An Empirically-Based Conditional Learning Progression for Climate Change

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Maryland and Delaware Climate Change Education, Assessment, and Research (MADE CLEAR)

Presented at the NARST Annual International Conference, Atlanta, GA, March 2018

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Introduction

Climate change encompasses a broad and complex set of concepts that is often challenging for students and educators. Using a learning progressions (LPs) knowledge system, we developed a conditional LP that described student learning of climate change. In this exploratory study, we present findings from written assessments of climate change (n=294) and in-depth interviews (n=27) with middle school students. We examined learners' understanding of four dimensions of climate change: The role of human activity, mechanism, impacts, and adaptation and mitigation. Findings were synthesized into a first step, conditional empirically supported LP for climate change that described a path from an initial to a sophisticated understanding of climate change.

Research question

How do learners progress over time from an initial to a more sophisticated understanding of climate change?

Background and Theoretical Perspective

LPs provide a knowledge system framework for researching and describing how student understanding develops and describes the increasingly sophisticated ways that learners think about a science topic (Lehrer and Schauble, 2016). The LP framework is a well suited analytical tool for investigating how student thinking develops over time (Duschl et al., 2007) and has been found productive for other climate change constructs such as sea level rise (Breslyn, 2016).

Using a LPs knowledge system framework, in this exploratory study, we report our efforts to identify, describe, and organize the development of learners' understanding of climate change in a first step, conditional empirically supported LP.

Context and participants

We conducted our study in 2016 within two Mid-Atlantic States in the United States. Data were collected from 6th and 8th grade middle school students (approximately ages 11-14) at three different middle schools.

Table 1: School location, characteristics, and demographics

Location	School characteristics	Demographics	Sample size
Site one (6th grade)	Suburban, technology-based charter school	65% African American, 5% Asian, 14% Hispanic, 10% White, 5% of two or more races	42
Site two (6th grade)	Suburban, dual language charter school	14% African American, 2% Asian, 57% Hispanic, 26% White, 1% of two or more races	221
Site three (8th grade)	Suburban, public school	33% African American, 3% Asian, 7 Hispanic, 54% White, 3% of two or more races	31

All sites used the same curriculum; however, teachers' implementations of the curriculum varied based on state and district curricular priorities, the regional climate change context, and teachers' own pedagogical preferences and content knowledge.

Data collection and analysis

In this study, data were collected before and after instruction through a multiple-choice instrument and participant interviews.

Multiple-choice Climate Science Knowledge Assessment Instrument (CSKAI). We used a researcher-crafted instrument, consisting of 18 multiple-choice items with distractors for each item. For select items, students were asked to provide written explanations (Hestness, McGinnis, & Breslyn, 2016).

Sample question: ***Which of the following would cause Earth's average global temperature to rise?***
a. Changes in the length of seasons
b. Changes in the thickness of Earth's atmosphere
c. Changes in the amounts of gases in the atmosphere
d. Changes in the amount of heat from Earth's molten core
Why is your choice the best answer?

Content knowledge interviews. We used a researcher-crafted interview protocol with a purposefully selected subset of students (n=14) who completed the CSKAI. The interviews followed the sequence of climate change constructs included in the CSKAI (human activity, mechanism, consequences, and mitigation/adaptation).

Sample question: Temperature data from the past 100 years show that the earth is getting warmer. How does human activity influence this warming trend, if at all?

Findings

Findings are reported here for students' alternate conceptions for the constructs *Human Activity* and *Mechanism*.

Human Activity

•Climate change was caused by pollution by humans (interview 52% pre, 41% post; CSKAI pre 28%, post 10%) and littering (interview 22% pre, 15% post).

• Nuclear power generation causes climate change: ▪ Using less nuclear power will reduce CO_2 (CSKAI pre 22%, post 22%) ▪ Nuclear generation produces CO_2 (CSKAI pre 54%, post 23%) ▪ Earth's temperatures are rising due to heat from nuclear power plants (CSKAI pre 19%, post 2%).

• Chlorofluorocarbons (CFCs) were not stated directly by students as a cause of human caused climate change, although deterioration of the ozone layer due to human activity was a persistent concept (interview: 48% pre, 41% post).

Mechanism

• Rising temperatures are due to changes in the amount of greenhouse gases in the atmosphere (CSKAI pre 34%, post 81%).

• Heat from the sun is trapped and warms the earth (CSKAI pre 51%, post 65%; interview: Pre 36%, post 64%).

• Heat trapped by greenhouse gases leads to more intense storms (CSKAI pre 27%, post 55%).

Findings (Mechanism cont.)

• CO_2 is removed from the atmosphere by escaping into space (interview 33% pre, 44% post).
• Ozone layer depletion causes an increase in temperatures (interview pre 48%, post 41%).
  ▪ A hole in the ozone layer lets heat enter earth's atmosphere (CSKAI pre 23%, post 6%).
  ▪ Banning chemicals that break down the ozone layer would reduce impacts of climate change (CSKAI pre 32%, post 15%).
  ▪ Ozone layer depletion will lead to future intense storms (CSKAI pre 37%, post 17%).
• The sun is "releasing more energy" and causing warming (CSKAI pre 19%, post 6%).

Findings for the constructs *Human Activity* and *Mechanism*, along with *Impacts* and *Mitigation & Adaptation*, are reported in the conditional LP for climate change.

Table 2: A first step, conditional empirical-based LP for climate change

Primary Constructs	Level 1	Level 2	Level 3	Level 4
Human activity	Students are able to explain that human activity is contributing to a warming earth. Students may state that human activity is producing gases or air pollution, but they do not relate this to CO_2 or use of fossil fuels	Students are able to explain that human use of fossil fuels for energy generates CO_2 and it is the primary cause of climate change. Students can explain that ozone and the ozone hole are not major factors in climate change	Students are able to name specific fossil fuels (e.g. coal, oil, gas) and can distinguish between non-fossil fuel energy sources (nuclear, wind, solar). Students can describe that plants remove some of the human generated CO_2 from the atmosphere and may mention the basics of the carbon cycle (such as photosynthesis and respiration)	Students are able to describe the rate at which humans use fossil fuels for energy and the rate at which CO_2 is recaptured by oceans and vegetation. Students can describe the current imbalance between these two rates and the related impact on the carbon cycle. Students are aware of other GHG's generated by human activities
Mechanism	Students are able to relate the presence of certain gases in the atmosphere to a warming earth but do not specify specific gases or the mechanism	Students are able to describe that greenhouse gases trap energy from the sun inside the earth's atmosphere causing the earth to warm and that CO_2 is primarily responsible for the enhanced GHE. Students acknowledge that excess CO_2 does not escape into outer space	Students are able to describe how energy from the sun reaches the earth's surface and is converted to heat energy and that some of the heat energy is absorbed by CO_2 and other GHGs that cannot escape into outer space and this energy is causing the earth to warm	Students are able to provide a mechanism for the enhanced GHE at the molecular level. Students also can connect the mechanism to human use of fossil fuels and the current imbalance in the carbon cycle and elevated CO_2 concentrations. Students are also aware of positive feedback loops, such as albedo, that influence the mechanism
Impacts	Students are able to explain that a warmer climate will affect humans and ecosystems but do not elaborate on specific impacts. They may confuse scientific certainty and projections with opinion and generally hold no realistic timeframe for climate change	Students are able to identify local and global impacts of climate change and can provide specific examples. They state that scientists are relatively certain that climate change is happening now or will happen in the near future	Students are able to describe local and global impacts of climate change and can provide examples of how these will vary geographically. They can explain that scientists use evidence from multiple sources and that climate change is happening now and is projected to increase in severity over time	Students are able to describe local and global impacts of climate change. They can also explain that climate models are based on multiple sources of evidence and can list several sources. They understand that future impacts are based on scientific projections and may vary but the models are reliable and continue to improve with scientific research
Mitigation & adaptation	Students are able to explain that simple actions individuals can take, such as conserving energy, can help slow climate change but cannot describe why. They can describe an action individuals can take to adapt to climate change	Students are able to identify a limited number of actions individuals, communities, and countries can take to slow the rate of climate change or identify simple measures to adapt to the impacts of climate change	Students are able to describe several scientifically valid mitigation and/or adaptation strategies to reduce the negative impacts of climate change. Students can also describe how these actions relate to the mechanism of climate change	Students are able to identify several scientifically valid mitigation and adaptation strategies at the national and international levels that can slow rate of climate change. Students can compare and contrast each strategy as well as its cost, effectiveness, and regional relevance

Key implication

Our conditional climate change learning progression offers an empirically supported conceptual framework for use by curriculum, instruction, and assessment developers, as well as by educators (in formal and informal settings) who have a professional responsibility (McGinnis et al., 2016) to guide students toward understanding a scientifically informed view of climate change.

Reference:
Breslyn, W., Drewes, A., McGinnis, J. R., Hestness, E., & Mouza, C. (2017). An empirically-based conditional learning progression for climate change. *Science Education International*, 28(3), 214-223.

This material is based upon work supported by the National Science Foundation under Grant No. 104262. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation