EXPLORING THE PREDICTORS AND OUTCOMES OF MIDDLE SCHOOL STUDENTS' INTEREST IN CLIMATE CHANGE EFFECTS ON FORESTS: RESULTS FROM TWO INTERVENTIONS

by

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A thesis submitted
in partial fulfillment of the requirements
for the degree of
Master of Science
(Natural Resources and Environment)
The University of Michigan
August 2015

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ABSTRACT

This thesis explored the development and outcomes of middle school students' interest in climate change. Research in science education and other domains suggests that, by fostering students' interest in climate change, it may be possible to increase their climate literacy, foster their mitigation and adaptation actions, and promote their lifelong engagement in this critical issue. The two studies completed for this thesis were conducted within the context of an educational intervention using a new two-week unit, entitled *Climate Change and Michigan Forests*, during its first two years of implementation in Ann Arbor Public Schools.

The first study explored select predictors of students' interest in climate change effects on forests, and the relationship between their interest in the topic and desire to learn more about it. Data were collected from 308 seventh-graders who participated in the unit using pre- and post-intervention questionnaires. Students had only moderate levels of interest in, and desire to learn more about, climate change effects on forests, and students' interest in science and in hands-on science activities played larger roles in their development of interest in climate change effects on forests than their perception of climate change risk. Increasing student interest in climate change through short educational interventions is likely to present a formidable challenge, and enhancing students' perception of climate change risk is unlikely to help educators achieve this goal.

The second study explored what effects interest, desire to learn more, and related factors had on students' learning about climate change effects on forests. Data were collected from 355 treatment and 121 comparison students. Treatment students' knowledge about climate change increased, but there was no meaningful connection between topic interest and topic knowledge. Instead, post-intervention knowledge was predicted by pre-intervention knowledge, overall interest in science, and the personal and societal importance students assigned to climate change. Different strategies appear to be required for supporting development of interest in, versus learning about, climate change. Emphasizing climate change's importance, however, is likely to support either outcome.

ACKNOWLEDGEMENTS

This work was supported by the USDA National Institute of Food and Agriculture McIntire-Stennis project 2013-32100-06099; and the National Science Foundation DEB 125664, with additional funding from the Michigan Alliance for Environmental and Outdoor Education and an SNRE Seed Grant.

First, thank you to my thesis advisor, Dr. Michaela Zint. She has been unwavering in her support for me throughout my time at SNRE, and she has made me a better social scientist and scholar. I also thank Dr. Inés Ibáñez, my thesis reader, for her work developing the unit, and for her valued advice and analytical insights.

Giselle Kolenic and Missy Plegue at the Center for Statistical Consulting and Research (CSCAR) provided invaluable support with the statistical methods and analysis. Several student research assistants helped with developing this curriculum, collecting data, and preparing reports: Linda Isakson, Meghan Kelly, Meghan Jacokes, Lindsay Bienick, and Karen Graves. Special thanks to Erin Burkett, who oversaw the development and implementation of the unit during the second year, and whose contributions were critical to the success of this project.

I thank our local implementation partners, Amy Deller-Antieau, science curriculum coordinator for Ann Arbor Public Schools; Janet Kahan, curriculum development consultant; and Dave Szczygiel, AAPS environmental educator. I also thank the teachers from Ann Arbor Public Schools who participated in the research: Susan Baker, Aina Bernier, Margaret Caird, Michael Conedera, Kathy Coppens, Stacey Greene, Dominic Held, Michael Johnson, Rene Limon, Richard Pierce, Rebecca Wancier, Jean Wilson; and their students.

Thank you to my friends and my family, particularly my parents, Thom and Gay Carman, who were always there to provide encouragement and a listening ear. Finally, thank you to my husband, Rich Bunnell. You remained my best friend and ally through this time-consuming and often stressful project, and I am so grateful for everything that you do.

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Influences on middle school students' interest in, and desire to learn more about, climate change effects on forests: An intervention-based path model of short-term interest development

Introduction

Interest in climate change and why it matters

Climate change is one of the defining challenges of our time. It has been described as a "wicked problem" (Hulme, 2009), one that is unique, complex, linked to other issues, and difficult to solve without creating additional challenges (Rittel & Webber, 1973). Climate change will persist for decades, and thus, children and young adults will be confronted with its effects well into the future (IPCC, 2014).

Because of the threats climate change poses to future human wellbeing, finding ways to engage students in this topic has been identified as an important climate change education need (Busch & Osborne, 2014; National Research Council, 2012b). One way of achieving this goal has consisted of explicitly or implicitly increasing students' perceptions of climate change risks; i.e., their beliefs about the likelihood of harm associated with climate change (Leiserowitz, Smith, & Marlon, 2011; Mead et al., 2012). Yet, the effects of enhancing students' perception of climate change risks may be mixed. While one study found that adolescents with greater perceptions of climate change risk are more likely to seek out information about climate change (Mead et al., 2012), other research suggests that increasing youth's environmental risk perceptions can frighten and disempower rather than engage them (Covitt, Gomez-Schmidt, & Zint, 2005).

One alternative, and currently a relatively underexplored way to foster youth's constructive engagement with climate change, may be to increase their interest in this topic (National Research Council, 2012b). Unlike risk, which tends to be accompanied mainly by negative emotions, interest can be affiliated with positive emotions (Sjöberg, 2007). Indeed, interest, defined here as students' autonomous preference for a topic or activity (Deci, 1992; Freeman, McPhail, & Berndt, 2002; Schiefele, Krapp, & Winteler, 1992), has been associated with a greater willingness to direct attention to a topic (Hidi, 2000; Hidi & Anderson, 1992; Krapp, 1999) and deeper learning about a topic (Deci, 1992; Krapp, 1999; Schiefele & Krapp, 1996).

The potential link between interest and learning may be especially important for increasing students' climate literacy, because studies consistently show that children's knowledge about climate change is limited and that misperceptions about climate change related issues are common (Leiserowitz et al., 2011; Shepardson, Niyogi, Choi, & Charusombat, 2009). Although no study has examined the link between interest in climate change and climate literacy directly, students' interest in climate change has been found to partially explain their enhanced performance on a climate change reading comprehension task (Strømsø, Bråten, & Britt, 2010) and their beliefs that climate change is occurring (Bråten, Gil, Strømsø, & Vidal-Abarca, 2009).

In addition to its potential for supporting learning, interest has been associated with other desirable outcomes. Students with stronger interests in the environment are more likely to (1) express a sense of responsibility toward the environment (Uitto, Juuti, Lavonen, Byman, & Meisalo, 2011), (2) feel a greater degree of self-efficacy to engage in environmentally sustainable behaviors (Uitto, Boeve-de Pauw, & Saloranta, 2013), and (3) express an intention to act in environmentally responsible ways (Fröhlich, Sellmann, & Bogner, 2013; Uitto & Saloranta, 2010), including through political participation (Levy & Zint, 2013). By fostering students' interest in climate change, it may be possible to increase not only their climate literacy but also their climate change mitigation and adaptation behaviors.

However, students' overall interest in science topics tends to decline as they reach adolescence (Barmby, Kind, & Jones, 2008; Osborne, Simon, & Collins, 2003; Potvin & Hasni, 2014); thus increasing their interest in climate change through formal educational interventions likely presents a formidable challenge. In addition, little is known about how to increase students' interest in climate change, including through educational interventions, or through enhancing students' perception of climate change risk.

A formal educational intervention to foster interest in climate change effects on forests

To address this knowledge gap we developed a two-week pilot unit, *Climate Change and Michigan Forests* (http://climatechangeandforests.org) to teach students about climate change and its effects on forests and potentially increase their interest in the topic. Based on authentic data from Dr. Inés Ibáñez's forest ecology research, the unit focuses on how scientists use mathematical modeling to predict the impacts of climate change on local trees and forest ecosystems, addressing the need to improve students' understanding of scientific modeling of climate change (Lombardi, Sinatra, & Nussbaum, 2013) as well as of scientific modeling in general (Davis et al., 2008). In accordance with the *Next Generation Science Standards*, the unit fuses (1) disciplinary core ideas including "Global Climate Change" and "Human Impacts on Earth Systems," (2) science and engineering practices including "Developing and Using Models" and "Analyzing and Interpreting Data," and (3) cross-cutting concepts including "Cause and Effect" and "Stability and Change" (National Research Council, 2012a; NGSS Lead States, 2013).

As part of the unit, students gather tree growth data, enter these data into an interactive online graphing tool, and examine how changes in temperature and precipitation affect tree growth. The graphing tool generates a scatterplot and lines of best fit based on simple linear equations, to allow students to predict how climatic factors influence growth of different tree species. Students also visit a forest located within walking distance of their school to gain firsthand experience with how scientists collect data for studying the impacts of climate change on trees and forests. Based on prior research investigating what makes science and science topics interesting for students, we expected this unit to increase students' interest in its focal topic, i.e., climate change effects on forests. For one, the unit was designed to be perceived as relevant to students' lives (Bergin, 1999; Schraw, Flowerday, & Lehman, 2001; Swarat, 2008) through its focus on local (vs. distant) trees and forests, with which children tend to feel a strong personal connection (Sobel, 1995), and by including a nearby field trip (Rickinson et al., 2004). In addition, the unit consists mainly of hands-on activities and represents how science is conducted in the "real world," which have been found to increase students interest in science and science practices (Bergin, 1999; Osborne et al., 2003; Potvin & Hasni, 2014).

An intervention-based path model for predicting short-term interest development in climate change

To begin to investigate how middle school students develop an interest in climate change through educational interventions, we developed a repeated-measures path model for predicting students' interest in, and desire to learn more, about climate change effects on forests (Figure 1).

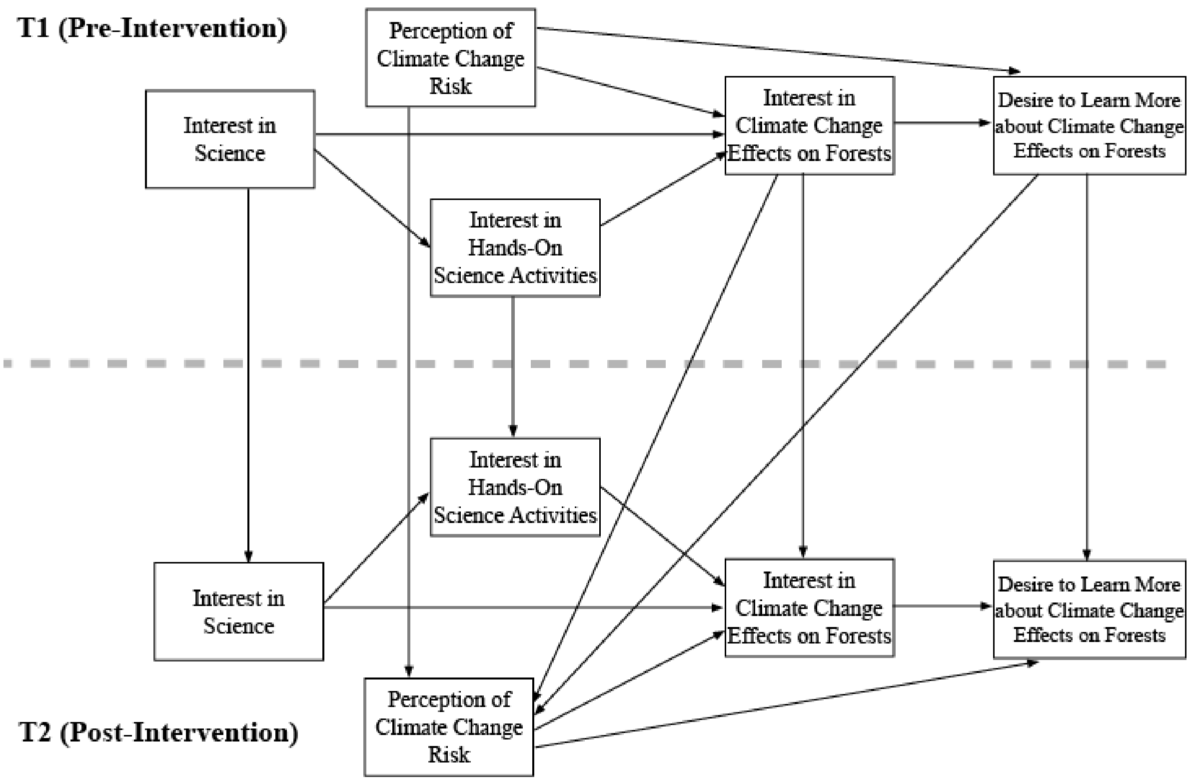


Figure 1. Hypothesized path model of factors predicting students' post-intervention *Interest in*, and *Desire to Learn More About, Climate Change Effects on Forests*

We sought to predict both of these outcomes to distinguish between students' preference for this topic (i.e., interest) and their motivation to seek out additional information or acquire more knowledge about it (i.e., desire to learn more). Interest in a topic is often not distinguished from a desire to learn more about it, including as part of large-scale international studies such as PISA and the Relevance of Science Education (ROSE) study (OECD, 2007; Sjøberg & Schreiner, 2010). Although the two are closely related (Hidi, 2000; Swarat, Ortony, & Revelle, 2012), there is some evidence to suggest that they should be treated as distinct (Boekaerts & Boscolo, 2002; Katz, Assor, Kanat-Maymon, & Bereby-Meyer, 2006; Nenninger, 1992). For one, short interventions, like our two-week unit, may not be long enough for in-depth interest development to occur (Hidi & Renninger, 2006), but they may spark students' desire to learn more about a topic (Ardoin et al., 2014). This is important because students' desire to learn more about a topic influences the extent to which they continue to engage with the topic in the future (Hidi & Renninger, 2006; Prenzel, 1992; Renninger & Hidi, 2011).

The hypothetical model includes three potential predictors of topic interest and desire to learn more: general interest in science, interest in hands-on science activities, and perception of climate change risk. While the determinants of students' interest in specific educational topics are numerous (Bergin, 1999; Renninger & Hidi, 2011), we selected general interest in science and perception of risk because these have predicted students' interest in a range of environmental topics, including climate change (Sjöberg, 2007; Uitto, Juuti, Lavonen, & Meisalo, 2006; Uitto & Saloranta, 2010). We also incorporated interest in hands-on science activities because the intervention includes many such activities, and there is evidence linking student interest in these activities to their interest in science and science topics (Potvin & Hasni, 2014; Swarat et al., 2012).

Interest in science is a *personal interest*, or a long-term interest closely associated with one's personal disposition, and characterized by repeated engagement with a topic, object, or activity on one's own (Hidi, 2000; Renninger, 2000). Interest in science is therefore a stable interest affected by a range of learning and life experiences over long periods of time (Krapp & Prenzel, 2011; Osborne et al., 2003; Potvin & Hasni, 2014). We did not anticipate interest in science to change as a result of the intervention, but expected it to predict students' interest in hands-on science activities, because existing personal interests can have a positive effect on interest in activities related to that interest (Hidi & Renninger, 2006). We also expected interest in science to predict interest in the topic of climate change effects on forests because it has been linked to interest in environmental science topics (Gough, 2002; Uitto et al., 2006).

Interest in hands-on science activities is a *situational interest*, or a short-term preference for specific activities as they occur (Hidi, 2000; Renninger, 2000). In our study, interest in hands-on science activities is conceptualized as a consistent situational interest in this type of activity (Swarat et al., 2012). We also did not anticipate this interest to change as a result of the intervention because the unit was not designed to enhance students' interest in its various hands-on science activities per se. However, because hands-on activities can spark interest in environmental science topics (Ardoin et al., 2014), we expected students' interest in the unit's hands-on science activities to predict their interest in climate change effects on forests.

Risk perception has been linked to adolescents' information-seeking behavior about climate change (Mead et al., 2012) and to their interest in a variety of environmental topics (Sjöberg, 2007). Sjöberg (2007) also speculated that risk perception, through its effect on interest, can influence learning, and result in revised risk perception, although he did not measure these proposed relationships. Although our unit was not explicitly designed to change students' perception of climate change risk, we expected that it might increase as a result. This is because in addition to Sjöberg's (2007) claim, simply learning about environmental risks through a formal educational intervention has been found to increase students' perceptions of these risks (Covitt et al., 2005).

The model also includes paths between the respective Time 1 and Time 2 factors. These stability coefficients were included to assess how strongly students hold the respective constructs. Given the short duration of the intervention, we expected that all pre-intervention constructs to be directly associated with their post-intervention counterparts but that the strengths of the respective relationships would vary.

Purpose of Study

One of our study's goals was to assess to what extent our pilot two-week climate change education unit changed students' interest in, and desire to learn more about, climate change effects on forests. Another goal was to test and refine a path model to predict students' short-term development of interest in climate change. This type of research is needed to learn more about the potential of relatively brief educational interventions for fostering student interest in climate change and other critical science topics. By exploring how select predictors of students' interest in climate change effects on forests, and their desire to learn more about this topic, relate to these two outcomes, we also sought to inform climate change education practice.

To the best of our knowledge, no studies have examined to what extent educational interventions foster students' interest in climate change and how. By exploring linkages over time, we are able to provide an understanding of the drivers of student's interest that cross-sectional studies cannot. More specifically, this approach allowed us to assess the impact of our intervention on the same students and to determine which constructs students hold more strongly than others over time.

Methods

Sample

Four teachers from three schools in Ann Arbor Public Schools volunteered to pilot test the unit and participate in the study with their seventh-grade (12- to 13-year-old) students. These teachers taught between 38 and 128 students and had 10 to 32 years of teaching experience.

Before implementing the unit, the four teachers took part in a one-day professional development. In return for their participation in both the professional development and the study, each teacher received a $500 stipend.

All of the students whose teachers participated in the unit's pilot test were eligible to take part in the study, as long as parents approved their participation by signing a permission form. Teachers reported that 58% of students were White or Caucasian, 19% Black or African American, 9% Hispanic or Latino, 5% Asian or Pacific Islander, 1% Native American, and the remaining 8% were part of another group.

Of the 319 students who experienced the pilot unit, 308 (97%) completed either the pre- or post- intervention instruments. Only data from students who completed both the pre- and post- instruments (n=121) were used for multilevel analyses. Of these students, 49% were male and 50% were female (1% did not indicate their gender). Path analyses were based on data from all students (n=308). Of these students, 48% were male and 44% were female (8% did not indicate their gender).

Pre- and post-intervention questionnaires

Students who participated in the study were asked by their teachers to complete identical online or hard copy questionnaires immediately before and after the two-week *Climate Change and Michigan Forests* unit (http://climatechangeandforests.org). The post-intervention questionnaires were administered right after completion of the unit.

The pre- and post-intervention instruments were designed to measure the five constructs identified in the introduction section (see Table 1 for an overview of all measures, listed by factor). Each of the 38 measures had five response options, labeled 1=strongly disagree, 3=neutral, 5=strongly agree.

Interest in Science items consisted of measures selected from the Interest in Science Survey (Lamb, Annetta, Meldrum, & Vallett, 2012) and the Science Aspiration and Career Choice Age 10-14 longitudinal study (Archer et al., 2013). These items focused on students' interest in science, including science careers (DeWitt et al., 2013; Osborne et al., 2003), as well as their personal enjoyment of studying science (Lamb et al., 2012; Osborne et al., 2003).

As suggested by its name, *Interest in Hands-on Science Activities* asked students to assess their level of interest in these activities, using a stem consistent with the one measuring *Interest in Climate Change Effects on Forests* (see further below).

Perception of Climate Change Risk items included modified measures and response options from the Yale Project on Climate Change Communication's "Climate Change in the American Mind" study (Leiserowitz et al., 2014). These items measured students' belief that climate change is occurring, caused by humans, and likely to affect them and others.

The *Interest in*, and *Desire to Learn More about*, *Climate Change Effects on Forests* items addressed topics covered by the unit. The stem for items to measure *Interest in Climate Change Effects on Forests* consisted of "This sounds interesting," followed by a list of topics covered in the unit. The structure for this scale, i.e. measuring interest in individual topics, was based on the Relevance of Science Education (ROSE) project (Sjøberg & Schreiner, 2010) and PISA (OECD, 2007), which assessed student interest in specific scientific topics. The stems, "This sounds interesting," and "I would like to learn more about this," were drawn from stem text by Swarat et al. (2012).

Teacher log

Teachers were asked to complete a log to collect information about their implementation of the pilot unit. As part of this log, teachers reported which lessons they taught, the amount of time they spent to prepare and teach the lessons, and offered suggestions for improving the unit. The four teachers reported completing all of the unit's lessons, including the field trip.

Analysis

Pearson's correlation coefficients indicated that the questionnaire items that were selected to measure our study's five constructs were correlated with each other. In light of this, an exploratory factor analysis with varimax rotation using SPSS v.22 was conducted to reduce the dimensionality of pre- and post-intervention data (Table 1). Factor loadings for each of the five factors ranged from 0.60 to 0.92 for pre-intervention measures and 0.52 to 1.00 for post-intervention measures. The amount of variance explained by the factors was also quite high, ranging from 52% to 63% for pre-intervention factors and 53% to 62% for post-intervention factors. Reliabilities were very satisfactory with Chronbach's α ranging from 0.74 to 0.94 for pre-intervention factors and 0.72 to 0.95 for post-intervention factors. Weighted factor scores were calculated based on the exploratory factor analysis' loadings and used in subsequent analyses. These scores were centered around 0, such that disagreement was reflected by a score less than 0 and agreement by a score greater than 0.

Table 1. Item loadings, variance explained, and reliability for the five measured factors

Desire to Learn More About Climate Change Effects on Forests	**Pre-Intervention (T1)**	**Post-Intervention (T2)**
I would like to learn more about this		
… Trees (in general)	0.78	0.80
… Forests (in general)	0.75	0.82
… Climate change (in general)	0.70	0.72
… How forests differ	0.71	0.79
… How trees and forests help the environment	0.73	0.78
… How scientists study climate	0.73	0.74
… How climate change may affect me	0.73	0.71
… How trees adapt to climate change	0.82	0.76
… Why tree species are different in different places	0.78	0.72
… How climate affects forests	0.85	0.83
… How climate affects trees	0.82	0.80
Amount of Variance Explained	*59%*	*59%*
Chronbach's α	*0.94*	*0.94*

Interest in Climate Change Effects on Forests	**T1**	**T2**
This sounds interesting		
… Trees (in general)	0.74	0.82
… Forests (in general)	0.75	0.79
… Climate change (in general)	0.66	0.80
… How forests differ	0.75	0.72
… How trees and forests help the environment	0.78	0.73
… How scientists study climate	0.72	0.81
… How climate change may affect me	0.72	0.72
… How trees adapt to climate change	0.78	0.83
… Why tree species are different in different places	0.79	0.72
… How climate affects forests	0.86	0.82
… How climate affects trees	0.82	0.84
Amount of Variance Explained	*58%*	*61%*
Chronbach's α	*0.94*	*0.95*

Interest in Hands-On Science Activities	**T1**	**T2**
This sounds interesting		
… Work with charts and graphs	0.60	0.58
… Work with real life tree samples	0.63	0.52
… Take scientific measurements	0.90	1.00
Amount of Variance Explained	*52%*	*53%*
Chronbach's α	*0.74*	*0.72*

Perception of Climate Change Risk	**T1**	**T2**
Ann Arbor is likely to be affected by climate change	0.76	0.76
Climate change is likely to have a big impact on people like me	0.85	0.76
Climate change is likely to have a big impact on people different from me	0.66	0.72
Michigan is already feeling the effects of climate change	0.82	0.78
Most scientists agree that humans are causing climate change	0.62	0.75
I am very concerned about climate change	0.64	0.66
Amount of Variance Explained	*53%*	*54%*
Chronbach's a	*0.87*	*0.87*

Interest in Science	**T1**	**T2**
I sometimes think about becoming a scientist when I grow up.	0.84	0.86
My science classes are interesting.	0.63	0.54
I would like to study science as a part of my job one day.	0.92	0.90
I plan to take more science classes in the future.	0.78	0.80
Science based jobs are extremely interesting to me.	0.87	0.86
My friends and I discuss science related topics.	0.68	0.72
Amount of Variance Explained	*63%*	*62%*
Chronbach's α	*0.91*	*0.90*

Initial multilevel analyses (Gelman & Hill, 2007; Raudenbush & Bryk, 2002) were conducted using Stata v.13 to account for the dependence in the outcomes due to repeated measures per student and students being nested within teachers. These models allowed for the exploration of within- and between-student and teacher variability. Intraclass correlations coefficients (ICC) were computed and indicated that a significant proportion of variation in the five factors was due to the repeated measures being nested within students and the clustering of students within teacher. The multilevel models were fit with a random intercept for student and a random intercept for teacher and estimated with restricted maximum likelihood estimation. Fixed effects in the model included gender and time. Gender was included as a covariate because it has been found to influence students' interest in science in general (Lamb et al., 2012; Osborne et al., 2003) and in the environmental and life sciences specifically (Potvin & Hasni, 2014; Uitto et al., 2006). Students who did not report their gender were excluded from the analysis. Time (pre/post) was also included in the model to directly assess the differences between the two time points when adjusting for gender and accounting for the clustering of students within teacher.

Path analyses were conducted using Stata v.13 to explore to what extent the hypothesized factors directly and indirectly explained students' post-intervention *Interest in,* and *Desire to Learn More about Climate Change Effects on Forests*. Manual backwards selection techniques and modification indices were used to arrive at the final model. The model was fit with full information maximum likelihood estimation and standardized results were requested. While the multilevel models used a random intercept to control for teacher effects, the final path model controlled for teacher effects by using clustered robust standard errors by teacher.

Model fit was assessed through several frequently used indicators (Kline, 2011): the $\chi 2$ statistic, comparative fit index (CFI), Tucker Lewis Index (TLI), and root mean square error of approximation (RMSEA). The $\chi 2$ should be low and non-significant to attest to a good fit between the sample and theoretical model (Kline, 2011), the CFI should be above 0.95, RMSEA close to 0.06, and TLI not below 0.9 (Hu & Bentler, 1999).

Results

The students who participated in this study rated each of the five measured constructs only moderately (i.e., *Interest in,* and *Desire to Learn More about, Climate Change Effects on Forests, Interest in Hands-On Activities, Interest in Science, Perception of Climate Change Risk*), both before and after the unit (Table 2).

Table 2. Descriptive statistics and paired t-test results for unweighted factors

	Pre-Test		**Post-Test**					
Factor Name	**Mean**	**SD**	**Mean**	**SD**	**Change**	**df**	**t**	**p**
Desire to Learn More about Climate Change Effects on Forests	3.62	0.83	3.15	1.00	-0.47	116	7.57	***
Interest in Climate Change Effects on Forests	3.60	0.85	3.21	1.04	-0.39	119	5.57	***
Interest in Hands-On Science Activities	3.55	1.00	3.13	1.08	-0.42	118	4.88	***
Interest in Science	3.06	1.06	2.94	1.11	-0.12	120	2.09	*
Perception of Climate Change Risk	3.64	0.75	3.82	0.78	+0.18	117	-2.50	*

* significant $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ and 1=strongly disagree to 5=strongly agree
H_0: Pre-test mean = post-test mean.

Although t-test results, comparing unweighted factor pre- and post-intervention means, suggested statistically significant differences between pre-test and post-test for all factors (Table 2), multilevel analyses of weighted factor means (controlling for gender and accounting for teacher dependence) indicated that time (i.e. the time period of the intervention) had no statistically significant coefficients for any factor, suggesting that there were no changes in students' responses as a result of their participation in the unit (Table 3).

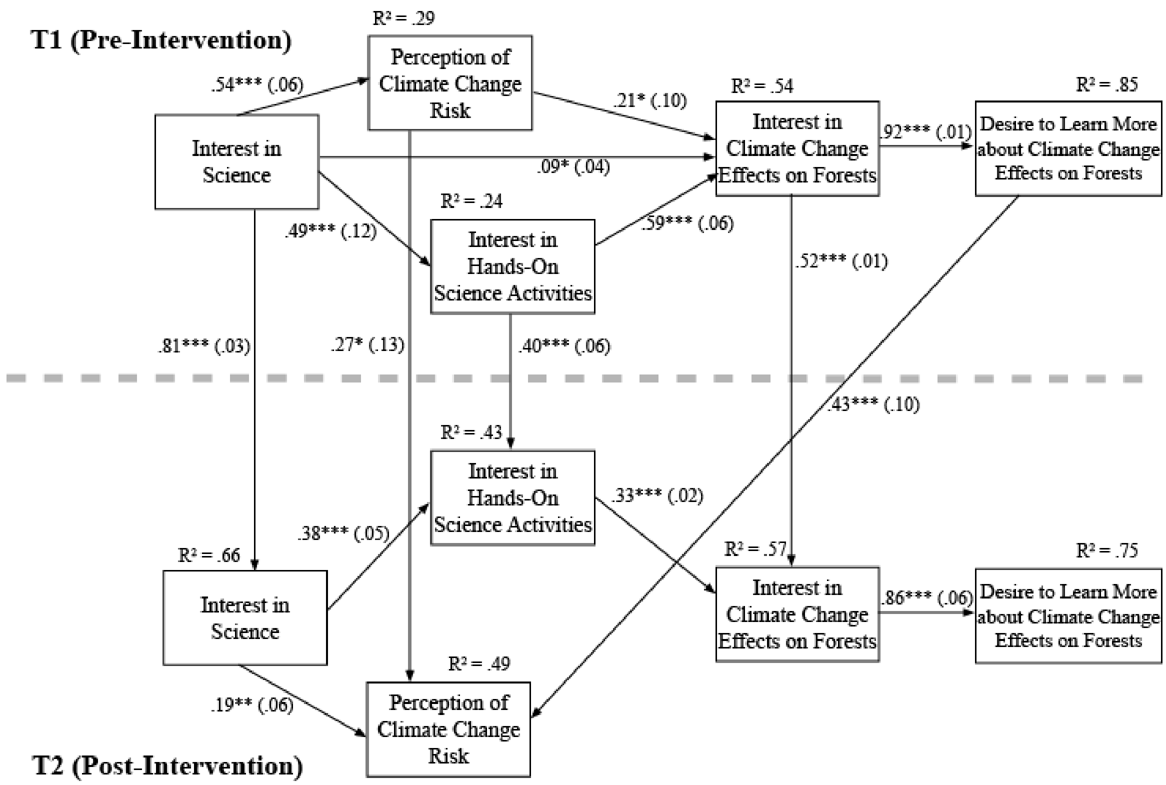
Table 3. Multilevel analysis results to assess pre- to post- intervention changes in the study's five weighted factors

Variable Name	**Desire to Learn More about Climate Change Effects on Forests**			**Interest in Climate Change Effects on Forests**			**Interest in Hands-On Science Activities**			**Interest in Science**			**Perception of Climate Change Risk**		
Potential Values	-3 to +3			-3 to +3			-3 to +3			-3 to +3			-3 to +3		
Unconditional Model (All Observations)															
L1 Residual Variance	0.25			0.29			0.37			0.17			0.41		
L2 Intercept Variance (Students nested within Teachers)	0.65			0.60			0.48			0.72			0.47		
L3 Intercept Variance (Teacher)	0.08			0.08			0.08			0.09			0.02		
Intraclass Correlation Coefficient (ICC) (Students nested within teachers)	66%			62%			52%			73%			52%		
Intraclass Correlation Coefficient (ICC) (Teacher)	75%			70%			60%			83%			54%		
Full Model (Matched Observations Only)	**Coef**	**SE**	**p**	**Coef**	**SE**	**p**	**Coef**	**SE**	**p**	**Coef**	**SE**	**p**	**Coef**	**SE**	**p**
Time (T1 = 0)	-0.09	0.07	0.17	-0.06	0.07	0.37	0.04	0.08	0.63	0.02	0.05	0.72	0.08	0.08	0.34
Gender (Male = 0)	-0.25	0.16	0.12	***-0.35***	***0.16***	***0.03***	***-0.36***	***0.15***	***0.02***	***-0.33***	***0.15***	***0.03***	***-0.38***	***0.12***	***0.00***
L1 Residual Variance	0.24			0.29			0.38			0.17			0.38		
L2 Intercept Variance (Students nested within Teachers)	0.65			0.59			0.49			0.62			0.26		
L3 Intercept Variance (Teacher)	0.05			0.04			0.08			0.10			0.02		
Differences in Means															
Pre-Intervention vs. Post-Intervention	-0.05			-0.06			0.04			0.02			0.06		
Male vs. Female (Post-Intervention)	-0.02			-0.28			-0.23			-0.21			-0.19		

Values where $p < 0.05$ are highlighted using ***bold italic***.
H_0: Mean coefficient = 0.

To explore the variables explaining the variability in students' post-intervention *Interest in*, and *Desire to Learn More about*, *Climate Change Effects on Forests*, a series of path models were tested. The initial, hypothesized path model (Figure 1) predicted students' *Interest in*, and *Desire to Learn More about*, *Climate Change Effects on Forests* quite to very well (pre-intervention R^2=0.54 and R^2=0.85, post-intervention R^2=0.62 and R^2=0.76, respectively). The statistically significant path coefficients (14 of 19) ranged from small to large (range: 0.10 to 0.92). However, the model fit indices indicated that further refinement of the model was necessary to achieve acceptable fit (CFI = 0.95, TLI = 0.92, RMSEA = 0.10, $\chi 2$ = 88.73, p < 0.001).

The final, most parsimonious path model (Figure 2) demonstrated sufficient overall model fit (CFI = 0.97, TLI = 0.95, RMSEA = 0.08, $\chi 2$ = 79.43, p < 0.001). It continued to predict students' pre- and post-intervention *Interest in,* and *Desire to Learn More about, Climate Change Effects on Forests* quite, to very well (pre-intervention R^2=0.54 and R^2=0.85, post-intervention R^2=0.57 and R^2=0.75, respectively), and the model's 15 statistically significant path coefficients ranged from small to large (range: .09-.92).



CFI = 0.97, TLI = 0.95, RMSEA = 0.08, χ^2 = 79.43, p < 0.001

Clustered robust standard errors by teachers are presented in parentheses.
* The path size is statistically significant at p < 0.05 ** p < 0.01 *** p < 0.001
H_0: Standardized path coefficient = 0.

Figure 2. Final path model of factors predicting students' post-intervention *Interest in,* and *Desire to Learn More, About Climate Change Effects on Forests*

The revised model shows that the paths influencing students' *Desire to Learn More about Climate Change* were very similar during the study's pre- and post-intervention time periods, with four of the five measured factors having the same direct relationships; i.e., *Interest in Science* -> *Interest in Hands-On Science Activities* -> *Interest in Climate Change Effects on Forests* -> *Desire to Learn More.* In this model, students' post-intervention *Desire to Learn More about Climate Change Effects on Forests* was thus only directly associated with their post-intervention *Interest* in these topics (mean standardized coefficient $\pm$ SE: 0.86$\pm$0.06). In addition, *Interest in Science* had a consistent direct relationship with *Perception of Climate Change Risk* during both time periods. *Perception of Climate Change*

Risk, however, only had a significant direct relationship with *Interest in Climate Change Effects on Forests* before, and not after, the intervention.

Four of the five stability coefficients; i.e., the direct effects of each pre-intervention (Time 1) factor on its corresponding post-intervention factor (Time 2), were statistically significant. The exception was the stability coefficient for *Desire to Learn More about Climate Change Effects on Forests*. Among the four statistically significant stability coefficients, the one for *Interest in Science* was the highest (0.81±0.03), followed by the one for *Interest in Climate Change Effects on Forests* (0.52±0.01), *Interest in Hands-On Science Activities* (0.40±0.06), and *Perception of Climate Change Risk* (0.27±0.13). The extremely high stability coefficient for interest in science is consistent with findings that this personal interest is difficult to change or increase through educational interventions, particularly through ones short in duration (Häussler & Hoffmann, 2002; Osborne et al., 2003) . The relatively more moderate stability coefficient for interest in hands-on science activities is also consistent with prior research suggesting that situational interests are easier to increase through educational interventions compared with personal interests (Ardoin et al., 2014; Bergin, 1999; Palmer, 2009).

In addition, there was one direct cross-time association from a pre-intervention measure to a post-intervention measure: pre-intervention *Desire to Learn More about Climate Change Effects on Forests* had a significant association with post-intervention *Perception of Climate Change Risk* (0.43±0.10).

Finally, we examined the indirect effects of pre- and post-intervention factors on post-intervention *Interest in,* and *Desire to Learn More about, Climate Change Effects on Forests* (Table 4). Indirect effects ranged from low to moderate for both *Interest in,* and *Desire to Learn More about, Climate Change Effects on Forests* (range: .11-.46 and .09-.45, respectively). Pre-intervention factors generally had larger indirect effects than their respective post-intervention factors, most likely because much of the variability in Time 2 factors was explained by Time 1 factors.

Pre-intervention *Interest in Science* (indirect effects coefficient±SE: 0.42±0.07) and *Interest in Hands-on Science Activities* (indirect effects: 0.46±0.04) had the largest indirect effects on post-intervention *Interest in Climate Change Effects on Forests*. Pre-intervention *Interest in Climate Change Effects on Forests* had the largest indirect effects on post-intervention *Desire to Learn More about Climate Change Effects on Forests* (indirect effects: 0.45±0.04), namely because of its direct effects on post-intervention *Interest in Climate Change Effects on Forests*. Pre-intervention *Perception of Climate Change Risk* had relatively smaller indirect effects on post-intervention *Interest in,* (indirect effects: 0.11±0.04) and *Desire to Learn More about, Climate Change Effects on Forests* (indirect effects: 0.09±0.04).

Table 4. Indirect (unstandardized) effects on post-intervention *Interest in, and Desire to Learn More about, Climate Change Effects on Forests*

	Indirect Effects Coefficient	Standard Error	p-value
Post-Intervention *Interest* in Climate Change Effects on Forests			
Pre-Intervention Factors			
Interest in Science	0.42	0.07	***
Interest in Hands-On Science Activities	0.46	0.04	***
Perception of Climate Change Risk	0.11	0.04	*
Interest in Climate Change Effects on Forests	N/A	N/A	N/A
Post-Intervention Factors			
Interest in Science	0.12	0.01	***
Interest in Hands-On Science Activities	N/A	N/A	N/A
Post-Intervention *Desire to Learn More* About Climate Change Effects on Forests			
Pre-Intervention Factors			
Interest in Science	0.37	0.08	***
Interest in Hands-On Science Activities	0.40	0.03	***
Perception of Climate Change Risk	0.09	0.04	*
Interest in Climate Change Effects on Forests	0.45	0.04	***
Post-Intervention Factors			
Interest in Science	0.11	0.01	***
Interest in Hands-On Science Activities	0.28	0.01	***

ns = not significant at $p < 0.05$, * significant at $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
H_0: Indirect effects coefficient = 0.

Discussion

Previous research suggests that students' interest in climate change may influence their knowledge about (Bråten et al., 2009), and acting on (Fröhlich et al., 2013; Levy & Zint, 2013) climate change; thus it is important to learn how to raise students' interest in climate change through educational interventions. To date, only a few studies have measured students' interest in climate change (Bråten et al., 2009; Strømsø et al., 2010; Uitto & Saloranta, 2010), and none have explored to what extent, or how, educational interventions can increase students' interest in this critical topic. The need for research on students' development of interest in climate change is further corroborated by our exploratory study, which revealed the following troubling results.

Troubling climate change interest findings

Among the troubling results were our study's Midwestern students' moderate level of interest in climate change effects on forests. Similarly modest levels of interest in climate change have also been observed among European students (Bråten et al., 2009; Strømsø et al., 2010; Uitto & Saloranta, 2010). Youth's lack of a strong interest in climate change should be of concern because their lives are already being impacted by climate change (IPCC, 2014), including through its effects on forests (S. Alexander et al., 1997). Moreover, youth without such an interest in climate change may be less likely to learn about, care about, or act on climate change (Deci, 1992; Fröhlich et al., 2013; Levy & Zint, 2013; Uitto & Saloranta, 2010), reducing the probability of success of climate change mitigation and adaptation efforts.

We were also troubled by the fact that the two-week pilot climate change unit did not increase students' interest in climate change effects on forests. This lack of a positive change in students' topic interest is of concern because the unit has a variety of features that have fostered students' interest in other science topics (Potvin & Hasni, 2014; Swarat et al., 2012). Despite our expectation that students would perceive the unit to have these features, it is possible that we did not succeed (e.g., that students did not consider the unit sufficiently relevant and representative of science). Alternatively, it may be that the unit did not incorporate features that are more critical to raising students' interest in climate change versus other science topics. For example, the unit may not have been sufficiently challenging (Csikszentmihalyi, 1990; Deci, 1992), or novel (Bergin, 1999; Palmer, 2009) to engage students. We also did not explore whether students consider the topic of climate change to be valuable or significant, which has been linked to topic interest (Hidi & Baird, 1986; Schiefele, 1991).

We were particularly troubled by the lack of increase in students' motivation to seek out additional information about climate change effects on forests as a result of the unit. This lack of change may have occurred because students' desire to learn more about climate change effects on forests was closely related to their interest in the topic, and interest remained the same at both time periods. Our unit also was not designed to increase students' response efficacy, which has been linked to adolescents' climate change information-seeking behavior (Mead et al., 2012). Had our unit been designed for this purpose and had we measured this predictor, there might have been an increase in students' desire to learn more about climate change effects on forests. Within the context of climate change education, where relatively short educational interventions are the norm, we believe it is critical that these interventions raise students' desire to learn more. Students who have a greater desire to learn more about climate change are more likely to seek out additional opportunities to engage with this topic on their own (Deci, 1992; Hidi & Renninger, 2006), which may, in turn, support their learning and acting on climate change.

Within this context, it is important to note that preliminary t-test results suggested that there were statistically significant pre- to post- intervention declines in each of the four types of interest measured as well as an increase in students' perception of climate change risks. However, once gender and teacher effects were accounted for, no statistically significant changes in these variables were identified. This confirms the importance of conducting multi-level analyses, controlling for teacher dependence and influences other than an educational intervention, when assessing changes in students' interests (DeWitt et al., 2013; Swarat et al., 2012).

Insights into short-term climate change interest development

As suggested by our exploratory study's outcomes, increasing students' interest in climate change through short educational interventions may indeed be a formidable challenge. To help overcome this challenge, a better understanding of the determinants of, and these determinants' relationships to students' development of interest in climate change, is needed. Our study, the first to investigate students' interest development in climate change, sheds some initial insights into this question for future studies to build on.

For one, although our study suggested that students' interest in climate change effects on forests was strongly associated with their motivation to learn more about this topic, results also indicated that these two constructs were distinct and should therefore be distinguished from each other. This conclusion is supported by our path analysis, which showed that the predictors and outcomes of topic interest and desire to learn more differed. These findings thus confirmed our expectation, as well as that that by select researchers (Boekaerts & Boscolo, 2002; Katz et al., 2006; Nenninger, 1992), that students' desire to learn about a topic should not be treated the same as their interest in that topic.

Moreover, it can be concluded that students' desire to learn more about a topic may be more amenable to change through short educational interventions than their interest in that topic. This is based on the lack of a statistically significant stability coefficient for desire to learn more, and the relatively high stability coefficient for topic interest. Indeed, the fact that R^2 for desire to learn declined from pre- to post-intervention suggests that something other than topic interest, and most likely participating in our unit, contributed to students' post-intervention desire to learn more. Measuring changes in students' desire to learn more about climate change may therefore be a more informative indicator of the success of relatively short climate change education interventions than measuring changes in their interest in this topic.

The lack of a statistically significant stability coefficient for desire to learn more about climate change effects on forests is particularly promising in that it suggests that students' information-seeking behavior may be quite amenable to change, including through short educational interventions. The important question within this context is how climate change education can increase students' climate change information-seeking behavior. Although we cannot answer this question, we can rule out enhancing students' perceptions of climate change risk as a definite means of developing students' interest in and information-seeking about this topic. Although students' perception of climate change risk appears relatively amenable to change, the influence of this factor on students' interest in climate change effects on forests was initially only moderate and nearly non-existent after the intervention.

The other relationships between the interest-related constructs were mostly consistent with what we expected based on existing research. As hypothesized, students' interest in hands-on science activities was directly related to their interest in climate change effects on forests, and mediated the effects of students' interest in science on their topic interest during both time periods. Also consistent with expectations, students' interest in science was directly related to their pre-intervention topic interest, and their interest in climate change effects on forests was directly related to their desire to learn more about this topic. In other words, students who were more interested in science and hands-on science activities were more likely to express a greater interest in climate change effects on forests and in turn, a greater desire to learn more about this topic.

Contrary to our expectations, we also learned that students' interest in science had another indirect relationship with their initial topic interest. This indirect relationship was mediated by students' initial perception of climate change risk. In fact, the greatest number of differences between the hypothesized and final path model involved students' perception of climate change risk. First, students with a stronger interest in science had a higher perception of climate change risk, before and after the intervention. Second, students with higher perceptions of climate change risk after the intervention were *not* more likely to express an interest in climate change effects on forests. Third, students with higher perceptions of climate change risk did not express a greater desire to learn more about the topic at either time period.

Our final path model's results with regard to the role of perception of climate change risk in students' climate change interest development were thus mostly consistent with prior researchers' findings, with some important differences. As Sjöberg's (2007) cross-sectional study did, we found a link between students' perception of climate change risk and topic interest, but only before the intervention. The lack of a link between perception of climate change risk and topic interest after the intervention may have occurred because pre-intervention interest explained much of post-intervention interest and thus, there was not enough variability to take into account perception of climate change risk. In addition, while there was no direct relationship between students' initial topic interest and their subsequent perception of climate change risk, there was a direct link between students' initial desire to learn more and their subsequent risk perception, as speculated by Sjöberg (2007). Students with a higher desire to learn more about climate change, may therefore be concluded to be more likely to develop more accurate perceptions of climate change risk as a result of an educational intervention. However, there was no statistically significant direct relationship between students' perception of climate change risk and their desire to learn more about this topic, as was suggested by Mead et al.'s (2012) study. There was a small indirect relationship between students' initial perception of climate change risk and their desire to learn more about climate change effects on forests before the intervention, but this relationship was mediated by interest in the topic. Based on these results, students with higher perceptions of climate change risk may be slightly more likely to seek out additional information on the topic, but probably only if they have an interest in it.

In summary, our study's results suggest that educators should not focus on enhancing students' perceptions of climate change risk as a means to increase their interest in, or desire to learn more, about this topic. This particular approach does not appear effective in achieving either of these outcomes. Instead, our study's findings indicate that educators can strengthen students' interest in, and desire to learn more, about climate change by involving them in hands-on climate science activities and striving to enhance their interest in science in general.

Limitations and Future Directions

As a result of this exploratory study, we learned that our pilot two-week climate change education unit did not increase students' interest in, or desire to learn more about, climate change effects on forests, despite the unit having features that have been associated with students' development of interest in other science topics. These findings suggest there is an important need for qualitative research to explore what makes learning about the specific topic of climate change interesting and especially, what may help to increase students' desire to learn more about this critical topic. Despite existing research (Blizard & Schuster, 2004; Sobel, 1995), suggesting that children feel a strong personal connection with trees and forests, it may be that this context may not have been sufficiently relevant to middle school students. Alternatively, it may be that the features that make learning about climate change interesting are not the same as the ones that make other science topics interesting. And importantly, there is a need to explore how to strengthen students' climate change information-seeking behavior, particularly as a result of short-term interventions, by discovering under what circumstances students decide that learning more about this topic is worthwhile.

We acknowledge that we did not ask students to report to what extent they felt our unit had the features that we believed it to have (e.g., to what extent students perceived it as relevant and representative of science). It is possible, that despite our attempts to design the unit to have these characteristics, we did not succeed. Future studies should verify that students perceive educational interventions to have the features expected to raise their interest in, and desire to learn more about, climate change.

Our study also allowed us to test and refine an initial model for predicting students' short-term interest development in climate change. This type of research is needed to learn more about how educational interventions can foster students' interest in, and desire to learn more about, this and other critical environmental challenges. Although our final model's fit was sufficient and predicted interest in, and desire to learn more about, quite well, the model could likely be enhanced by adding other predictors. Promising factors include (1) response efficacy, which has been linked to climate change information-seeking behavior (Mead et al., 2012), (2) perceived topic value (Hidi & Baird, 1986; Renninger, 2000; Schiefele, 1991) which research on framing suggests influences a range of responses to climate change (Moser, 2010), and (3) level of interest in the educational intervention itself, which has also been identified as playing a role in interest development (Hidi & Renninger, 2006; Renninger & Hidi, 2011).

Lastly, there is an important need to test how climate change education efforts may affect the development of interest in this topic among different populations. The students who participated in our study were from a relatively affluent school district. Environmental justice research suggests that students from less affluent school districts, who may have fewer ways to protect themselves from climate change impacts, may respond quite differently to climate change education interventions (Taylor, 2014).

We encourage the pursuit of the type of research proposed in this section. Such research is needed to provide insight into how to design educational interventions so that they can contribute to addressing climate change as well as other critical societal challenges.

CHAPTER 2

Exploring the relationship between middle school students' interest in, and knowledge about, climate change: Results from an intervention-based path model

Introduction

How can we engage students in learning about, and acting on, climate change? This question is of growing interest to educators in light of the mounting recognition of the threats posed by climate change (Busch & Osborne, 2014; National Research Council, 2012b).

One promising, but relatively unexplored, way to engage students in climate change may be through fostering their interest in this topic. Interest, defined here as a student's autonomous preference for a topic, object, or activity (Deci, 1992; Freeman et al., 2002; Schiefele et al., 1992), has been associated with a greater willingness to direct attention to a topic (Hidi, 2000; Hidi & Anderson, 1992) as well as deeper learning about that topic (Deci, 1992; Krapp, 1999; Schiefele & Krapp, 1996). Interest is also linked to long-term and repeated engagement with a topic over time (Hidi & Renninger, 2006; Renninger, 2000). By fostering students' interest in climate change, it may therefore be possible to increase not only their immediate knowledge about this issue but also to motivate life-long learning about it.

Interest has also been linked to a number of sought-after environmental education outcomes. Recent studies have found that students with interests in the environment have (1) expressed a greater sense of responsibility toward the environment (Uitto et al., 2011), (2) felt a higher degree of self-efficacy to engage in environmentally sustainable behaviors (Uitto et al., 2013), and (3) expressed stronger intentions to act in environmentally responsible ways (Fröhlich et al., 2013; Uitto & Saloranta, 2010), including through political participation (Levy & Zint, 2013). Students with an interest in climate change may therefore also be more likely to engage in climate change mitigation and adaptation behaviors.

To date, however, only a few studies of students' interest in climate change have been conducted. These studies' results suggest that students' interest in climate change is moderate (Bråten et al., 2009; Strømsø et al., 2010; Uitto & Saloranta, 2010), which is troubling considering the significant threats posed by climate change. Our first year of research explored students' short-term interest development in climate change during an educational intervention. Although students' interests did not change in response to the intervention, we learned that students' interest in science and hands-on science activities played more important roles in their development of interest in climate change than their perception of climate change risk. Two other studies have investigated the effects of student interest in climate change. In the first study, interest in climate change partially explained students' beliefs that climate change is occurring (Bråten et al., 2009). In the second study, interest predicted enhanced performance on a climate change reading comprehension task when measured alone, but no longer had a significant effect after additional factors were considered (Strømsø et al., 2010).

The aims of the current study were to (1) replicate select findings from our initial exploratory study, (2) improve the model of short-term interest development in climate change introduced in that same study, and (3) begin to explore to what extent students' interest in climate change predicted their knowledge about this topic.

About the study's educational intervention

As was the case with our initial interest study, the educational intervention consisted of a two-week middle school unit entitled *Climate Change and Michigan Forests* (http://climatechangeandforests.org). The unit focuses on how scientists use mathematical modeling to predict the impacts of climate change on local trees and forest ecosystems, based on authentic data from forest ecology research by Dr. Inés Ibáñez. As part of the unit, students gather tree growth data, enter the data into an online, interactive graphing tool, and examine how changes in temperature and precipitation affect tree growth. The graphing tool generates a scatterplot and lines of best fit based on simple linear equations, to allow students to predict how climatic factors influence different tree species' growth. Students also visit a forest located within walking distance of their school to gain firsthand experience with how scientists collect data for studying the impacts of climate change on trees and forests.

Several unit design decisions were made with the goal of fostering student interest in the unit and, subsequently, climate change. For one, trees and forests were chosen as the unit's context because many young children are interested in, and feel a personal connection to, nearby forests (Blizard & Schuster, 2004; Sobel, 1995). We also incorporated scientific modeling activities because they can serve as a trigger for interest development (Lehrer & Schauble, 2006), and middle school students have selected these activities as ones they are most interested in conducting during class and find most useful for their learning (Freeman et al., 2002). Lastly, a field trip was included because research has shown that these types of learning experiences can also have a positive effect on student interest (Dohn, 2011).

To improve students' knowledge about climate change effects on forests, we designed the unit in accordance with the 5E learning cycle (Karpudewan, Roth, & Abdullah, 2015; Songer, 2006) and *Next Generation Science Standards* (National Research Council, 2012a; NGSS Lead States, 2013). The climate change concepts included in the unit, including human-related drivers of climate change and effects of climate change on local ecosystems, also address important misperceptions about climate change that middle school students have been identified to hold (Leiserowitz et al., 2011; Shepardson, Roychoudhury, Hirsch, Niyogi, & Top, 2014).

More about interest and interest development

As stated earlier, interest refers to a student's autonomous preference for a topic, object, or activity (Deci, 1992; Freeman et al., 2002; Schiefele et al., 1992). Interest is divided into two types: situational and individual interest (Hidi, 2000; Renninger, 2000). Situational interest denotes a short-term preference for specific activities as they occur. Individual interest, also referred to as personal interest, is more closely associated with one's personal disposition and characterized by repeated engagement with a topic, object, or activity on one's own.

To explain how interest develops over time, the 4-phase model of interest development was proposed based on a comprehensive review of interest research (Hidi & Renninger, 2006). This model further subdivides situational and individual interests into (1) triggered situational interest (a short-term interest based on the immediate enjoyment of a specific activity), (2) maintained situational interest (an interest in persisting or revisiting an activity), (3) emerging individual interest (an interest in engaging with a wider array of related content), and (4) well-developed individual interest (an enduring personal interest in re-engaging with content over long periods). Each phase builds on the prior phase and represents a deeper level of learner interest.

Our study incorporated two key premises of the 4-phase model of interest development (Hidi & Renninger, 2006; Renninger & Hidi, 2011) to the development of students' short term interest in climate change effects on forests: First, that existing individual (topic) interests can positively affect triggered situational (activity) interest in learning activities on that topic, and second, that situational interests affect individual topic interest development. These premises suggest that interest development relies on internal (psychological) and external (educational intervention) factors that reinforce each other over time (Krapp, 1999; Prenzel, 1992; Valsiner, 1992).

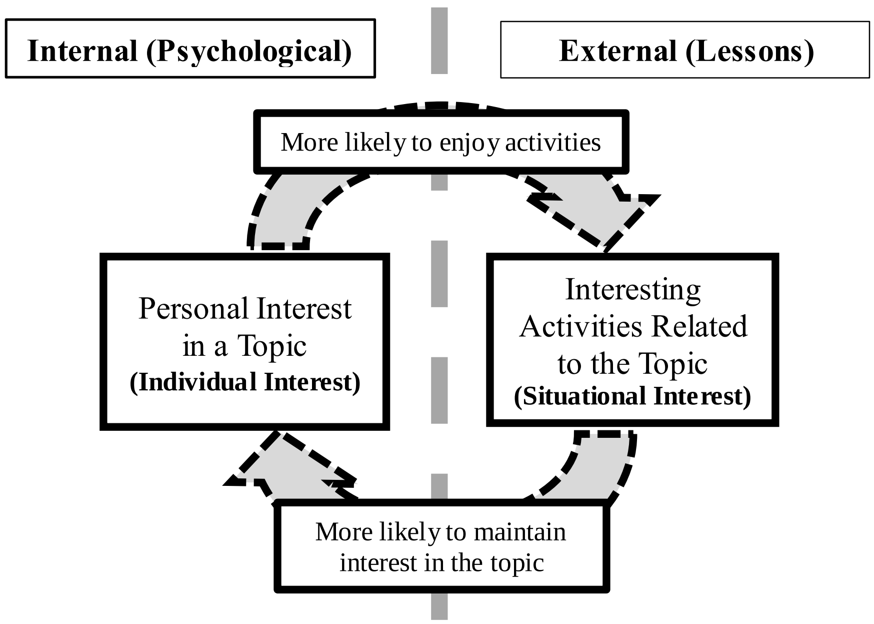


Figure 3. Conceptual drawing of the relationship between internal and external influences on interest development

About the relationship between interest and knowledge

There is some evidence to suggest that there is a link between students' interest in a topic and their knowledge about that topic. For example, a number of studies have shown that students who are interested in a topic perform better on reading comprehension tasks (P. A. Alexander, Kulikowich, & Schulze, 1994; Schiefele & Krapp, 1996; Shirey, 1992; Tobias, 1994). Longer-term studies of the link between interest in science and science knowledge that have found a positive but weak, and often also mediated, relationship between these two constructs (Krapp & Prenzel, 2011; Osborne et al., 2003; Potvin & Hasni, 2014; Schiefele et al., 1992).

As part of our study, we measured students' pre- and post-intervention knowledge about climate change to examine the effect of students' interest in climate change on their knowledge about this topic.

The study's hypothetical model

To investigate how middle school students develop an interest in climate change through a short educational intervention, and to what extent their interest in this topic relates to their knowledge about this topic, we developed a repeated-measures path model (Figure 4). This model built on insights from another model that we tested as part of the initial exploratory study. Building on that prior study's model, however, this one (1) applied the 4-phase model of interest development, (2) examined the link between students' topic interest and topic knowledge, and included (3) perceived topic value and domain interest as potential additional predictors of the model's focal variables. The following paragraphs describe the variables in the hypothetical model in greater detail and provide more information about why and how they were included in the model.

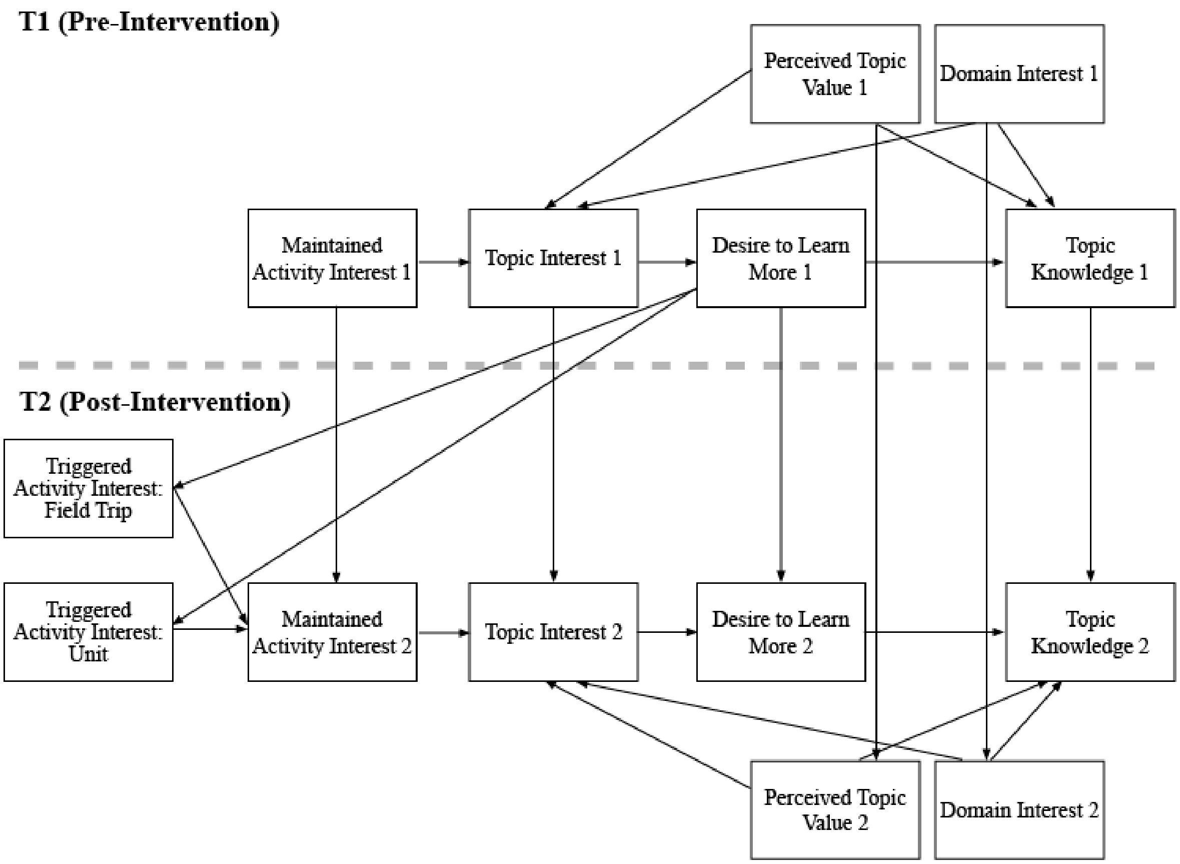


Figure 4. Hypothesized model of factors predicting students' interest development and topic knowledge

The 4-phase model of interest development suggests that triggered situational interests and maintained situational interests lead to emerging individual interest and, over time, to well-developed individual interest. Consistent with this model, our model incorporates triggered and maintained situational interests. We distinguish between triggered situational interest in the field trip versus the unit overall to explore their respective effects. We also measured students' maintained interest in hands-on science activities (Bergin, 1999; Swarat et al., 2012). These situational interests were included because activities, like our unit's, can foster students' emerging topic interests (Bergin, 1999; Hidi & Renninger, 2006; Jack & Lin, 2014).

Our model also includes topic interest as a measure of students' emerging individual interest (Hidi & Renninger, 2006). Consistent with prior research, topic interest is included as a mediator between situational interests and topic knowledge (Hidi, 2006; Nenninger, 1992).

Because our two-week educational intervention was too short to lead to the formation of well-developed individual interest in climate change, we did not include this variable in the model. Instead, we measured students' "desire to learn more." Students' desire to learn more refers to their motivation to seek out additional information about a topic and is different from their interest (i.e., preference) in a topic (Boekaerts & Boscolo, 2002; Katz et al., 2006; Nenninger, 1992), including within the context of climate change. We included this variable in the model because short educational interventions may not be long enough for interest development to occur (Hidi & Renninger, 2006), but these interventions can spark students' desire to learn more (Ardoin et al., 2014). Measuring students' desire to learn more about a topic is valuable because it serves as an indicator of the extent to which their topic interest may persist over time (Hidi & Renninger, 2006; Renninger, 2000). In addition, students' desire to learn more has been found to prompt new triggered activity interests (Hidi & Renninger, 2006) and serve as a mediator between topic interest and topic knowledge (Ainley, Hidi, & Berndorff, 2002; Nenninger, 1992; Schraw et al., 2001).

To explore the relationship between students' topic interest and topic knowledge, the model also includes measurements for the latter. In our study, topic knowledge refers to students' understanding of the concepts addressed in the unit.

Lastly, the model also includes two additional variables, perceived topic value and domain interest.

Perceived topic value refers to the importance, relevance, or meaningfulness students assign to a topic (Brophy, 1999; OECD, 2007; Schiefele, 1991), and has been found to relate to both topic interest and topic knowledge. To date, many researchers have treated this concept as a component of interest. For example, Renninger (2000) defined perceived value as one of two characteristics, along with increased knowledge, of long-term interest, and Schiefele (1991) conceptualized perceived value as a component of any kind of interest. When perceived topic value has been measured as a distinct concept, it was found to be positively related to science knowledge (OECD, 2007). We included perceived topic value as a separate variable to explore how its effects on knowledge may differ from interest, and because science educators and climate change communication researchers have suggested that appealing to what learners and receivers care about and value can influence how they respond to climate change (Moser, 2010; National Research Council, 2012a).

Domain interest refers to a students' individual interest in a broader school subject, such as math or science. Although domain interest is not included in the 4-phase model of interest development (Hidi & Renninger, 2006), Tobias (1994) suggests that domain interest likely positively affects interest in reading about a topic within that domain, as well as knowledge about topics within that domain. Empirical studies provide additional support for the relationships between domain interest, topic interests, and topic knowledge. For example, Tapola et al. (2013) found that fifth- and sixth-grade students' domain interest in math was positively related (beta coefficient = 0.38) to students' situational interest in a lesson on electrical circuit construction. Moreover, within the context of climate change, Dijkstra & Goedhart (2012) found a positive correlation (r = 0.20) between secondary students' interest in science and their knowledge about climate change. In light of this prior research, we included domain interest in the model to explore its effects on interest in, and knowledge about, climate change.

Research Questions

As suggested by this introduction, our study sought to answer four research questions. The first one focuses on assessing the effectiveness of the intervention and the remaining questions on students' short-term interest development as well as predicting their post-intervention knowledge.

(1) To what extent did the *Climate Change and Michigan Forests* unit change students' interest in, and knowledge about, climate change effects on forests?
(2) How does students' topic interest develop over the course of a short intervention (i.e., how do their activity interests, topic interest, and desire to learn more relate)?
(3) To what extent are students' activity interests, topic interest, and desire to learn more related to their knowledge about climate change effects on forests?
(4) What roles do perceived topic value and domain interest play in the development of students' interest in, and their knowledge about, climate change effects on forests?

By answering these questions, we sought to learn about the potential of relatively brief educational interventions to foster students' interest in climate change. We also strove to inform climate change education practice by examining how students' interests relate to their knowledge about this topic.

Our study is unique in that it has explored how students' interest in climate change develops over the course of a short educational intervention; only our first year pilot study has done something similar. Moreover, studies of students' interest in climate change and related topics, and the relationship between their interest and climate change knowledge, have focused either on the immediate effects on single reading comprehension tasks (Strømsø et al., 2010) or the long-term effects of interest on general knowledge (Dijkstra & Goedhart, 2012).

Methods

Design

The data for this study were collected from middle school students in the Ann Arbor Public Schools district. A quasi-experimental design was employed (Shadish, Cook, & Campbell, 2002), collecting data from a treatment group of students who experienced the *Climate Change and Michigan Forests* unit, and a comparison group of students who participated in their district's regular science curriculum.

All of the district's teachers were provided with the opportunity to take part in the study, and chose whether to be part of the treatment or comparison group. Teachers in the treatment group completed a one-day professional development before implementing the unit. Each teacher received a stipend for their participation: Treatment group teachers received $500, while comparison group teachers received $100.

Students participating in the study were asked to complete online pre- and post-intervention questionnaires, as long as their parents approved by signing a permission form. Treatment group students completed the pre-intervention questionnaire just before participating in the unit and the post-intervention questionnaire closely thereafter. Comparison group students completed the pre- and post-questionnaires two weeks apart (matching the duration of the unit), at the same times as treatment group students, without participating in the unit.

The teachers in the treatment group reported that 79% of their students were White or

Caucasian, 7% Black or African American, 3% Hispanic or Latino, 3% Asian or Pacific Islander, 1% Native American, and the remaining 6% were part of another ethnicity (including multiracial). Comparison students' ethnicities are not available because teachers in the comparison group were not asked to share this information. However, we anticipate a similar distribution because treatment and comparison teachers taught in the same schools. All participating teachers taught the unit in their life sciences class and had a mean of 13 years full-time teaching experience (range: 4-34 years).

Sample

The treatment group consisted of 467 seventh- and eighth-grade (ages 12 to 14) students, who were taught by six teachers at five schools in the district. Five of these six teachers taught seventh-grade students, and one taught a combined class of seventh- and eighth-grade students. The comparison group consisted of 177 seventh-grade students, taught by four teachers from three of the same schools. A total of 429 students in the treatment group (92%) completed the pre-intervention and 399 (85%) completed the post-intervention questionnaire. Of these, 355 students (76%) could be matched. Similarly, 177 total students in the comparison group (100%) completed the pre-intervention and 158 (89%) the post-intervention questionnaire. Of these, 124 (70%) questionnaires could be matched. Only data from matched questionnaires were used in the analysis. In the treatment group, 168 students of the students were male (47%) and 187 were female (53%). In the comparison group, 63 students were male (51%) and 61 were female (49%).

Pre- and post-intervention questionnaires

The pre- and post-intervention questionnaires were identical for treatment and comparison group students, with the exception of questions asking treatment group students about their interest in the unit and field trip.

The study's seven interest-related constructs were measured using 37 items (Table 5). These items were selected and adapted from existing scales. One construct was measured using five-point semantic differential options. The measures for the remaining constructs had five response options labeled 1=strongly disagree, 3=neutral, 5=strongly agree.

Topic Interest (InterestCC) was measured using the stem "This sounds interesting" (Swarat et al., 2012), followed by a list of topics addressed by the unit. This approach to assessing topic interest, by measuring interest in relevant subtopics, was validated by Drechsel, Carstensen, and Prenzel (2011) using data from PISA 2006 (OECD, 2007) and was also employed by the Relevance of Science Education (ROSE) project (Sjøberg & Schreiner, 2010).

Activity interest was measured through three constructs: *Maintained Activity Interest (HOInterest)*, *Triggered Activity Interest: Field Trip (FTInterest)*, and *Triggered Activity Interest: Unit (UnitInterest)*. The *Maintained Activity Interest* scale employed the same stem "This sounds interesting," as *Topic Interest*, followed by a list of hands-on science learning activities. This scale was designed to measure students' interest in these activities, independent of the unit (Hidi & Renninger, 2006). The *Field Trip* scale was used to measure triggered activity interest (Hidi & Renninger, 2006) in the unit's field trip activities. Some measures for this scale were selected from Orion et al.'s (1997) Science Outdoor Learning Environment Inventory (SOLEI). Other measures focused on field trip features expected to be engaging, based on Rickinson et al.'s (2004) research synthesis. The *Unit* scale measured triggered activity interest in the unit's various other activities, using semantic differential options from the interest sub-construct of the Study Interest Questionnaire (Schiefele, Krapp, Wild, & Winteler, 1993).

D*esire to Learn More (LearnCC)* was measured using the stem "I would like to learn more about this," followed by the same list of topics as for *Topic Interest*, matching Swarat et al. (2012)'s approach.

Perceived Topic Value (ValueCC) included a series of items drawn from PISA 2006's (OECD, 2007) "Personal" and "Social Value of Science" scales, adapted to focus on climate change and its effects on forests.

Domain Interest (ScienceInterest) was measured using select items from the Interest in Science Survey (Lamb et al., 2012) and the Science Aspiration and Career Choice Age 10-14 longitudinal study (Archer et al., 2013).

Students' *Topic Knowledge* about climate change and its effects on forests *(Achievement)*, was measured using 17 multiple choice (5 response options including "I don't know") and four true-false items (3 response options including "I don't know"), for a total of 21 questions. Select questions focused only on climate change were drawn from Leiserowitz et al.'s (2011) study of adolescents' climate change knowledge. The remaining questions were designed specifically for the study, aligned with the unit's learning objectives. Dr. Ibáñez validated the scientific accuracy of all questions. Classical test analysis (Crocker & Algina, 2006) results confirmed the appropriateness of the questions and that none needed to be removed.

Teacher logs

Treatment group teachers completed logs to describe their enactment of the unit. As part of this log, teachers reported which lessons they taught, modifications they made to the lessons, and suggestions for future revisions. All six treatment group teachers reported completing all of the unit's lessons, including the field trip. One teacher reported making modifications to add more challenging content for a class that included eighth-graders. No other substantive changes to the unit were reported.

Analysis

We calculated the total number of multiple choice and true-false questions (out of 21) students answered correctly to generate their *Topic Knowledge* score. The interest-related constructs were reduced using confirmatory factor analysis. Factor loadings for the seven constructs were high, ranging from 0.55 to 0.91 for pre-intervention measures and 0.54 to 0.94 for post-intervention measures (Table 5). Reliabilities were very satisfactory with Chronbach's α ranging from 0.69 to 0.90 for pre-intervention factors and 0.66 to 0.94 for post-intervention factors. Factor item means were used for all subsequent analyses.

Table 5. Confirmatory factor analysis results for the seven interest-related factors

	Pre-Intervention		**Post-Intervention**	
Topic Interest ***(Factor Name: InterestCC)***	**Treatment**	**Comparison**	**Treatment**	**Comparison**
This sounds interesting … Trees (in general)	0.68	0.69	0.80	0.65
… Forests (in general)	0.67	0.64	0.80	0.59
… Climate change (in general)	0.56	0.72	0.76	0.72
… How scientists study climate change	0.71	0.58	0.79	0.73
… How trees are adapted to different climates	0.80	0.66	0.85	0.81
… How climate change affects forests	0.80	0.68	0.92	0.85
… How climate change affects trees	0.84	0.75	0.91	0.79
Chronbach's Alpha	*0.88*	*0.87*	*0.94*	*0.89*
Desire to Learn More ***(Factor Name: LearnCC)***	**Treatment**	**Comparison**	**Treatment**	**Comparison**
I would like to learn more about … Trees (in general)	0.73	0.68	0.82	0.73
… Forests (in general)	0.70	0.55	0.78	0.61
… Climate change (in general)	0.63	0.73	0.76	0.78
… How scientists study climate change	0.65	0.61	0.78	0.77
… How trees are adapted to different climates	0.81	0.67	0.87	0.85
… How climate change affects forests	0.86	0.83	0.89	0.83
… How climate change affects trees	0.88	0.89	0.93	0.85
Chronbach's Alpha	*0.90*	*0.89*	*0.93*	*0.92*
Perceived Topic Value ***(Factor Name: ValueCC)***	**Treatment**	**Comparison**	**Treatment**	**Comparison**
Climate change is a very important issue to me.	0.69	0.67	0.75	0.70
Trees and forests are very important to me.	0.48	0.70	0.65	0.77
Climate change will be an important issue in the future.	0.79	0.74	0.81	0.72
I think it's important to know how climate change impacts forests.	0.75	0.78	0.81	0.80
Trees and forests are valuable to society.	0.59	0.61	0.64	0.63
Climate change will impact forests in ways that affect all people.	0.73	0.77	0.76	0.74
Chronbach's Alpha	*0.83*	*0.85*	*0.87*	*0.86*
Maintained Activity Interest ***(Factor Name: HOInterest)***	**Treatment**	**Comparison**	**Treatment**	**Comparison**
This sounds interesting … Working with charts and graphs	0.68	0.56	0.77	0.69
Working with real-life tree samples	0.58	0.49	0.69	0.54
Taking scientific measurements	0.87	0.75	0.85	0.75
Chronbach's Alpha	*0.72*	*0.69*	*0.79*	*0.66*
Domain Interest ***(Factor Name: ScienceInterest)***	**Treatment**	**Comparison**	**Treatment**	**Comparison**
I sometimes think about becoming a scientist when I grow up.	0.85	0.86	0.83	0.85
I would like science to be a part of my job one day.	0.89	0.91	0.88	0.89
I plan to take more science classes in the future.	0.74	0.83	0.81	0.83
Jobs in science are extremely interesting to me.	0.87	0.86	0.92	0.88
My friends and I discuss science related topics.	0.62	0.57	0.64	0.45
Chronbach's Alpha	*0.89*	*0.89*	*0.91*	*0.89*
Triggered Activity Interest: Unit ***(Factor Name: UnitInterest)***	**Treatment**	**Comparison**	**Treatment**	**Comparison**
Boring … Exciting	n/a	n/a	0.88	n/a
Worthless … Valuable	n/a	n/a	0.71	n/a
Dull … Interesting	n/a	n/a	0.92	n/a
Chronbach's Alpha	*n/a*	*n/a*	*0.87*	*n/a*
Triggered Activity Interest: Field Trip ***(Factor Name: FTInterest)***	**Treatment**	**Comparison**	**Treatment**	**Comparison**
I liked the field trip.	n/a	n/a	0.89	n/a
It was fun to take scientific measurements.	n/a	n/a	0.85	n/a
I learned a lot during the field trip.	n/a	n/a	0.73	n/a
The field trip was fun.	n/a	n/a	0.89	n/a
What we did during field trip helped me understand what we learned in class.	n/a	n/a	0.66	n/a
Taking scientific measurements was interesting.	n/a	n/a	0.75	n/a
Chronbach's Alpha	*n/a*	*n/a*	*0.92*	*n/a*

Multilevel analyses (Gelman & Hill, 2007; Raudenbush & Bryk, 2002) were conducted using Stata v.13 to test for pre-post intervention differences in the six repeated constructs, while accounting for the dependence in outcomes due to repeated measures per student and students being nested within teachers. These models allowed for the exploration of within- and between-student and teacher variability. Intraclass correlations coefficients (ICC) were computed and indicated that a significant proportion of variation in the six factors was due to the repeated measures being nested within students and the clustering of students within teacher. The multilevel models were fit with a random intercept for student and teacher and estimated with restricted maximum likelihood estimation. Fixed effects in the model included gender, time, group (treatment or comparison), and time-group interaction. Gender was included as a covariate because has been associated with students' interest in science generally (Lamb et al., 2012; Osborne et al., 2003) and in the environmental and life sciences specifically (Potvin & Hasni, 2014; Uitto et al., 2006). Time (pre/post-intervention) was included in the model to directly assess the differences between the two time points. Group was included to measure differences between treatment and comparison groups. The time-group interaction indicates the differences between the treatment and comparison groups in the two time periods, when adjusting for gender and accounting for the clustering of students within teacher.

Path analyses were conducted using Stata v.13 to explore to what extent the hypothesized factors directly and indirectly explained students' post-intervention *Desire to Learn More* and *Topic Knowledge*. Manual backwards selection techniques and modification indices were used to arrive at the final model. The model was fit with full information maximum likelihood estimation and standardized results were requested. To control for teacher effects on student interest development and learning (Logan & Skamp, 2013; Osborne et al., 2003), the final path model included clustered robust standard errors by teacher.

Model fit was assessed through several frequently used indicators (Kline, 2011): the $\chi 2$ statistic, comparative fit index (CFI), Tucker Lewis Index (TLI), and root mean square error of approximation (RMSEA). The $\chi 2$ should be low and non-significant to attest to a good fit between the sample and theoretical model (Kline, 2011), the CFI should be above 0.95 and RMSEA less than .08 for a reasonably close fit (Hu & Bentler, 1999), and TLI not below 0.9 (Hu & Bentler, 1999).

Results

Basic statistics

Participating students rated both the unit and field trip as moderately interesting (*Triggered Activity Interest: Unit* mean=3.03, *Triggered Activity Interest: Field Trip* mean=3.50). Their *Maintained Activity Interest*, *Topic Interest*, and *Desire to Learn More* were also moderate at both time periods for both groups (mean range: 3.10-3.49). In some contrast, students rated their *Interest in Science* slightly lower (mean range: 2.91-3.03), and their *Perceived Topic Value* slightly higher (mean range: 3.79-4.17). In fact, *Perceived Topic Value* was the only one of the interest-related factors with means above 4.0. Lastly, the mean *Topic Knowledge* scores for students in the treatment group were 8.68 before, and 13.72 after, the intervention whereas they were 8.04 before, and 8.15 after, the intervention for students in the comparison group.

Table 6. Descriptive statistics for study factors (paired observations only)

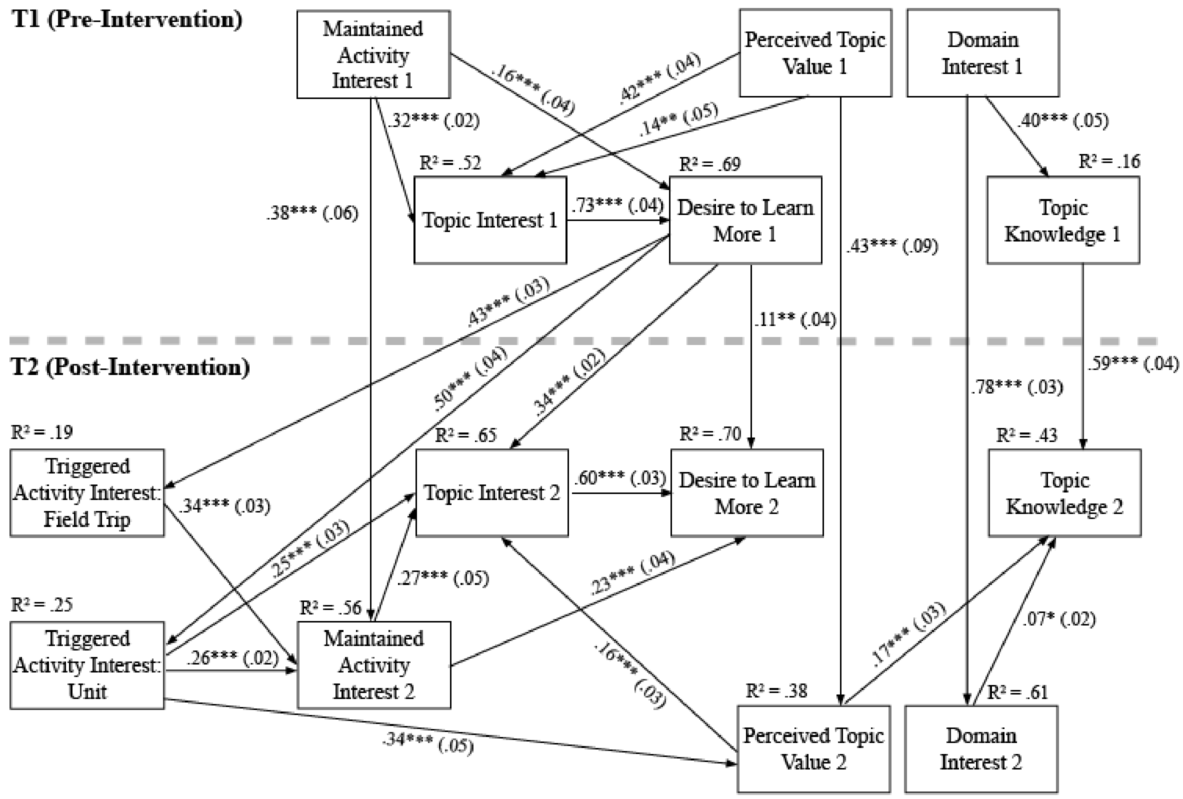
		Treatment			
		Pre-Intervention		Post-Intervention	
Factor Name	**n**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Triggered Activity Interest: Unit	354	N/A	N/A	3.03	1.10
Triggered Activity Interest: Field Trip	312	N/A	N/A	3.50	1.00
Maintained Activity Interest	352	3.49	0.94	3.34	1.02
Topic Interest	353	3.43	0.81	3.34	0.97
Desire to Learn More	325	3.41	0.85	3.10	0.98
Interest in Science	345	2.91	1.10	2.96	1.11
Perceived Topic Value	351	4.08	0.72	4.17	0.78
Topic Knowledge	355	8.68	4.48	13.72	5.03
		Comparison			
		Pre-Intervention		**Post-Intervention**	
Factor Name	**n**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Maintained Activity Interest	124	3.42	0.89	3.35	0.93
Topic Interest	123	3.40	0.81	3.30	0.84
Desire to Learn More	111	3.25	0.85	3.30	0.88
Interest in Science	122	2.96	1.16	3.03	1.11
Perceived Topic Value	124	3.79	0.87	3.85	0.78
Topic Knowledge	125	8.04	4.73	8.15	4.44

Note: Triggered Activity Interest: Unit and Triggered Activity Interest: Field Trip were only measured for the treatment group, post-intervention.

Path model fit

The model fit indices for the hypothesized model (Figure 4) indicated that further refinement of the model was necessary to achieve acceptable fit (CFI=0.91, TLI=0.87, RMSEA=0.11, $\chi2$=322.43, $p<0.001$).

The subsequent, revised model (Figure 5, Table 7) (1) demonstrated sufficient overall model fit (CFI=0.95, TLI=0.94, RMSEA=0.08, $\chi2$=199.40, $p<0.001$), (2) predicted students post-intervention *Desire to Learn More* very well ($R^2 = 0.70$) and *Topic Knowledge* quite well ($R^2 = 0.43$), and (3) its path coefficients, all of which were significant and positive, ranged from small to large (range: 0.07-0.78).



CFI = 0.95, TLI = 0.94, RMSEA = 0.08, χ^2 = 199.40, p < 0.001

Clustered robust standard errors by teachers are presented in parentheses.
* The path size is statistically significant at $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$
H_0: Standardized path coefficient = 0.

Figure 5. Final path model of factors predicting students' interest development and topic knowledge

Table 7. Summary of direct and total effects for factors in the final path model

	DIRECT Effects		**TOTAL Effects**				**DIRECT Effects**		**TOTAL Effects**		
Outcome Variable <- Predictor Variable	**Std. Coef**	**p**	**Std. Coef**	**p**	**R^2**	**Outcome Var <- Predictor Var**	**Std. Coef**	**p**	**Std. Coef**	**p**	**R^2**
Pre-Intervention Outcomes											
Achievement1					0.17	InterestCC1					0.52
<- ScienceInterest1	0.40	***	0.40	***		<- ValueCC1	0.42	***	0.42	***	
LearnCC1					0.69	<- HOInterest1	0.32	***	0.32	***	
<- InterestCC1	0.73	***	0.73	***		<- ScienceInterest1	0.14	**	0.14	**	
<- HOInterest1	0.16	***	0.39	***							
<- ValueCC1	*n/a*	*n/a*	0.30	***							
<- ScienceInterest1	*n/a*	*n/a*	0.10	**							
Post-Intervention Outcomes											
Achievement2					0.43	InterestCC2					0.65
<- Achievement1	0.59	***	0.59	***		<- LearnCC1	0.34	***	0.56	***	
<- ValueCC2	0.17	***	0.17	***		<- HOInterest2	0.27	***	0.27	***	
<- ScienceInterest2	0.07	***	0.07	***		<- UnitInterest	0.25	***	0.37	***	
<- ScienceInterest1	*n/a*	*n/a*	0.30	***		<- ValueCC2	0.16	***	0.16	***	
<- ValueCC1	*n/a*	*n/a*	0.08	***		<- InterestCC1	*n/a*	*n/a*	0.41	***	
<- LearnCC1	*n/a*	*n/a*	0.03	***		<- HOInterest1	*n/a*	*n/a*	0.32	***	
<- InterestCC1	*n/a*	*n/a*	0.02	***		<- ValueCC1	*n/a*	*n/a*	0.24	***	
<- HOInterest1	*n/a*	*n/a*	0.01	**		<- ScienceInterest1	*n/a*	*n/a*	0.06	**	
<- UnitInterest	*n/a*	*n/a*	0.06	***		<- FTInterest	*n/a*	*n/a*	0.09	***	
ScienceInterest2					0.61	HOInterest2					0.56
<- ScienceInterest1	0.78	***	0.78	***		<- HOInterest1	0.38	***	0.48	***	
ValueCC2					0.38	<- FTInterest	0.34	***	0.34	***	
<- ValueCC1	0.43	***	0.48	***		<- UnitInterest	0.26	***	0.26	***	
<- UnitInterest	0.34	***	0.34	***		<- LearnCC1	*n/a*	*n/a*	0.27	***	
<- LearnCC1	*n/a*	*n/a*	0.17	***		<- InterestCC1	*n/a*	*n/a*	0.20	***	
<- InterestCC1	*n/a*	*n/a*	0.12	***		<- ValueCC1	*n/a*	*n/a*	0.08	***	
<- HOInterest1	*n/a*	*n/a*	0.07	***		<- ScienceInterest1	*n/a*	*n/a*	0.03	*	
<- ScienceInterest1	*n/a*	*n/a*	0.02	**		FTInterest					0.19
LearnCC2					0.70	<- LearnCC1	0.43	***	0.43	***	
<- LearnCC1	0.11	**	0.51	***		<- InterestCC1	*n/a*	*n/a*	0.31	***	
<- InterestCC2	0.60	***	0.60	***		<- HOInterest1	*n/a*	*n/a*	0.17	***	
<- HOInterest2	0.23	***	0.39	***		<- ValueCC1	*n/a*	*n/a*	0.13	***	
<- InterestCC1	*n/a*	*n/a*	0.36	***		<- ScienceInterest1	*n/a*	*n/a*	0.04	**	
<- HOInterest1	*n/a*	*n/a*	0.34	***		UnitInterest					0.25
<- ValueCC1	*n/a*	*n/a*	0.20	***		<- LearnCC1	0.50	***	0.50	***	
<- ScienceInterest1	*n/a*	*n/a*	0.05	*		<- InterestCC1	*n/a*	*n/a*	0.36	***	
<- UnitInterest	*n/a*	*n/a*	0.28	***		<- HOInterest1	*n/a*	*n/a*	0.19	***	
<- FTInterest	*n/a*	*n/a*	0.13	***		<- ValueCC1	*n/a*	*n/a*	0.15	***	
<- ValueCC2	*n/a*	*n/a*	0.10	***		<- ScienceInterest1	*n/a*	*n/a*	0.05	**	

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

H_0: Standardized mean coefficient = 0.

Results by research question

The following paragraphs report our study's results, as associated with each of the four research questions.

Question 1: To what extent did the Climate Change and Michigan Forests unit change students' interest in, and knowledge about, climate change effects on forests?

Multilevel analyses of the factor means indicated that the treatment group changed significantly in two of the six repeated factors as a result of the intervention (Table 8): The mean coefficient for the time-group interaction on students' *Topic Knowledge* was positive (mean coefficient±SE: 4.93 ± 0.40), indicating an increase in student knowledge after the intervention, while the mean coefficient for *Desire to Learn More* was negative (-0.38 ± 0.09), indicating a decrease in their desire to learn more.

Table 8. Multilevel analysis results to assess pre- to post-intervention changes in the study's six repeated measures

Factor Name	Topic Knowledge			Domain Interest			Maintained Activity Interest			Perceived Topic Value			Topic Interest			Desire to Learn More		
Potential Values	0-21			1-5			1-5			1-5			1-5			1-5		
Unconditional Model (All Observations)																		
L1 Residual Variance	16.39			0.26			0.40			0.25			0.32			0.36		
L2 Intercept Variance (Students nested within teacher)	8.87			0.95			0.51			0.30			0.43			0.50		
L3 Intercept Variance (Teacher)	3.04			0.01			0.02			0.07			0.03			0.02		
Intraclass Correlation Coefficient (ICC) (Students nested within teacher)	31%			78%			55%			48%			55%			57%		
Intraclass Correlation Coefficient (ICC) (Teachers)	42%			79%			57%			60%			59%			60%		
Full Model (Paired Observations Only)	**Coef.**	**SE**	**p**	**Coef.**	**SE**	**p**	**Coef.**	**SE**	**P**	**Coef.**	**SE**	**p**	**Coef.**	**SE**	**p**	**Coef.**	**SE**	**p**
Time (T1 = 0)	0.10	0.34	0.76	0.07	0.07	0.30	-0.07	0.08	0.36	0.06	0.06	0.36	-0.10	0.07	0.16	0.05	0.08	0.48
Comparison (Comparison = 0)	0.08	0.96	0.93	-0.08	0.14	0.55	0.09	0.11	0.41	0.17	0.18	0.33	-0.03	0.14	0.84	0.20	0.12	0.10
Comparison#Time	***4.93***	***0.40***	***0.00***	-0.01	0.08	0.89	-0.09	0.09	0.35	0.03	0.07	0.71	0.02	0.08	0.85	***-0.38***	***0.09***	***0.00***
Gender (Male = 0)	-0.30	0.38	0.44	***-0.37***	***0.09***	***0.00***	***-0.29***	***0.08***	***0.00***	-0.10	0.06	0.09	***-0.23***	***0.07***	***0.00***	***-0.16***	***0.07***	***0.03***
L1 Residual Variance	7.34			0.26			0.40			0.25			0.32			0.32		
L2 Intercept Variance (Students nested within teacher)	13.75			0.93			0.51			0.29			0.42			0.49		
L3 Intercept Variance (Teacher)	1.55			0.01			0.00			0.06			0.02			0.01		

Values where $p < 0.05$ are highlighted using ***bold italic***.

H_0: mean coefficient = 0.

Question 2: How does students' topic interest develop over the course of a short intervention (i.e., how do their activity interests, topic interest, and desire to learn more relate)?

Students' *Desire to Learn More* (LearnCC) was strongly associated with their *Topic Interest* (InterestCC) at both time periods (mean standardized coefficient ± SE for T1: 0.73±0.04, T2: 0.60±0.03), indicating, not surprisingly, that students with a stronger interest in climate change effects on forests were more likely to want to learn more about this topic. In addition, students' *Desire to Learn More* (LearnCC) was moderately associated with their *Maintained Activity Interest* (HOInterest), both directly (T1: 0.16±0.04, T2: 0.23±0.04) and mediated by *Topic Interest* (InterestCC). Thus, students who were interested in hands-on science activities were also more likely to find the climate change and forest topics interesting as well as to express a desire to learn more about this topic.

Students' initial *Desire to Learn More* (LearnCC1) had several direct cross-time associations. For one, this factor was directly related to students' post-intervention *Topic Interest* (InterestCC2; 0.34±0.02), meaning that students who initially expressed a greater desire to learn more were more likely to express a greater topic interest after the unit. This cross-time relationship is not surprising given the strong relationships between topic interest and desire to learn more during both time periods. In addition, students' initial *Desire to Learn More* (LearnCC1) had relatively strong direct relationships with the two *Triggered Activity Interest* factors (UnitInterest, 0.50±0.04; FTInterest, 0.43±0.03, respectively). In other words, students who were motivated to learn more about climate change effects on forests before participating in the unit were more likely to find the unit and field trip interesting.

Students' *Triggered Activity Interest* factors had, in turn, a mix of direct and indirect associations with the interest related factors in the model. *Triggered Activity Interest: Field Trip* (FTInterest) had a direct relationship with *Maintained Activity Interest* (HOInterest2; 0.34±0.03), which also mediated its relationship with *Topic Interest* (InterestCC2; mean standardized total effects coefficient: 0.09) and *Desire to Learn More* (LearnCC2, total effects: 0.13). Students' *Triggered Activity Interest: Unit* (UnitInterest) similarly had a direct relationship with *Maintained Activity Interest* (HOInterest2; 0.26±0.02) that mediated its effect on both *Topic Interest* (InterestCC2; total effects: 0.37) and *Desire to Learn More* (LearnCC2, total effects: 0.28). Unlike *Triggered Activity Interest: Field Trip* (FTInterest), however, *Triggered Activity Interest: Unit* (UnitInterest) also had a direct effect on post intervention *Topic Interest* (InterestCC2; 0.25±0.03). Overall, students' *Triggered Activity Interest* thus played a role in their interest development, with their interest in the unit playing a larger role than their interest in the field trip.

Question 3: To what extent are students' activity interests, topic interest, and desire to learn more related to their knowledge about climate change effects on forests?

The path model shows that students' *Desire to Learn More* (LearnCC) had no direct impact on *Topic Knowledge* (Achievement) before or after the intervention. Instead, the path model reveals there was only an extremely small, although statistically significant, indirect relationship between students' initial *Desire to Learn More* (LearnCC1) and their *Topic Knowledge* (Achievement2) after the intervention (total effects: .03). This indirect effect stems from the direct paths between students' initial *Desire to Learn More* (LearnCC1), *Triggered Situational Interest: Unit* (UnitInterest), *Perceived Topic Value* (ValueCC2), and post-intervention *Topic Knowledge* (Achievement2). In combination these results suggest that the almost negligible relationship between students' initial desire to learn more about climate change effects on forests, and their subsequent knowledge about this topic is mediated by their interest in the unit and how much importance they assign to the topic of climate change and its effects on forests.

Question 4: What roles do perceived topic value and domain interest play in the development of students' interest in, and their knowledge about, climate change effects on forests?

There were several relationships between perceived topic value and domain interest with this study's focal outcomes of interest.

Perceived Topic Value (ValueCC) was directly related to *Topic Interest* (InterestCC) both before and after the intervention. The relationship between these two factors was initially relatively strong (coefficient ± SE for T1: 0.42±0.04) but had only less than half of strength subsequently (T2: 0.16±0.03), but this result may be explained by the fact that post-intervention *Topic Interest* (InterestCC2) included more predictors than pre-intervention *Topic Interest* (InterestCC1). Importantly, *Perceived Topic Value* (ValueCC2) also had a direct, moderate highly significant relationship with *Topic Knowledge* (Achievement2) after the intervention (0.17±0.03), but not before the intervention. While the unit may be responsible for this relationship, we cannot conclusively attribute it to the intervention due to the number of predictors in the model.

When compared to *Perceived Topic Value*, *Domain Interest* (ScienceInterest1) had a much smaller direct relationship with *Topic Interest* (InterestCC1) before the intervention (0.14±0.05), and no direct relationship afterward. Thus, students who were more interested in science were also slightly more interested in climate change effects on forests, but only before, and not after, the intervention. *Domain Interest* (ScienceInterest), however, was the only factor in the model that had a direct relationship with *Topic Knowledge* (Achievement) both before and after the intervention. While this direct relationship was relatively strong before the intervention (0.40±0.05), it was much smaller afterward (0.07±0.02). This suggests that students who had a greater interest in science generally were more likely to be more knowledgeable about climate change and forest topics initially, but that their general interest in science had little additional effect on their subsequent topic knowledge, while controlling for Time 1 and 2 factors. Lastly, students' pre-existing *Domain Interest* (ScienceInterest1) had a moderate total effect on post-intervention *Topic Knowledge* (Achievement2, total effects: 0.30) as a result of the large stability coefficient between topic knowledge at Time 1 and Time 2 (0.59±0.04). Thus, students with greater pre-existing interest in science came into the unit with more topic knowledge and these students were also more likely to answer more questions correctly on the post-test.

In combination, results suggest that the relationships between the variables in the model largely carried over from Time 1 to Time 2, and that students' topic knowledge after the intervention was primarily determined by how knowledgeable they were about the topic originally, how interested they were in science in general, and the extent to which they assigned value to this topic.

Discussion

Our study's goals were to (1) assess to what extent a climate change education unit changes students' interest in, and knowledge about climate change effects on forests, (2) investigate how students' interest in climate change effects on forests develops over the course of a short educational intervention (3) study to what extent students' interest in climate change effects on forests is linked to their knowledge about this topic, and to (4) examine what roles perceived topic value and domain interest play in students' interest in, and knowledge about climate change effects on forests. Based on the study's results, we offer four main new insights as related to students' interest in, and knowledge about climate change as well as interest development theory. Each of these four contributions is discussed next:

Short-term educational interventions can decrease students' desire to learn more about climate change while nonetheless increasing their knowledge about this issue

As a result of participating in our unit, students' desire to learn more about climate change effects on forests decreased, while their actual knowledge about this topic nonetheless increased. One reason for the decline in students' desire to learn more may be that our unit was not sufficiently engaging for them, as they rated it only moderately interesting. Another possible explanation for the decrease in desire to learn more may be explained by Rotgans and Schmidt's (2014) knowledge deprivation hypothesis. When Rotgans & Schmidt found a negative correlation between topic interest (which included measures for desire to learn) and learning among high school students after an educational intervention, they suggested that interest derives from a "thirst for knowledge" (Rotgans & Schmidt, 2014, p. 38) and that, when this thirst is satisfied, interest decreases. Because students' knowledge about climate change effects on forests increased as a result of the intervention, it is possible that their "thirst for knowledge" was satisfied. However, our model suggested that there is no direct link between desire to learn more and learning. An alternative explanation is that students felt that their learning goals (which drive their desire to learn more) were met by the unit, but their actual performance is not related to whether or not they felt they met their learning goals (Voss & Schauble, 1992).

The 4-phase model of interest development can also be applied to predict short-term interest development

To gain insight into how students develop an interest in climate change, we applied the 4-phase model of interest development (Hidi & Renninger, 2006; Renninger & Hidi, 2011). Although the 4-phase model is intended to explain long-term interest development, our application illustrates that it can also predict students' initial interest development over the course of a short educational intervention. Consistent with the 4-phase model, for example, our model showed that existing individual interests (here: desire to learn more about climate change effects on forests) influenced triggered situational interest in activities on that topic (here: in the field trip and unit) and (2) situational interests (here: in the field trip, unit, and hands-on science activities) affected subsequent emerging individual interest (here: interest in the climate change effects on forests). Our results thus also confirm that students' development of interest in climate change, similar to their development of interest in other topics, is based on both internal (psychological) and external (e.g., educational activities) influences that reinforce each other over time (Krapp, 1999; Prenzel, 1992; Valsiner, 1992).

Different types of interest affect learning about climate change differently

Our study's model shows that different types of interest (i.e., domain interest, activity interests, and topic interest) have different effects on students' learning about climate change.

When compared to the other interests in the study's model, students' general interest in science (i.e., domain interest) was the strongest predictor of students' learning about the effects of climate change of forests, although its effects were only moderate. Students who were more interested in science before the intervention were also more knowledgeable about climate change effects on forests, and because they already knew more, they also learned more. These findings are consistent with prior research showing that students with greater domain interest are likely to be more knowledgeable about topics within that domain (Tobias, 1994) and that prior knowledge is linked to better performance on related learning tasks (P. A. Alexander et al., 1994; Tobias, 1994). Students who were less interested in science were still likely to learn from the unit, as their performance also improved, but they were unlikely to perform as well as their peers who had a greater interest in science.

In contrast, the total effects of students' interest in the field trip and unit on learning were much smaller than that of their general interest in science. In others words, triggered activity interest supported learning, but not as much as domain interest. While situational interests in activities may provide other benefits, including support for subsequent interest development (Hidi & Renninger, 2006), their effects on learning in our study were very small as well as mediated by perceived topic value. These findings are consistent with Tapola et al. (2013), who identified a weak link between situational interest in a learning task and learning from that task, but inconsistent with Laukenmann et al. (2003), who discovered a significant link between situational interest and learning. The latter may, however, have been due to how the authors measured situational interest (i.e.; they included perceived topic value). Within this context, we were also somewhat surprised, in light of past research (Dohn, 2011; Palmer, 2009), that students' interest in the field trip did not play a more extensive role in either their interest development or learning.

Lastly, the relationship between students' pre-intervention topic interest in climate change effects on forests and their actual learning about this issue, was negligible. An essentially non-existent connection between these two variables was also found by Strømsø et al. (2010) but goes against the arguments by a number of other researchers that topic interest and desire to learn play mediating roles in the learning process (Hidi, 2006; Nenninger, 1992; Schraw et al., 2001; Shirey, 1992).

The importance students assign to climate change supports their interest and learning about this topic

To the best of our knowledge no previous studies have explored to what extent middle school students consider climate change an important topic, nor how the value students assign to climate change influences their interest in, and learning about, this issue. The students who participated in our study considered the climate change effects on forests to be quite an important topic. Moreover, the personal and societal value students assigned to this topic proved to be an important predictor of both their interest in (before and after the intervention), and knowledge about this issue (after the intervention). Work conducted in other educational contexts have found similar links between perceived topic value and interest as well as perceived topic value and learning (Brophy, 1999; Schiefele, 1991). Furthermore, by measuring perceived topic value as a construct distinct from interest, we were able to show that the former can serve as a mediator between situational interest and learning. As such we are able to offer a more nuanced understanding of the relationship between activity interest and learning than put forth by Laukenmann et al. (2003). These authors suggested that there is a direct relationship between activity interest and learning, but we suspect this was the case because they measured perceived topic value as part of situational interest.

Implications for Educators: Fostering Interest in, and Learning about, Climate Change

Our study suggests that short educational interventions can foster both interest development and learning about climate change. However, because topic interest and topic knowledge do not appear to be closely connected, educators should not assume that by fostering one, they will also support the other. In addition, students' interest in, and knowledge about climate change, appear to be predicted by different factors.

If educators' goal is to develop interest in climate change, our results suggest that educators should focus on implementing activities that students find engaging (i.e., that trigger situational interest). Although our field trip and unit were not effective in achieving this goal, it may be possible to foster a greater interest in, and desire to learn more about, climate change through activities with elements of surprise (Dohn, 2011; Palmer, 2009), ones based on in-depth scientific inquiry approaches (Jack & Lin, 2014; Potvin & Hasni, 2014), or focusing on career options (Tyler-Wood, Ellison, Lim, & Periathiruvadi, 2012). Educators may also be able to support activity enjoyment by relating climate change to other issues students are interested in (Bergin, 1999; Hidi & Renninger, 2006; National Research Council, 2012a; Uitto et al., 2006).

If the goal is to support learning about climate change, our results suggest that educators should appeal to students' broader domain interest in science (i.e., focusing on climate change as a scientific topic). We acknowledge, however, that this may prove challenging, as many students' interest in science declines during middle school (Osborne et al., 2003; Potvin & Hasni, 2014).

One strategy our study uncovered that may to support increases in both interest in, and knowledge about, climate change, appears to be teaching students about why climate change is important to their lives and society (Brophy, 2008). This recommendation is based on the findings that students' perceived topic value of climate change effects on forests was associated with both of these outcomes. Educators may therefore want to consider involving students in discussions of how their own lives might be impacted by climate change, or in other activities that allow them to personally engage with this issue (Jack & Lin, 2014).

Study Limitations

This study has many of the same limitations as our initial exploratory study. For one, our study was purely quantitative, and thus, cannot offer the type of in-depth insights a qualitative investigation can. Interviews with students, for example, would have allowed us to explore why their desire to learn more about climate change effects on forests decreased as a result of the intervention. Other researchers have had some success with learning about strategies and activities for increasing students' interest in climate change by taking such a qualitative approach (Ardoin et al., 2014; Freeman et al., 2002).

Second, while our path model included both situational and individual interests (consistent with the 4-phase model of interest development), adding more or alternative variables may yield a better-fitting model of students' short term interest development in climate change. Potential variables included influences on individual interest such as parents' and friends' interests (Bergin, 1999; Deci, 1992) as well as behavioral response efficacy, which has been found to predict adolescents' climate change information-seeking (Mead et al., 2012). There are influences on situational interest that could be included such as to what extent activities present optimal learning challenges (i.e.; they should be perceived as neither too easy, nor too difficult) (Csikszentmihalyi, 1990; Deci, 1992), share novel information (Bergin, 1999; Dohn, 2011), or use narrative structure (Bergin, 1999; Monroe & De Young, 1994).

Third, our study's students were from a relatively affluent and well-educated school district, which limits the generalizability of study results. Environmental justice research suggests that climate change education interventions can be received differently by less affluent populations (Taylor, 2014). Furthermore, the district's community is politically liberal and thus, students' parents were more likely to already be concerned about climate change. Parents' views can affect students' likelihood of information-seeking regarding climate change (Mead et al., 2012) and thus, students from more conservative communities may have responded differently to the unit.

A final limitation of our study is its sample size, which was not large enough for structural equation modeling analysis. In contrast to path analysis, this type of analysis would have allowed for the incorporation of measurement error.

Future Research Directions

We encourage research to address the limitations described above and also suggest exploring the following:

First, we suggest investigating what causes students' desire to learn more about climate change to decline as a result of educational interventions, as was the case in our study. Such research can provide insight into how to reverse this effect. Based on interest research conducted in other contexts, one possibility that should be tested is if declines in desire to learn more occur as a result of students' satisfaction with the knowledge they gained from an educational intervention. (Rotgans & Schmidt, 2014) and another, if they occur because students have met their personal learning goals (Voss & Schauble, 1992).

Second, we encourage research on students' perceptions of the importance of climate change effects on forests. Our study showed that the importance students assigned to climate change effects on forests was linked to their interest in, and knowledge about, this topic, and that it is possible for educational interventions to affect these perceptions. Because our study is the first to have identified these relationships, it is important that results be replicated. Moreover, our study does not provide insights into the route through which perceived topic value affects both interest in, and learning about, climate change (Brophy, 1999).

Finally, future research should explore what alternative instructional methods may increase students' interest in climate change as well as its effects on forests specifically. One promising method may consist of issue investigation and related approaches. Student-directed instructional activities help students internalize the importance of environmental issues (Brophy, 1999) and have also been found to support interest development in other contexts (Deci, 1992; Jack & Lin, 2014; Potvin & Hasni, 2014).

APPENDICES

Appendix 1: Supplemental Tables and Figures

Chapter 1

Teacher Effects Testing

We tested for differences in multilevel models with and without teacher effects using likelihood-ratio tests (Table 9). We found statistically signficant teacher effects for three factors: *Assessment Test Score* ($p < 0.001$), *Value of Climate Change and Forest Topics* ($p < 0.001$), and *Interest in Climate Change Effects on Forests* ($p = 0.03$), indicating a need to control for teacher effects in both the multilevel model and final path model.

Table 9. Measurement of potential teacher effects using likelihood-ratio tests of multilevel models (Chapter 1)

Variable Name	Desire to Learn More about Climate Change Effects on Forests	Interest in Climate Change Effects on Forests	Interest in Hands-On Science Activities	Interest in Science	Perception of Climate Change Risk
Potential Values	-3 to 3	-3 to 3	-3 to 3	-3 to 3	-3 to 3
Model Controlling for Teacher Effects (Paired Observations) (Teacher Model)					
L1 Residual Variance	0.24	0.29	0.37	0.17	0.38
L2 Intercept Variance (Students nested within teacher)	0.65	0.62	0.51	0.63	0.29
L3 Intercept Variance (Teachers)	0.04	0.03	0.07	0.09	0.01
Intraclass Correlation Coefficient (ICC) (Students nested within teacher)	70%	66%	54%	72%	43%
Intraclass Correlation Coefficient (ICC) (Teachers)	74%	69%	61%	81%	45%
Model NOT Controlling for Teacher Effects (Paired Observations) (No-Teacher Model)					
L1 Residual Variance	0.24	0.29	0.37	0.17	0.38
L2 Intercept Variance (Student)	0.68	0.64	0.56	0.70	0.30
Intraclass Correlation Coefficient (ICC) (Student)	74%	69%	60%	81%	44%
Likelihood-Ratio Test (No-Teacher Model Nested within Teacher Model)					
chi-square value	1.80	1.03	4.56	6.77	0.70
p-value	0.18	0.31	***0.03***	***0.01***	0.40

Values where $p < 0.05$ are highlighted using ***bold italic***.

H_0: Chi-square value for likelihood-ratio test = 0.

Correlations

Analysis showed that all constructs included in the path model were positively and significantly correlated with each other.

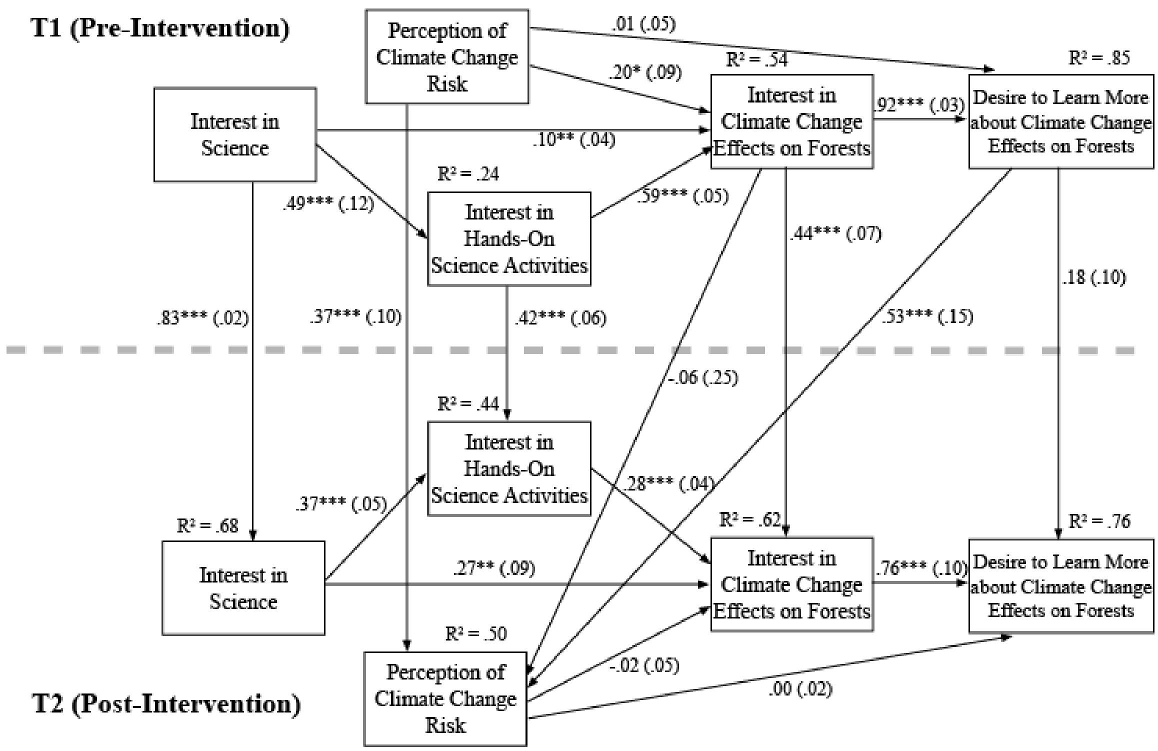
Table 10. Pairwise correlations of path model factors (Chapter 1)

	Construct Name	1	2	3	4	5	6	7	8	9
1	Desire to Learn More about Climate Change Effects on Forests (Pre)	--								
2	Desire to Learn More about Climate Change Effects on Forests (Post)	**0.73**	--							
3	Interest in Climate Change Effects on Forests (Pre)	**0.92**	**0.65**	--						
4	Interest in Climate Change Effects on Forests (Post)	**0.75**	**0.87**	**0.70**	--					
5	Interest in Hands-On Science Activities (Pre)	**0.62**	**0.46**	**0.70**	**0.57**	--				
6	Interest in Hands-On Science Activities (Post)	**0.54**	**0.60**	**0.54**	**0.64**	**0.61**	--			
7	Interest in Science (Pre)	**0.43**	**0.48**	**0.49**	**0.50**	**0.50**	**0.56**	--		
8	Interest in Science (Post)	**0.52**	**0.63**	**0.50**	**0.61**	**0.57**	**0.57**	**0.81**	--	
9	Perception of Climate Change Risk (Pre)	**0.37**	0.17	**0.42**	<u>0.21</u>	**0.31**	**0.33**	**0.54**	**0.43**	--
10	Perception of Climate Change Risk (Post)	**0.53**	**0.45**	**0.52**	**0.47**	**0.39**	**0.38**	**0.44**	**0.50**	**0.45**

<u>Underline</u> indicates the value is statistically significant at $p < 0.05$.
Boldface indicates the value is statistically significant at $p < 0.01$
Other values are not statistically significant.
H_0: Mean correlation coefficient = 0.

Results of Hypothesized Path Model

The initial, hypothesized path model (Figure 6) predicted students' *Interest in,* and *Desire to Learn More about, Climate Change Effects on Forests* quite to very well (pre-intervention R^2=0.54 and R^2=0.85, post-intervention R^2=0.62 and R^2=0.76, respectively). The statistically significant path coefficients (14 of 19) ranged from small to large (range: 0.10 to 0.92). However, the model fit indices indicated that further refinement of the model was necessary to achieve acceptable fit (CFI = 0.95, TLI = 0.92, RMSEA = 0.09, $\chi 2$ = 88.73, p < 0.001).



CFI = 0.95, TLI = 0.92, RMSEA = 0.09, χ^2 = 88.73, p < 0.001

Clustered robust standard errors by teachers are presented in parentheses.

* The path size is statistically significant at p < 0.05 ** p < 0.01 *** p < 0.001

H_0: Mean standardized path coefficient = 0.

Figure 6. Results for hypothesized path model (Chapter 1)

Chapter 2

Classical Test Analysis of Knowledge Assessment

We tallied the total number of correct questions (out of 21) to create one construct for the knowledge analysis, *Knowledge Assessment Score*. Before tabulating these scores, we conducted classical tests (Crocker & Algina, 2006) on the pre- and post-intervention responses for both groups in order to determine whether any questions should be eliminated from the analysis. This analysis included an analysis of frequencies of correct answers to assess question difficulty, verified that individual items correlate to the overall knowledge assessment score, and calculated the overall test and individual item reliability. Based on classical test results, we determined that no questions needed to be eliminated.

Table 11. Knowledge assessment classical test results

#	Question Text	Pre-Intervention						Post-Intervention					
		Treatment			Comparison			Treatment			Comparison		
		A	B	C	A	B	C	A	B	C	A	B	C
1	Which climate factors directly influence tree growth? The slope of the land	0.284	0.261	0.808	0.241	0.228	0.833	0.539	0.228	0.875	0.285	0.214	0.810
2	Which climate factors directly influence tree growth? Temperature	0.788	0.290	0.806	0.724	0.453	0.824	0.970	0.301	0.871	0.774	0.375	0.801
3	Which climate factors directly influence tree growth? Precipitation	0.780	0.433	0.800	0.731	0.477	0.823	0.950	0.270	0.871	0.715	0.467	0.796
4	Which climate factors directly influence tree growth? Pollinators	0.237	0.161	0.812	0.228	0.338	0.829	0.459	0.291	0.872	0.234	0.263	0.807
5	Which is an adaptation that helps a tree live in a specific climate?	0.477	0.505	0.795	0.359	0.568	0.819	0.692	0.641	0.859	0.394	0.386	0.801
6	What is weather?	0.433	0.366	0.803	0.310	0.446	0.825	0.675	0.555	0.862	0.350	0.433	0.797
7	Michigan's winter has been very cold this year. What does this suggest about climate change?	0.154	0.221	0.809	0.110	0.228	0.833	0.299	0.321	0.871	0.124	0.144	0.811
8	The "greenhouse effect" refers to:	0.490	0.462	0.797	0.586	0.429	0.825	0.796	0.542	0.863	0.606	0.360	0.801
9	What is the main factor scientists believe is contributing to current changes in climate?	0.300	0.380	0.802	0.310	0.405	0.826	0.754	0.566	0.862	0.299	0.387	0.800
10	Look at the above image. What does this tree core tell us about the tree's annual growth pattern?	0.581	0.356	0.804	0.538	0.211	0.836	0.766	0.512	0.864	0.482	0.359	0.802
11	What is the independent variable in the graph above?	0.441	0.395	0.801	0.372	0.445	0.824	0.678	0.523	0.864	0.387	0.444	0.797
12	According to the line of best fit shown in the graph above, what happens to Tulip Poplar tree growth as April average temperature increases?	0.532	0.429	0.799	0.455	0.448	0.824	0.825	0.539	0.864	0.394	0.443	0.797

A = Overall mean percent of correct responses for item (0.0 = no students answered correctly, 1.0 = all students answered correctly), indicates item difficulty

B = Discriminatory correlation coefficient (range: -1.0 to 1.0), shows whether individual items correlate with the overall knowledge assessment score

C = Chronbach's alpha if item is deleted (range: 0.0 to 1.0), indicates item reliability

#	Question Text	Pre-Intervention						Post-Intervention					
		Treatment			Comparison			Treatment			Comparison		
		A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
13	Scientific models …	0.273	0.269	0.808	0.200	0.233	0.833	0.645	0.453	0.866	0.263	0.222	0.809
14	Imagine your teacher showed your class the scientific model above. What is a characteristic of this model?	0.590	0.527	0.794	0.462	0.570	0.817	0.793	0.570	0.862	0.431	0.513	0.793
15	Based on the information in this graph, which of these six tree species would experience the largest decrease in annual growth with increased precipitation?	0.620	0.526	0.794	0.538	0.442	0.824	0.823	0.538	0.863	0.547	0.532	0.792
16	Based on the above growth equations, which species would experience the largest increase in growth with increased temperature?	0.391	0.370	0.803	0.310	0.365	0.828	0.580	0.345	0.870	0.336	0.510	0.794
17	Based on the graph above, what can we predict about the impact of climate change on Tulip Poplar trees?	0.265	0.405	0.801	0.200	0.460	0.824	0.530	0.568	0.862	0.175	0.312	0.804
18	Based on the graphic above, which months of the year are in the growing season (the average temperatures above freezing)?	0.262	0.307	0.806	0.255	0.360	0.828	0.512	0.481	0.865	0.263	0.393	0.800
19	What type of biome does this graphic represent?	0.292	0.142	0.814	0.283	0.262	0.833	0.468	0.207	0.875	0.358	0.092	0.817
20	Which of the following best describes is the relationship between precipitation and tree growth?	0.358	0.412	0.800	0.345	0.503	0.822	0.698	0.634	0.859	0.416	0.372	0.802
21	Compare the two U.S. maps showing the distribution of northern white cedar trees. Based on the information given, what will happen to the future northern white cedar tree distribution as a result of climate change?	0.377	0.452	0.798	0.303	0.467	0.823	0.695	0.639	0.860	0.285	0.426	0.798
	Overall Chronbach's α	*0.810*			*0.833*			*0.871*			*0.809*		

A = Overall mean percent of correct responses for item (0.0 = no students answered correctly, 1.0 = all students answered correctly), indicates item difficulty

B = Discriminatory correlation coefficient (range: -1.0 to 1.0), shows whether individual items correlate with the overall knowledge assessment score

C = Chronbach's alpha if item is deleted (range: 0.0 to 1.0), indicates item reliability

Teacher Effects Testing

We tested for differences in multilevel models with and without teacher effects using likelihood-ratio tests (Table 12). We found statistically signficant teacher effects for three factors: *Assessment Test Score* ($p<0.001$), *Value of Climate Change and Forest Topics* ($p<0.001$), and *Interest in Climate Change Effects on Forests* ($p = 0.03$), indicating a need to control for teacher effects in both the multilevel model and final path model.

Table 12. Measurement of potential teacher effects using likelihood-ratio tests of multilevel models (Chapter 2)

Factor Name	Topic Knowledge	Domain Interest	Maintained Activity Interest	Perceive d Topic Value	Topic Interest	Desire to Learn More
Potential Values	0 to 21	1 to 5	1 to 5	1 to 5	1 to 5	1 to 5
Model Controlling for Teacher Effects (Paired Observations) (Teacher Model)						
L1 Residual Variance	20.63	0.27	0.41	0.45	0.26	0.33
L2 Intercept Variance (Students nested within teacher)	6.93	0.95	0.56	0.24	0.25	0.45
L3 Intercept Variance (Teachers)	2.05	0.01	0.00	0.06	0.06	0.02
Intraclass Correlation Coefficient (ICC) (Students nested within teacher)	23%	78%	58%	32%	44%	57%
Intraclass Correlation Coefficient (ICC) (Teachers)	30%	78%	58%	39%	54%	59%
Model NOT Controlling for Teacher Effects (Paired Observations) (No-Teacher Model)						
L1 Residual Variance	20.63	0.27	0.41	0.45	0.26	0.33
L2 Intercept Variance (Students only)	8.37	0.96	0.56	0.29	0.30	0.47
Intraclass Correlation Coefficient (ICC) (Students only)	29%	78%	58%	39%	54%	59%
Likelihood-Ratio Test (No-Teacher Model Nested within Teacher Model)						
chi-square value	18.20	0.67	0.20	28.39	34.46	4.90
p-value	***0.00***	0.41	0.66	***0.00***	***0.00***	***0.03***

Values where $p < 0.05$ are highlighted using ***bold italic***.
H_0: Chi-square value for likelihood-ratio test = 0.

Pairwise Correlations of Factors

Nearly all constructs included in the path model were positively and significantly correlated with each other.

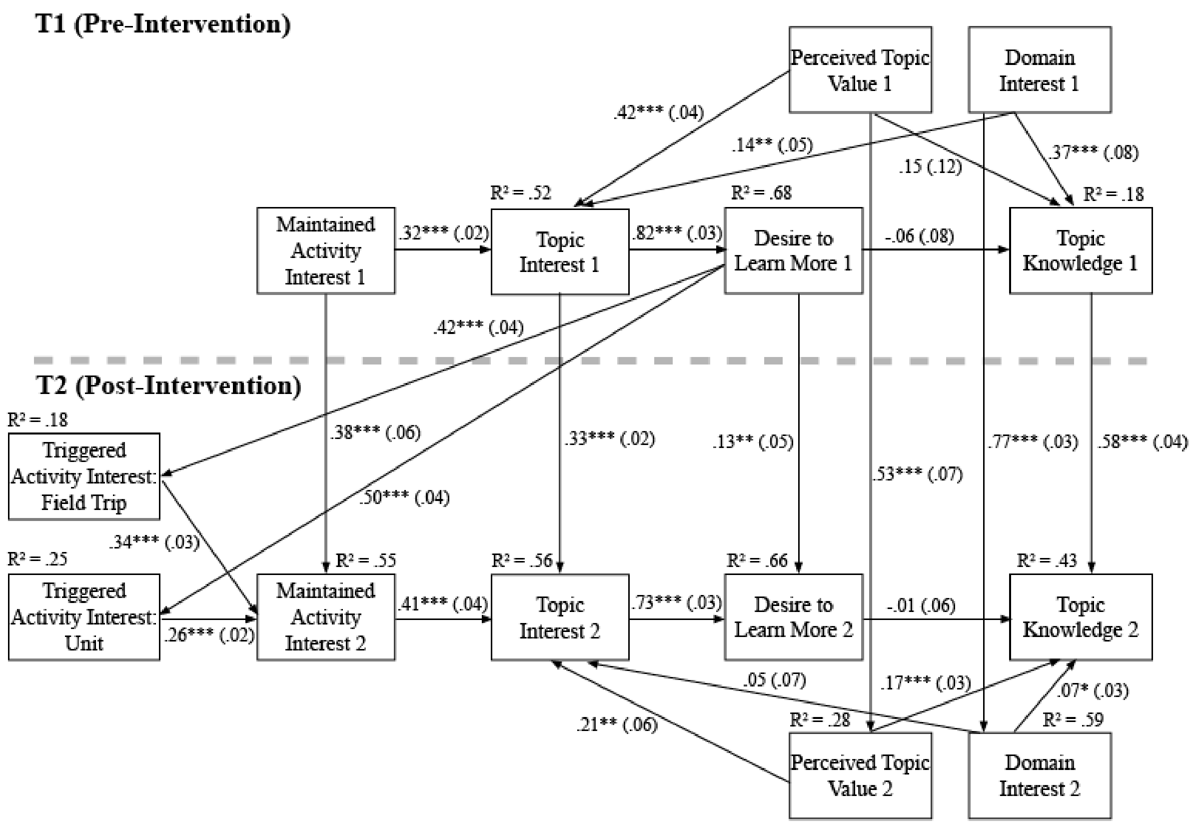
Table 13. Pairwise correlations of path model factors (Chapter 2)

#	**Factor Name**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	Topic Knowledge (Pre)	--												
2	Topic Knowledge (Post)	**0.65**	--											
3	Domain Interest (Pre)	**0.40**	**0.37**	--										
4	Domain Interest (Post)	**0.39**	**0.36**	**0.78**	--									
5	Maintained Activity Interest (Pre)	**0.23**	**0.15**	**0.45**	**0.45**	--								
6	Maintained Activity Interest (Post)	**0.17**	**0.19**	**0.43**	**0.47**	**0.59**	--							
7	Perceived Topic Value (Pre)	**0.27**	**0.25**	**0.42**	**0.36**	**0.52**	**0.34**	--						
8	Perceived Topic Value (Post)	**0.33**	**0.38**	**0.38**	**0.46**	**0.32**	**0.46**	**0.54**	--					
9	Topic Interest (Pre)	**0.26**	**0.20**	**0.45**	**0.37**	**0.60**	**0.45**	**0.64**	**0.37**	--				
10	Topic Interest (Post)	**0.22**	**0.21**	**0.44**	**0.45**	**0.50**	**0.67**	**0.51**	**0.54**	**0.60**	--			
11	Desire to Learn More (Pre)	**0.17**	**0.14**	**0.44**	**0.40**	**0.61**	**0.49**	**0.57**	**0.39**	**0.82**	**0.66**	--		
12	Desire to Learn More (Post)	**0.16**	**0.20**	**0.39**	**0.44**	**0.47**	**0.67**	**0.39**	**0.47**	**0.50**	**0.82**	**0.61**	--	
13	Triggered Situational Interest: Unit	**0.17**	**0.22**	**0.38**	**0.42**	**0.37**	**0.61**	**0.35**	**0.49**	**0.44**	**0.66**	**0.50**	**0.63**	--
14	Triggered Situational Interest: Field Trip	0.10	0.13	**0.41**	**0.46**	**0.42**	**0.65**	**0.28**	**0.41**	**0.34**	**0.59**	**0.44**	**0.60**	**0.67**

Underline indicates the value is statistically significant at $p < 0.05$.
Boldface indicates the value is statistically significant at $p < 0.01$
Other values are not statistically significant.
H_0: Mean correlation coefficient = 0.

Results of Hypothesized Path Model

The hypothesized path model (Figure 7) tested the effects of the interest factors from the Four-Phase Model on *Knowledge* with the additional covariates, *Perceived Topic Value Climate Change Effects on Forests Topics* and *Interest*. The final path model predicts students post-intervention *Topic Knowledge* moderately well ($R^2 = 0.43$) but did not meet the criteria for acceptable model fit (CFI = 0.91, TLI = 0.87, RMSEA = 0.11, $\chi 2 = 322.43$, $p < 0.001$), justifying additional analysis. Of the 24 path coefficients in the model, 20 are statistically significant, and the values ranged from small to large (range: 0.07-0.77).



CFI = 0.91, TLI = 0.87, RMSEA = 0.11, $\chi^2 = 322.43$, $p < 0.001$

Clustered robust standard errors by teachers are presented in parentheses.

* The path size is statistically significant at $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

H_0: Mean standardized path coefficient = 0.

Figure 7. Results for hypothesized path model (Chapter 2)

Appendix 2: Data Collection Instruments

Notes: (1) All questions used identical text and response options in both the pre-test and the post-test except where noted. (2) Some questions were excluded from the final analysis. (3) Interest assessment frequencies are reported only for the treatment group in the post-intervention time period. Knowledge assessment frequencies are reported for both groups at both time periods.

Year 1 Interest Assessment

Q1. Thank you for filling out this questionnaire! By doing this, you are helping to make a science education program better for you and future students. In this questionnaire, you will be asked how interested you are in topics related to trees, forests and climate change. Please be completely honest when you answer the questions. Your answers to these questions will be kept anonymous (we don't ask for your name) and your answers will not affect your grade. Your teacher and your parents will not read your answers to these questions. If you do not understand a question, do not mark a response on the answer sheet. Leave that question blank and move on to the next one. Your teacher can help you if you do not understand certain words or any of the directions for completing this questionnaire.

Q2. Enter your teacher's last name in the box (NOT your name)
Your teacher's last name

Q3. Please write today's date (ask your teacher if you are not sure)
Today's date

Q4. Create an ID number: Enter your birth month, followed by birth day, followed by how many brothers or sisters you have.*
For example, if you were born February 12 and have 1 brother and 1 sister you would write: 02122
Ask your teacher for help if you are not sure how to do this.
*NOTE: If you are a twin, triplet, etc., then ADD ONE MORE DIGIT after the number of brothers/sisters. Add a 1 if you were born first, a 2 if you were born second, etc.
Your ID Number

Q5. Are you a ...
n= 192
❍ Boy (50%)
❍ Girl (50%)

<u>POST-TEST ONLY QUESTIONS:</u>

Q13. You may recognize some of the questions from a similar questionnaire you completed a few weeks ago. Make sure and answer all the questions again according to what you think NOW.

Q14. You recently learned about trees, forests, and climate change in science class. Did you like learning about these topics?
n=209

- ❍ *I do NOT remember learning about trees, forests and climate change (1%)*
- ❍ *No - I did not like learning about trees, forests and climate change (38%)*
- ❍ *Yes – I liked learning about trees, forests and climate change (61%)*

Q6. Think about how much you agree with each of the following statements, then mark your answer for each statement.

	This sounds interesting.							I would like to learn more about this.						
	n	Strongly Agree (5)	Somewhat Agree (4)	Neutral (3)	Somewhat Disagree (2)	Strongly Disagree (1)	Mean	n	Strongly Agree (5)	Somewhat Agree (4)	Neutral (3)	Somewhat Disagree (2)	Strongly Disagree (1)	Mean
Trees (in general)	241	15%	29%	32%	14%	10%	3.2	229	13%	23%	35%	17%	12%	3.1
Forests (in general)	241	21%	29%	29%	11%	10%	3.4	227	19%	23%	33%	13%	12%	3.2
Climate change (in general)	241	20%	28%	29%	13%	10%	3.3	229	20%	19%	32%	16%	13%	3.2
How trees and forests help people	238	21%	28%	29%	14%	8%	3.4	229	20%	19%	32%	18%	11%	3.2
What climate change is	241	17%	25%	29%	17%	12%	3.2	228	15%	20%	30%	21%	14%	3.0
What trees need to grow	240	13%	28%	30%	16%	13%	3.1	227	15%	19%	35%	16%	15%	3.0
How forests differ	241	21%	23%	28%	16%	12%	3.3	227	18%	19%	35%	14%	14%	3.1
How trees and forests help the environment	240	22%	29%	27%	13%	9%	3.4	228	19%	20%	34%	15%	12%	3.2

Q9. Think about how much you agree with each of the following statements, then mark your answer for each statement.

	This sounds interesting.							I would like to learn more about this.						
	n	Strongly Agree (5)	Somewhat Agree (4)	Neutral (3)	Somewhat Disagree (2)	Strongly Disagree (1)	Mean	n	Strongly Agree (5)	Somewhat Agree (4)	Neutral (3)	Somewhat Disagree (2)	Strongly Disagree (1)	Mean
How scientists study climate	242	19%	17%	30%	21%	13%	3.1	231	16%	17%	33%	20%	14%	3.0
How much precipitation (rain, snow, etc.) forests need to be healthy	239	13%	24%	33%	15%	15%	3.0	232	13%	26%	35%	14%	12%	3.2
How climate change may affect me	241	23%	34%	22%	14%	7%	3.5	232	24%	32%	26%	10%	8%	3.5
How trees adapt to climate change	240	19%	26%	31%	15%	9%	3.3	232	19%	22%	38%	13%	8%	3.3
Why tree species are different in different places	240	21%	27%	27%	14%	11%	3.3	231	19%	21%	35%	13%	12%	3.2
What harms trees and forests	241	27%	29%	26%	8%	10%	3.6	229	16%	26%	35%	10%	13%	3.2
How temperature affects the world around me	241	23%	25%	31%	12%	9%	3.4	230	20%	26%	32%	12%	10%	3.3
How climate affects forests	241	16%	23%	33%	16%	12%	3.2	229	14%	20%	38%	14%	14%	3.0
How climate affects trees	242	16%	21%	36%	15%	12%	3.1	229	13%	17%	38%	15%	17%	3.0

Q10 Think about how much you agree with each of the following statements, then mark your answer for each statement.

	This sounds interesting.							I would like to learn more about this.						
	n	Strongly Agree (5)	Somewhat Agree (4)	Neutral (3)	Somewhat Disagree (2)	Strongly Disagree (1)	Mean	n	Strongly Agree (5)	Somewhat Agree (4)	Neutral (3)	Somewhat Disagree (2)	Strongly Disagree (1)	Mean
Listen to an explanation of climate processes	240	9%	15%	23%	23%	30%	2.5	226	12%	15%	22%	23%	28%	2.6
Work with charts and graphs	238	12%	17%	26%	19%	26%	2.7	225	20%	15%	25%	17%	23%	2.9
Use computer programs	239	33%	22%	21%	11%	13%	3.5	225	32%	17%	20%	14%	17%	3.3
Do worksheets	239	12%	15%	22%	20%	31%	2.6	225	10%	9%	25%	21%	35%	2.4
Work with real life tree samples	239	41%	23%	19%	8%	9%	3.8	225	36%	20%	21%	12%	11%	3.6
Listen to explanations of scientific processes	239	17%	16%	26%	18%	23%	2.9	226	10%	17%	27%	20%	26%	2.7
Take scientific measurements	238	19%	18%	27%	15%	21%	3.0	228	33%	15%	23%	11%	18%	3.3
Go on a field trip	237	58%	14%	14%	4%	10%	4.0	226	73%	11%	7%	4%	5%	4.4

Q11. Next, let us know how much you agree with the following statements by marking an answer for each statement.

	Strongly Agree (5)	Somewhat Agree (4)	Neutral (3)	Somewhat Disagree (2)	Strongly Disagree (1)	Mean
I sometimes think about becoming a scientist when I grow up. (n= 240)	18%	15%	17%	23%	27%	2.8
My parents encourage me to study science. (n=240)	21%	22%	28%	17%	12%	3.2
My teachers encourage me to study science. (n=239)	30%	29%	25%	7%	9%	3.6
My science classes are interesting. (n=237)	19%	24%	27%	12%	18%	3.2
I would like to study science as a part of my job one day. (n=240)	17%	12%	25%	17%	29%	2.7
At least some of my friends enjoy science. (n=240)	23%	30%	21%	13%	13%	3.4
I plan to take more science classes in the future. (n=240)	26%	19%	29%	10%	16%	3.3
My parents help me with my science homework. (n=240)	13%	12%	33%	18%	24%	2.7
Science based jobs are extremely interesting to me. (n=240)	18%	12%	29%	20%	21%	2.9
I do well in my science classes. (n=238)	42%	30%	18%	6%	4%	4.0
My friends and I discuss science related topics. (n=240)	14%	13%	26%	18%	29%	2.6
My parents see science as more important than other subjects. (n=240)	6%	10%	31%	25%	28%	2.4

Q12. Please share your opinions on climate change. How much do you agree with the following statements?

	Strongly Agree (5)	Somewhat Agree (4)	Neutral (3)	Somewhat Disagree (2)	Strongly Disagree (1)	Mean
Ann Arbor is likely to be affected by climate change (n=238)	39%	28%	26%	3%	4%	4.0
Climate change will mostly affect areas that are far away from here (n=238)	19%	18%	37%	15%	11%	3.2
Climate change is likely to have a big impact on people like me (n=238)	27%	30%	27%	9%	7%	3.6
Climate change is likely to have a big impact on people different from me (n=238)	29%	31%	31%	5%	4%	3.8
Michigan is already feeling the effects of climate change (n=237)	32%	36%	22%	5%	5%	3.9
I am uncertain that climate change is really happening (n=237)	11%	11%	23%	24%	31%	2.4
Most scientists agree that humans are causing climate change (n=238)	44%	31%	16%	4%	5%	4.1
It is uncertain what the effects of climate change will be (n=236)	15%	20%	38%	18%	9%	3.1
I am very concerned about climate change (n=236)	22%	20%	33%	12%	13%	3.3
I am willing to greatly reduce my energy use to help tackle climate change (n=236)	25%	25%	30%	9%	11%	3.4

<u>POST-TEST ONLY QUESTIONS:</u>

Q15. What did you like most about learning about trees, forests and climate change? [OPEN END]

Q16. What did you like least about learning about trees, forests and climate change? [OPEN END]

Q17. What else would you like us to know? [OPEN END]

Year 2 Interest Assessment

Note: Interest assessment frequencies are reported only for the treatment group in the post-intervention time period.

Q1. Thank you for filling out this questionnaire! By doing this, you are helping to make a science education program better for you and future students.

In the first section, you will be asked how interested you are in topics related to trees, forests, and climate change. In the second section, we ask you to answer a series of multiple choice and true/false questions.

POST-TEST ONLY TEXT: *You may recognize some of the questions from a similar questionnaire you completed a few weeks ago.* ***Make sure you answer all the questions again according to what you think NOW****.*

Please be completely honest when you answer the questions. Your answers will be kept anonymous (we don't ask for your name) and will not affect your grade. Your teacher and your parents will NOT read your answers to these questions.

Q2. Select your science teacher's last name:
Your teacher's last name (drop down menu)

Q3. Select your class period/class hour for your science class. (Ask your teacher if you are not
sure)
(drop-down, 1-8)

Q4. Please write today's date (ask your teacher if you are not sure)
Today's date

Q5. **Create an ID number:** Enter your birth month, followed by birth day, followed by how many brothers or sisters you have.*
For example, if you were born February 12 and have 1 brother and 1 sister you would write: 02122
Ask your teacher for help if you are not sure how to do this.
*NOTE: If you are a twin, triplet, etc., then ADD ONE MORE DIGIT after the number of brothers/sisters. Add a 1 if you were born first, a 2 if you were born second, etc.
Your ID Number

Q6. Are you a ...
n=469
❍ Boy (51%)
❍ Girl (49%)

Q8 Think about **how much you agree or disagree with each of the following statements**, then mark your answer for each statement.

	This sounds interesting.							I would like to learn more about this.						
	n	Strongly Agree (5)	Somewhat Agree (4)	Neutral (3)	Somewhat Disagree (2)	Strongly Disagree (1)	Mean	n	Strongly Agree (5)	Somewhat Agree (4)	Neutral (3)	Somewhat Disagree (2)	Strongly Disagree (1)	Mean
Trees (in general)	395	14%	31%	35%	14%	6%	3.3	371	9%	24%	39%	17%	11%	3.0
Forests (in general)	393	19%	37%	28%	12%	4%	3.6	368	13%	30%	36%	13%	8%	3.3
Climate change (in general)	387	19%	33%	27%	12%	9%	3.4	367	17%	24%	33%	15%	11%	3.2
How scientists study climate change	391	11%	25%	33%	17%	14%	3.0	368	9%	20%	36%	18%	17%	2.8
How trees are adapted to different climates	390	15%	35%	26%	15%	9%	3.3	369	11%	25%	34%	18%	12%	3.0
How climate change affects forests	389	16%	32%	29%	14%	9%	3.3	365	11%	15%	38%	24%	12%	3.1
How climate change affects trees	390	17%	31%	28%	16%	8%	3.3	368	11%	21%	39%	17%	12%	3.0

Q9. Think about how much you agree or disagree with each of the following statements, then mark your answer for each statement.

	Strongly Agree (5)	Somewhat Agree (4)	Neutral (3)	Somewhat Disagree (2)	Strongly Disagree (1)	Mean
Climate change is a very important issue to me. (n=395)	32%	31%	23%	8%	6%	3.8
Trees and forests are very important to me. (n=395)	38%	33%	22%	5%	2%	4.0
Climate change will be an important issue in the future. (n=394)	63%	23%	10%	3%	1%	4.4
I think it's important to know how climate change impacts forests. (n=393)	37%	31%	24%	5%	3%	3.9
Trees and forests are valuable to society. (n=395)	68%	19%	10%	2%	1%	4.5
Climate change will impact forests in ways that affect all people. (n=393)	55%	25%	14%	3%	3%	4.2

Q10. Think about how much you agree or disagree with each of the following statements, then mark your answer for each statement.

I **am interested** in …

	Strongly Agree (5)	Somewhat Agree (4)	Neutral (3)	Somewhat Disagree (2)	Strongly Disagree (1)	Mean
Listening to an explanation of climate processes (n=391)	8%	18%	32%	24%	18%	2.7
Working with charts and graphs (n=390)	11%	25%	28%	18%	18%	2.9
Working with real-life tree samples (n=388)	33%	31%	23%	7%	6%	3.8
Listening to explanations of scientific processes (n=391)	6%	18%	33%	23%	20%	2.7
Taking scientific measurements (n=389)	18%	22%	33%	15%	12%	3.2

Q11. Next, let us know how much you agree or disagree with the following statements by marking an answer for each statement.

	Strongly Agree (5)	Somewhat Agree (4)	Neutral (3)	Somewhat Disagree (2)	Strongly Disagree (1)	Mean
I sometimes think about becoming a scientist when I grow up. (n=385)	14%	20%	26%	17%	23%	2.8
My parents encourage me to study science. (n=386)	20%	26%	32%	11%	11%	3.3
I would like science to be a part of my job one day. (n=387)	15%	23%	33%	12%	17%	3.1
I plan to take more science classes in the future. (n=385)	27%	25%	26%	9%	13%	3.4
Jobs in science are extremely interesting to me. (n=385)	15%	19%	30%	17%	19%	3.0
My friends and I discuss science related topics. (n=386)	8%	15%	22%	19%	36%	2.4

Q12. How much do you agree or disagree with the following statements?

	Strongly Agree (5)	Somewhat Agree (4)	Neutral (3)	Somewhat Disagree (2)	Strongly Disagree (1)	Mean
Plants and animals have as much right as people to live. (n=391)	68%	18%	10%	2%	2%	4.5
People are clever enough to keep from ruining the earth. (n=392)	22%	25%	20%	17%	16%	3.2
People are supposed to rule over the rest of nature. (n=392)	9%	8%	22%	21%	40%	2.2
People are treating nature badly. (n=393)	48%	29%	15%	5%	3%	4.1
If things don't change, we will have a big disaster in the environment soon. (n=392)	53%	26%	14%	3%	4%	4.2

POST-TEST QUESTIONS ASKED ONLY TO TREATMENT GROUP:

Q13. Learning about Michigan forests and how they will be impacted by climate change was:

	1	2	3	4	5	Mean	n	
Boring	23%	20%	29%	19%	9%	2.7	392	Exciting
Hard to understand	6%	8%	24%	32%	30%	3.7	390	Easy to understand
Worthless	8%	10%	29%	34%	19%	3.4	391	Valuable
Dull	20%	20%	25%	23%	12%	2.9	389	Interesting

Q14. Did you go on a field trip as part of learning about Michigan forests and how they will be impacted by climate change? (n=391)

- Yes (89%)
- No (7%)
- Not sure (4%)

[ASK IF Q14 = Yes only]
Q15. Which activities did you participate in during the field trip? Be sure to indicate your role in each activity.

		I took the measurement	I watched the measurement	I wrote down the information
Taking light measurements using a light meter		n=336	n=329	n=333
	Yes	44%	80%	35%
	No	51%	15%	62%
	Don't know	5%	5%	3%
Measuring tree diameter at breast height (DBH)		n=331	n=327	n=331
	Yes	47%	78%	32%
	No	46%	17%	64%
	Don't know	7%	5%	4%
Taking a core sample from a tree		n=346	n=319	n=329
	Yes	79%	83%	26%
	No	18%	14%	69%
	Don't know	3%	3%	5%
Taking soil moisture measurements using a soil moisture meter		n=341	n=322	n=328
	Yes	39%	75%	27%
	No	56%	19%	68%
	Don't know	5%	6%	5%
Measuring air temperature		n=334	n=326	n=328
	Yes	34%	76%	34%
	No	60%	16%	60%
	Don't know	6%	8%	6%

Q16. How much do you agree with the following about the field trip?

	Strongly Agree (5)	Somewhat Agree (4)	Neutral (3)	Somewhat Disagree (2)	Strongly Disagree (1)	Mean
I liked the field trip. (n=348)	28%	38%	18%	11%	5%	3.7
It was fun to take scientific measurements. (n=349)	24%	31%	24%	13%	8%	3.5
I learned a lot during the field trip. (n=347)	24%	29%	28%	13%	6%	3.5
The field trip was fun. (n=344)	26%	28%	26%	13%	8%	3.5
I was uncomfortable during the field trip because the weather was bad. (n=344)	8%	13%	26%	27%	26%	3.5
What we did during field trip helped me understand what we learned in class. (n=346)	20%	29%	30%	14%	7%	3.4
I did not know what to do during the field trip. (n=348)	4%	10%	16%	31%	39%	2.1
Taking scientific measurements was interesting. (n=346)	22%	28%	27%	14%	9%	3.4
The only thing I liked about the field trip was that I was able to get out of school. (n=349)	13%	22%	23%	18%	23%	2.8
The activities on the field trip were new to me. (n=349)	29%	36%	23%	8%	4%	3.8
I did not like being outdoors. (n=349)	5%	6%	15%	19%	55%	1.9
There was a lot of wasted time during the field trip. (n=349)	6%	9%	21%	28%	36%	2.2
I liked the field trip instructor (or instructors). (n=348)	37%	30%	22%	8%	3%	3.9

Year 2 Knowledge Assessment

Note: (1) Frequencies are provided for <u>all students</u> in both time periods. (2) Correct answers to each question are highlighted in **boldface.**

Q17. In the next section, you will be asked 21 multiple choice and true/false questions about trees, forests, and climate change. Please do your best answering these questions!

For these questions, if you do not know the answer, do NOT guess. Instead, select "I don't know" as your response.

Q18. **Which climatic factors directly influence tree growth?**

	True	False	I don't know
A. The slope of the land			
B. Temperature			
C. Precipitation			
D. Insect pollinators			

Question Number	Response Chosen	Treatment Group		Comparison Group	
		Pre-Test	Post-Test	Pre-Test	Post-Test
Q18A		(n=420)	(n=380)	(n=166)	(n=156)
	True	29%	26%	35%	37%
	False	**28%**	**53%**	**23%**	**31%**
	DK	43%	21%	42%	32%
Q18B		(n=422)	(n=389)	(n=167)	(n=155)
	True	**79%**	**96%**	**69%**	**77%**
	False	4%	1%	11%	6%
	DK	17%	3%	20%	17%
Q18C		(n=421)	(n=387)	(n=169)	(n=155)
	True	**77%**	**94%**	**70%**	**71%**
	False	5%	2%	10%	7%
	DK	18%	4%	20%	22%
Q18D		(n=418)	(n=376)	(n=164)	(n=155)
	True	42%	35%	42%	46%
	False	**23%**	**45%**	**21%**	**25%**
	DK	35%	20%	37%	29%

Q19. Which is an adaptation that helps a tree live in a specific climate?
A. An oak tree produces acorns, which are carried away and planted in the ground by squirrels
B. The leaves of a black cherry tree are an important food source for a variety of moth and butterfly caterpillars that return as adults to pollinate flowers
C. Dead trees provide nest sites for cavity nesting birds such as eastern screech owls and black-capped chickadees
D. The needles of an evergreen tree in northern Michigan have a thick, waxy coating that stops water loss
E. I don't know

Response Chosen	Treatment Group		Comparison Group	
	Pre-Test (n=421)	Post-Test (n=388)	Pre-Test (n=169)	Post-Test (n=155)
A	7%	12%	7%	16%
B	7%	5%	9%	8%
C	3%	2%	6%	7%
D	**45%**	**66%**	**35%**	**37%**
E	38%	15%	43%	32%

Q20. What is weather?
A. The average climate
B. Changing temperature based on Earth's distance from the sun
C. The state of the atmosphere at a specific time and place
D. The state of the atmosphere averaged over a long period of time
E. I don't know

Response Chosen	Treatment Group		Comparison Group	
	Pre-Test (n=425)	Post-Test (n=389)	Pre-Test (n=170)	Post-Test (n=157)
A	11%	9%	12%	16%
B	28%	17%	35%	34%
C	**42%**	**65%**	**33%**	**34%**
D	4%	5%	8%	5%
E	15%	4%	12%	11%

Q21. Michigan's winter has been very cold this year. What does this suggest about climate change?
A. This neither proves nor disproves that climate change is happening
B. This is evidence that climate change is happening
C. This is evidence that climate change is NOT happening
D. This is evidence that climate change is slowing down
E. I don't know

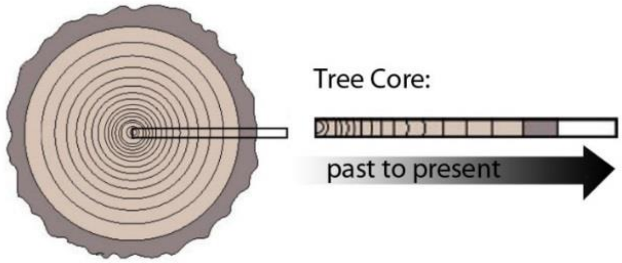
Response Chosen	Treatment Group		Comparison Group	
	Pre-Test (n=421)	Post-Test (n=387)	Pre-Test (n=170)	Post-Test (n=155)
A	**14%**	**27%**	**12%**	**13%**
B	51%	47%	41%	38%
C	4%	3%	6%	8%
D	7%	5%	13%	10%
E	24%	18%	28%	31%

Q22. The “greenhouse effect” refers to:
A. How pollution causes acid rain
B. How certain gases in the atmosphere trap heat
C. The protective effects of earth’s ozone layer
D. How plants grow
E. I don’t know

Response Chosen	Treatment Group		Comparison Group	
	Pre-Test (n=420)	Post-Test (n=390)	Pre-Test (n=172)	Post-Test (n=156)
A	5%	3%	5%	5%
B	**48%**	**78%**	**56%**	**58%**
C	13%	6%	13%	13%
D	8%	5%	6%	7%
E	26%	8%	20%	17%

Q23. What is the main factor scientists believe is contributing to current changes in climate?
A. An increase in the number of sunspots is causing the sun to get warmer
B. The hole in the ozone layer is letting in more radiation
C. Air pollution, like smog
D. Too much carbon dioxide in the atmosphere from burning fossil fuels
E. I don’t know

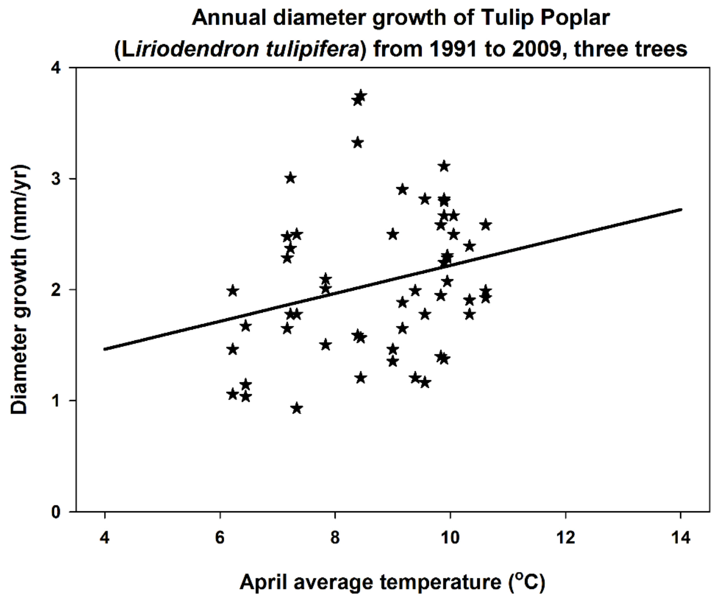
Response Chosen	Treatment Group		Comparison Group	
	Pre-Test (n=423)	Post-Test (n=385)	Pre-Test (n=170)	Post-Test (n=153)
A	2%	1%	2%	3%
B	12%	3%	13%	13%
C	17%	8%	11%	19%
D	**28%**	**73%**	**29%**	**29%**
E	41%	15%	45%	36%



Q25. Look at the above image. What does this tree core tell us about the tree's annual growth pattern?

A. The tree's amount of annual growth decreased in recent years, compared with the past
B. The tree did not experience annual growth
C. The tree's amount of annual growth was the same over time
D. The tree's amount of annual growth increased in recent years, compared with the past
E. I don't know

Response Chosen	Treatment Group		Comparison Group	
	Pre-Test (n=422)	Post-Test (n=389)	Pre-Test (n=172)	Post-Test (n=155)
A	18%	13%	17%	14%
B	2%	2%	2%	4%
C	4%	3%	6%	10%
D	**57%**	**75%**	**52%**	**48%**
E	19%	7%	23%	24%



Q26. What is the independent variable in the graph above?

A. Growth

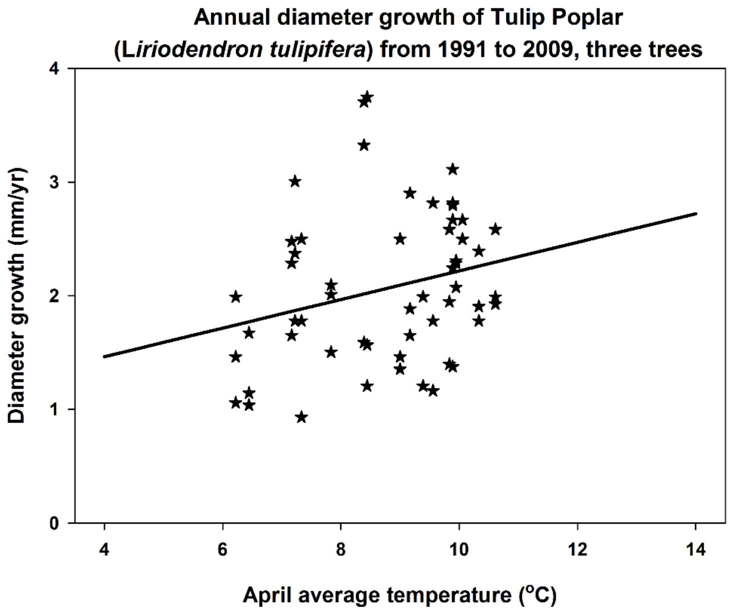
B. Temperature

C. The line

D. The data points

E. I don't know

Response Chosen	Treatment Group		Comparison Group	
	Pre-Test (n=423)	Post-Test (n=390)	Pre-Test (n=169)	Post-Test (n=154)
A	19%	20%	21%	20%
B	**42%**	**64%**	**36%**	**37%**
C	8%	4%	6%	8%
D	6%	4%	3%	2%
E	25%	8%	34%	33%



Q27. According to the line of best fit shown in the graph above, what happens to Tulip Poplar tree growth as April average temperature increases?

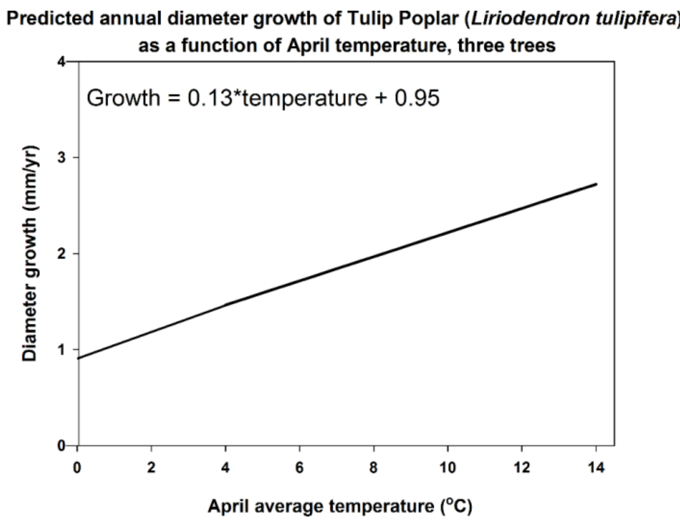
A. Tree growth increases
B. Tree growth decreases
C. Tree growth stays the same
D. There is no relationship between temperature and tree growth
E. I don't know

Response Chosen	Treatment Group		Comparison Group	
	Pre-Test (n=414)	Post-Test (n=389)	Pre-Test (n=169)	Post-Test (n=154)
A	**51%**	**80%**	**43%**	**38%**
B	6%	3%	5%	7%
C	2%	1%	4%	9%
D	6%	3%	7%	5%
E	35%	13%	41%	41%

Q28. Scientific models:

A. calculate the likelihood of every possible outcome
B. are used to understand only complex ideas
C. represent a part of the real world
D. must be a graph or equation
E. I don't know

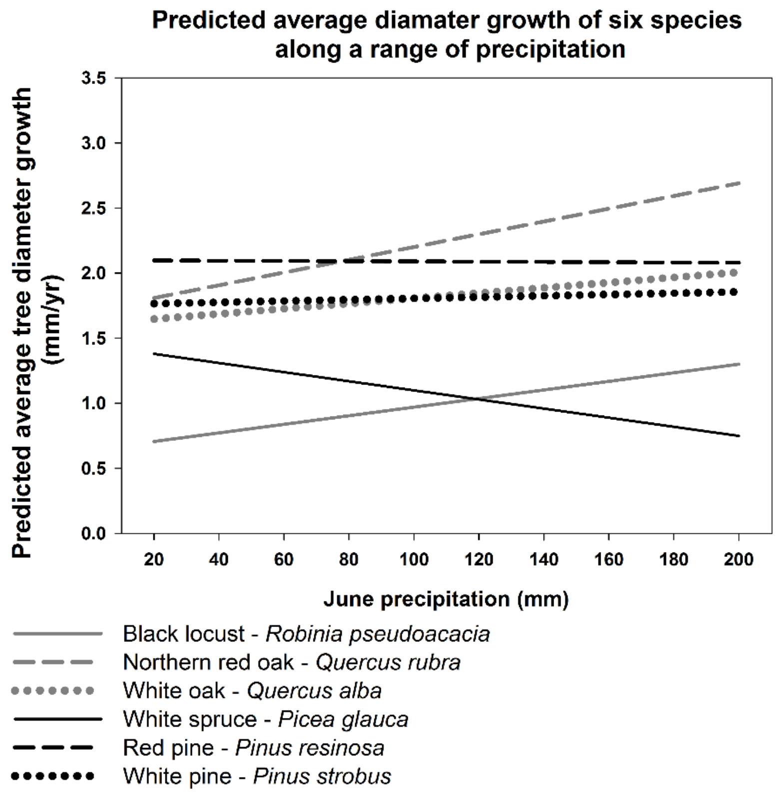
Response Chosen	Treatment Group		Comparison Group	
	Pre-Test (n=421)	Post-Test (n=386)	Pre-Test (n=168)	Post-Test (n=151)
A	14%	11%	18%	17%
B	13%	13%	12%	13%
C	**26%**	**62%**	**19%**	**28%**
D	5%	2%	4%	5%
E	42%	12%	47%	37%



Q29. Imagine your teacher showed your class the scientific model above. What is a characteristic of this model?

A. It shows the relationship between two variables
B. It is only useful to scientists
C. It captures every detail about the world
D. It can only represent one point in time
E. I don't know

Response Chosen	**Treatment Group**		**Comparison Group**	
	Pre-Test (n=419)	Post-Test (n=383)	Pre-Test (n=168)	Post-Test (n=156)
A	**55%**	**76%**	**45%**	**39%**
B	4%	4%	5%	5%
C	2%	3%	3%	5%
D	5%	5%	6%	9%
E	34%	12%	41%	42%



Q30. Based on the information in this graph, which of these six tree species would experience the largest decrease in annual growth with increased precipitation?

A. Black locust
B. Northern red oak
C. White pine
D. White spruce
E. I don't know

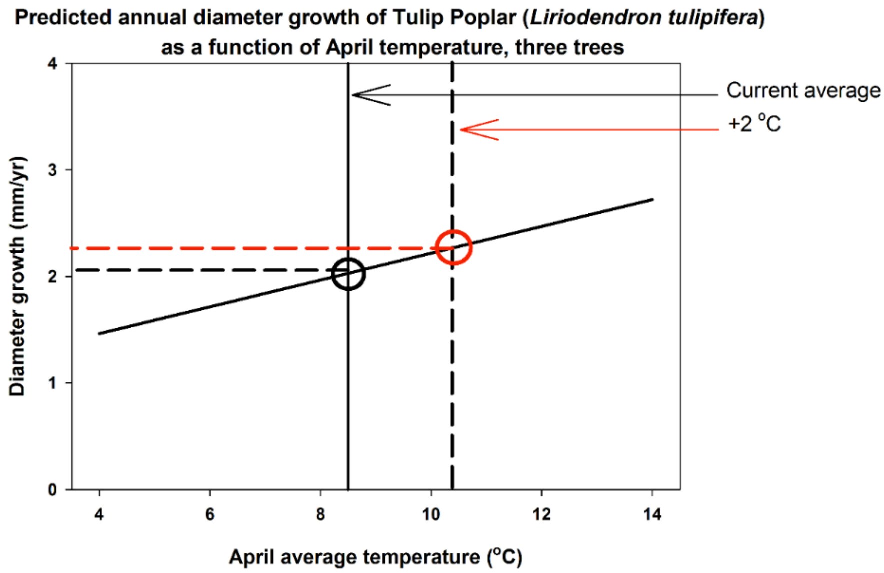
Response Chosen	Treatment Group		Comparison Group	
	Pre-Test (n=424)	Post-Test (n=385)	Pre-Test (n=168)	Post-Test (n=156)
A	5%	6%	3%	6%
B	6%	6%	7%	6%
C	5%	3%	6%	9%
D	**59%**	**78%**	**54%**	**53%**
E	25%	7%	30%	26%

Tree Species	Growth Equation
Black Locust	Growth = 0.12*temperature – 0.18
Red Oak	Growth = 0.23*temperature + 0.18
White Spruce	Growth = -0.11*temperature + 2.09
Red Pine	Growth = -0.05*temperature + 2.54

Q31. Based on the above growth equations, which species would experience the largest <u>increase</u> in growth with increased temperature?

A. Black locust
B. Red oak
C. White spruce
D. Red pine
E. I don't know

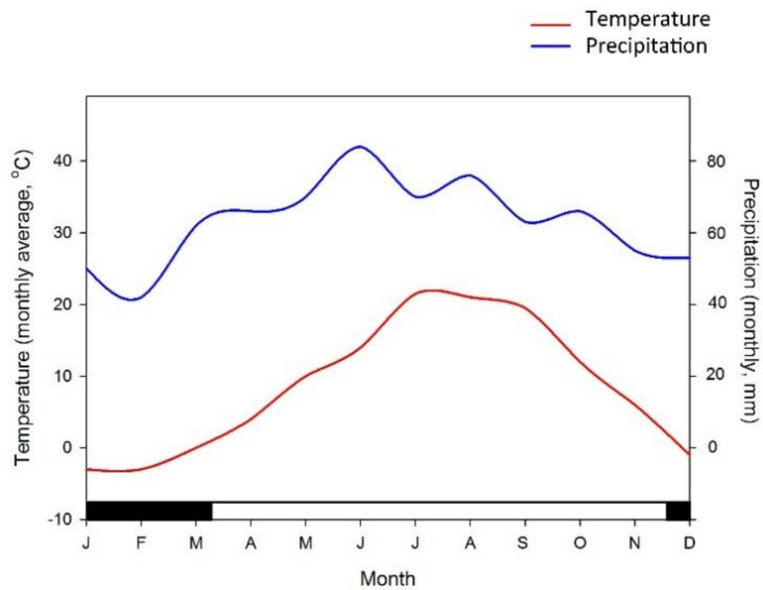
Response Chosen	**Treatment Group**		**Comparison Group**	
	Pre-Test (n=419)	Post-Test (n=383)	Pre-Test (n=167)	Post-Test (n=156)
A	4%	3%	4%	5%
B	**37%**	**56%**	**29%**	**32%**
C	6%	5%	9%	6%
D	28%	23%	30%	30%
E	25%	13%	28%	27%



Q32. Based on the graph above, what can we predict about the impact of climate change on Tulip Poplar trees?

A. Climate change will cause Tulip Poplars to die out.
B. Climate change will lead to decreased diameter growth of Tulip Poplars.
C. Climate change will lead to increased diameter growth of Tulip Poplars.
D. No prediction can be made based on this graph.
E. I don't know

Response Chosen	Treatment Group		Comparison Group	
	Pre-Test (n=414)	Post-Test (n=377)	Pre-Test (n=168)	Post-Test (n=158)
A	3%	6%	3%	4%
B	7%	9%	5%	11%
C	**25%**	**50%**	**19%**	**18%**
D	4%	5%	8%	8%
E	61%	30%	65%	59%



Q33. Based on the graphic above, which months of the year are in the growing season (the average temperatures above freezing)?

A. Mid-March through mid-November
B. March through November
C. June through September
D. January through mid-March and mid-November through December
E. I don't know

Response Chosen	Treatment Group		Comparison Group	
	Pre-Test (n=420)	Post-Test (n=376)	Pre-Test (n=168)	Post-Test (n=154)
A	**25%**	**50%**	**24%**	**25%**
B	12%	11%	11%	13%
C	21%	18%	23%	22%
D	9%	10%	14%	10%
E	33%	11%	28%	30%

Q34. What type of biome does this graphic represent?

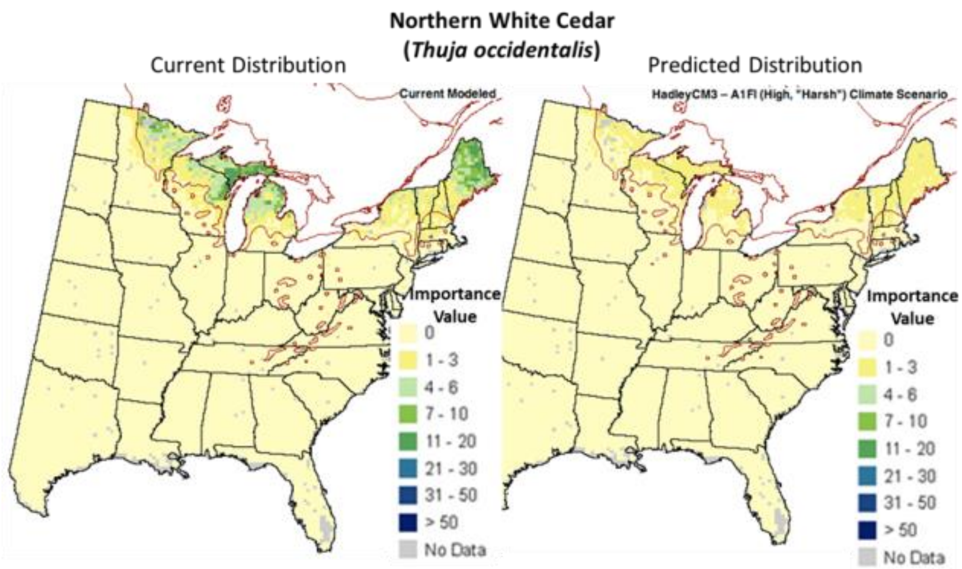
A. Tropical
B. Temperate
C. Desert
D. Boreal
E. I don't know

Response Chosen	Treatment Group		Comparison Group	
	Pre-Test (n=415)	Post-Test (n=377)	Pre-Test (n=167)	Post-Test (n=157)
A	14%	18%	8%	9%
B	**28%**	**45%**	**29%**	**37%**
C	3%	3%	7%	5%
D	5%	11%	2%	6%
E	50%	23%	54%	43%

Q35. Which of the following best describes the relationship between precipitation and tree growth?

A. There is no relationship between precipitation and tree growth
B. Tree growth always increases as precipitation increases
C. The relationship between precipitation and tree growth depends on tree species
D. Tree growth always decreases as precipitation increases
E. I don't know

Response Chosen	Treatment Group		Comparison Group	
	Pre-Test (n=421)	Post-Test (n=382)	Pre-Test (n=166)	Post-Test (n=155)
A	2%	3%	2%	3%
B	25%	11%	23%	18%
C	**35%**	**66%**	**34%**	**39%**
D	3%	5%	2%	6%
E	35%	15%	39%	34%



Note: "Importance value" refers to tree abundance. Colors with a higher Importance Value have a higher number of trees.

Q36. Compare the two U.S. maps showing the distribution of northern white cedar trees. Based on the information given, what will happen to the future northern white cedar tree distribution as a result of climate change?

A. More white cedars will grow in the Northeast and Great Lakes region than currently
B. More white cedars will grow in Southern states than currently
C. No changes will occur to the white cedar distribution in the future
D. Fewer white cedars will grow in the Northeast and Great Lakes region than currently
E. I don't know

Response Chosen	Treatment Group		Comparison Group	
	Pre-Test (n=420)	Post-Test (n=378)	Pre-Test (n=165)	Post-Test (n=156)
A	8%	8%	9%	8%
B	5%	4%	6%	9%
C	3%	3%	7%	4%
D	**35%**	**67%**	**28%**	**27%**
E	49%	18%	50%	52%

Appendix 3: Complete Replication Syntax

Chapter 1

Table 1: Exploratory Factor Analysis Using SPSS v.21

```
*************************
Climate change interest survey
Few students completed both pre/and post and so all analysis are based on only those students with
matching pre/post data (i.e., ID)!
*********************************************************************************
***
Factor Analysis
Note that have both pre and post and so these factors need to consist of same measures
The factor analysis here is based on initial analyses to determine which measures to use
*********************************************************************************
****
Final EFA for LearnCC1 (Pre-Intervention Desire to Learn More about Climate Change Effects on
Forests)
Initial factor analysis removed items with low factor loading
These items are removed for final EFA, using a forced one-factor solution (same for all subsequent
factors)
*************************************************************

FACTOR
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 /MISSING LISTWISE
 /ANALYSIS Q6B_1_1 Q6B_2_1 Q6B_3_1 Q6B_7_1 Q6B_8_1
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RELIABILITY
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 /MODEL=ALPHA
 /SUMMARY=TOTAL.

*************************************************************
Final EFA for LearnCC2 (Post-Intervention Desire to Learn More about Climate Change Effects on
Forests)
*************************************************************
```

```
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 /MISSING LISTWISE
  /ANALYSIS Q6B_1_2 Q6B_2_2 Q6B_3_2 Q6B_7_2 Q6B_8_2
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  /FORMAT SORT
  /PLOT EIGEN
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  /EXTRACTION PAF
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  /SAVE REG(ALL)
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RELIABILITY
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  /SUMMARY=TOTAL.
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****

Final EFA for InterestCC1 (Pre-Intervention Interest in Climate Change Effects on Forests)

****

```
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  /FORMAT SORT
  /PLOT EIGEN
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  /EXTRACTION PAF
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  /ROTATION VARIMAX
  /SAVE REG(ALL)
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  /MODEL=ALPHA
  /SUMMARY=TOTAL.
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****
Final EFA for InterestCC2 (Post-Intervention Interest in Climate Change Effects on Forests)
****

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  /FORMAT SORT
  /PLOT EIGEN
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PAF
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /SAVE REG(ALL)
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  /SUMMARY=TOTAL.
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****
Final EFA for HOInterest1 (Pre-Intervention Interest in Hands-On Science Activities)
****

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RELIABILITY
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************************************************************
Final EFA for HOInterest2 (Post-Intervention Interest in Hands-On Science Activities)
************************************************************

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  /PLOT EIGEN
  /CRITERIA FACTORS(1) ITERATE(25)
  /EXTRACTION PAF
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  /SAVE REG(ALL)
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************************************************************
Final EFA for Percep1 (Pre-Intervention Perception of Climate Change Risk)
************************************************************

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  /PLOT EIGEN
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  /EXTRACTION PAF
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  /ROTATION VARIMAX
  /SAVE REG(ALL)
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  /VARIABLES=Q12_1_1  Q12_3_1 Q12_4_1 Q12_5_1 Q12_7_1 Q12_9_1
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /SUMMARY=TOTAL.

************************************************************
Final EFA for Percep2 (Post-Intervention Perception of Climate Change Risk)
```

```
************************************************************

FACTOR
  /VARIABLES=  Q12_1_2  Q12_3_2 Q12_4_2 Q12_5_2 Q12_7_2 Q12_9_2
 /MISSING LISTWISE
  /ANALYSIS Q12_1_2  Q12_3_2 Q12_4_2 Q12_5_2 Q12_7_2 Q12_9_2
  /PRINT UNIVARIATE INITIAL CORRELATION SIG KMO EXTRACTION ROTATION
  /FORMAT SORT
  /PLOT EIGEN
  /CRITERIA FACTORS(1) ITERATE(25)
  /EXTRACTION PAF
  /CRITERIA FACTORS(1) ITERATE(25)
  /ROTATION VARIMAX
  /SAVE REG(ALL)
  /METHOD=CORRELATION.

RELIABILITY
  /VARIABLES=Q12_1_2  Q12_3_2 Q12_4_2 Q12_5_2 Q12_7_2 Q12_9_2
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /SUMMARY=TOTAL.

************************************************************
```

Final EFA for ScienceInterest1 (Pre-Intervention Interest in Science)

```
************************************************************

FACTOR
  /VARIABLES=Q11_1_1 Q11_4_1 Q11_5_1  Q11_7_1 Q11_9_1  Q11_11_1
 /MISSING LISTWISE
  /ANALYSIS Q11_1_1 Q11_4_1 Q11_5_1 Q11_7_1 Q11_9_1  Q11_11_1
  /PRINT UNIVARIATE INITIAL CORRELATION SIG KMO EXTRACTION ROTATION
  /FORMAT SORT
  /PLOT EIGEN
  /CRITERIA FACTORS(1) ITERATE(25)
  /EXTRACTION PAF
  /CRITERIA FACTORS(1) ITERATE(25)
  /ROTATION VARIMAX
  /SAVE REG(ALL)
  /METHOD=CORRELATION.

RELIABILITY
  /VARIABLES=Q11_1_1 Q11_4_1 Q11_5_1  Q11_7_1 Q11_9_1  Q11_11_1
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /SUMMARY=TOTAL.

************************************************************
```

Final EFA for ScienceInterest2 (Post-Intervention Interest in Science)

```
************************************************************

FACTOR
```

```
 /VARIABLES=Q11_1_2 Q11_4_2 Q11_5_2 Q11_7_2 Q11_9_2  Q11_11_2
/MISSING LISTWISE
 /ANALYSIS Q11_1_2 Q11_4_2 Q11_5_2  Q11_7_2 Q11_9_2  Q11_11_2
 /PRINT UNIVARIATE INITIAL CORRELATION SIG KMO EXTRACTION ROTATION
 /FORMAT SORT
 /PLOT EIGEN
 /CRITERIA FACTORS(1) ITERATE(25)
 /EXTRACTION PAF
 /CRITERIA FACTORS(1) ITERATE(25)
 /ROTATION VARIMAX
 /SAVE REG(ALL)
 /METHOD=CORRELATION.

RELIABILITY
 /VARIABLES=Q11_1_2 Q11_4_2 Q11_5_2
   Q11_7_2 Q11_9_2 Q11_11_2
 /SCALE('ALL VARIABLES') ALL
 /MODEL=ALPHA
 /SUMMARY=TOTAL.

************************************************************
Factor analysis generated new variables with weighted means
Rename with variable names for analysis
************************************************************

rename variables FAC1_1 = LearnCC1 FAC1_2 = LearnCC2 FAC1_3 = InterestCC1 FAC1_4 =
InterestCC2 FAC1_5 = HOInterest1 FAC1_6 = HOInterest2 FAC1_7 = Percep1 FAC1_8 = Percep2
FAC1_9 = ScienceInterest1 FAC1_10 = ScienceInterest2.
execute.
```

Table 2: Paired T-Tests for Unweighted Factors Using Stata v.13

```
*generate rowmean variables (unweighted means of items included in factors)
egen InterestCC1_unw = rowmean(Q6A_1_1 Q6A_2_1 Q6A_3_1 Q6A_7_1 Q6A_8_1 Q9A_1_1
Q9A_3_1 Q9A_4_1 Q9A_5_1 Q9A_8_1 Q9A_9_1)
egen InterestCC2_unw = rowmean(Q6A_1_2 Q6A_2_2 Q6A_3_2 Q6A_7_2 Q6A_8_2 Q9A_1_2
Q9A_3_2 Q9A_4_2 Q9A_5_2 Q9A_8_2 Q9A_9_2)
egen LearnCC1_unw = rowmean(Q6B_1_1 Q6B_2_1 Q6B_3_1 Q6B_7_1 Q6B_8_1 Q9B_1_1
Q9B_3_1 Q9B_4_1 Q9B_5_1 Q9B_8_1 Q9B_9_1)
egen LearnCC2_unw = rowmean(Q6B_1_2 Q6B_2_2 Q6B_3_2 Q6B_7_2 Q6B_8_2 Q9B_1_2
Q9B_3_2 Q9B_4_2 Q9B_5_2 Q9B_8_2 Q9B_9_2)
egen HOInterest1_unw = rowmean(Q10A_2_1 Q10A_5_1 Q10A_7_1)
egen HOInterest2_unw = rowmean(Q10A_2_2 Q10A_5_2 Q10A_7_2)
egen ScienceInterest1_unw = rowmean(Q11_1_1 Q11_4_1 Q11_5_1 Q11_7_1 Q11_9_1 Q11_11_1)
egen ScienceInterest2_unw = rowmean(Q11_1_2 Q11_4_2 Q11_5_2 Q11_7_2 Q11_9_2 Q11_11_2)
egen Percep1_unw = rowmean(Q12_1_1 Q12_3_1 Q12_4_1 Q12_5_1 Q12_7_1 Q12_9_1
Q12_10_1)
egen Percep2_unw = rowmean(Q12_1_2 Q12_3_2 Q12_4_2 Q12_5_2 Q12_7_2 Q12_9_2
Q12_10_2)

*mean for unweighted factors (paired)
```

sum InterestCC1_unw InterestCC2_unw LearnCC1_unw LearnCC2_unw HOInterest1_unw HOInterest2_unw ScienceInterest1_unw ScienceInterest2_unw Percep1_unw Percep2_unw if ID==1

*paired t-tests
ttest InterestCC1_unw==InterestCC2_unw
ttest LearnCC1_unw==LearnCC2_unw
ttest HOInterest1_unw==HOInterest2_unw
ttest ScienceInterest1_unw==ScienceInterest2_unw
ttest Percep1_unw==Percep2_unw

Table 3: Multi-Level Models Using Stata v.13
*****Multilevel model allows for determining changes over time for each factor*
**Reshape data from wide format to long format (puts Time 1 and Time 2 on separate lines) to allow comparison*
preserve
egen UNIQID = concat(TeacherCode Gender IDb), punct (_)

*drop duplicates
duplicates report UNIQID
duplicates tag UNIQID, generate(dupe)

*1 paired dupe, rest unpaired dupes within same time period
tab UNIQID if dupe==1 & ID==1
drop if UNIQID == "4_2_06051" & ID==.

drop dupe
duplicates tag UNIQID, generate(dupe)

duplicates drop UNIQID, force
reshape long ScienceInterest HOInterest Percep InterestCC LearnCC, i(UNIQID) j(Time)

**keep only needed factors for simpler dataset*
keep UNIQID ID Time TeacherCode Gender ScienceInterest HOInterest Percep InterestCC LearnCC

**save new dataset as a separate file*
save "Climate_Change_Curriculum_Combined_MLA_Reshaped_Data.dta", replace

*****Mixed multilevel model for each interest factor*
*******Test model: ScienceInterest (Interest in Science): Measurement of change from pre-intervention to post-intervention*
**Unconditional Model – controls for variance within classrooms and students alone*
xtmixed ScienceInterest || TeacherCode: || UNIQID:, reml variance

**Final model adds fixed effects for gender and time*
xtmixed ScienceInterest ib1.Time ib1.Gender if ID==1 || TeacherCode: || UNIQID:, reml variance

**means for table*
mean ScienceInterest if Time==1 & ID==1
mean ScienceInterest if Time==2 & ID==1

**means for gender (post-test only)*

```
mean ScienceInterest if Gender==1 & Time==2 & ID==1
mean ScienceInterest if Gender==2 & Time==2 & ID==1

******Run rest on loop – same commands for each factor
*unconditional model, then final model (accounting for time and effects), then marginal means
foreach var in HOInterest InterestCC LearnCC Percep {
	display
	display "***MULTILEVEL Model Results for `var'***"
	display
xtmixed `var' || TeacherCode: || UNIQID:, reml variance
xtmixed `var' ib1.Time ib1.Gender if ID==1 || TeacherCode: || UNIQID:, reml variance
	display "***Marginal Means for `var'***"
mean `var' if Time==1 & ID==1
mean `var' if Time==2 & ID==1
mean `var' if Gender==1 & Time==2 & ID==1
mean `var' if Gender==2 & Time==2 & ID==1
}
```

Table 9: Likelihood Ratio Tests of Teacher Effects Using Stata v.13

```
***************************
*testing for teacher effects using likelihood ratio testing of 2-level compared with 3-level models
(student *within teacher vs. student alone) for each construct
***************************
*loop command to run the same unconditional model for each factor
*first model is 3-level model (student and students within classroom)
*second model is 2-level model (students alone)
*final command is likelihood ratio test to determine if the two models are significantly different
foreach var in InterestCC LearnCC HOInterest ScienceInterest Percep {
	display
	display "***TEACHER EFFECTS TEST FOR `var'***"
	display
		xtmixed `var' if ID==1 || TeacherCode: || UNIQID:, reml variance
		estimates store teacher
		xtmixed `var' if ID==1 || UNIQID:, reml variance
		estimates store noteacher
		lrtest teacher noteacher
	}

restore
```

Figure 2: Final Path Model Analysis Using Stata v.13

```
*****FINAL path model
*version without teacher effects to estimate model fit
quietly sem (ScienceInterest1 -> HOInterest1, ) (ScienceInterest1 -> Percep1, ) ///
 (ScienceInterest1 -> InterestCC1, ) (ScienceInterest1 -> ScienceInterest2, ) ///
 (HOInterest1 -> InterestCC1, ) (HOInterest1 -> HOInterest2, ) ///
 (Percep1 -> InterestCC1, ) (Percep1 -> Percep2, ) (InterestCC1 -> LearnCC1, ) ///
 (InterestCC1 -> InterestCC2, ) (LearnCC1 -> Percep2, ) (ScienceInterest2 -> ///
 HOInterest2, ) (ScienceInterest2 -> Percep2, ) (HOInterest2 -> ///
```

```
 InterestCC2, ) (InterestCC2 -> LearnCC2, ), method(mlmv) standardized ///
 cov( e.ScienceInterest2*e.InterestCC2) nocapslatent
*model fit statistics
estat gof, stats(all)

*run version clustered SE by teacher
sem (ScienceInterest1 -> HOInterest1, ) (ScienceInterest1 -> Percep1, ) ///
 (ScienceInterest1 -> InterestCC1, ) (ScienceInterest1 -> ScienceInterest2, ) ///
 (HOInterest1 -> InterestCC1, ) (HOInterest1 -> HOInterest2, ) ///
 (Percep1 -> InterestCC1, ) (Percep1 -> Percep2, ) (InterestCC1 -> LearnCC1, ) ///
 (InterestCC1 -> InterestCC2, ) (LearnCC1 -> Percep2, ) (ScienceInterest2 -> ///
 HOInterest2, ) (ScienceInterest2 -> Percep2, ) (HOInterest2 -> ///
 InterestCC2, ) (InterestCC2 -> LearnCC2, ), method(mlmv) vce(cluster TeacherCode) ///
 standardized cov( e.ScienceInterest2*e.InterestCC2) nocapslatent
*r2
estat eqgof
```

Table 4: Indirect Effects Testing Using Stata v.13

```
*****run path model as above, then:
estat teffects, standardized
```

Table 10: Pairwise Correlations of Factors Using Stata v.13

```
***test for pairwise correlations of factors (justifies use of path analysis)
pwcorr InterestCC1 InterestCC2 LearnCC1 LearnCC2 HOInterest1 HOInterest2 ///
Percep1 Percep2 ScienceInterest1 ScienceInterest2, sig
```

Figure 6: Hypothesized Path Model Analysis Using Stata v.13

```
**Syntax for HYPOTHESIZED path model
*first use version without teacher effects to estimate model fit – “quietly” command means that
results *will not appear in output
quietly sem (ScienceInterest1 -> ScienceInterest2, ) (ScienceInterest1 -> ///
HOInterest1, ) (ScienceInterest1 -> InterestCC1, ) (ScienceInterest2 -> ///
HOInterest2, ) (ScienceInterest2 -> InterestCC2, ) (Percep1 -> Percep2, ) ///
(Percep1 -> InterestCC1, ) (Percep1 -> LearnCC1, ) (HOInterest1 -> HOInterest2, ) ///
(HOInterest1 -> InterestCC1, ) (Percep2 -> InterestCC2, ) (Percep2 -> LearnCC2, ) ///
(HOInterest2 -> InterestCC2, ) (InterestCC1 -> Percep2, ) (InterestCC1 -> ///
LearnCC1, ) (InterestCC1 -> InterestCC2, ) (LearnCC1 -> Percep2, ) (LearnCC1 -> ///
LearnCC2, ) (InterestCC2 -> LearnCC2, ), method(mlmv) standardized ///
cov( Percep1*ScienceInterest1) nocapslatent
*output model fit statistics (Stata cannot calculate them when clustered standard error is
estat gof, stats(all)

*re-output model with clustered standard error by teacher (path coefficients and model fit statistics
will not change)
sem (ScienceInterest1 -> ScienceInterest2, ) (ScienceInterest1 -> ///
HOInterest1, ) (ScienceInterest1 -> InterestCC1, ) (ScienceInterest2 -> ///
HOInterest2, ) (ScienceInterest2 -> InterestCC2, ) (Percep1 -> Percep2, ) ///
(Percep1 -> InterestCC1, ) (Percep1 -> LearnCC1, ) (HOInterest1 -> ///
HOInterest2, ) (HOInterest1 -> InterestCC1, ) (Percep2 -> InterestCC2, ) ///
```

```
(Percep2 -> LearnCC2, ) (HOInterest2 -> InterestCC2, ) (InterestCC1 -> ///
Percep2, ) (InterestCC1 -> LearnCC1, ) (InterestCC1 -> InterestCC2, ) ///
(LearnCC1 -> Percep2, ) (LearnCC1 -> LearnCC2, ) (InterestCC2 -> LearnCC2, ), ///
method(mlmv) vce(cluster TeacherCode) standardized cov( Percep1*ScienceInterest1) nocapslatent

*output R2 for each factor
estat eqgof
```

Chapter 2

Topic Knowledge Tabulation Using Stata v.13

```
*generate correct answer variable (Q#_A)
gen Q18_1_A = 2
gen Q18_2_A = 1
gen Q18_3_A = 1
gen Q18_4_A = 2
gen Q19_A = 4
gen Q20_A = 3
gen Q21_A = 1
gen Q22_A = 2
gen Q23_A = 4
gen Q25_A = 4
gen Q26_A = 2
gen Q27_A = 1
gen Q28_A = 3
gen Q29_A = 1
gen Q30_A = 4
gen Q31_A = 2
gen Q32_A = 3
gen Q33_A = 1
gen Q34_A = 2
gen Q35_A = 3
gen Q36_A = 4

*flag whether each question was correct (1) or incorrect (0) by comparing answer given to correct
*answer, create new variable (Q#_C)
foreach var in Q18_1 Q18_2 Q18_3 Q18_4 Q19 Q20 Q21 Q22 Q23 Q25 Q26 Q27 Q28 Q29 Q30
Q31 Q32 Q33 Q34 Q35 Q36{
foreach num of numlist 1 2{
generate `var'_`num'_C = 1 if `var'_`num'==`var'_A
replace `var'_`num'_C = 0 if `var'_`num'_C ==.
replace `var'_`num'_C = . if `var'_`num'==.
tab `var'_`num' `var'_`num'_C
}
}

*reorder variables so all pre-test responses are before all post-test responses in dataset
order Q18_1_1_C Q18_2_1_C Q18_3_1_C Q18_4_1_C Q19_1_C Q20_1_C Q21_1_C Q22_1_C
Q23_1_C Q25_1_C Q26_1_C Q27_1_C Q28_1_C Q29_1_C Q30_1_C Q31_1_C Q32_1_C
Q33_1_C Q34_1_C Q35_1_C Q36_1_C, before (Q18_1_2_C)
```

**calculate total scores (TotalMCScore) for pre-test and post-test by calculating total number of correct*
**answers*
sort Control
egen Achievement1 = rowtotal(Q18_1_1_C Q18_2_1_C Q18_3_1_C Q18_4_1_C Q19_1_C Q20_1_C Q21_1_C Q22_1_C Q23_1_C Q25_1_C Q26_1_C Q27_1_C Q28_1_C Q29_1_C Q30_1_C Q31_1_C Q32_1_C Q33_1_C Q34_1_C Q35_1_C Q36_1_C), missing
by Control: sum Achievement1
egen Achievement2 = rowtotal(Q18_1_2_C Q18_2_2_C Q18_3_2_C Q18_4_2_C Q19_2_C Q20_2_C Q21_2_C Q22_2_C Q23_2_C Q25_2_C Q26_2_C Q27_2_C Q28_2_C Q29_2_C Q30_2_C Q31_2_C Q32_2_C Q33_2_C Q34_2_C Q35_2_C Q36_2_C), missing
by Control: sum Achievement2

<u>Table 5: Confirmatory Factor Analysis for Interest Factors Using Stata v.13</u>
******CFA by construct*
**Constructs (measured T1 and T2): ScienceInterest (Domain Interest), HOInterest (Maintained Activity Interest), ValueCC (Perceived Topic Value), InterestCC (Topic Interest), LearnCC (Desire to Learn More)*
**Constructs (measured T2 only): UnitInterest (Triggered Situational Interest: Unit), FTInterest (Triggered Situational Interest: Field Trip)*

**CONSTRUCT: ScienceInterest (interest in science, Domain Interest)*
**treatment group*
sem (ScienceInterest1 -> Q11_1_1 Q11_5_1 Q11_7_1 Q11_9_1 Q11_11_1) ///
(ScienceInterest2 -> Q11_1_2 Q11_5_2 Q11_7_2 Q11_9_2 Q11_11_2) ///
if PrePost==3 & Control==0, standardized nocapslatent latent(ScienceInterest1 ScienceInterest2)
variance(ScienceInterest1@1 ScienceInterest2@1)
**comparison group*
sem (ScienceInterest1 -> Q11_1_1 Q11_5_1 Q11_7_1 Q11_9_1 Q11_11_1) ///
(ScienceInterest2 -> Q11_1_2 Q11_5_2 Q11_7_2 Q11_9_2 Q11_11_2) ///
if PrePost==3 & Control==1, standardized nocapslatent latent(ScienceInterest1 ScienceInterest2)
variance(ScienceInterest1@1 ScienceInterest2@1)

**calculate reliability (chronbach's alpha) and generate final factor variable using unweighted mean of final items*
alpha Q11_1_1 Q11_5_1 Q11_7_1 Q11_9_1 Q11_11_1, gen(ScienceInterest1) item
alpha Q11_1_2 Q11_5_2 Q11_7_2 Q11_9_2 Q11_11_2, gen(ScienceInterest2) item
**tabulate alpha for treatment and comparison*
sort Control
by Control: alpha Q11_1_1 Q11_5_1 Q11_7_1 Q11_9_1 Q11_11_1, item
by Control: alpha Q11_1_2 Q11_5_2 Q11_7_2 Q11_9_2 Q11_11_2, item
estimates clear

**CONSTRUCT: HOInterest (interest in hands-on science activities, Maintained Activity Interest)*
**treatment group*
sem (HOInterest1 -> Q10_2_1 Q10_5_1 Q10_7_1) ///
(HOInterest2 -> Q10_2_2 Q10_5_2 Q10_7_2) ///
if PrePost==3 & Control==0, standardized nocapslatent latent(HOInterest1 HOInterest2)
variance(HOInterest1@1 HOInterest2@1)

comparison group
sem (HOInterest1 -> Q10_2_1 Q10_5_1 Q10_7_1) ///
(HOInterest2 -> Q10_2_2 Q10_5_2 Q10_7_2) ///
if PrePost==3 & Control==1, standardized nocapslatent latent(HOInterest1 HOInterest2)
variance(HOInterest1@1 HOInterest2@1)

calculate reliability (chronbach's alpha) and generate final factor variable
alpha Q10_2_1 Q10_5_1 Q10_7_1 , gen(HOInterest1) item
alpha Q10_2_2 Q10_5_2 Q10_7_2 , gen(HOInterest2) item
tabulate alpha for treatment and comparison
by Control: alpha Q10_2_1 Q10_5_1 Q10_7_1 , item
by Control: alpha Q10_2_2 Q10_5_2 Q10_7_2 , item

CONSTRUCT: ValueCC (consider CC & forests important, Perceived Topic Value)
treatment group
sem (ValueCC1 -> Q9_1_1 Q9_2_1 Q9_3_1 Q9_4_1 Q9_5_1 Q9_6_1) ///
(ValueCC2 -> Q9_1_2 Q9_2_2 Q9_3_2 Q9_4_2 Q9_5_2 Q9_6_2) ///
if PrePost==3 & Control==0, standardized nocapslatent latent(ValueCC1 ValueCC2)
variance(ValueCC1@1 ValueCC2@1)
comparison group
sem (ValueCC1 -> Q9_1_1 Q9_2_1 Q9_3_1 Q9_4_1 Q9_5_1 Q9_6_1) ///
(ValueCC2 -> Q9_1_2 Q9_2_2 Q9_3_2 Q9_4_2 Q9_5_2 Q9_6_2) ///
if PrePost==3 & Control==1, standardized nocapslatent latent(ValueCC1 ValueCC2)
variance(ValueCC1@1 ValueCC2@1)

calculate reliability (chronbach's alpha) and generate final factor variable
alpha Q9_1_1 Q9_2_1 Q9_3_1 Q9_4_1 Q9_5_1 Q9_6_1, gen(ValueCC1) item
alpha Q9_1_2 Q9_2_2 Q9_3_2 Q9_4_2 Q9_5_2 Q9_6_2, gen(ValueCC2) item
tabulate alpha for treatment and comparison
by Control: alpha Q9_1_1 Q9_2_1 Q9_3_1 Q9_4_1 Q9_5_1 Q9_6_1, item
by Control: alpha Q9_1_2 Q9_2_2 Q9_3_2 Q9_4_2 Q9_5_2 Q9_6_2, item

CONSTRUCT: InterestCC (interested in forests and CC, Topic Interest)
treatment group
sem (InterestCC1 -> Q8A_1_1 Q8A_2_1 Q8A_3_1 Q8A_4_1 Q8A_5_1 Q8A_6_1 Q8A_7_1) ///
(InterestCC2 -> Q8A_1_2 Q8A_2_2 Q8A_3_2 Q8A_4_2 Q8A_5_2 Q8A_6_2 Q8A_7_2) ///
if PrePost==3 & Control==0, standardized nocapslatent latent(InterestCC1 InterestCC2)
variance(InterestCC1@1 InterestCC2@1)
comparison group
sem (InterestCC1 -> Q8A_1_1 Q8A_2_1 Q8A_3_1 Q8A_4_1 Q8A_5_1 Q8A_6_1 Q8A_7_1) ///
(InterestCC2 -> Q8A_1_2 Q8A_2_2 Q8A_3_2 Q8A_4_2 Q8A_5_2 Q8A_6_2 Q8A_7_2) ///
if PrePost==3 & Control==1, standardized nocapslatent latent(InterestCC1 InterestCC2)
variance(InterestCC1@1 InterestCC2@1)

calculate reliability (chronbach's alpha) and generate final factor variable
alpha Q8A_1_1 Q8A_2_1 Q8A_3_1 Q8A_4_1 Q8A_5_1 Q8A_6_1 Q8A_7_1, gen(InterestCC1) item
alpha Q8A_1_2 Q8A_2_2 Q8A_3_2 Q8A_4_2 Q8A_5_2 Q8A_6_2 Q8A_7_2, gen(InterestCC2) item
tabulate alpha for treatment and comparison

by Control: alpha Q8A_1_1 Q8A_2_1 Q8A_3_1 Q8A_4_1 Q8A_5_1 Q8A_6_1 Q8A_7_1, item
by Control: alpha Q8A_1_2 Q8A_2_2 Q8A_3_2 Q8A_4_2 Q8A_5_2 Q8A_6_2 Q8A_7_2, item

**CONSTRUCT: LearnCC (want to learn more about forests and CC, Desire to Learn More)*
**treatment group*
sem (LearnCC1 -> Q8B_1_1 Q8B_2_1 Q8B_3_1 Q8B_4_1 Q8B_5_1 Q8B_6_1 Q8B_7_1) ///
(LearnCC2 -> Q8B_1_2 Q8B_2_2 Q8B_3_2 Q8B_4_2 Q8B_5_2 Q8B_6_2 Q8B_7_2) ///
if PrePost==3 & Control==0, standardized nocapslatent latent(LearnCC1 LearnCC2)
variance(LearnCC1@1 LearnCC2@1)
**comparison group*
sem (LearnCC1 -> Q8B_1_1 Q8B_2_1 Q8B_3_1 Q8B_4_1 Q8B_5_1 Q8B_6_1 Q8B_7_1) ///
(LearnCC2 -> Q8B_1_2 Q8B_2_2 Q8B_3_2 Q8B_4_2 Q8B_5_2 Q8B_6_2 Q8B_7_2) ///
if PrePost==3 & Control==1, standardized nocapslatent latent(LearnCC1 LearnCC2)
variance(LearnCC1@1 LearnCC2@1)

**calculate reliability (chronbach's alpha) and generate final factor variable*
alpha Q8B_1_1 Q8B_2_1 Q8B_3_1 Q8B_4_1 Q8B_5_1 Q8B_6_1 Q8B_7_1, gen(LearnCC1) item
alpha Q8B_1_2 Q8B_2_2 Q8B_3_2 Q8B_4_2 Q8B_5_2 Q8B_6_2 Q8B_7_2, gen(LearnCC2) item
**tabulate alpha for treatment and comparison*
by Control: alpha Q8B_1_1 Q8B_2_1 Q8B_3_1 Q8B_4_1 Q8B_5_1 Q8B_6_1 Q8B_7_1, item
by Control: alpha Q8B_1_2 Q8B_2_2 Q8B_3_2 Q8B_4_2 Q8B_5_2 Q8B_6_2 Q8B_7_2, item

**CONSTRUCT: UnitInterest (found curriculum materials interesting, Triggered Situational Interest: Unit)*
**NOTE: only measured for treatment group in post-test*
**removed Q13_2 due to low loading*
**factor loadings*
sem (UnitInterest -> Q13_1_2 Q13_3_2 Q13_4_2) if PrePost==3 & Control==0, nocapslatent
latent(UnitInterest) standardized

**calculate reliability (chronbach's alpha) and generate final factor variable*
alpha Q13_1_2 Q13_3_2 Q13_4_2, gen(UnitInterest) item

**CONSTRUCT: FTInterest (interest in FT activities, Triggered Situational Interest: Field Trip)*
**simplified model based on factor loadings*
**factor loadings*
sem (FTInterest -> Q16_1_2 Q16_2_2 Q16_3_2 Q16_4_2 Q16_6_2 Q16_8_2) ///
if PrePost==3 & Control==0, nocapslatent latent(FTInterest) standardized

**calculate reliability (chronbach's alpha) and generate final factor variable*
alpha Q16_1_2 Q16_2_2 Q16_3_2 Q16_4_2 Q16_6_2 Q16_8_2, generate(FTInterest) item

<u>Table 6: Factor Descriptives Using Stata v.13</u>
by Control: sum ScienceInterest1 ScienceInterest2 HOInterest1 HOInterest2 InterestCC1 InterestCC2 LearnCC1 LearnCC2 ValueCC1 ValueCC2 UnitInterest FTInterest Achievement1 Achievement2 if PrePost==3

<u>Figure 5, Table 7: Final Path Modeling Analysis Using Stata v.13</u>
***final path model -- removes non-significant paths and adds path suggested by*
**modification indices*

**model without clustered standard error (needed for calculating model fit)*

```
quietly sem (HOInterest1 -> InterestCC1, ) (HOInterest1 -> LearnCC1, ) ////
(HOInterest1 -> HOInterest2, ) (InterestCC1 -> LearnCC1, ) ///
(LearnCC1 -> FTInterest, ) (LearnCC1 -> UnitInterest, ) (LearnCC1 -> InterestCC2, ) ///
(LearnCC1 -> LearnCC2, ) (Achievement1 -> Achievement2, ) ///
(FTInterest -> HOInterest2, ) (UnitInterest -> HOInterest2, ) ///
 (UnitInterest -> InterestCC2, ) (UnitInterest -> ValueCC2, ) ///
 (HOInterest2 -> InterestCC2, ) (HOInterest2 -> LearnCC2, ) ///
 (InterestCC2 -> LearnCC2, ) (ValueCC1 -> InterestCC1, ) ///
 (ValueCC1 -> ValueCC2, ) (ScienceInterest1 -> InterestCC1, ) ///
 (ScienceInterest1 -> Achievement1, ) (ScienceInterest1 -> ScienceInterest2, ) ///
 (ScienceInterest2 -> Achievement2, ) (ValueCC2 -> InterestCC2, ) ///
 (ValueCC2 -> Achievement2, ) if Control==0 & PrePost==3, method(mlmv) ///
 cov( HOInterest1*ValueCC1 HOInterest1*ScienceInterest1 ///
 e.FTInterest*e.UnitInterest ValueCC1*ScienceInterest1) nocapslatent standardized
```

**model fit indicators*

```
estat gof, stats(all)
```

**with teacher clusters SE for reporting*

```
 sem (HOInterest1 -> InterestCC1, ) (HOInterest1 -> LearnCC1, ) ///
 (HOInterest1 -> HOInterest2, ) (InterestCC1 -> LearnCC1, ) (LearnCC1 -> ///
 FTInterest, ) (LearnCC1 -> UnitInterest, ) (LearnCC1 -> InterestCC2, ) ///
 (LearnCC1 -> LearnCC2 , ) (Achievement1 -> Achievement2, ) (FTInterest -> ///
 HOInterest2, ) (UnitInterest -> HOInterest2, ) (UnitInterest -> ///
 InterestCC2, ) (UnitInterest -> ValueCC2, ) (HOInterest2 -> InterestCC2, ) ///
 (HOInterest2 -> LearnCC2, ) (InterestCC2 -> LearnCC2, ) (ValueCC1 -> ///
 InterestCC1, ) (ValueCC1 -> ValueCC2, ) (ScienceInterest1 -> InterestCC1, ) ///
 (ScienceInterest1 -> Achievement1, ) (ScienceInterest1 -> ScienceInterest2, ) ///
 (ScienceInterest2 -> Achievement2, ) (ValueCC2 -> InterestCC2, ) ///
 (ValueCC2 -> Achievement2, ) if Control==0 & PrePost==3, method(mlmv) ///
 vce(cluster TeacherCode) standardized cov( HOInterest1*ValueCC1 ///
 HOInterest1*ScienceInterest1 e.FTInterest*e.UnitInterest ///
 ValueCC1*ScienceInterest1) nocapslatent
```

**indirect and total effects*

```
estat teffects, standardized
```

**individual r2*

```
 estat eqgof
```

Table 8: Multi-Level Model Analysis Using Stata v.13

**Reshape data from wide format to long format*

```
preserve
reshape long Achievement ScienceInterest HOInterest ValueCC InterestCC LearnCC, i(UNIQID)
j(Time)
```

**keep only needed factors for simpler dataset*

```
keep UNIQID Time TeacherCode PrePost Control Gender ClassHour Achievement ScienceInterest
HOInterest ValueCC InterestCC LearnCC
```

```
save "Climate_Change_Curriculum_Combined_MLA_Reshaped_Data.dta", replace

*Run a mixed model for total score
*Keep all people regardless of number of time points
*Unconditional Model
xtmixed Achievement || TeacherCode: || UNIQID:, reml variance
*use these results to calculate icc's using random effects table
*proportion of variation in outcome due to between student variation within teachers
*(uniqueid code variance)/(teacher code variance+uniqueid code variance+residual variance)
*proportion of variation in outcome due to variation between classes
*(teacher code var+unique id code variance)/(teacher code variance+uniqueid code variance +
*residual variance)
*Model also includes interaction between time and control
*Model includes only those with pre and post
xtmixed Achievement ib1.Time##ib1.Control ib1.Gender if PrePost==3 || TeacherCode: || UNIQID:,
reml variance

*means for table
mean Achievement if Time==1 & Control==1 & PrePost==3
mean Achievement if Time==2 & Control==1 & PrePost==3
mean Achievement if Time==1 & Control==0 & PrePost==3
mean Achievement if Time==2 & Control==0 & PrePost==3

*means for gender
mean Achievement if Gender==1 & PrePost==3
mean Achievement if Gender==2 & PrePost==3


****repeat for interest components: paired constructs only
foreach var in ScienceInterest HOInterest ValueCC InterestCC LearnCC {
display
display "***Multilevel model for `var'***"
display
xtmixed `var' || TeacherCode: || UNIQID:, reml variance
xtmixed `var' ib1.Time##ib1.Control ib1.Gender if PrePost==3 || TeacherCode: || UNIQID:, reml
variance
display
display "***Marginal means for `var'***"
display
mean `var' if Time==1 & Control==1 & PrePost==3
mean `var' if Time==2 & Control==1 & PrePost==3
mean `var' if Time==1 & Control==0 & PrePost==3
mean `var' if Time==2 & Control==0 & PrePost==3
mean `var' if Gender==1 & PrePost==3
mean `var' if Gender==2 & PrePost==3
        }
```

Table 12: Likelihood Ratio Tests of Teacher Effects Using Stata v.13

```
***************************
*test for teacher effects (2-level compared with 3-level models for each) for paired data only
```

```
**************************
foreach var in InterestCC LearnCC HOInterest ScienceInterest ValueCC Achievement {
        display
        display "***TEACHER EFFECTS TEST FOR `var'***"
        display
                xtmixed `var' if PrePost==3 & Control==0 || TeacherCode: || UNIQID:, reml variance
                estimates store teacher
                xtmixed `var' if PrePost==3 & Control==0 || UNIQID:, reml variance
                estimates store noteacher
                lrtest teacher noteacher
        }
restore
```

Table 11: Classical Test Analysis of Knowledge Assessment Using Stata v.13

```
***pretest
*means for each item (mean column)
mean Q18_1_1_C Q18_2_1_C Q18_3_1_C Q18_4_1_C Q19_1_C Q20_1_C Q21_1_C Q22_1_C
Q23_1_C Q25_1_C Q26_1_C Q27_1_C Q28_1_C Q29_1_C Q30_1_C Q31_1_C Q32_1_C
Q33_1_C Q34_1_C Q35_1_C Q36_1_C if Control==0

mean Q18_1_1_C Q18_2_1_C Q18_3_1_C Q18_4_1_C Q19_1_C Q20_1_C Q21_1_C Q22_1_C
Q23_1_C Q25_1_C Q26_1_C Q27_1_C Q28_1_C Q29_1_C Q30_1_C Q31_1_C Q32_1_C
Q33_1_C Q34_1_C Q35_1_C Q36_1_C if Control==1

*chronbach's alpha (test scale, bottom row), alpha if removed (alpha column), and total discrim corr
(ir-
*cor column)
sort Control
by Control: alpha Q18_1_1_C Q18_2_1_C Q18_3_1_C Q18_4_1_C Q19_1_C Q20_1_C Q21_1_C
Q22_1_C Q23_1_C Q25_1_C Q26_1_C Q27_1_C Q28_1_C Q29_1_C Q30_1_C Q31_1_C
Q32_1_C Q33_1_C Q34_1_C Q35_1_C Q36_1_C, item label asis

***posttest
*means for each item (mean column)
mean Q18_1_2_C Q18_2_2_C Q18_3_2_C Q18_4_2_C Q19_2_C Q20_2_C Q21_2_C Q22_2_C
Q23_2_C Q25_2_C Q26_2_C Q27_2_C Q28_2_C Q29_2_C Q30_2_C Q31_2_C Q32_2_C
Q33_2_C Q34_2_C Q35_2_C Q36_2_C if Control==0

mean Q18_1_2_C Q18_2_2_C Q18_3_2_C Q18_4_2_C Q19_2_C Q20_2_C Q21_2_C Q22_2_C
Q23_2_C Q25_2_C Q26_2_C Q27_2_C Q28_2_C Q29_2_C Q30_2_C Q31_2_C Q32_2_C
Q33_2_C Q34_2_C Q35_2_C Q36_2_C if Control==1

*chronbach's alpha (test scale, bottom row), alpha if removed (alpha column), and total discrim corr
(ir-cor column)
by Control: alpha Q18_1_2_C Q18_2_2_C Q18_3_2_C Q18_4_2_C Q19_2_C Q20_2_C Q21_2_C
Q22_2_C Q23_2_C Q25_2_C Q26_2_C Q27_2_C Q28_2_C Q29_2_C Q30_2_C Q31_2_C
Q32_2_C Q33_2_C Q34_2_C Q35_2_C Q36_2_C, item label asis
```

Table 13: Pairwise Correlations of Factors Using Stata v.13

pwcorr Achievement1 Achievement2 ScienceInterest1 ScienceInterest2 HOInterest1 HOInterest2 ValueCC1 ValueCC2 InterestCC1 InterestCC2 LearnCC1 LearnCC2 UnitInterest FTInterest, sig

Figure 7: Hypothesized Path Modeling Analysis Using Stata v.13

***hypothesized path model*

quietly sem (HOInterest1 -> InterestCC1,) (HOInterest1 -> HOInterest2,) (InterestCC1 -> LearnCC1,) (InterestCC1 -> InterestCC2,) (LearnCC1 -> Achievement1,) (LearnCC1 -> FTInterest,) (LearnCC1 -> UnitInterest,) (LearnCC1 -> LearnCC2,) (Achievement1 -> Achievement2,) (FTInterest -> HOInterest2,) (UnitInterest -> HOInterest2,) (HOInterest2 -> InterestCC2,) (InterestCC2 -> LearnCC2,) (LearnCC2 -> Achievement2,) (ValueCC1 -> InterestCC1,) (ValueCC1 -> Achievement1,) (ValueCC1 -> ValueCC2,) (ScienceInterest1 -> InterestCC1,) (ScienceInterest1 -> Achievement1,) (ScienceInterest1 -> ScienceInterest2,) (ScienceInterest2 -> InterestCC2,) (ScienceInterest2 -> Achievement2,) (ValueCC2 -> InterestCC2,) (ValueCC2 -> Achievement2,) if Control==0 & PrePost==3, method(mlmv) cov(HOInterest1*ValueCC1 HOInterest1*ScienceInterest1 e.FTInterest*e.UnitInterest ValueCC1*ScienceInterest1 e.ValueCC2*e.ScienceInterest2) nocapslatent

**model fit*

estat gof, stats(all)

**clustered standard errors for reporting*

```
sem (HOInterest1 -> InterestCC1, ) (HOInterest1 -> HOInterest2, ) ///
 (InterestCC1 -> LearnCC1, ) (InterestCC1 -> InterestCC2, ) (LearnCC1 -> ///
 Achievement1, ) (LearnCC1 -> FTInterest, ) (LearnCC1 -> UnitInterest, ) ///
 (LearnCC1 -> LearnCC2, ) (Achievement1 -> Achievement2, ) (FTInterest -> ///
 HOInterest2, ) (UnitInterest -> HOInterest2, ) (HOInterest2 -> ///
 InterestCC2, ) (InterestCC2 -> LearnCC2, ) (LearnCC2 -> Achievement2, ) ///
 (ValueCC1 -> InterestCC1, ) (ValueCC1 -> Achievement1, ) (ValueCC1 -> ///
 ValueCC2, ) (ScienceInterest1 -> InterestCC1, ) (ScienceInterest1 -> ///
 Achievement1, ) (ScienceInterest1 -> ScienceInterest2, ) (ScienceInterest2 -> ///
 InterestCC2, ) (ScienceInterest2 -> Achievement2, ) (ValueCC2 -> ///
 InterestCC2, ) (ValueCC2 -> Achievement2, ) if Control==0 & PrePost==3, ///
 method(mlmv) vce(cluster TeacherCode) cov( HOInterest1*ValueCC1 ///
 HOInterest1*ScienceInterest1 e.FTInterest*e.UnitInterest ///
 ValueCC1*ScienceInterest1 e.ValueCC2*e.ScienceInterest2) nocapslatent standardized
```

**individual r2*

estat eqgof

Appendix 4: IRB Human Subjects Approval Documentation

eResearch M REGULATORY MANAGEMENT

Date: 8/3/2015, 2:31:02 PM

Print Close

1. General Study Information

All questions marked with a red asterisk (*) require a response. Questions without a red asterisk may or may not require a response, depending on those questions' applicability to this study.

1.1 * Study Title:
Evaluation of a middle school science curriculum on how Michigan forests will be impacted by climate change

1.1.1 Full Study Title:

1.1.2 If there are other U-M studies related to this project, enter the eResearch ID number (HUM#) or IRBMED Legacy study number. Examples of related projects include, but are not limited to:

- Projects funded under the same grant
- IRBMED Legacy study being migrated into eResearch
- Previously approved Umbrella applications (such as Center Grants or approvals for release of funding)
- Previously approved projects for which this is a follow up study

1.2 * Principal Investigator: Michaela Zint
Note: If the user is not in the system, you may Create A New User Account...

1.3 Study Team Members:

Study Team Member	Study Team Role	Appointment Dept	Appointment Selection Complete?	Student	Friend Account	COI Review Required	Edit Rights	Accepted Role?	PEERRS Human Subjects?
Michaela Zint	PI	Sch of Nat Resources & Environ	Yes	no	No	no	yes	N/A	yes
Jennifer Carman	Research Staff		No	yes	No	no	yes	Yes	yes
Erin Burkett	Administrative Staff		N/A	no	No		yes	N/A	no

1.8 * Project Summary:
This exploratory study will investigate to what extent a set of forestry and climate change science instructional materials, developed under the direction of the principal investigator, can enhance middle school student knowledge of climate change science and foster students' interest in regional trees/forests, science, and science careers.

Pre-and-post-tests will be used in the classroom to quantitatively assess changes in students' knowledge as related to trees, forests, climate change science and climate change impacts. These questionnaires will also include measures to assess changes in students interest in the topics outlined above.

Personal interviews with students will be conducted to obtain supplemental, in-depth insights about students responses and to inform improvements to the pilot curriculum.

Teachers pilot testing the curriculum will be asked to complete a log, recording their experiences with the curriculum and to offer their feedback on how to improve it.

This study will result in the refinement of a unique education resource that enables students to investigate the impact of climate change on regional trees/forests. Data from this pilot study will be used to recruit partnerships with the U.S. Forest Service's Department of Education and the American Forest Foundation's Project Learning Tree, among others, to help disseminate the curriculum. Study results may lead to a peer-reviewed journal.

There are also immediate benefits for participating Ann Arbor Public School teachers and their students who will have the opportunity to learn about regional trees/forests and climate change in an interactive way that will meet current and forthcoming state and national science standards.

1.8 * Select the appropriate IRB:
Health Sciences and Behavioral Sciences

1.9 * *Estimated* Study Start Date (Not required for IRBMED): *(mmlddlyyyy)*
3/8/2013

1.10 * *Estimated* Duration of Study:
3/8/2013 - 8/30/2014 as we hope to conduct another round of data collection next year

01-1. Application Type

1-1.1* Select the appropriate application type.
Exempt Human Subject Research

01-2. Standard Study Information

1-2.1* Who initiated this study?
Investigator

If other, please specify:

1-2.2* Are you or any students working on this project being paid from a federally funded training grant?

● Yes ◉ **No**

1-2.3 This study is currently associated with the following department. To associate this research with a different department, click Select. If the department has defaulted to "student", click select to specify the department through which this application is being submitted.
Sch of Nat Resources & Environ

1-2.4 Will the study utilize resources from the following centers?
Select all that apply:
There are no items to display

1-2.6* Has the scientific merit of this study already been peer reviewed (i.e., reviewed by one or more recognized authorities on the subject)?

Yes No

1-2.6.1* List the peer-review organization(s).

Peer Review Organization
External sponsor review process (e.g. study selection)
Unit Review (e.g. department chair, other departmental/unit review)

1-2.7* Is this a clinical trial?

Yes **No**

Study Team Detail

1.4 Team Member:

Michaela Zint
Preferred email: zintmich@umich.edu
Business phone 734-763-6961
Business address: Sch Of Natural Res & Env 2045 Dana 48109-1115

1.5 Function with respect to project:

PI

1.6 Allow this person to EDIT the application, including any supporting documents/stipulations requested during the review process:

yes

1.7 Include this person on all correspondences regarding this application: ***(Note: This will include all committee correspondence, decision outcomes, renewal notices, and adverse event submissions.)***

Credentials: *Required for PI, Co-Is and Faculty Advisors*

Upload or update your CV, resume, or biographical sketch.

Name	Version
Zint CV I History	0.02

Conflict of Interest Detail: *Required for all roles except Administrative Staff*

Current Disclosure Status in M-Inform: *This study team member has not yet disclosed in M-Inform.*

D1 Do you have an outside interest or relationship with a non-UM entity that relates to this research in one of the following ways:

- The entity is sponsoring this research
- The entity's products are used in this research
- The entity has licensed your invention (e.g. device, compound, drug, software, survey, evaluation or other instrument) being used in this research
- Part of the work on this project will be subcontracted to the outside entity
- Other relationship not listed above

no

D2 If "Yes" to the question above, name the entity or entities and provide a brief description of the relationship(s).

Study Team Detail

1.4 Team Member:

Jennifer Carman

Preferred email: jpcarman@umich.edu

Business phone

Business address: LSA UG: Environment 1120 USB 48109-2215

1.5 Function with respect to project:

Research Staff

1.6 Allow this person to EDIT the application, including any supporting documents/stipulations requested during the review process:

yes

1.7 Include this person on all correspondences regarding this application: ***(Note: This will include all committee correspondence, decision outcomes, renewal notices, and adverse event submissions.)***

yes

Credentials: *Required for PI, Co-Is and Faculty Advisors*

Upload or update your CV, resume, or biographical sketch.

Name	Version

There are no items to display

Conflict of Interest Detail: *Required for all roles except Administrative*

Staff

Current Disclosure Status in M-Inform: *This study team member has not yet disclosed in M-Inform.*

D1 Do you have an outside interest or relationship with a non-UM entity that relates to this research in one of the following ways:

- The entity is sponsoring this research
- The entity's products are used in this research
- The entity has licensed your invention (e.g. device, compound, drug, software, survey, evaluation or other instrument) being used in this research
- Part of the work on this project will be subcontracted to the outside entity
- Other relationship not listed above

D2 If "Yes" to the question above, name the entity or entities and provide a brief description of the relationship(s).

Study Team Detail

1.4 Team Member:

Erin Burkett
Preferred email: erinbur@umich.edu
Business phone
Business address: Program in the Environment 1120 Undergraduate Science 48109-2215

1.5 Function with respect to project:

Administrative Staff

1.6 Allow this person to EDIT the application, including any supporting documents/stipulations requested during the review process:

yes

1.7 Include this person on all correspondences regarding this application: ***(Note: This will include all committee correspondence, decision outcomes, renewal notices, and adverse event submissions.)***

yes

Credentials: *Required for PI, Co-Is and Faculty Advisors*

Upload or update your CV, resume, or biographical sketch.

Name	Version

There are no items to display

Conflict of Interest Detail: *Required for all roles except Administrative Staff*

Current Disclosure Status in M-Inform: *This study team member has not yet disclosed in M-Inform.*

D1 Do you have an outside interest or relationship with a non-UM entity that relates to this research in one of the following ways:

- The entity is sponsoring this research
- The entity's products are used in this research
- The entity has licensed your invention (e.g. device, compound, drug, software, survey, evaluation or other instrument) being used in this research
- Part of the work on this project will be subcontracted to the outside entity
- Other relationship not listed above

D2 If "Yes" to the question above, name the entity or entities and provide a brief description of the relationship(s).

1. Sponsor/Support Information

The following sections request details about the current or pending sponsorship/support of this study. Consider all of the choices below and complete the appropriate sections.

* Note: At least one of the following sections must be answered. Multiple sponsors or sources of support must be added one at a time.

1.1 External Sponsor(s)/Support:

	Type	Name	Other Direct Sponsor/Support	Support Type	Has PAF?
View	Government - Federal with Stimulus Plan (American Recovery and Reinvestment Act) funding: Choose this option for appropriate triage of the application		US Forest Service McIntire-Stennis	Financial	yes

2.5 Internal UM Sponsor(s)/Support: [Including department or PI discretionary funding]

Type	Department Sponsor	Support Type

There are no items to display

2.8 Check here if the proposed study does not require external or internal sponsorship or

External Sponsor Detail

2.2 * Direct Sponsor/Support:

If the Direct Sponsor/Support does not appear in the Select list, enter the name of the Direct Sponsor/Support below:

US Forest Service McIntire-Stennis

2.2.1* Sponsor Type:

Government - Federal with Stimulus Plan (American Recovery and Reinvestment Act) funding: Choose this option for appropriate triage of the application

If other, please specify:

2.2.2 * Support Type: Financial

2.2.3 * Is the support confirmed?

Yes No

2.2.4 * Is there an existing Proposal Approval Form (PAF) for this IRB Application Yes No

2.2.5 * Please select the PAF(s) associated with this study. Clicking the Add button will allow for the selection of a PAF based on selected criteria. After the PAF(s) has been associated with the human subjects research application, clicking on the PAF link will access the Proposal Management system and will display the current PAF information. Access to the PAF is based on account information in the Proposal Management system.

Proposal ID
12-PAF07661

2.3* Is this a subcontract to UM?

Yes **No**

1. UM Study Functions

1.1 * Indicate all functions that will be performed at University of Michigan locations. Select all that apply:

Recruitment (including screening)
Interaction (e.g., information gathering, survey, interview, focus groups, etc.)
Intervention (e.g., use of drug or device, medical procedures, educational intervention, group intervention, social/psychological intervention etc.)
Qualitative research (e.g., 'member checking', open-ended questions, etc.)
Primary or secondary analysis (data/specimen)

If other, please specify.

5-3. Research Design - Exempt Project

Completion of this section is required based on the response provided to question 1-1.1

5-3.1 Upload scientific protocol if one is available.

Name	Version

There are no items to display

5-3.2* Describe the objective and specific aims of the project. ***If included in the attached protocol, please indicate the section.***

This exploratory research will investigate to what extent the pilot climate change and forestry instructional materials we have developed, have the potential to generate middle school students' interest in climate change science (careers) and regional trees and forests and to identify aspects of the curriculum to which their interest can be attributed. These questions are important to answer because interest in science is an important predictor of academic achievement in science and because of the need to attract more students to science careers. Learning about the extent to which the instructional materials we have developed contribute to these outcomes is also important to ensuring that teachers will be motivated to use them in their classroom. Finally, these questions are of great interest to organizations like the National Science Foundation, a potential funder of subsequent educational research.

5-3.3* Describe the scientific design of the project. ***If included in the attached protocol, please indicate the section.***

For this pilot test, data from all participating teachers (n=6) and their classes of students (n=530) will be asked to participate. Teachers will complete a log to track curriculum implementation. All students will complete pre/post-tests. Twenty students will be asked to participate in an interview (1 student from each class). These students will be selected based on their teachers' recommendations of which students is most likely to be the most talking/forthcoming.

5-3.4* Describe the subject population for the project.

All teachers who will pilot test the curriculum and their respective students will be asked to participate in the study (i.e. all teachers will be asked to complete the teacher logs and all of their students will be asked to complete the quantitative pre-post-questionnaires). Only 1 student in each classroom will be asked to participate in the interview. This student will be selected by their respective teacher.

5-3.5* Will the study involve recruitment and/or participation of subjects in order to produce new data ***(e.g., surveys, interaction, intervention)*****?**

(●) **Yes** ( ) No

5-3.6* How will the study team interact with human subjects?

5-3.7* How will the study team be recruiting subjects?

The five teachers who have helped to developed the curriculum have already agreed to participate. Parental permission for students to participate will be sought as soon as IRB approval is obtained. Students will be asked by their teachers to complete pre/post-tests before they are administered before and after the curriculum. No identifing information will be collected from students to ensure their privacy.

5-3.8* Describe the setting for the research.

5-3.9* Indicate which of the following established subject pools, if any, will be used for recruitment.

Select all that apply:

N/A

Provide Related UM IRB Project Number or Subject Pool Description:

5-3.10* Indicate which methods will be used for recruitment?

Check all that apply:

Face-to-face contact (e.g. during a health care visit or an interview at a home address, etc.)

If Other, please indicate below:

5-3.11* Risk Level

Click "Add" to enter the risk level associated with this study.

	Level Of Risk
View	No more than minimal risk

5-3.12* Will the research involve the access, collection, use, maintenance, or disclosure of University of Michigan protected health information (PHI)? PHI is:

- **information about a subjects past, present, or future physical or mental health, the provision of healthcare to a subject, or payment for the provision of healthcare to a subject; AND**
- **that is maintained by a University of Michigan school, department, division, or other unit that is part of the University's HIPAA-covered component (e.g. healthcare provider, healthcare plan, or healthcare clearinghouse).**

Yes **No**

5-3.13* Will subjects receive payment or other incentives for their participation in the study?

Yes **No**

5-3.11.1 * What is the level of risk of harm to the subjects resulting from this research?

No more than minimal risk

12. Exemption Category

Completion of this section is required based on the response provided to question 1-1.1.

12.1* Which of the following exemption criteria applies to the study?

EXEMPTION #1 of the 45 CFR 46.101.(b):

Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

12-1. Exempt Category 1 - Investigational Strategies in Educational Setting

Completion of this section is required based on the response provided to question 12.1.

12-1.1* Is the research conducted in an established or commonly accepted educational setting?

● **Yes** ● No

12-1.1.1* Describe the educational setting.

Local Ann Arbor middle schools

12-1.2* Does the research involve normal educational practices such as research on regular and special educational instruction strategies, or research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods?

● **Yes** ● No

12-1.2.1* Explain how the research fits the definition of normal educational practice.

Students experience a science education curriculum that is designed to help them meet MI science education objectives. The study explores what they learned from the curriculum and their interest in the topics they learned about.

12-1.3* Upload tests, surveys and/or interview questions.

Name	Version
Student Interview I History	0.01
Student Post-test I History	0.02
Student Pre-test I History	0.01
Teacher Log I History	0.01

44. Additional Supporting Documents

44.1 Please upload any additional supporting documents related to your study that have not already been uploaded. Examples include, but are not limited to, data collection sheets, newsletters, subject brochures, and instructional brochures.

Name	Version
Support letter from ann arbor schools I History	0.01

45. End of Application

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