The Effectiveness of the Geospatial Curriculum Approach on Urban Middle Level Students' Climate Change Understandings

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Climate change science is a challenging topic for student learning. This study examined the effectiveness of a geospatial curriculum approach to promote climate change science understandings in an urban school district with eighth grade students and investigated whether teacher- and student-level factors accounted for students' climate change knowledge achievement. The participants included 12 science teachers and 956 eighth-grade students. Data included a pre- and post-test climate change assessment measures for both teachers and students and a teacher measure of geospatial science-technological pedagogical content knowledge. Paired-sample t-tests revealed statistically significant gains from pre-test to post-test on their climate change knowledge). Both ordinary least squares (OLS) multiple regression and 2-level hierarchical linear modeling (HLM) found that student initial climate change knowledge and gender were significant predictors for students' post-test scores. Students' pre-test scores was the strongest significant predictor of the post-test scores. The findings provide support that a geospatial curriculum approach is an effective science curriculum approach for learners in urban middle level education.

Introduction

Climate change science topics are included prominently as disciplinary core ideas in recent U.S. science education curriculum frameworks (NRC, 2012). They are also viewed globally as being significant for both citizens and policy makers to understand in order to support decisions to mitigate anthropogenic effects of human-induced climate change (IPCC, 2007). However, climate change science is a challenging topic for student learning. Research conducted during the past two decades have revealed that secondary students show knowledge deficits about specific climate change concepts and also have misunderstandings that are fundamental to understanding the science underlying climate change that pertain to the atmosphere, greenhouse effect and the climate system (Bodzin, Peffer, & Kulo, 2012). Secondary students do not have a basic understanding about the volumetric composition of atmospheric gases (Bodzin et al., 2012), greenhouse gas sources and their composition in the atmosphere (Punter, Ochando-Pardo, & Garcia, 2011), and the role of water vapor as a key greenhouse gas (Schreiner, Henriksen, & Hansen, 2005). Studies have also found that students have incomplete understandings of how the greenhouse effect works (Varma & Linn, 2012) and have erroneous understandings about the cause-effect relationship between the greenhouse effect, global warming, and ozone layer depletion (Kılınç, Stanisstreet, & Boyes, 2008). In addition, both students and adults often confuse the time scale between weather and climate (Shepardson, Niyogi, Choi, & Charusomba, 2009). This confusion may reflect misunderstandings about geologic time, an important component of paleocliamatology.

Secondary students also have misunderstandings about anthropogenic sources that contribute to human-induced climate change. Studies have found that some students assume that all forms of pollution contribute to the greenhouse effect (Pruneau et al., 2001) and some students generalize that all air pollutants are greenhouse gases (Punter et al., 2011). Recent research has shown that secondary students have incorrect beliefs that acts of environmental stewardship that include cleaning up litter at the beach, protecting endangered species, reducing insecticides, reducing the use of Freon, and reducing nuclear energy use would help reduce global warming (Boyes, Skamp, & Stanisstreet, 2009; Kılınç et al., 2011).

To address the issues with climate change understandings among middle level learners, we developed a coherent 20-day climate change science curriculum for urban grade eight students using a geospatial curriculum approach. The curriculum integrates the geospatial technology Google Earth and other Web-based learning activities to support student understandings of climate change science. Teaching with geospatial technologies focuses learners on spatial analysis of patterns, relationships, and trends in geospatial data and phenomena. Many climate change effects on our planet have a geospatial component and can be visualized and understood through spatial analyses with geospatial technologies. Previous studies have found that integrating geospatial technologies within a coherent curriculum has been effective for enhancing middle level students' understandings of energy resources (Bodzin, Fu, Peffer, & Kulo, 2013) and land use change (Bodzin, 2011).

The goal of this study was twofold: (1) to examine the efficacy of a technology-integrated curriculum that used geospatial technologies to promote urban middle level students' understandings of important climate change science concepts and (2) to investigate factors related to both students and teachers that may account for the variance in students' climate change knowledge achievement.

The climate change curriculum

The Climate Change curriculum (henceforth *Climate Change*) used a geospatial curriculum design approach to learning. This approach supported teacher enactment by intentionally incorporating a curriculum framework and targeted design principles. See Bodzin, Anastasio and Kulo (2014) for a detailed explanation of this approach.

The geospatial investigations in *Climate Change* were developed with the virtual globe application Google Earth since it employs an interface that may be modified in ways to enhance initial data visualization displays for learners. The initial geospatial data visualizations for each activity were designed in such a way that they are quick and intuitive for both students and teachers to use, thus decreasing interface issues that have been previously reported by classroom use of other geospatial technologies such as GIS desktop platforms (Bednarz, 2004).

The *Climate Change* curriculum included a coherent sequence of topics and learning activities designed to promote learner understandings about the atmosphere, Earth system energy balance, weather and climate, greenhouse gases, paleoclimatology, and environmental impacts of human-induced climate change. Five lessons during the 20-day curriculum used the geospatial curriculum approach with Google. The curriculum also included lessons with a Web-based interactive carbon calculator and geologic timeline, inquiry-based laboratories, demonstrations, readings, and modeling activities aligned to the curriculum learning goals. The *Climate Change* curriculum is available online at http://www.ei.lehigh.edu/eli/cc.

Research questions

The primary aim of this study was to examine the effectiveness of a curriculum using a geospatial curriculum approach to promote climate change science understandings in an urban school district with eighth grade students. This curriculum implementation study was guided by the following research questions:

1. Whether and to what extent can a geospatial curriculum approach promote climate change understandings with students in urban middle level education?
2. What factors related to both students and teachers may account for students' climate change knowledge achievement?

Methods and participants

Twelve eighth-grade Earth and space science teachers, including one pre-service teacher, implemented the *Climate Change* curriculum with their students during the 2011-2012 academic school year. The participants taught 1,060 students (ages 13-15) at all four middle schools in the same urban school district in the northeast region of the United States. The school district is located in a medium-sized city with a population of about 100,000 residents. Seven teachers were male and five were female. The teachers had a wide range of teaching experiences from a pre-service science teacher to a teacher with 38 years of teaching experience. Content area certifications were quite varied and included general K-8 certifications, middle school science certifications, and secondary-level science content area certifications. One teacher taught science to two classes composed only of English language learners. Data attrition resulted from students who were not in school due to suspensions and truancy or did not return signed consent forms. During October and November 2011, all teachers attended three days of professional development to become acquainted with the *Climate Change* learning activities.

Climate change assessment measure

The climate change assessment measure included 28 multiple choice items and 3 open-ended response items that aligned to current climate change knowledge goals stated in the recent U.S. reform documents *Climate Literacy: The Essential Principles of Climate Sciences* (U.S. Global Change Research Program, 2009) sand the *Framework for K-12 Science Education* (NRC, 2012). The assessment items were designed to measure climate change learning goals expected to be achieved by students by the completion of eighth grade.

The items were grouped into three subscales corresponding to three main climate change science topic areas:

(1) Atmosphere, greenhouse effect, and climate system (AGC) [17 items],

(2) Human-induced climate change (HCC) [7 items]

(3) Paleoclimatology (PC) [4 items]

The multiple-choice items include distractors that address misunderstandings and knowledge deficits about climate change from the existing literature. The AGC items were designed to address students' understandings about the definition and source contribution to the greenhouse effect, the role of water vapor as a key greenhouse gas, atmospheric composition, weather and climate, and essential features of the climate system. The HCC items addressed understandings about anthropogenic sources that contribute to climate change, environmental impacts, and solutions to climate change at a personal and societal level. The PC items focused on student understandings of paleoclimatology. Each multiple-choice item is assigned one point for a correct answer and zero points for an incorrect answer or blank response, yielding possible total scores ranging from 0 to 28. A criterion-based rubric was developed to score three open-ended questions using a 0-4 point scale. Thus the possible scores on the open-ended items ranged from 0-12. See Bodzin et al. (in press) for a more detailed discussion about the climate change assessment measure. The reliability (Cronbach's alpha) for all 28 multiple-choice items was 0.860 and the reliability for the three subscale topic areas were 0.785 for AGC, 0.613 for HCC, and 0.647 for PC.

Teacher measures

The teachers completed two measures at the end of their third day of the *Climate Change* professional development sessions. These included (1) the measure for the 28-item multiple-choice items from the climate change assessment described above (possible total scores ranging from 0 to 28) and (2) the measure from Geospatial Science-Technological Pedagogical Content Knowledge [GS-TPACK] instrument (Bodzin et al., 2012). The GS-TPACK instrument was designed to measure teachers' perceived knowledge of how geospatial technology interacts with their pedagogical content knowledge in ways that produce effective science teaching and student learning opportunities. The instrument includes 23 Likert-type items that are scored with a six-point scale of 1 (strongly disagree) to 6 (strongly agree), with the possible total scores ranging from 23 to 138. The reliability (Cronbach's alpha) of the GS-TPACK instrument is 0.961.

Data analysis

To address the first research question, paired-sample t-tests were conducted in IBM SPSS 21 to examine whether the mean scores of the climate change assessment items were significantly different between the pre-test and the post-test. Since 47 students did not complete the pre-test and 57 other students did not complete the post-test, 956 students were included in the analysis.

All open-ended response items were coded by one researcher and 25% of the items were coded by a second researcher independently. They were found to be in agreement 93% of the time. Any discrepant cell placements on the rubric were resolved via discussions between the coders.

The second research question investigates whether the student- and teacher-related factors may account for the variance in students' climate change post-test scores. The outcome variable was the student climate change post-test scores from the 28 multiple-choice items. The student predictor variables included gender (female = 1 and male = 0) and their climate change pre-test scores on the same 28 multiple-choice items. The teacher-related factors included (1) teacher climate change content knowledge; (2) GS-TPACK; and (3) years of teaching experience.

Two approaches in total were tried to address the second research question. We first tried the ordinary least squares [OLS] multiple regression analysis using the blockwise method in IBM/SPSS 21 to investigate how well the teacher factors accounted for the variance in students' climate change post-test scores, after controlling for students' gender and pre-test scores. The two student variables were entered in Block 1 and the three teacher variables were in Block 2.

Secondly, for the purpose of incorporating the data structure that students were nested within teachers, we conducted a series of two-level hierarchical linear models [HLM] (Raudenbush & Bryk, 2002) for the second research question. The HLM were run using SAS PROC MIXED with the full maximum likelihood method.

We started from the unconditional means model also referred to as one-way ANOVA with random effects. This simple model allows us to calculate the intraclass correlation coefficient (ICC) to determine how much variance in student climate change post-test scores is attributable to inter-teacher variation. The two-level regression equations consist of (1) Level 1 (student level; within-teacher): $y_{ij} = \beta_{0i} + r_{ij}$, expressing the post-test score for a typical student i of teacher j (y_{ij}) by the sum of an intercept for the students within teacher j (β_{0i}) and a random error (r_{ij}); and (2) Level 2 (between-teacher): $\beta_{0i} = \gamma_{00} + \upsilon_{0i}$, expressing the intercept as the sum of a grand mean (γ_{00}) and random deviations from the mean due to teacher variation (υ_{0i}). Combined, the 2-level HLM is given by: $y_{ij} = \gamma_{00} + \upsilon_{0j} + r_{ij}$, where $\upsilon_{0j} \sim N(0, \tau_{00})$ and $r_{ij} \sim N(0, \sigma^2)$. We computed the ICC using the output for the variance among students within teachers ($\sigma^2 =$

22.81) and variance between teachers (τ_{00} = 20.33). The resultant ICC 20.33/(20.33 + 22.81) = 0.47, indicates that 47% of the variance in student climate change post-test scores is due to teacher heterogeneity. This substantial proportion of variance would be inappropriately ignored in OLS regression. Therefore, we further expanded the unconditional HLM by iteratively adding student- and teacher-related variables. After comparing the nested models based on -2 log likelihood difference given their degree of freedom, we decided on the following random intercept and slope model, including (1) student gender and pre-test scores at Level 1, and (2) at Level 2, the three teacher variables for the intercept, and random effect terms for the intercept and the pre-test slope:

Level 1: $y_{ij} = \beta_{0j} + \beta_{1j}Pre\text{-}test_{ij} + \beta_{2j}Female_{ij} + r_{ij}$,

Level 2: $\beta_{0j} = \gamma_{00} + \gamma_{01}Knowledge_j + \gamma_{02}GSTPACK_j + \gamma_{03}Years_j + \upsilon_{0j}$,

$\beta_{1j} = \gamma_{10} + \upsilon_{1j}$, and $\beta_{2j} = \gamma_{20}$.

Combined, the 2-level HLM is given by:

$$y_{ij} = \gamma_{00} + \gamma_{20}\, Female_{ij} + \gamma_{01}Knowledge_j + \gamma_{02}GSTPACK_j + \gamma_{03}Years_j + (\gamma_{10} + \upsilon_{1j})\, Pre\text{-}test_{ij} + \upsilon_{0j} + r_{ij} \quad .$$

Holding teacher factors constant, γ_{00} is the intercept (predicted student outcome) for the male group, γ_{20} is the intercept change for the female group, and γ_{10} is the pre-test slope. γ_{01} to γ_{03} are the student outcome changes due to the effects of the three teacher factors. Because the pre-test was taken before the students were taught by the teachers with the *Climate Change* curriculum, it would not be meaningful to add the three teacher factors for the level-2 slope of the student pre-test scores as we did for the level-2 intercept. The random effects υ_{0j} is the departure from the average male intercept, υ_{1j} is departure from the average pre-test slope, both due to teacher variability, and r_{ij} the random error for student *i* of teacher *j*.

Results

The pre-test and post-test assessment data were organized and sorted to include only those students who had completed both assessments (N = 956). Correct responses were tallied for the items. Paired-sample *t*-test analyses were conducted to compare the pre-test and post-test results of the multiple-choice items. Overall results regarding the use of the *Climate Change* curriculum showed significant improvement in urban middle level students' climate change science understandings for the entire assessment and for each topic area subgroup (Table 1). The large effect sizes were derived from dividing the pre- and post-test mean score difference by the pooled standard deviation (Cohen, 1988) for the entire assessment and for each topic subgroup. The standard effect size for the urban students in our study had an effect size of 1.29 for the entire climate change assessment measure. These results speak favourably to using the geospatial curriculum approach to promote growth in students' climate change understandings.

Paired *t*-tests for each individual item also revealed significant gains ($p < .001$) from pre-test to post-test for all but one item indicating that students had difficulty distinguishing heat capacity from the albedo effect. Item analysis revealed seven post-test items that were not answered correctly by more than half of the students. After the curriculum implementation, many students still had misunderstandings about the volumetric composition of atmospheric gases, the source of ozone in the lower troposphere, the magnitude of average annual temperature rise in most places during the past 50-60 years, and the time scale differences between weather and climate. In addition, many students had difficulty distinguishing significant greenhouse gases from non-greenhouse gases.

Paired-sample *t*-test analyses were also conducted to compare the pre-test and post-test results of the open-ended response items. Students' scores significantly increased from pre-test to post-test (Table 1) with a medium effect size of 0.54. Overall, the students' proficiency levels in their responses increased. After the curriculum implementation, more students were able to articulate an increased number of different types of human activities that are causing the long-term increase of carbon dioxide levels over the last 100 years, identify a larger number of behaviors they could implement to reduce or prevent further emissions of carbon dioxide into the atmosphere, and identify a greater number of societal practices to lower the levels of carbon dioxide in the atmosphere.

Table 1. Paired-sample t-tests for climate change pre- and post-test achievement: Overall and subscale multiple-choice (MC) items (Top) and overall open-response items (Bottom).

	Pre-test Mean (SD)	Post-test Mean (SD)	*t* test[a]	Effect Size[b]
Entire MC Assessment (38 items in total)	11.41 (4.50)	17.33 (5.95)	39.92***	1.29
Atmosphere, greenhouse effect, & climate system (17 MC items)	6.23 (2.64)	9.47 (3.87)	31.01***	1.00
Human-induced climate change (7 MC items)	3.55 (1.76)	4.99 (1.67)	24.75***	0.80
Paleoclimatology (4 MC items)	1.63 (1.12)	2.87 (1.25)	29.43***	0.95
Entire *Open-response* Assessment (3 items in total)	6.12 (2.75)	7.66 (1.92)	16.21***	0.54

Notes. $N = 956$. *** $p < .001$

a. Two-tailed paired-sample *t* test.
b. Calculated by dividing the difference between post-test and pre-test mean scores by the pooled standard deviation (square root of the average of the squared standard deviations).

OLS regression analysis on student climate change post-test scores

OLS multiple regression analysis using the hierarchical/blockwise method in IBM/SPSS 21 was conducted to investigate whether and how well three teacher factors accounted for the variance in students' climate change post-test scores, after controlling for students' gender and pre-test scores. The two student variables were entered in Block 1 and the three teacher variables were in Block 2. We first checked the data and OLS regression assumptions with satisfactory findings. Next, a linear relationship was found between the outcome and each predictor based on the scatterplots and correlation matrix (Table 2). Finally, there was no multi-collinearity issue due to high correlations between the predictors, based on the correlation matrix and the collinearity statistics (tolerance values ranging from .81 to .99, and all variance inflation factor values below 1.24). The explanatory variables had Pearson correlations that ranged from -.14 to .34 with each other, and from -.05 to .65 with the outcome (Table 2). Pre-test scores was the variable that had the highest correlation with the post-test scores (r = .65).

Table 2. Pearson correlations (one-tailed) among variables predicting the CC post-test xcores

	Student CC post-test	Student gender	Student CC pre-test	Teaching years	Teacher CC knowledge
Student Gender	-.10***				
Student CC Pre-test	.65***	-.08**			
Teaching Years	.27***	-.01	.15***		
Teacher CC Knowledge	-.05	-.03	-.14***	.20***	
Teacher GS-TPACK	.05	-.01	.05	.34***	-.04

Notes. N = 956. CC = Climate change.
** $p < .01$. *** $p < .001$.

The results for the regression are presented in Table 3. Student gender and the pre-test score in Model 1 significantly explained 42% of the variance in the climate change post-test scores, $R^2 = .42$, $F_{(2, 953)} = 344.10$, $p < .001$. Pre-test score was a significant predictor for the outcome ($p < .001$) and gender was marginally significant ($p = .058$). In the full model (Model 2), after controlling for student gender and pre-test scores, the teacher variables contributed 3% additional variance in the outcome, $R^2 = 0.45$, $\Delta R^2 = .03$, $F_{increment\ (3,\ 950)} = 18.70$, $p < .001$. Climate change pre-test scores was still a significant predictor for the outcome ($p < .001$) and gender was also significant ($p = .047$). Among the teacher variables, years of teaching was a significant predictor for the outcome ($p < .001$), GS-TPACK was marginally significant ($p = .060$), and teacher knowledge in climate change was non-significant ($p = .92$).

In Model 2, assuming the values for the pre-test score and the three teacher variables all to equal 0, the predicted post-test score for a typical male student was 8.46 out of a possible total of 28.00, whereas being a female student had 0.57 lower points than a male student in the post-test score, $p = .047$. Pre-test scores was the strongest significant predictor of the outcome: controlling for everything else, each point increase in the climate change pre-test score was associated with 0.81-point increase in the post test score, $\beta = 0.62$, $p < .001$. The pre-test scores had a semi-partial correlation at .596, indicating that this variable uniquely explained 36% ($sr^2 = .596^2 = .36$) of the variance in the outcome. The second strongest significant predictor of the outcome was teachers' years of teaching: controlling for everything else, each-year increase in teaching was associated with 0.25-point increase in the post-test score. However, the squared semi-partial correlation for teachers' years of teaching uniquely explained only 3% of the variance in the outcome ($sr^2 = .17^2 = .03$).

Table 3. Hierarchical Multiple Regression Analysis for the Student CC Post-test Scores (N = 956)

Variable	Model 1				Model 2			
	B	*SE B*	*β*	*sr*	*B*	*SE B*	*β*	*sr*
Intercept	7.91***	0.44			8.46***	1.98		
Student Gender	-0.56†	0.30	-0.05	-.05	-0.57*	0.29	-0.05	-.05
Student CC Pre-test	0.85***	0.03	0.64	.64	0.81***	0.03	0.62	.60
Teaching Years					0.25***	0.03	0.19	.17
Teacher CC Knowledge					-0.01	0.05	0.00	-.002
Teacher GS-TPACK					-0.03†	0.01	-0.05	-.05
R^2 (F)	.42 (344.10***)				.45 (156.53***)			
$\Delta R^2(\Delta F)$					.03 (18.70***)			

Notes. *B* = unstandardized coefficient, *SE* = standard error, *β* = standardized coefficient, and *sr* = semi-partial correlation. For Student Gender, Female = 1.

Results from HLM:

Both student variables (gender and pre-test) were significant predictors for student post-test scores, $p < .05$. Controlling for everything else, the post-test scores were 0.66 point lower for female students than males students, $p = .01$, and each-point increase on the pre-test was associated with 0.68-point increase on the post-test scores. None of the teacher variables (climate change knowledge, GS-TPACK, and teaching years) had significant association with the student post-test scores, $p > .05$. The teacher variation was significant on the average post-test scores (p =.047), but non-significant, or marginally significant, for the pre-test slope ($p = .089$). That is to say, the student post-test score means across the 12 teachers were significantly different from each other, but the effects of student pre-test scores on their post-test scores were almost equal (or marginally significantly different) regardless of their teachers. The student-level residual variance decreased by 39%, from 22.81 in the unconditional model to 13.98 in the random intercept and slope model, which is a substantial decrease due to the student- and teacher-level variables and the two random effect terms in Level 2.

Discussion

The aim of this study was to develop a coherent climate change science curriculum for urban middle level students using a geospatial curriculum approach, determine its ability to impact climate change science content knowledge gains, and investigate both teacher and student factors that may account for climate change knowledge achievement. The results from this study provide support for the effectiveness of the geospatial curriculum approach to enhance the climate change content knowledge of urban middle level students. The findings also provide support that a geospatial curriculum approach may be an effective science curriculum approach for learners in urban middle level education.

Virtual globes such as Google Earth are interactive visualization tools that can be designed to enable learners to manipulate, analyze, and synthesize spatial data in novel ways and support the development of contextually rich learning environments that promote higher order thinking skills, meaningful learning and authentic scientific inquiry (Bodzin & Anastasio, 2006). Visualizing the spatial relationships among data sets assists in the cognitive aspect of learning and promotes deeper understanding of content (Stinton & Lund, 2007). In the *Climate Change* curriculum, interactive visual interfaces and tools that are inherent to Google Earth provided students with useful ways to analyze spatial data to investigate the effects of increased anthropogenic climate change. For example, using Google Earth, students are provided with a user-friendly tool set to analyze changes in Arctic sea ice melt data, observe spatiotemporal evidence of declining coral reefs, and analyze predicted effects of sea level rise in coastal areas on the landscape. These types of geospatial learning activities provide learners with more enhanced learning opportunities to understand certain components of climate change science compared to more typical curriculum approaches of science learning that occur in U.S. urban middle level classrooms that may rely more on non-technology integrated approaches to learning.

After receiving instruction with *Climate Change*, students had a better understanding of how human activities affect climate change. After the curriculum implementation, the students identified more anthropogenic sources that contribute to climate change, environmental impacts, and solutions to enhanced anthropogenic climate change at a personal and societal level. Students identified a variety of actions that they and their families could undertake to reduce their carbon footprint. It is likely that curriculum coherence may have played an important role to promote student learning. *Climate Change* was designed with learning goals coherence (Schwartz et al., 2008) to help students develop deep understandings about climate change science with a carefully planned interrelated set of conceptual topics and geospatial learning activities based on important climate change science learning goals using a novel curriculum design model. The curriculum focused on developing deep and rich understandings of fundamental climate change science concepts in the areas of the atmosphere, Earth system energy balance, weather and climate, greenhouse gases, paleoclimatology, and environmental impacts of human-induced climate change. Connections among these areas were made explicit through the geospatial and other learning activities.

Previous studies described earlier in this paper have indicated that the teaching and learning of climate change science is conceptually challenging. While significant gain scores were noted for all but one assessment item, many students still had difficulty understanding certain climate change concepts. A four-week curriculum may not be enough time to devote to the teaching and learning of climate change science with urban middle level learners to enable deep meaningful understandings for all concepts pertaining to atmospheric composition, time scale differences between weather and climate, albedo effect, and greenhouse gases. More explicit instruction beyond what was implemented with the *Climate Change* curriculum in the classroom may be needed to enhance learner understandings of these topics.

The second research question investigated factors related to both students and teachers that may account for students' climate change knowledge achievement. The results from the OLS multiple regression and the 2-level HLM both found the student climate change pre-test scores to be a significant factor for the post-test scores ($p < .05$) and gender at least marginally significant ($p < .10$). However, years of teaching experience was significant in the OLS regression ($p < .05$) but non-significant in the HLM ($p > .05$). As revealed in the HLM, the students had significantly different post-test score means across the 12 teachers, but almost equal (or marginally different) slopes (effects) for their pre-test scores across the teachers. The almost uniform effects for the pre-test among the teachers made sense in terms of the temporal design of this study: the pre-test was taken before the students were taught by the teachers with the *Climate Change* curriculum.

In the USA, the Next Generation Science Standards (Achieve Inc., 2013) has recently been released to help guide states to develop a coherent science education curriculum across the grade levels. The content areas of Earth's systems, weather and climate, and human impacts are included as core standard areas for the middle level science curriculum and include climate change science concepts. The findings from this study illustrate that implementing a coherent middle level climate change science curriculum using a geospatial curriculum approach to learning can enhance urban middle level students' understandings of important climate science topics and help foster a deeper understanding of climate change science.

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