key content areas used by our teacher candidates within methods courses and paired field-based experiences. To support this process, various forms of technology have been integrated into the program. These technologies include: Nova-data loggers, digital microscopes, Discovery Dome- inflatable planetarium and full-dome media shows; Lego Education WeDos with clam shell computers; and on-line asynchronous international science discourse. Teacher candidates experience the technology as learners before applying the technology within a field placement. Candidates are then required to design curriculum using the principles of UDL that recognizes the widely diverse learners in current classrooms and build in options to support learning differences from the beginning so curriculum is inherently designed to support all learners. After designing and delivering instruction in partnership with cooperating teachers, candidates reflect on the teaching and suggest areas of redesign and growth.

The purpose of this specific study is to determine whether using technology with student-centered inquiry enhanced the development of shared language among elementary students with diverse learning needs. Using the principles of Universal Design for Learning as our framework, we incorporated LEGO™ WeDos in student-centered inquiry into simple machines to meaningfully merge science instruction with deliberate support for content-specific language acquisition.

Participants

This study was implemented with 158 third and fourth grade students in six different inclusive general education classrooms across four different schools. Of these 158 students, gender was split evenly, 79% were Caucasian, 15% Latino, and 5% African American/Bi-racial. 10% of students were English Language Learners and a further 9% were students identified with disabilities (learning disabilities, autism and emotional-behavioral disorders). Additionally, 58 English Language Learners in a summer enrichment program also participated in this study. Again, gender was evenly split while 66% of these ELLs were Latino, 28% were of Asian descent, and 6% were Caucasian, with 50% of these ELLs eligible to receive free lunch.

Study design

WeDo was used as the educational intervention, a student-centered inquiry into simple machines. WeDo uses visual literacy to operationalize the principles of simple machines through tethered robot construction. The LEGO® Education WeDo Construction Set was designed to be an easy-to-use set to introduce young students to robotics. Students were able to build LEGO models featuring working motors and sensors; program their models; and explore a series of cross-curricular, theme-based activities while developing their skills in science, technology, engineering, and mathematics as well as language, literacy, and social studies. The Construction Set comes with printed building instructions and visual literacy software for 12 models and contains more than 150 elements including a motor, tilt sensor, motion sensor, and LEGO USB Hub. Preceding the WeDo inquiry, students were given an objective, multiple-choice pre-test to assess baseline knowledge related to simple machine mechanisms (pulleys, gears, etc), definition of terms, and concepts related to simple machines. This was followed by the WeDo inquiry, using science notebooks and the 5R Instructional Model (Weinburgh, Silva, Malloy, Marshall, &

Smith, 2012) to provide specific support for content-specific language acquisition. The 5R instructional model was selected as a protocol for content-specific language acquisition. *Reveal* involved identifying and introducing academic words that do not have a comparable every day word. Examples of these were often the name of a piece of equipment or part of a structure. These words had to be specifically revealed to students by providing the word or term along with a visual model of the structure or demonstration of how to use the equipment. *Replace* involved modeling or replacing everyday words that children use with a corresponding scientific word. *Reposition* involved deliberately situating the new scientific word into phrases and descriptions that are more like “talking science” (Weinburgh et al., 2012). *Repeat* simply meant taking every opportunity to use newly introduced words, aiming for at least 6 to 10 uses in order for students to incorporate into their repertoire (Weinburgh et al., 2012). Finally, *Reload* involved reminding students of the academic words that emerged from earlier lessons, by “reloading” the vocabulary. Students used their science notebooks in combination with the 5R model to sketch and record their own definitions for academic terms, as well as to practice recording observations using content-specific terminology. Following the WeDo inquiry, students completed the post-test, which presented the same questions as the pre-test in a different order. The pre-and post-test used text in a multiple choice format with photographs of various parts of simple machines from the WeDo robots that students had to identify and define. In addition, pictures of simple machine parts from other machines were also used to assess generalization or transfer of knowledge to other contexts.

Results

Paired sample t-tests for pre and post test mean score comparison yielded statistically significant increases for all learners across all inclusive classrooms [$t(131) = -14.73$, $p<.000$], English Language Learners across all inclusive classrooms [$t(12) = -4.15$, $p<.001$], and Special Education Learners across all inclusive classrooms [$t(10) = -5.86$, $p<.000$], suggesting that WeDo as an instructional intervention was equally effective for all learners. The gain score (from pre to post-test) and post-test means of students who were native speakers with no disabilities, English Language learners, and Special Education learners did not present with significant differences using a one-way ANOVA ($F(2,129) = .084$, $p=.920$) , again evidenced equal-access to the simple machine science curriculum provided by WeDo.

Similarly, ELLs in the summer enrichment program also demonstrated statistically significant gains from pre-test to post-test [$t(57)= -6.308$, $p< .000$]. Additionally, pre-test scores, post-test scores, and gain scores for students grouped by language proficiency Level 1(29.3%), Level 2 (34.5%), Level 3 (29.3%), and Level 4 (6.9%) were compared using a one-way ANOVA. No statistical difference among ELL students at different levels of English proficiency were detected on pretests or gain scores, however statistically significance difference in post-test scores between the proficiency levels was detected. ($F(3,54) = 3.89$, $p=.014$). A Tukey HSD determined that Level 2 students scored lower on the posttest ($m=8.35$) than Level 4 students ($m=14.5$).

Finally, independent sample t-tests used to compare mean scores on pre, post, and change scores between ELL students in traditional heterogeneous classrooms and ELL summer school which exclusively hosted ELL students, which dictated homogeneous grouping of ELLs. Statistically significant differences were detected between ELLs in traditional heterogeneous classrooms on the pretest ($t(70)= -2.30$, $p < .024$), post-test ($t(70)= -4.42$, $p < .000$), and average gain scores ($t(70)= -2.66$, $p < .010$). This may provide support for the efficacy of heterogeneous grouping to provide ELLs with native English-speaking peers as language models. However, it should also be noted that ELLs in the traditional classroom were comprised primarily of students with 4/5 levels of language proficiency (62%), while in the summer school enrichment program, only 6% of the ELLs were at a level 4 proficiency.

Discussion

The findings from this study suggest that students benefited equally from We-Do regardless of language barriers and/or identified disabilities and that WeDo provides an engaging and effective platform for creating an inquiry-based learning experience in simple machines that is accessible to diverse learners. There are however, some noted limitations to the current study. Foremost, given the participants were students in classrooms and programs that served as field experience sites for pre-service teachers at IUPUC, they are primarily convenience samples, rather than randomized or purposefully selected samples, which limits generalizability. Similarly, because different teacher candidates were assigned to the various classrooms, this study design does not provide control for treatment or intervention effects. Though the WeDo visual literacy format allows students to complete the robot construction fairly independently, the teacher candidate is instrumental in integrating and implementing the 5R instructional model and science notebooks for content-specific language acquisition. Lastly, to strengthen the empirical case for WeDo as an instructional intervention to promote student gains in conceptual knowledge, skills, and scientific terminology related to simple machines, researchers plan to randomly assign classrooms to simple machines taught through traditional center-based instruction as the intervention, with WeDo provided as a culminating activity (pre-test, stations, post-test, We-Do). This would provide a type of comparison/control group for more rigorous examination of WeDo as the intervention activity (pre-test, WeDo, post-test).

Still, the initial findings from this study suggest that WeDos provide a significantly successful mode for engagement and learning for elementary learners in the area of simple machines, particularly for at-risk learners. Identifying effective instructional supports, particularly for instruction in the STEM areas for our most vulnerable populations of students is critical and timely. Despite an increased national focus on science, technology, engineering, and mathematics (STEM) instruction, students with disabilities continue to struggle with STEM content at both the K-12 and postsecondary levels (Basham & Marino, 2013). In fact, currently the United States is ranked 27th in science and 30th in mathematics on the latest Program of International Student Assessment (Baldi et al., 2007). Students with disabilities perform even lower than their peers without disabilities on these standardized measures and often become disenfranchised with STEM content as early as middle school (Marino, 2010). As a result, very few students with disabilities pursue STEM related careers, even though many are highly capable of making valuable contributions (Leddy, 2010). Similarly, according to a recent *Education Week* article, the United States gets poor grades for stimulating minority interest in STEM careers, particularly for students who speak Spanish at home (Robelen, 2010). These STEM related fields offer numerous life and work opportunities for at-risk learners (Basham & Marino, 2010). In many countries, including the United States, careers requiring an applied understanding of STEM are quickly replacing traditional manufacturing jobs (Kaku, 2011). Identifying and integrating instructional technologies, such as WeDo that incorporate the principles of UDS can be utilized to engage students and increase usability of STEM curricular materials. Understanding efficacious instructional support strategies can help teachers provide effective instruction for a wide range of learners, particularly in the STEM content areas.

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