A Climate Change Curriculum Based on Synthesis Science

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Introduction

A hallmark of science in the Anthropocene is the increasing use of synthesis efforts to distill ever-growing data into the best available scientific knowledge. Thousands of scientists contribute substantial amounts of time towards these efforts, with the aim of producing authoritative work as a basis for informing both further research priorities and policy decisions. Organizations such as the IPCC are increasing their efforts to disseminate their scientific findings to broader audiences, for example, using text and video summaries targeted for policymakers. However, the results of such synthesis efforts have rarely been disseminated further back in the pipeline, in the classrooms where scientific literacy is shaped.

Here we describe an effort to develop a coherent framework for teaching climate change in higher education. The framework is (1) derived from research on effective climate communication, and (2) aligned with the latest IPCC reports, to facilitate teaching climate literacy relevant for the decision context that students will face. Such a framework is useful both for teachers in designing course learning outcomes and collaborating across departments and institutions, and for students in achieving deep learning.

Resources to teach climate change using the framework

We analyzed a selection of books and websites representing an initial snapshot of available climate change resources to help develop the Components and Elements, then assess which Core Topics and Components they covered. A topic or component was considered addressed if there was any mention of it in the resource. We found that the selected textbooks covered a larger variety of Components than the web resources, but no one resource covered all Components (though the Houghton and Burroughs books missed only one out of 18).

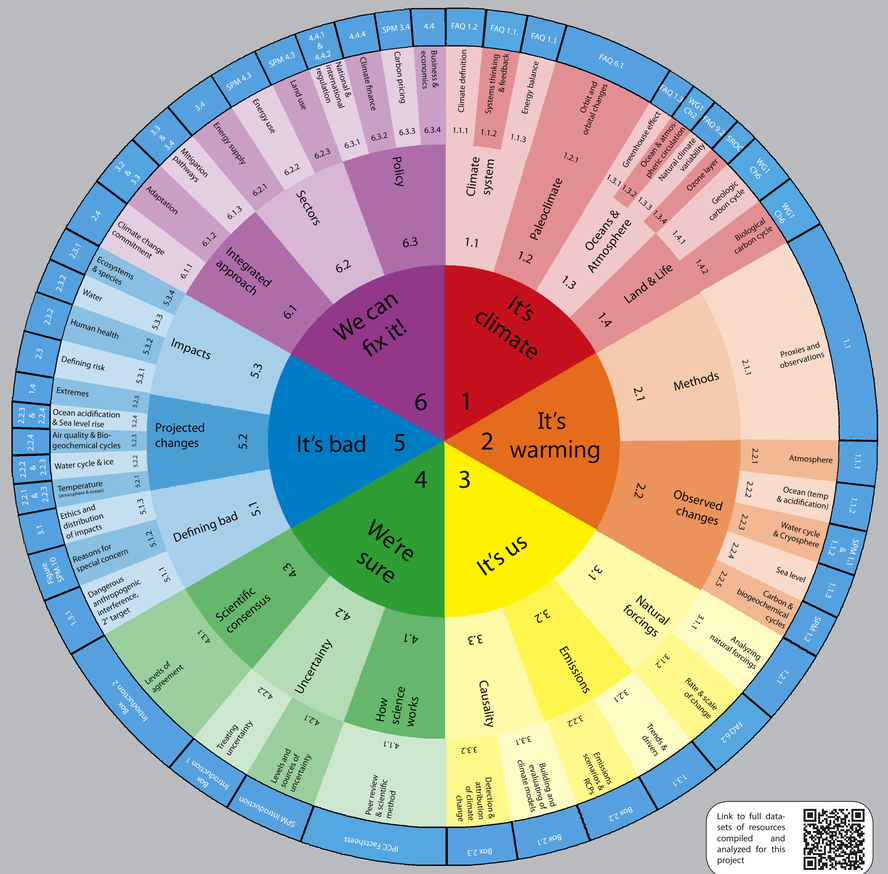
The best-covered Core topic was "it's warming," with two-thirds of resources addressing this topic, while two of the Components of scientific certainty about anthropogenic climate change were only addressed by 3 or 4 resources, with no coverage of 'How science works' (important for understanding the context of scientific agreement). Currently, a combination of resources can be used to address the entire framework, drawing on these and other resources to formulate teaching activities and class readings. A full analysis including page numbers and web links can be found on the website, which will be expanded in the future.

Source

Core topic		Component	Mann & Kump	Houghton	Burroughs	C2ES	NOAA	UN	NASA	John Cook	The Guardian	Nicholas	Total
It's climate	1.1	Climate system	✓	✓	✓		✓		✓				5
	1.2	Paleoclimate	✓	✓	✓		✓						4
	1.3	Ocean & Atmosphere	✓	✓	✓	✓	✓		✓				6
	1.4	Land & Life	✓	✓	✓		✓		✓				5
It's warming	2.1	Methods	✓	✓	✓	✓	✓		✓	✓			7
	2.2	Observed Changes	✓	✓	✓	✓	✓			✓	✓		7
It's us	3.1	Natural forcings	✓	✓	✓	✓	✓		✓				6
	3.2	Emissions	✓	✓	✓	✓	✓		✓		✓		7
	3.3	Causality	✓	✓	✓	✓	✓		✓				6
We're sure	4.1	How science works											0
	4.2	Uncertainty		✓	✓					✓			3
	4.3	Scientific consensus		✓	✓		✓			✓			4
It's bad	5.1	Defining bad	✓	✓	✓								3
	5.2	Projected Changes	✓	✓	✓	✓	✓		✓				6
	5.3	Impacts	✓	✓	✓	✓	✓		✓	✓		✓	8
We can fix it	6.1	Integrated approach	✓	✓	✓	✓	✓					✓	6
	6.2	Sectors	✓	✓	✓	✓	✓	✓				✓	7
	6.3	Policy		✓	✓	✓		✓			✓	✓	6
		TOTAL	14	17	17	11	14	2	9	5	3	4	

Developing a framework for teaching climate change

We developed our conceptual framework in an iterative process between analyzing and coding the content of the IPCC Fifth Assessment Report (Summaries for Policymakers from Working Groups I, II, and III, as well as the Synthesis Report) and content of other reference sources listed below. The resulting framework consists of six Core topics we suggest for inclusion in a comprehensive climate change curriculum, shown at the center of the wheel: (1) It's climate, (2) It's warming, (3) It's us, (4) We're sure, (5) It's bad, and (6) We can fix it (below). Core Topic 1 is based on physical fundamentals necessary to understand the climate system. Core Topics 2-6 are adapted from Krosnick et al. (2006) and Ding et al. (2011). Each Core Topic is broken down into 2-4 major Components in the second ring, which are further divided into concrete Elements in the third ring. The fourth (outermost) ring shows the alignment of our framework with sections in the full IPCC Climate Change 2014 Synthesis Report (or other IPCC materials as noted, including the 2007 Working Group I FAQ.



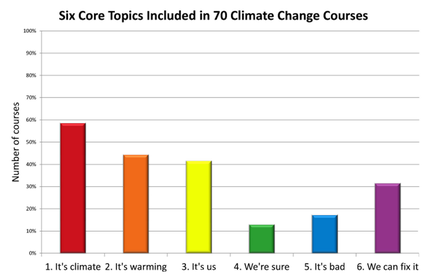
Link to full datasets of resources compiled and analyzed for this project

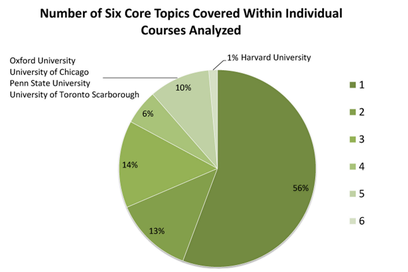
Majority of top universities teach only one out of six core topics

We studied the curricula of 70 courses on climate change currently being taught at top universities worldwide. Courses were selected based on university inclusion in at least two of the following four categories: QS Top 100 universities overall and Top 100 Environmental Sciences; Higher Times top 100 universities in physical sciences; and members of the International Sustainable Campus Network (ISCN). Curricula were assessed based on syllabi provided by course instructors (all of whom were contacted by email), or course descriptions on University websites if syllabi were not provided. If any of the Components or Elements within a Core Topic was mentioned, the course was counted as including that Core Topic.

Looking across all courses analyzed, we found that nearly 60% of all courses cover the topic "It's climate," describing the function of the natural climate system. However, this was the only core topic covered by the majority of courses. Less than 13% of all courses analyzed teach the 4th core topic, "We're sure", and less than 20% focus on the impacts of climate change ("it's bad").

Looking within specific courses, we found that the majority of courses (56%) focus on one single topic. Only 11% of the courses analyzed teach five or six of the topics, thereby creating an incomplete picture of the different aspects of climate change.





Overcoming misconceptions and promoting deep learning

Students are prone to a variety of misconceptions, which must be uncovered and overcome to achieve deep learning. We have identified teaching activities that address misconceptions in each of the six core topics (right), as well as the following general teaching principles that can be used in guiding new activities that promote deep learning:

- Teacher's enthusiasm and passion for subject[1]
- Teacher/student and student/student rapport in class & outside discussions[1]
- Clarity and organization in presenting analytical and conceptual understanding of ideas[2]
- Active learning[3] and student-centered discussions lead to better retention, transfer of knowledge, motivation and problem-solving ability[4]
- Teach observations before terms and facts[5]
- Teach scientific ways of thinking[6]

Principle	Misconception	Challenges	Undergrad teaching activities	Graduate teaching activities
It's natural	Climate is like long-term weather, unpredictable[8]	Cooling in some places despite global warming[7]	Plot CO_2 concentrations over time, estimate rate of change[8]	Analyze global temperature record, evaluate short- and long-term changes[7]
It's warming	Human activities cause greenhouse effect, which is like global warming[8]	Oversimplified "blanket"[9] model not appropriate[10]	Build model greenhouse and measure temperature compared with control[11]	
It's us	Climate changes due to natural variability instead of human activities[3]	Public debate can cause denial or resistance to learning[12]	Explore increase in atmospheric CO_2 with online model. Future levels estimated with future emission scenarios linked to IPCC predictions[13]	
We're sure	Climate change is deeply contested among scientists[14]	56% in US believe this[10]	Evaluate both positive and negative evidence in context of hypothesis; pie charts to convey numerical information[7]	
It's bad	Even if happening, consequences will be manageable	Consequences remote or terrifying; don't lead to action[7]	Google Earth tour of glacial change, measure changes[15]	Case study about different impacts, e.g. hurricanes[16]
We can fix it	It's governments and businesses that need to act. There's little an ordinary citizen can do[13]	Connection between personal lifestyle, society and GC not seen[17]	Student lifestyle project: measure CO_2 footprint, learn impact of behavior[17]	Cross-disciplinary approach, bring together knowledge from other cultures[18]

Conclusions

We have developed a simple, rigorous, and comprehensive framework for a climate change curriculum based on the latest synthesis science from the IPCC. Our analysis shows that currently, the majority of undergraduate courses in climate change focus on only one or a few aspects of the issue, and thus are unlikely to train fully climate-literate students. We review existing resources, activities, and approaches for teaching climate change in a way that builds on student knowledge and critical thinking and integrates across six core topics enable students to understand and engage with the latest synthesis science.

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