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The Effect of Globally Collaborative Project Based Learning on Secondary Students' Achievement in Advanced Placement Environmental Science

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ABSTRACT

Prior research suggests skill-based and social benefits for American K-12 students who engage in project-based learning (PBL) and global collaboration projects (GCPs) in the classroom. Yet, little is known how both PBL and GCP combined may improve student achievement, especially in the sciences. This quasi-experimental, explanatory sequential mixed-methods study examined the impact of students' participation in a Global Collaboration PBL (GCPBL) in Advanced Placement Environmental Science (APES) on student achievement. Using a nonequivalent, two-group, pre-test and post-test design, purposefully selected APES classes used a common 3-month PBL (intervention) on global food supply and world hunger environmental science content based upon the APES standards. PBL assessment included a pretest and posttest and a group poster to convey information learned on the APES topic. Treatment classrooms participated in a GCPBL with classrooms in Mexico, whereas control classrooms engaged in the same PBL, but without any globally collaboration. While no significant differences in achievement were evidenced by pre- and post-test scores and PBL products (posters) between control (PBL) and treatment (GCPBL) classrooms, all students scored significantly higher on the post-test than pre-test, and control classrooms had slightly larger gains. Findings suggest further considerations are warranted about the potential of GCPBL in environmental science learning.

Keywords: academic achievement, advanced placement, environmental science, global collaborations, project based learning

INTRODUCTION

There are several issues that are global in nature: poverty; world hunger; climate change; water access and quality; pollution of air, water, and soil; and sustainability, among others. Issues such as poverty and hunger affect all humans in all countries, and need to be examined thoroughly so students can truly understand scientific phenomena that they may not directly experience (Suarez-Orozco & Sattin, 2007; Sussmuth, 2007). Suarez-Orozco and Sattin, (2007) suggest the education of many American learners today is disconnected from the realities of a global world. With an ever growing competitive economy (Wagner, 2010), evolving communication technologies, and global environmental challenges, it is imperative that American K-12 students have the multi-disciplinary knowledge, and interpersonal skills to learn, work, and function as global citizens of the 21st century (Trilling & Fadel, 2009). Therefore, there is an urgent need to implement

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curriculum and pedagogies that instill these skills within the American public-school system (Balistreri, Di Giacomo, Ptak, & Noisette, 2012). These proficiencies are commonly referred to as *21st century skills*. These are "the skills, knowledge and expertise students must master to succeed in work and life; it is a blend of content knowledge, specific skills, expertise and literacies" (P21, 2015, p. 1). These 21st century skills consist of: content knowledge that includes global awareness and economic, financial, civil, health, and environmental literacy in addition to core subjects; life and career skills which include initiative, social skills, productivity and responsibility; learning and innovation skills; and technology skills (see P21, 2007).

To develop global citizens in the twenty-first century, one should not use the twentieth-century factory model of education (Prather & Field, 2001; Suarez-Orozco & Sattin, 2007); rather, American K-12 schools should embrace and embed instructional strategies that facilitate a global education and develop students' abilities to solve current and future global problems (Wagner, 2010). For this study, the author has defined *global education* as a curriculum that provides learning opportunities for students to develop the knowledge, competencies or skills, and mindedness to prepare for citizenship in a global society. To meet this challenge, American K-12 educators have started facilitating international interactions (i.e. globally collaborative assignments and projects) among students to correspond with the realities of the 21st century (Longview Foundation, n.d.). Yet, current standards, curriculum, and instruction neither include, nor prioritize, global education. *Project based learning* (PBL) is a vetted pedagogical tool to engage K-12 students in real world problems, questions, or challenges through group collaboration (Larmer, Ross, & Mergendoller, 2009). *Global collaboration projects* (GCPs) are PBLs that involve students working with students in a different geographical locations using technology (Lindsay & Davis, 2013) on a common goal or issue. Social-constructivism is a foundation for global education, 21st century skills, PBL, and GCPs, since students and teachers are engaged in real-world or international issues that offer diverse opportunities for socialization and discourse with their peers. Through creation of these opportunities for students to collaborate with peers in other countries, students may garner a better understanding of the global issues that may not impact themselves, but do impact their international peers. A social, global connection may also provide additional learning of *content* related to learning goals. If these learning experiences are situated in a real-world, relevant academic context, such as environmental science, there is potential to increase student achievement.

The research literature does not explore the efficacy of peer to peer global collaboration in terms of academic achievement or augmenting students' understanding of global-scale environmental science concepts and issues. Therefore, the intention of this research was to explore how global interactions in an Advanced Placement Environmental Science (APES) classroom enhanced students' understanding of the concept of global food allocation and distribution, and consequential world hunger issues.

NATIONAL ASSESSMENT OF STUDENTS' UNDERSTANDINGS OF ENVIRONMENTAL SCIENCE CONCEPTS

The Advanced Placement (AP®) program allows high school students to take college-level courses while in high school, and potentially earn college credit by taking a nationally standardized exam at the end of the school year (Warne, 2017). One such course is APES, and its assessment (exam) is a mixed format exam – two 90-minute sessions consisting of a multiple-choice and free-response section. The multiple-choice section consists of 100 questions and the free-response section contains four questions. A student's final or composite score is the total score of the weighted multiple-choice (60%) and free-response (40%) sections, converted to a single number ranging from 1 to 5. Students who score a 3 or above on their APES exam may be granted course credit and/or be exempted from taking similar introductory courses in the college or university that the student is admitted (Morgan & Ramist 1998). Although the number of students taking AP courses and exams has increased in the last ten years, the percentage of students earning proficiency (i.e. earning a total score of 3 or above) on the exams has decreased; in 2006, 63.7% of students were proficient on AP math or science exams (College Board, 2006) as compared to 61.4% in 2017 (College Board, 2017). It should be noted, however, that as AP courses grew in popularity and more AP Exams were given, there was an overall downward trend in pass rates (Judson, 2017). Among the science, technology, engineering, and math (STEM) AP Courses, this is particularly salient in APES. In 2017, 49% of AP students had a passing AP Exam score (College Board, 2017), yet APES was deemed as the lowest scoring science with only 9.3% of APES students scoring a 5, 24.4% scoring a 4, 15.5% scoring a 3, 24.6% scoring a 2, and 26.3% scoring a 1. As course content remains largely the same, one would ask what knowledge a student needs to know and skills to demonstrate in order to be successful on the APES examination (Flanagan, 2016).

Regardless of scores, the APES exam is a valuable metric for assessing students' environmental understanding of high school science students throughout the U.S. Correlational coefficients are computed to measure internal consistency (Cronbach & Meehl, 1955; Ewing, Huff, & Kaliski, 2010). The most recently released reliability coefficient (2007-2008) for the multiple-choice questions is generally very high, between 0.86 and 0.94; the AP Exam's validity is ensured through curriculum surveys and comparative and longitudinal studies (Morgan & Ramist, 1998).

STUDENTS' KNOWLEDGE GAPS RELATED TO THEIR ACHIEVEMENT IN ENVIRONMENTAL SCIENCE

There are numerous studies that identify the need for environmental education, what they *should* learn, or the attitudes of teachers or students towards environmental issues (Duckworth, Walker-Levy, & Levy, 2005; Kirkwood-Tucker, Morris, & Lieberman, 2011; Rickinson & Lundholm, 2008); however, there are few current studies that document what environmental science content students know or do not know. Based on previous APES Exams, the College Board (2006; 2017) identified that globally, students had trouble quantifying and explaining the energy efficiency of grain production versus that of meat production. Students were generally able to discuss advantages of a diet with meat to a diet with no meat, but not the advantages or disadvantages of a diet with little meat. Students were able to identify human activities, other than anthropogenic climate change, that decrease the amount of freshwater flowing into wetlands, but could not describe these activities in detail. Many APES students confused pesticides with fertilizers as potential sources of phosphate runoff, and incorrectly identified organic fertilizers as substances low in phosphorus. If current global environmental, political and social problems, such as access to water and world hunger, are to be solved, we need a generation of scientifically literate citizens who can take an active role and make informed judgments (Hodson, 2003; Kirkwood-Tucker et al., 2011). Adding experiences that connect students to international peers can enable students to develop more contextual understanding of global issues and potentially improve achievement scores.

STRATEGIES FOR STRENGTHENING STUDENTS' UNDERSTANDINGS OF AND ACHIEVEMENT IN ENVIRONMENTAL SCIENCE

PBL is an active, student-centered instructional approach to teaching and learning that investigates genuine problems and solutions while developing 21st century skills (Boss, 2011; Cervantes, 2013). This dynamic group approach includes technology tools for students to collaborate, research, communicate, create, and publish "authentic" products on engaging topics of interest (Boss, 2013, p. 5). PBL goals align well to the Common Core State Standards and the Next Generation Science Standards, as they focus on students' conceptual knowledge and critical thinking skills. (Condliffe et al., 2017). Numerous studies examined the value of PBL pedagogy and its effect on student achievement, attitudes and behaviors (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000; S. A. Campbell, 2012; Capraro, Capraro, & Morgan, 2013; Chang, 2001; Hasni et al., 2016; Hernandez-Ramos & De La Paz, 2009; Lin, Ma, Kuo, & Chou, 2015; Mudrich, 2017; Schneider, Krajcik, Marx, & Soloway, 2002; Stratford & Finkel, 1996; Thomas, 2000). The *uniqueness* of PBL is the artifact construction that reflects students' gained knowledge and/or attitudes of the explored issue, and presented to the public using videos, photographs, posters or models (Kokotsaki, Menzies, & Wiggins, 2016). Research shows that PBL has been effective in the science classroom.

The Use of PBL in High School Science Classrooms

Chang (2001) studied the effects of PBL instruction on students' earth science achievement in Taiwan. Tenth grade earth science students participated in a two-week, pretest–posttest experiment, where the experimental group students received the PBL, and the control group received a direct teaching method. In the PBL group, students had to define and place a real-world science problem (natural hazards) into context, research the problem, collect data, and analyze their own solutions to the problem. Results showed that the PBL was more effective in promoting students' achievement than the direct teaching method, as the students in the experimental group scored significantly higher in areas of knowledge and comprehension.

Al-Balushi and Al-Aamri (2014) also examined achievement, where 11th grade female students were divided into two groups – an experimental group that conducted five environmental-based projects, and a control group that studied the content using traditional methods. Results indicated that the experimental group's participation in projects had a significant positive impact on their environmental knowledge and science attitudes, as they outperformed the control group on both instruments. Further, the most attitudinal impact was observed in the projects for which students created a documentary movie, an environmental exhibit, and a school-wide environmental campaign (Al-Balushi & Al-Aamri, 2014). A meaningful engagement and more contextual effect could be possible if these projects were conducted while collaborating with peers across the world.

Leveraging PBL and global education to enhance secondary students' understanding of and achievement in environmental science

Global education can further develop higher-order cognitive skills and content understanding (Boix Mancilla & Gardner, 2007; Cheng, 2007; Hett, 1993; Hugonnier, 2007; Suarez-Orozco & Sattin, 2007). Schleicher (2012) acknowledged that current curricula are more learner-centered; therefore, the educational system needs to create new avenues for student-driven learning in a connected society. Reimers (2009) argued for the use of technology in education to promote and create global learning communities that support the development of global awareness and competency among students. With the increased availability of technology and Internet access, students are leaving the traditional classroom and conducting science inquiries around the world, thus leveling the playing field and flattening classrooms (Lindsay & Davis, 2013).

Like PBL, GCP could be ascribed to foster improved 21st century skills (Cook, Bell, Nugent, & Smith, 2016) and increase students' engagement, motivation, social skills and achievement in students (Atwater, 1996; Cui, 2013). In a classroom using GCP, students and teachers can connect to communicate, collaborate, and create a shared artifact with other students anywhere on the globe. These interactions "foster cultural understanding and global awareness in the process of learning" (Lindsay & Davis, 2013, p. 7). Therefore, the authors theorize that GCP combined with PBL may provide an avenue for students to develop not only social and affective skills, but perhaps enhancing cognitive skills also. This is especially relevant in environmental education because of the global context of current environmental issues. Translation tools allow students to overcome language barriers and make meaningful connections. Increased enthusiasm, engagement, achievement scores, and global mindedness are all potential outcomes of participating in PBL enhanced with global collaboration (Cook, Smith, Lan, & Carpenter, 2016; Lindsay & Davis, 2013; Merryfield, 2002). Although there have been studies about the types and benefits of global collaborations (Bickmore, 2009; Cook, Bell, et al., 2016; Daniels, Cajander, Pears, & Clear, 2010; Johnson & Johnson, 2010; Kirkwood-Tucker, 2009; McTighe & Seif, 2010; Merryfield & Harris, 1992; Nugent, Smith, Cook, & Bell, 2015; Tye & Tye, 1999), little is known about the relationship between students' content acquisition as evidenced by academic achievement from participating in GCPs in the secondary science classroom. While PBL methods have been linked to increased student achievement in STEM courses compared to traditional methods (Blumenfeld et al., 2000; Hasni et al., 2016; Schneider et al., 2002), there is a lack of empirical research with outcomes focused on student achievement of environment science in classes using PBL with a global collaboration component and comparing that achievement with a PBL with no global collaboration. This research sought to assess if a Globally Collaborative PBL (GCPBL) augments students' understandings of environmental science related to global hunger in an APES context.

Theoretical Framework

The theoretical foundation for this study in PBL as the vehicle for the GCP lies in the social-constructivist learning paradigm (Shepard, 2008), which blends and borrows concepts from cognitive, constructivist, and social learning theories. Cognitive theory states that learning is an active process in sense-making, where existing knowledge can either enhance or impede new learning, and intelligent thought involves self-awareness and monitoring (Shepard, 2008). With social learning theory, people learn via modeling and observing behavior, attitudes, and outcomes of those behaviors (Bandura, 1977). In constructivism, knowledge is constructed by the learner (Driver, Asoko, Leach, Scott, & Mortimer, 1994); as children grow and develop from a young age, their knowledge continues to build upon itself as they experience life events. A subset of social learning theories, constructionism states that students can create knowledge through discovering patterns, using technology, and collaborating with other students to create a product. Thus, knowledge constructed from a social experience like GCPs is related to understandings science content. This study used GCPBL to explore social constructivist pedagogies and encourage environmental science content acquisition.

The purpose of this study was to explore the effect of an identical PBL in comparable APES classrooms, some classrooms with a GC component and some classrooms without a GC component, on APES students' understanding of worldwide food allocation and distribution, or put more simply, the causes and consequences of the global food supply.

RESEARCH QUESTIONS

This study was framed by the following research question, to what extent does a participation in a GCPBL augment APES students' understandings (achievement) of global food supply and world hunger issues compared to participation in an identical PBL (intervention) without GC?

1. Is there a significant difference in students' knowledge of hunger within the control (PBL), treatment (GCPBL), and between control and treatment groups in pre- and post-test scores?
2. Is there a significant difference in students' knowledge of hunger between the control (PBL) and treatment (GCPBL) groups in project artifacts (posters)?

HYPOTHESES

1. Science content understanding will increase a higher degree for the treatment group as a result of the combining PBL with GC.

RESEARCH METHODOLOGY

For this research, a quasi-experimental, explanatory sequential mixed methods design was used; it is a two-stage design in which quantitative data is collected and analyzed, followed by collection and analysis of qualitative data to help explain the quantitative results (Creswell, 2014; Creswell & Plano Clark, 2011). In the first, quantitative phase of the study, AP exam-like items were used for pre- and post-test scores collected from all APES students in the control and treatment groups. In the second phase, qualitative data were collected through coding of student PBL and GCPBL artifacts (posters that communicate the importance of understanding world hunger issues) to explore changes and differences between the control (PBL) and treatment (GCPBL) APES classes related to the concepts of food supply and global hunger issues. The rationale for selecting this design is that the combination of quantitative and qualitative approaches will provide a more complete understanding of the inferences and conclusions by using both approaches rather than a singular approach (Creswell, 2014; Creswell & Plano Clark, 2011; Onwuegbuzie & Leech, 2003; Tashakkori & Teddlie, 1998). This study is from a larger study exploring the affordances of GCPBL on students' global mindedness and 21st century skills (Sahabi, 2018).

Participants

Smithville Independent School District (pseudonym) is one of Texas' largest, serving over 100,000 students among 115 campuses in south central Texas. Two teachers, who taught two sections of APES at two different high schools in the same district, were selected. The researcher was one of the two teacher participants and the second teacher had similar years of teaching experience in APES in Smithville. To address potential partiality, the researcher chose another APES teacher and students to a) not appear biased for using her own students, and b) add more data points for the aggregate data used (class average test score). Participants in this study were purposefully selected APES classes, containing 82 students distributed across four classes at two suburban high schools in Smithville. There were 38 students in two classrooms of the control group, approximately 16 years old. This comprised of 15 males and 23 females, who self-reported as 42% Caucasian, 32% Hispanic, 3% African-American, 8% Asian, and 15% who identified as *Multi-ethnic*. Sixty-eight percent of this group visited countries outside of the U.S., and 21% has lived in countries outside of the U.S. There were 44 students in two classrooms of the treatment group, approximately 16 years old. This comprised of 17 males and 27 females, who self-reported as 43% Caucasian, 21% Hispanic, 5% African-American, 2% Asian, and 29% who identified as *Multi-ethnic*. Seventy-three percent of this group has visited countries outside of the U.S., and 11% have lived in countries outside of the U.S. Since the participants in this study self-selected the AP course, they were not placed randomly; students were already assigned to classrooms. This nonequivalent control group design (D. T. Campbell & Stanley, 1963) involved an experimental group and control group that were given a pretest and posttest, but the groups did not have pre-experimental equivalence.

Intervention

A *World Hunger PBL* was developed by two teachers focused on the APES standards of populations and land/water, which fall under the global issue of world hunger. In the fall semester, each teacher randomly chose one class section to complete the *World Hunger GCPBL* (meaning students collaborated with students in another country as treatment), while their other section completed the *World Hunger* PBL (meaning without collaborating with students in another country as a control). All other aspects of the PBL were identical (i.e. lesson plans, lecture notes, videos, quizzes, assessments, and lab exercises) for both teachers and classrooms.

World Hunger PBL (Control)

This study addressed one environmental issue, world hunger, which is at the forefront of social and political agendas. In May 2015, world leaders gathered with the goal to create a path tailored to ensure that all people be armed with the knowledge and skills to be effective global citizens (United Nations Educational & Cultural, 2015). In drafting the transformative global education agenda, Education 2030, the heads of various intergovernmental organizations, local governments, educators, and civilians envisioned a plan that built on Sustainable Development Goals (SDGs), calling for an "equitable quality education for all" and recognizing that education is a "main driver of development and in achieving the other proposed SDGs" (United Nations Educational & Cultural, 2015, p. 67). In 2016, the United Nations released 17 SDGs to fight poverty, inequality and climate change over the next 15 years (United Nations Educational & Cultural, 2015). The global collaboration project topics in this study were taken from the SDGs, particularly 2 (Zero Hunger) and 10 (Reduced Inequalities). Additionally, the *Topic Outline of APES* (College Board, 2013) indicates that 10-15% of the AP Exam covers land and water use (e.g. agriculture, food requirements/ nutrition, Tragedy of the Commons), and 10-15% covers populations (e.g. population ecology, impacts of human population dynamics, strategies for sustainability) – the topics covered in this study. Since the nature of the global issue of hunger content is relevant to the APES curriculum and aligned to UN directives, the APES course component related to world hunger was selected for this study. In addition, high school aged students (aged 15 to 19) in APES courses are cognitively prepared to examine global issues of concern (Warne, 2017), yet limited in their global experiences (Balistreri, Di Giacomo, Ptak, & Noisette, 2012), making them ideal for understanding the science content presented, engage in 21st century skill growth, and expand their global mindedness.

World Hunger CGPBL (Treatment)

In creation of the World hunger GCPBL, a Google Plus community was created for students to post and respond to their international peers. Both teachers communicated with a Mexican teacher, an established contact of the researcher, via email and drafted a Google doc to finalize the activities and due dates. One class at each American school worked with 10th grade students in a Mexico City school. Ten groups were composed of three American students and three Mexican students, while 10 groups were composed of three American students and four Mexican students. Each group needed at least one Gmail address that would post to and respond on the Google Plus community. There were a total of four activities: an introductory slide creation; a bilingual hunger survey; a journal reflection/discussion; and a poster (see descriptions and products of these activities in **Table 1**). These activities are listed in their chronological order as they were conducted during the study. Groups were assigned numbers that were used in posts along with activity number (e.g. Team 6, Post #1). Groups were encouraged and able to correspond and asynchronously ask questions before moving on to the next activity. While the treatment groups posted communication and their products to the Google Plus community, the control groups posted their products on Google Classroom. **Appendix 1** contains aspects of activities 1, 2, and 4 as examples.

Table 1. World Hunger Project activities

Activity Number	Description	Product
1	American and Mexican groups produced slideshows to establish contact and introduce themselves to their peers.	Google Slideshow
2	Mexican students created a bilingual (Spanish/English) survey on the topic of local and global hunger issues.	Google forms survey posted on social media (Twitter and Instagram) using the hashtag #GlobalCollaboration
3	Students described their feelings about world hunger and responded to several questions, communicating back and forth upon viewing background information.	Journal entries and correspondence on the Google + community page.
4	Students collaborated and created a Google slide to generate awareness about the global issue or provide a solution for world hunger.	A picture was converted from a Google slide and posted on social media using the hashtags #EndWorldHunger and #GlobalCollaboration

161. Factors contributing to the rise in world hunger include all of the following EXCEPT:

a. unequal distribution of available food supplies
b. loss of or decline in arable land
c. increasing rate of population growth
d. increasing poverty in developing countries
e. increasing consumption of vegetable protein in place of meat protein

Figure 1. Sample unit test question regarding factors contributing to world hunger

PBL COMMON CONTENT-BASED ASSESSMENTS

The data collected and analyzed for measuring students' understanding of environmental concepts and issues during this study were pre-post test scores from an APES styled unit exam and coding of student artifacts (PBL posters).

Hunger Unit Exam

Prior to the PBL and GCPBL, all students took a 30-item, selected response (A-E) unit pre-test on food supply and world hunger (or hunger for short) to measure students' understandings of environmental science content understanding and achievement. To measure the impact of GCPBL on growth in achievement (compared to control PBL), at the end of the project and unit, all students took the same 30-question selected response exam as a post-test. All questions for this exam were patterned upon questions from official, released APES examinations and were directly related to AP content on hunger and nutrition, agriculture, global economics, and land and water use (see **Figure 1** for a sample test question). Questions were pulled from previously released AP Exams or a test bank of questions from the textbook used in Smithville ISD.

The APES textbook authors created a test bank with other veteran APES teachers who patterned the questions after the AP Exam (e.g., five distracters, questions that matched terms, and questions relating to tables, graphs, or figures). According to the textbook authors, "the test items have been checked for relation with the text content and notation, overall usability, and accuracy" (Friedland, Relyea, & Courard-Hauri, 2012, p. *xx*). Content validity of the hunger unit test was established via judgmental validation by three APES teachers with more than seven years of classroom experience, such that they rated the questions to determine if the items were relevant to the dimensions of hunger issues as stated in the course description (College Board, 2013) and assessed if the questions adequately represented the science content of the topics and standards (Creswell, 2014; Tashakkori & Teddlie, 1998). Their ratings affirmed the questions as they were written, establishing concurrent validity from content validity, in that the questions were deemed valid based on their relevance and alignment to the *College Board standards* (Goal 5) (College Board, 2013). Test-retest reliability was not established as a pilot test was not administered prior to this study. This was mitigated by

Table 2. Summary of template analysis method

APES Science Content Topic	Key Terms (Codes)	Example	Data Source
Population	impacts of human population on hunger	150 million children are malnourished End World Hunger	PBL poster products ($N = 23$)
Land and Water Use	feeding a growing population human nutrition fishing global economics	we produce enough food for every person to consume 2700 calories everyday	

the fact that the students were given alternate forms of the test (scrambled questions), and there was a three-month time gap between the pre- and posttest.

PBL Poster Artifacts

Students were also assessed on science content understanding from an artifact: a World Hunger GC/PBL product (a poster). The intent of the poster was to communicate and inform peers about the concerns of global food supply and world hunger, and of what they learned as a result of the GC/PBL, at the end of the unit before the post-test administration. Student pairings were provided latitude on the poster content and presentation, as long as it related to communication of the presented topics in the unit related to environmental science. Students were encouraged to incorporate graphics into their posters to visually convey the importance of this issue using the content knowledge gained from their respective GC/PBLs. See **Appendix 1**, Activity 4 for two examples of PBL posters students created from the intervention.

Data Collection

The data collection procedure chosen for this study was designed to use that collected through test scores, poster artifacts, and demographic data of students. The data was collected from September to January of the 2016-2017 school year. The quantitative phase consisted of collection of pre-post unit test scores. Scores from the administrations of the unit exam were entered into a Google spreadsheet, using each student's unique study ID number. In the second, qualitative, phase, GC/PBL artifacts were coded and quantified, for the qualitative themes to link to the quantitative results for the intent of explanation (Creswell & Plano Clark, 2011).

Data Analysis

Scores from each test administration were aggregated at the classroom level and analyzed with paired samples t-tests to examine the change in average score between each pre- and posttest in both the control and treatment classes. Independent samples t-tests were run for the data taken from the pre- and posttest to test whether there were statistically significant differences between the two groups before and after the intervention. Descriptive statistics were run to determine mean and standard deviation for each set of scores, and a Cohen's *d* effect size value was calculated for all results. Effect size was calculated by dividing the mean difference between the paired groups by the standard deviation of this difference for paired samples, and dividing mean difference by the pooled standard deviation for independent samples.

World Hunger Project poster artifacts (N=23) were divided into control (10 artifacts for the PBL) and treatment (13 for GCPBL) groups. A codebook was developed by the researcher and colleague. This template analysis for the student-created products was based on the topic outline of College Board's (2013) AP Environmental Science content standards and was coded *a priori* from topics III and IV, related to *human population* and *land and water use*. Population was subdivided into two coded subcategories of *human population biology* (e.g. population ecology; carrying capacity; reproductive strategies; and survivorship) and *human population impact* related to world hunger. Land and water use was subdivided into three subcategories of *global agriculture* (e.g. nutrition, feeding a large and growing population); *global fishing* (fishing techniques, overfishing, aquaculture; relevant laws and treaties), and *global economics* (globalization; World Bank; Tragedy of the commons, and relevant laws and treaties). **Table 2** displays a summary of the key terms and characteristic responses that were used to code each source of qualitative data. Once the categories and subcategories were established, the agreement was made to record each time elements of the categories were observed. Each poster was coded using content analysis and scored (0 = not observed; 1 = observed) according the number of observations recorded for each of the categories. Each occurrence of each of the codes was recorded into a spreadsheet and totaled for each construct to develop frequency counts. Each poster was coded separately by two raters and the frequencies compared; each poster was discussed (if there was disagreement) until there was full agreement on each artifact's codes.

Table 3. Means, standard deviations and paired samples t-tests for pre/post Hunger Test scores

Classroom Groups	Pre/post	N	*M*	*SD*	*df*	*t*	*p*
Control (PBL only)	Pre	2	59.90	1.05	1	53.81	.012
	Post	2	79.81	1.58			
Treatment (CGPBL)	Pre	2	61.23	1.66	1	18.51	.034
	Post	2	77.70	2.92			

Mixed Methods Analysis

In this study, mixing occurred in two places: at the study design stage when formulating the research questions; and when interpreting outcomes of science content understanding by research question for quantitative (research question 1) and qualitative data (research question 2) to holistically interpret augmentation in students' environmental science understanding (achievement) through participation in a GCPBL as compared to an identical PBL with any globally collaborative components. Credibility was established by interpreting the constructed realities of the participants in their context through collection of artifacts, prolonged engagement throughout the study by observing all activities, and peer debriefing with a professor outside of the context (Erlandson, Harris, Skipper, & Allen, 1993). Triangulation (Creswell & Plano Clark, 2011; Erlandson et al., 1993; Lincoln & Guba, 1985) involved gathering data from two different measurements, using different methods (quantitative and qualitative), and implementing the intervention in different classrooms, thus enhancing validity and reliability. In this study, the researcher used purposive sampling and supplied a highly detailed description of the research methodology to allow readers to make their own judgments about its transferability. The researcher, however, does not claim that the results of this study apply to all other situations. In this study, both dependability and confirmability were established through an audit trail and intercoder agreement (Creswell, 2014) from cross-checking codes by a second rater outside of the context. Although half of the participants were the researcher's students, the researcher did her best to reduce bias by keeping records of all data (i.e. unit exam scores, GMS scores and responses, and PBL products) and communication across teachers involved, in order to show objectivity and that any negative findings were not suppressed. It should also be noted that a second campus was chosen for this study for the researcher to not appear biased for using her own students, as well as developing generalizability. The second campus had a similar student population and AP Exam pass rate, so the groups would be as equal as possible before the study, thereby increasing reliability.

RESULTS

The goal of this research was to describe if and how a unique pedagogy, such as a CGPBL with international (e.g. Mexican) peers, could lead to potential changes in student achievement as compared to a control PBL activity without global collaboration.

Research Question 1: Is there a significant difference in students' knowledge of hunger within the control (PBL), treatment (GCPBL), and between control and treatment groups in pre- and post-test scores?

Paired sample t-tests were run to compare changes, within the control (PBL) and treatment (GCPBL) groups, to evaluate any significant changes in scores between test administrations. The means, standard deviations, and *t*-test comparisons for pre- and posttest scores for both groups are displayed in **Table 3.** While students in both groups had a large increase in score between pre-test and post-test, there were no statistically significant changes between administrations for either group. The effect size *d* was 38.05 and 13.09 for the control and treatment groups, respectively. The control group had a slightly higher change in score (19.91) than the treatment group (16.47). Examining the means, albeit statistically not significant, the data showed there were considerable learning gains in science content for both control and treatment groups.

Independent samples t-tests were used to compare pre- and posttest scores between control and treatment groups in terms of total score. The means, standard deviations, and *t*-test comparisons for pre- and posttest scores on the content (hunger) assessment for both groups are displayed in **Table 4**.

Table 4. Means, standard deviations and independent samples t-tests for pre/post Content test scores

Content Test	Classroom Groups	N	*M*	*SD*	*df*	*t*	*p*
Pretest	Control (PBL only)	2	59.90	1.05	2	.899	.440
	Treatment (GCPBL)	2	61.23	1.66			
Posttest	Control (PBL only)	2	79.81	1.58	2	-.956	.463
	Treatment (GCPBL)	2	77.70	2.92			

Table 5. PBL artifacts – frequency counts of Observed elements of selected APES standards

APES Standards	Control Posters (N = 10)	Treatment Posters (N = 13)
Population		
pop biology / ecology	3	7
human population impact	8	7
Land and Water Use		
agriculture	7	4
fishing	0	0
global economics	12	14

Table 6. PBL artifact frequency counts of Observed elements of selected APES standards

Chi-Square Analyses of APES Standards in GC/PBL posters

Statistical Test	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.323[a]	1	.570		
Continuity Correction[b]	.096	1	.757		
Likelihood Ratio	.323	1	.570		
Fisher's Exact Test				.613	.379
Linear-by-Linear Association	.318	1	.573		
N of Valid Cases	62				

[a] 0 cells (.0%) have expected count less than 5.
[b] Computed only for a 2x2 table

There were no significant differences between the pre-test scores or posttest scores of the control and treatment groups. The effect size *d* was 1.39 and 2.25 for the pre-test and posttest comparisons, respectively. Although both groups seemed to learn science content after using a PBL format, the control group scored 2.11 points higher on the posttest than the treatment group using the additional global collaboration.

Research Question 2: Is there a significant difference in students' knowledge of hunger between the control (PBL) and treatment (GCPBL) groups in project artifacts (posters)?

The final activity for the World Hunger GC/PBL was to create a poster to address the global issue and post the image on social media to reach a larger audience. Posters were coded for each observation of elements/characteristics (value of 1 (observed) or 0 (not observed)) of *human population* and *land and water use* for science content for each of the 23 posters created upon the end of the World Hunger GC/PBL. **Table 5** is a summary of codes counted by category and subcategory, partitioned by control and treatment groups. Aspects of population were observed 11 times in the control posters and 14 times in the treatment posters. The control group posters contained more images or words that involved human population impact, such as a world map made of grain representing lack of food, than population biology. The treatment group included equal observations of human impact and population biology concepts, such as indicating how many people lack food. The control group had 19 observations of land and water use, including more aspects of agriculture, such as images of healthy foods, while the treatment group included 18 observations. The treatment group's posters included more observations of global economics, such as images that illustrate disparity; for example citing the concept of the *Tragedy of the Commons*.

A chi-square test (see **Table 6**) was conducted between control and treatment groups' PBL posters to determine if GCPs affected students' curriculum content knowledge of population and land and water use. Results indicated that all expected frequencies were greater than five and there was no statistically significant association between the control and treatment groups for content knowledge ($\chi^2(1) = .323$, $p = .570$). The association was small (Cramer's V = .072), suggesting the global collaboration supplement did not positively augment science content acquisition in students participating in the GCPBL.

DISCUSSION OF RESULTS

The goal of this study was to understand if GCP integrated into PBL (or GCPBL) augmented students' understandings of environmental science related to global hunger in an APES context. While the quantitative results revealed no statistically significant differences in achievement scores between groups, both the control and treatment groups scored higher on the hunger unit test after completing the World Hunger Project PBL. This could be anticipated as the learning gains at the end of the unit were evidenced by using the same test (Butler, 2010). Although results indicated there was no significant change in score from pretest to posttest within the control or treatment groups, there were gains observed when examining group means. This finding supports prior scholarship finding increases in environmental science content knowledge following exposure to an environmental science unit, course, or program (Arcury, 1990; Armstrong & Impara, 1991; Bradley, Waliczek, & Zajicek, 1999).

Although not significant, the qualitative data suggests students in the treatment groups included more elements of global economics, disparity, and statistics or data in their poster products. Examples included posters that contained slogans for ending world hunger through policy (e.g. reducing meat, working together, personal responsibility of not wasting food, and need versus greed). This is compared to the treatment group posters, which held more poignant and nuanced perspectives on experiences of individuals grappling with food insecurity globally, and the role of the individual in ameliorating global food imbalance. Therefore, the participation in the GCPBL did not detract from student learning of the science, yet this anecdotal observation warrants further study into the affective affordances of GCPBL on students' abilities to empathize on global environmental issues.

Previous research in comparing PBL classroom pedagogy to traditional (direct instruction) pedagogies (Al-Balushi & Al-Aamri, 2014; Chang, 2001; Drake & Long, 2009; Geier et al., 2008; Kubick, 2012; Schneider et al., 2002; Thomas, 2000) demonstrated that students in PBL-classrooms learned more science content than their peers in traditional classrooms. Yet, the results of this study cannot compare, thereby support or refute previous findings, regarding improvement in science knowledge through selected response classroom tests, as there were no studies comparing a PBL control with a GCPBL experimental group. Additionally, the current literature exploring relationships between academic achievement (science content knowledge) and GCPs remains lacking. While some studies on global collaborations or PBL have included academic content (Hernandez-Ramos & De La Paz, 2009; Marx et al., 2004; Maxwell, Mergendoller, & Bellisimo, 2005; Parker et al., 2013) there are few empirical studies that measure science content understanding (via more than one assessment modality) resulting from short or long-term participation in global collaborations to learn science.

This study was predicated upon an assumption that there would be significant gains in achievement scores as a result of a PBL supplemented with global collaboration. The reality was that achievement scores were similar among the PBL (control) and GCPBL (treatment) students. It is important to note that this study examined several factors and constructs, but during only one project at one duration in time. Where other studies on environmental science knowledge and attitudes have used brief, general knowledge tests (Al-Balushi & Al-Aamri, 2014; Bradley et al., 1999; Levine & Strube, 2012), this study focused on one topic (hunger and food) from one unit in a course designed to include GCPs; therefore, the test questions centered on a specific area. Hence, global food insecurity, like other diffuse and complex global issues like climate change may be too challenging for the students to contextualize. It is important for students to connect to a real-world issue through collaboration with students in different locations (i.e. contexts) and expand not only content knowledge, but civic awareness and environmental activism via social media (Barraza & Walford, 2002; Karahan & Roehrig, 2015; Merryfield, Lo, Po, & Kasai, 2008; Rosenthal, 1990).

As mentioned above, the literature has shown some benefits of PBLs that task students to collaborate with students in a different geographical location (e.g. mainly within the same country). Communicating and working with students of a different culture allows students to see solutions or design from a different perspective, a skill they will need for future science careers. Being able to internalize a new perspective so they may use that new knowledge, and create an artifact with peers (such as the case with the World Hunger GCPBL), is the very essence of a socio-constructivist pedagogy. Anecdotally, students were excited to work with foreign students and engaged in the process of this GCPBL; a large majority said they would do it again. When asked what other countries they would want to work with, countries in all parts of the world were named (e.g. Australia, Nigeria, Cambodia, Sweden, Ethiopia, etc.), not just western European or North American countries. Students were curious to continue communicating with peers from across the world in science topics related disease, pollution, women's rights, poverty, architecture, children living in slums, water distribution, engineering, and oil spills.

LIMITATIONS

Limitations of this study included the small sample size of two groups containing four classes of APES students located in south central Texas. Thus, the findings may not necessarily be generalizable to all APES teachers and at all school sites. Since the unit of analysis was the classroom, as the treatment was applied to classes and not individual students, the sample size is correct. Due to the nature of this unit of analysis, all tests run were of little to no significant significance; however, a larger sample size (more classrooms) would improve the power and effect of the tests, perhaps with a different result. The data from this study represented a Western perspective, as data were only collected from the American students. Therefore, the benefits to the global peers (Mexican students) due to their participation in the global collaboration PBL is unknown. It has been shown that cultural differences can affect students' perception of and attitudes toward environmental issues (Barraza & Walford, 2002); thus, replicating this study in other countries may produce different results.

Another study limitation was a restriction to an environmental science course, within a single topic area. Other studies of environmental science knowledge with (Al-Balushi & Al-Aamri, 2014; Bradley et al., 1999; Kwan & So, 2008; Levine & Strube, 2012) have been short-term (2 days, 10 days, 2 months), whereas this study was longer (three months). Future studies should include following the same group of students from beginning to end of the school year, in order to observe content understanding upon participation in several global collaborations, while comparing to other campuses that teach the same content but with no global collaboration.

CONCLUSION

This study sought to explore the affordances in student achievement of GCPBLs as combining PBL and GCP pedagogies so students could use their previous knowledge, co-construct new meanings to deepen content understanding, and convey multiple perspectives toward a global issue, such as the presented case of world hunger issues. This research addressed a deficiency in the literature, by measuring changes in student achievement upon participation in a GCPBL as compared to a control PBL related to environmental science content. Although educators and scholars recognize the benefits of global education, it is not well known how these experiences influence students' content acquisition and understanding in science-based courses. This research contributes to the extant literature suggesting that students, teachers, and schools may enhance students' achievement in science by leveraging the infusion of creative pedagogies (collaboration projects with other countries) within an ever-important context (global applications). In turn, when students engage in GCPs (i.e. participating in collaboration projects with students in other countries), they increase their content knowledge (e.g. science), so they may further understand global environmental issues and able to act as global citizens. Further research is needed in this domain, to measure, along with achievement, other cognitive and affective affordances of GCPBL in K-12 science classrooms. With training in PBL and GCPs, teachers can learn how to align their subject standards to global activities without sacrificing relevance or content (Kubick, 2012). In a time of accountability and teaching to the test, it is important for teachers to know they are preparing their students to pass the standardized exam while being engaged and in charge of their learning; prior research has shown that PBL classrooms do just as well or better on standardized exams (Larmer, Mergendoller, & Boss, 2015; Parker et al., 2013).

Disclosure statement

No potential conflict of interest was reported by the authors.

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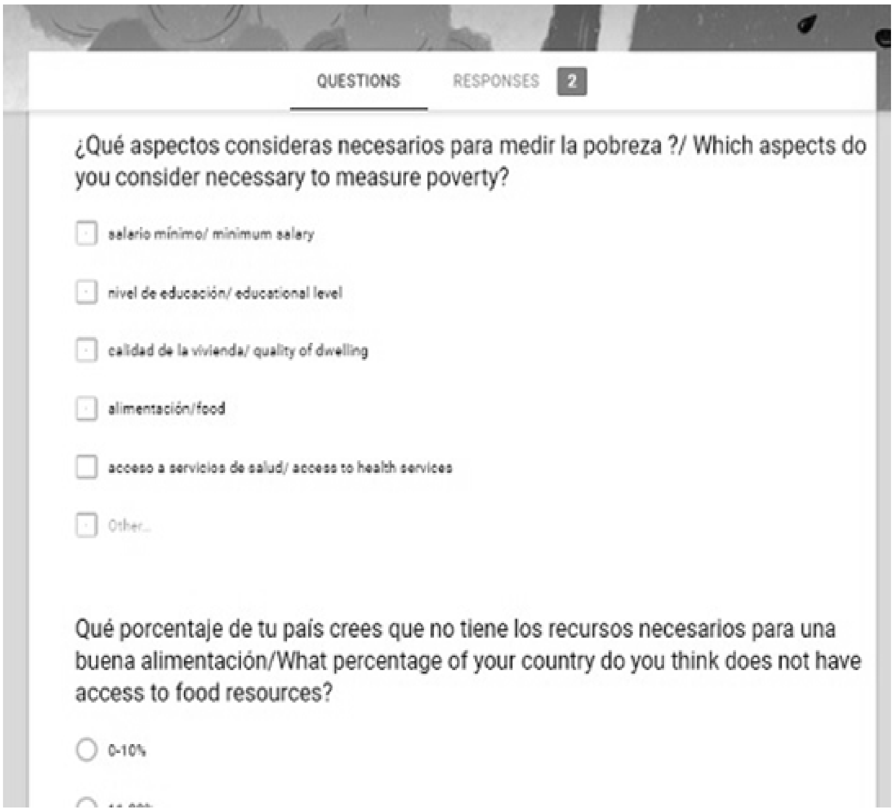
APPENDIX 1

Samples of GCPBL activities

Activity 1. Introductory slides



Activity 2. Spanish portion of a bilingual survey

Activity 3.

Activity 4. World Hunger Posters