Assessing Student Interest and Desire to Learn More About Climate Change Effects on Forests in Middle School: An Intervention-Based Path Model

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Abstract

Raising students' interest in climate change may motivate them to learn about this topic as well as to address and adapt to this defining challenge of our time. To investigate how to increase students' interest in climate change through educational interventions, we conducted an initial study during a two-week pilot unit about how scientists predict the impacts of climate change on local forests. Pre- and post- intervention data were collected from 308 seventh-grade students (ages 12-13) and examined using exploratory factor, multilevel, and path analyses. Students had only moderate levels of interest in, and desire to learn more about, climate change and forests, and these levels did not change as a result of the intervention. Students' interest in science (personal interest) and in hands-on science activities (situational interest) played more important roles in their development of interest in climate change effects on forests than their perception of climate change risk. Findings suggest that increasing student interest in climate change issues 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. Future research should build on our intervention-based model of short-term interest development in climate change to generate additional insights about fostering students' desire to learn more about this critical topic.

Key words: interest, desire to learn, climate change, middle school, exploratory factor analysis

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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 consequences well into the future (IPCC, 2014).

Because of threats that climate change poses to future generations, we must find ways to educate students on this topic (Busch & Osborne, 2014; National Research Council, 2012a). One way of achieving this goal is 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). However, the success of enhancing students' perceptions of climate change risks may be mixed. While one study found that adolescents (ages 13 to 17) 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 youths' (ages 13 to 18) environmental risk perceptions can frighten and disempower rather than engage them (Covitt, Gomez-Schmidt, & Zint, 2005).

One alternative, and a relatively underexplored way to foster students' constructive engagement with climate change, may be to increase their interest in this topic (National Research Council, 2012a). Unlike risk, which tends to be accompanied mainly by negative emotions, interest can be affiliated with positive emotions (Sjöberg, 2007). 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 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); thus increasing students' interest in climate change may support improved learning and knowledge about it.

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 (a) express a sense of responsibility toward the environment (Uitto, Juuti, Lavonen, Byman, & Meisalo, 2011), (b) feel a greater degree of self-efficacy to engage in environmentally sustainable behaviors (Uitto, Boeve-de Pauw, & Saloranta, 2013), and (c) 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 knowledge but also their climate change mitigation and adaptation behaviors. However, this could be challenging to accomplish through formal educational interventions because students' overall interest in science topics tends to decline as they reach adolescence (Barmby, Kind, & Jones, 2008; Osborne, Simon, & Collins, 2003; Potvin & Hasni, 2014).

A Formal Educational Intervention to Foster Interest in Climate Change Effects on Forests

To address this gap in the existing research, 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 one co-author'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. This addresses 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 (a) disciplinary core ideas including "Global Climate Change" and "Human Impacts on Earth Systems," (b) science and engineering practices including "Developing and Using Models" and "Analyzing and Interpreting Data," and (c) cross-cutting concepts including "Cause and Effect" and "Stability and Change" (National Research Council, 2012b; NGSS Lead States, 2013).

This unit was designed to teach students about how scientists make predictions about the effects of climate change on tree growth and distribution using simple predictive models. The lessons also meet several of the climate literacy principles identified by the National Oceanic and Atmospheric Administration (NOAA, 2009), which are included in the supplemental materials. Finally, the lessons address specific knowledge gaps that youth in the United States have about climate change, including anthropogenic causes of climate change and the differences between weather and climate (Leiserowitz et al., 2011). As part of the unit, students learn about how different tree species are adapted to different climates. They then gather tree growth data, enter these data into an interactive online graphing tool, and construct simple mathematical models to 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 climate change effects on forests for two reasons. First, 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 trees and forests, with which children tend to feel a strong personal connection (Sobel, 1995). Second, the unit consists mainly of hands-on activities representing how science is conducted in the "real world," which have been found to increase students' interest in school science (Bergin, 1999; Osborne et al., 2003; Potvin & Hasni, 2014). Furthermore, our unit also includes a field trip to a nearby forest (Rickinson et al., 2004) in which students take measurements of tree growth using scientific instruments such as tree increment borers. This field trip is designed both to include hands-on activities and to enhance the feeling of local connection to trees, and thus support students' interest in climate change effects on forests.

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 model for predicting students' interest and desire to learn more about climate change effects on forests (Figure 1).

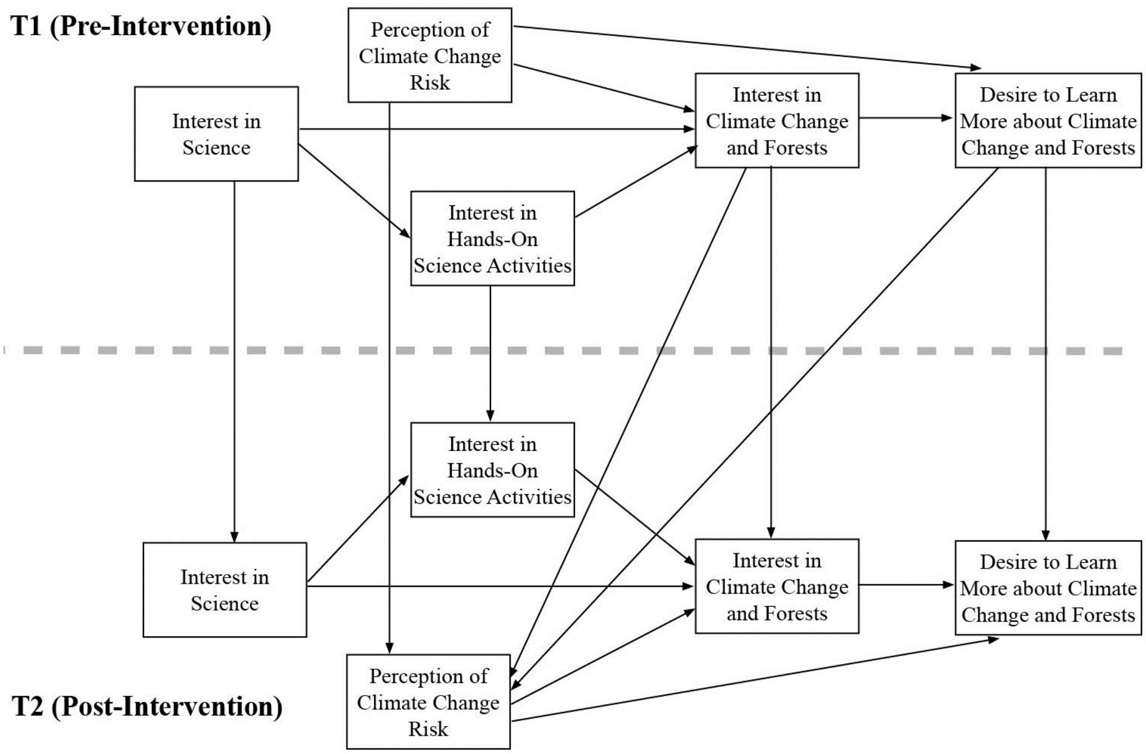


Figure 1. Hypothesized path model of factors predicting students' post-intervention *Interest in*, and *Desire to Learn More About, Climate Change Effects on Forests*

We predicted interest and desire to learn more as separate outcomes to distinguish between students' preference for this topic (i.e., interest) and their motivation to seek out additional information and acquire more knowledge about it (i.e., desire to learn more). Interest in a topic is not always distinguished from a desire to learn more about it, including as part of large-scale international studies such as the Programme for International Student Assessment (PISA) 2006 and the Relevance of Science Education (ROSE) study (OECD, 2007; Sjøberg & Schreiner, 2010). Although the two concepts 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). Furthermore, short interventions, like our two-week unit, are not 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 who want to learn more about a topic may be more likely to seek opportunities 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 there are numerous determinants of students' interest in specific educational topics (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 through the modeling and field trip components, 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 individual engagement with a topic, object, or activity (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. Instead, we expected students' interest in science to predict their 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 a link has been found between interest in science and 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 directly enhance students' interest in its various hands-on science activities. Instead, 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.

Perception of risk 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 suggested 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 perception of risk might increase as a result of participation. 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 matching Time 1 and Time 2 factors. These stability coefficients were included to assess how strongly students hold the respective factors. Given the short duration of the intervention, we expected all pre-intervention factors to be directly associated with their post-intervention counterparts but that the strengths of the respective relationships would vary.

Purpose of Study

The primary goal was to test and refine a path model of students' short-term development of interest in climate change during the educational intervention. Because we tested this model using pre- and post-intervention questionnaires, our secondary goal was to assess the extent to which our pilot two-week climate change education unit changed students' interest and desire to learn more about climate change effects on forests. Our research questions align with these goals:

(1) To what extent do selected predictors – namely science interest, interest in hands-on activities, and perception of climate change risk – relate to middle school students' interest in, and desire to learn more about, climate change over the course of a short-term intervention?
(2) To what extent did the two-week pilot unit change student interest in, and desire to learn more about, climate change effects on forests?

Intervention-based research is required to learn more about the potential of relatively brief educational units to foster student interest in climate change and other critical science topics. Furthermore, by exploring selected predictors of students' interest in climate change effects on forests, and of their desire to learn more about this topic, we sought to inform climate change education practice.

To the best of our knowledge, no studies have examined the extent to which educational interventions foster students' interest in climate change, and what factors may play a role in that process. Furthermore, by exploring linkages over time, we are able to provide an understanding of the drivers of students' interest that cross-sectional studies cannot. More specifically, this approach allows us to assess the impact of our intervention when controlling for students' pre-existing interests and risk perceptions.

Methods

Sample

In one Midwestern town's school district, four teachers from three schools volunteered to pilot test the unit and participate in the study with their seventh-grade (12- to 13-year-old) students. These teachers had 10 to 32 years of teaching experience. They taught a total of 38 to 128 students, based on an average class size of 19 to 33 students and 2 to 4 classes per teacher.

Before implementing the unit, the four teachers took part in a one-day professional development session. In this session teachers reviewed lesson content and activity logistics, as well as the field trip instructions, with the curriculum development team. 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 questionnaires. Only data from students who completed both the pre- and post-questionnaires (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. The post-intervention questionnaires were administered within two school days of the completion of the unit.

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

Interest in Science items were selected from the Interest in Science Survey (Lamb, Annetta, Meldrum, & Vallett, 2012) and the ASPIRES 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 stem text consistent with the one measuring *Interest in Climate Change Effects on Forests* (see further below).

Perception of Climate Change Risk items included modified question text 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 themselves 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 the Programme for International Student Assessment (PISA) 2006 (OECD, 2007), which assessed student interest in specific scientific topics. The stem texts, "This sounds interesting," and "I would like to learn more about this," were drawn from stem text by Swarat et al. (2012).

Teacher Log

To confirm that all students experienced all of the unit activities, teachers were asked to complete a log reporting which lessons they taught, the amount of time they spent to prepare and teach the lessons, and suggestions for improving the unit. The four teachers reported completing all of the unit's lessons and activities, including the field trip. This check ensured that students from different classes received the same material.

Analysis

Pearson's correlation coefficients indicated that the questionnaire items that were selected to measure our study's five factors 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, so 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

Factor name and items included	Pre-Intervention (T1) α	Pre-Intervention (T1) Variance Explained	Pre-Intervention (T1) Item Loading	Post-Intervention (T2) α	Post-Intervention (T2) Variance Explained	Post-Intervention (T2) Item Loading
Factor: Desire to Learn More About Climate Change Effects on Forests	*0.94*	*59%*		*0.94*	*59%*	
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
Factor: Interest in Climate Change Effects on Forests	*0.94*	*58%*		*0.95*	*61%*	
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
Factor: Interest in Hands-On Science Activities	*0.74*	*52%*		*0.72*	*53%*	
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
Factor: Interest in Science	*0.91*	*63%*		*0.90*	*62%*	
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
Factor: Perception of Climate Change Risk	*0.87*	*53%*		*0.87*	*54%*	
[Name of city] 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

[Name of state] 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

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 factors 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

Unweighted pre- and post-intervention descriptive statistics

	Pre-Test	Post-Test

Factor Name	Mean	SD	Mean	SD
Desire to Learn More about Climate Change Effects on Forests	3.62	0.83	3.15	1.00
Interest in Climate Change Effects on Forests	3.60	0.85	3.21	1.04
Interest in Hands-On Science Activities	3.55	1.00	3.13	1.08
Interest in Science	3.06	1.06	2.94	1.11
Perception of Climate Change Risk	3.64	0.75	3.82	0.78

1=strongly disagree to 5=strongly agree

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 of pre- to post- intervention changes by factor

Factor 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 Coefficients	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	*	-0.36	0.15	*	-0.33	0.15	*	-0.38	0.12	**
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		

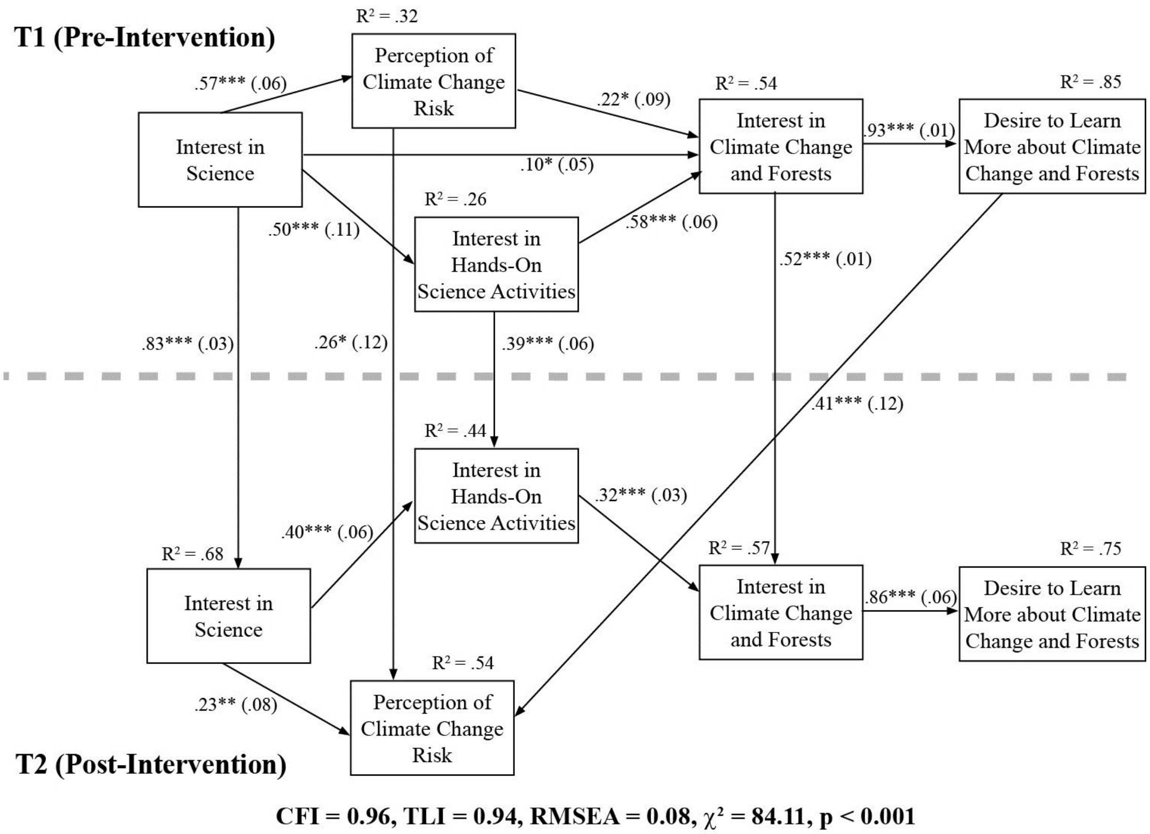
* p < 0.05 ** p < 0.01 *** p < 0.001

Note: Detailed results are presented in the supplemental materials.

To explore the factors 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* moderately 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* moderately 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 (β) ranged from small to large (range: .09-.92).



Note: Clustered robust standard errors by teachers are presented in parentheses.
* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

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 this topic (β=0.86). 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. 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* (β=0.43).

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 (β=0.81), followed by the one for *Interest in Climate Change Effects on Forests* (β=0.52), *Interest in Hands-On Science Activities* (β=0.40), and *Perception of Climate Change Risk* (β=0.27). The extremely high stability coefficient for *Interest in Science* is consistent with findings that this personal interest is difficult to change or increase through short educational interventions (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).

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: 0.42) and *Interest in Hands-on Science Activities* (indirect effects: 0.46) 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), 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) and *Desire to Learn More about Climate Change Effects on Forests* (indirect effects: 0.09).

Table 4a

Indirect (unstandardized) effects on Interest in Climate Change Effects on Forests *(post-intervention)*

Predictors	Indirect Effects Coefficient	SE	p
Pre-Intervention Predictors of Post-Intervention Interest			
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 Predictors of Post-Intervention Interest			
Interest in Science	0.12	0.01	***
Interest in Hands-On Science Activities	N/A	N/A	N/A

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

Table 4b

Indirect (unstandardized) effects on Desire to Learn More about Climate Change Effects on Forests *(post-intervention)*

Predictors	Indirect Effects Coefficient	SE	p
Pre-Intervention Predictors of Post-Intervention Desire to Learn More			
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 Predictors of Post-Intervention Desire to Learn More			
Interest in Science	0.11	0.01	***
Interest in Hands-On Science Activities	0.28	0.01	***

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

Discussion

Our study's middle school students expressed a moderate level of interest in climate change effects on forests. Similarly modest levels of interest in climate change have been observed in studies of European students in early secondary school, late secondary school, and college (Bråten, Gil, Strømsø, & Vidal-Abarca, 2009; Strømsø, Bråten, & Britt, 2010; Uitto & Saloranta, 2010). Youths' lack of a strong interest in climate change is troubling because their lives are already being impacted by climate change (IPCC, 2014), including through its effects on forests (Alexander et al., 1997). Previous research suggests that students' interest in climate change may influence their knowledge about this issue (Bråten et al., 2009), and their intention to act on it (Fröhlich et al., 2013; Levy & Zint, 2013); thus it is important to learn how to raise students' interest in climate change through educational interventions. Our study suggests that increasing students' interest in climate change through short educational interventions may be a formidable challenge. To help overcome this challenge, researchers must develop a better understanding of the determinants of student interest in this topic.

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 predictors of students' interest in this critical topic. Our study offers several insights into factors relevant to students' interest in climate change, and how interventions may affect interest development. Furthermore, our study opens several avenues for future research.

Insights into Short-Term Climate Change Interest Development

Our first research question asked to what extent students' interest in science, interest in hands-on science activities, and perception of climate change risk predicted their interest in and desire to learn more about climate change effects on forests over the course of a brief intervention. In answer to this research question, many of the relationships between the interest-related factors were consistent with what we expected.

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 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 subsequently, a greater desire to learn more about this topic.

Furthermore, while our final path model's results regarding the role perception of climate change risk in students' climate change interest development were consistent with some prior research findings, there were also some important differences. First, consistent with Sjöberg's (2007) cross-sectional study, we found a link between students' perception of climate change risk and topic interest before the intervention. Sjöberg's (2007) research, however, did not account for how this relationship may change after educational interventions. We found that it did not. After the intervention, students with higher perceptions of climate change risk were *not* more likely to express an interest in climate change effects on forests. Second, we found a surprising relationship between perception of risk and interest in science. Contrary to our expectations that these factors were unrelated when accounting for students' interest in climate change, students with a stronger interest in science had a higher perception of climate change risk, both before and after the intervention. One previous cross-sectional study found a correlation between students' interest in school science and their attitudes toward climate change (Dijkstra & Goedhart, 2012), but unlike our study did not account for students' interest in, or their desire to learn more about, climate change. Our study suggests that both interest in science generally, and a desire to learn more about climate change specifically, may play roles in students' perceptions of climate change risk in the context of educational interventions.

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 Sjöberg (2007) hypothesized. Students with a greater desire to learn more about climate change may therefore be more likely to develop more accurate perceptions of climate change risk as a result of an educational intervention. While desire to learn more about climate change predicted perception of climate change risk *across* time periods (from Time 1 to Time 2), there was no statistically significant direct effect of students' perception of climate change risk on their desire to learn more about this topic *within* either time period. This is in contrast to Mead et al.'s (2012) study, which linked adolescents' perception of climate change risk to a greater likelihood to seek information related to climate change. A small indirect relationship exists 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 a preexisting interest in climate change.

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 climate change. 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.

Developing an Intervention to Increase Students' Interest in Climate Change

Our second research question asked to what extent the two-week pilot unit changed students' interest in, and desire to learn more about, climate change effects on forests. In answer to this research question, we were troubled 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 real-world science). Furthermore, although existing research suggests that children feel a strong personal connection with trees and forests (Blizard & Schuster, 2004; Sobel, 1995), this context may not have been sufficiently relevant to middle school students. Alternatively, the features that make learning about climate change interesting may not be the same as the ones that make other science topics interesting.

We were particularly troubled by the lack of increase in students' desire 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. 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.

Although we did not find an increase in desire to learn more due to our intervention, 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.

Limitations and Future Directions

As a result of this initial study, we learned that our pilot two-week climate change education unit did not increase students' interest 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. Our study provides initial insights into factors that predict and do not predict interest in climate change effects on forests, but does not provide a comprehensive examination of all possible factors. 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. Future studies on students' climate change interests could benefit from including such qualitative research. Additionally, 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 designed it to have (e.g., to what extent students perceived it as relevant and representative of real-world science). We also did not collect detailed data from teachers during the professional development or classroom implementation other than the high-level feedback included in teacher logs. It is possible, therefore, that despite our attempts to design the unit to have characteristics to promote interest development, we did not succeed, or the unit was not enacted as anticipated as a result of the professional development teachers received. Future studies should verify that students perceive educational interventions to have the features expected to raise their interest and desire to learn more about climate change, and should collect additional, more detailed, information on teacher implementation of the unit.

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. Our final model's fit was sufficient and predicted interest in and desire to learn more about climate change 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.

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