Appropriating a Climate Science Discourse about Uncertainty in Online Lessons

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Abstract: In an online lesson on climate change, pairs of students make claims in the context of uncertainties, using graphs from authentic scientific publications designed originally for public use. As students grapple with describing and delimiting sources of uncertainty discerned from these rather sophisticated graphs, they migrate from attributing uncertainty to themselves to climate-related phenomena. The dialogue between students appears to be instrumental in the strengthening of uncertainty-based claims and explanations.

Discourse about Uncertainty

Some of the earliest studies on human experience with uncertainty noted the distinction between internal attributions of uncertainty and external ones (Kahneman & Tversky, 1982). To attribute uncertainty internally to the competence of the self forecloses personal agency to resolve or delimit uncertainties arising from natural phenomena. To attribute uncertainty externally suggests a disposition to make sense of the indeterminacy of events in the world. Science curricula have traditionally downplayed or ignored the essential uncertainty of scientific practice, discouraging those students otherwise disposed to look externally to not bother trying. This inaccurate depiction of science deprives students of agency to formulate and explain claims based on limited and fallible evidence and thereby diminishes incentives to learn science (Lemke, 1990). Content understanding is enhanced with attention to the scientific practices of constructing and critiquing claims (Ford, 2008). For this reason, scientific practices have become a central feature of the Next Generation Science Standards (NGSS Lead States, 2013). The online lessons described here on the topic of climate science are part of a suite of lessons where public concerns intersect with controversies within specific fields of science. Climate change is a collective problem complicated by, and perhaps even limited by, citizens' abilities to participate in productive conversation about it (Corner, 2012). These lessons provide scaffolded instruction around scientific graphical representations as well as user-friendly simulations so as to facilitate explanations and conversation. Students make claims based on evidence while also reflecting specifically on how certain they are and to which factors they attribute any uncertainty.

Analyzing Screen Captures

The students described here participated in a series of online tasks on climate science in a public high school in the northeast of the United States. We recorded their work via computer screen capture, a process that also captured their talk. This paper limits itself to two episodes, as the analysis is ongoing and results are preliminary. The first episode involves a lesson on solar irradiance and the second involves future trends in temperature. In our analysis we transcribe student talk and then search for themes, using methods of interaction analysis (Jordan & Henderson, 1995). Our guiding concern is to determine interactional factors that contribute to the written responses that students provide in these online tasks. Each task sits on a single webpage along which students can scroll and into which they submit a series of responses to prompts. Due to constraints in our study at the time, our data do not include video of the students themselves, only their shared screen. Though this is not ideal, it is still feasible to inspect their interaction via their speech and, at times, their cursor movements.

Appropriating an uncertainty-infused discourse

These lessons discursively position students as competent agents capable of making claims. They orient students to features of authentic graphical representations by providing some contextual information. This is necessary because interpretation goes beyond merely taking up presented evidence. Interpretation is predicated on ways of seeing and making things see-able distinctive to a given discipline (e.g., "highlighting", Goodwin, 1994). That is, people have to be taught to see. So, the extent to which students can draw evidence from data depends crucially on how the data are framed for them. Explicitly addressing uncertainty as part of scientific activity raises questions for students as to how to construe uncertainty in relation to themselves. Typical curricular materials rarely elevate or highlight uncertainty as a salient and productive aspect of scientific practice. It is perhaps counterintuitive to dwell on uncertainty when cultivating the making of claims. But concerted reflection on the tentative and provisional nature of scientific claims should foster greater confidence in them, not less (Latour, 2004). This is because the means of creating an argument conveys essential information about its strength and durability. The students working on these tasks tend to engage in considerable uncertainty-related talk as they prepare written responses to uncertainty-enriched argumentation prompts. In doing so they "appropriate" (Levrini, Fantini, Tasquier, Pecori, & Levin, 2015) climate science discourse in order to deal with what for them are novel forms of uncertainty. To appropriate a discourse is a matter in part of identifying oneself as a legitimate practitioner and of having the resources available to begin to participate successfully.

Uncertainties in the Solar Irradiance Task: General Imitation versus Waviness

In the Solar Activity Task (see Figure 1), students are told they will make arguments based on evidence. They are first prompted to make claims about whether, "Based on the graph, is Earth's temperature dependent on the level of solar activity?" Since this is an original graph from a scientific publication, let us first note the rich senses of uncertainty embedded in it that the general public would encounter. Both the following year's temperature and solar activity are highly uncertain based on what we know about the present one, as indicated by the light-colored, erratically-varying lines. This uncertainty in yearly fluctuations is managed somewhat by means of a darker, relatively smooth lines described as the "11 yr average" for each quantity. Based on our knowledge of the 11-year average for a given year, the 11-year average for the next year is comparatively less uncertain. By taming somewhat the fluctuations in quantities in this way, it becomes more feasible to see beyond year-to-year variations so as to inspect trends over decades. The original authors' intent was to show to the general public that solar activity and temperature run parallel (until about 1960) and then diverge.

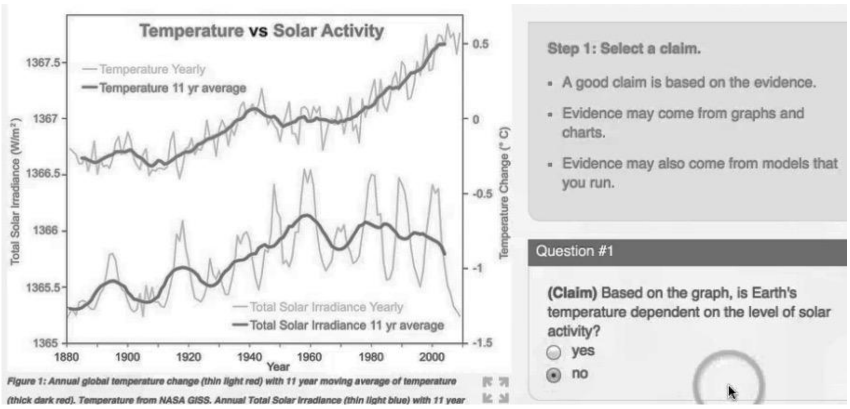


Figure 1. Cropped Portion of Screenshot of the Solar Activity Webpage for Annie and Betty.

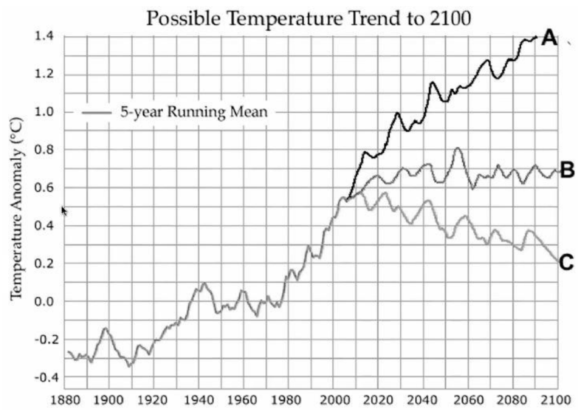
The audience for this lesson consists of students rather than the general public. In providing a limited synopsis, the webpage for the lesson explains that, "The graph shows Earth's air temperature and solar activity (irradiance) from 1880 to 2009. Solar activity includes sunspots, solar flares, and other solar weather events. The light-colored lines show the yearly measurements, and the darker lines show the average of 11 years of temperature or solar irradiance data. Earth's temperature is affected by many different factors" (cropped out of Figure 1). By giving students the task of making claims with only limited additional information, the task frames the interpretation of this authentic scientific graph as an activity students are capable of doing as well as any other public person. And they can presumably do so without having to attend to the layered meanings of some terms (e.g., the unit, W/m^2) or deeper reflections on the data processing of measurements (e.g., How the earth comes to have a singular temperature for a given year).

Table 1 illustrates the kind of conversation that can transpire with a task of this kind. The left column includes the time elapsed in seconds since the beginning of the episode, to provide information on the duration of turns of speech. In the right column, brackets indicate overlapping speech. The two speakers are Annie and Betty (all names are pseudonyms). In Line 1, Annie reads the question out loud and the two students take some time to think about a response. In Lines 2 and 3, they do not initially agree as to which bullet to select, "yes" or "no." In Line 3 Annie asks rhetorically whether temperature imitates solar activity, answering her own question negatively. In Line 4, Betty signals disagreement, while nevertheless expressing some new doubt in that it may only imitate it partially. In Lines 5 and 7 Annie contrasts an imitation that is (merely) general in some way with a waviness that shows lack of (authentic) imitation. In Lines 6 and 8 Betty agrees but it is unclear whether this agreement is in regard to the general imitation or to the lack of imitation in waviness. In Lines 7-9 Annie elaborates further, characterizing the waviness in terms of some curve being especially "spikey." She appears to indicate the Total Solar Irradiance Yearly, since it is the most erratic-looking. In Line 10, Betty at first goes back to her initial pick of, "yes," despite having just agreed to what Annie had just been saying about the waviness. But after a pause, she assents to Annie's preferred answer. In Line 11 Annie follows up by elaborating on the lack of dependence in terms of not fitting. Later, after Line 11, Annie and Betty wrote, “The temperature and solar activity do not match in terms of “fitting together” because their graphs are not aligned, the temperature is not dependent on the solar activity.” Betty appears to initially construe imitation in terms of a correspondence between the darker lines up to 1960 (“for a little bit”). What is uncertain, then, is the permanence of this relation between 11-year running means. But Annie construes imitation in terms of how erratic the light lines are. What is uncertain is how well measures remain stable from year to year. By virtue of their discussion these competing and complementary notions of imitation and uncertainty become increasingly visible to them both.

Table 1: Discussion around the claim prompt for the Solar Irradiance task.

Line #, seconds, Speaker	Talk and Interaction
Line 1, 0, Annie	(Hovers cursor over the bullets for "yes" and "no." Reads Question #1 out loud.) *Based on the graph, is Earth's temperature dependent on the level of solar activity?* (Pauses, makes mock music sound)
Line 2, 13.9, Betty	*Yeah.*
Line 3, 14.8, Annie	*Yes? Does it like imitate it? It [doesn't imitate it.]*
Line 4, 22.3, Betty	*[A little bit.] A little bit.*
Line 5, 24.4, Annie	*In terms of like general but like [waves],*
Line 6, 26.6, Betty	*[Yeah]*
Line 7, 27.1, Annie	*no. Do you see it?*
Line 8, 28.4, Betty	*Yeah.*
Line 9, 28.6, Annie	*It does it really spikey. These are like mmm mmm mmm* mmm (Tone rises and falls). *So, yes or no?*
Line 10, 34.7, Betty	*Yes.* (Pauses for 6 seconds) *No. No, I don't think so.*
Line 11, 43.8, Annie	*Cause they don't fit.*

This short episode was selected due to the two senses of imitation and uncertainty students found within the graphs. Their initial opposing responses are due to differing interpretations as to which features of the graph are most relevant to the question of dependence between quantities. Betty attends to the similarity of the long-term slopes of the 11-year average lines (dark) whereas Annie attends to the relative noisiness of the yearly data (light-colored lines). Both take agency for basing arguments in terms of the evidence (as opposed to searching for a received, normative, correct answer). Uncertainty for them is not akin to doubt (personal) but is related to the vicissitudes of the phenomena (external). That said, Annie appears to be more committed to her initial view and also appears to be more articulate and persuasive. On this reading of events, Betty defers to Annie in a way that abdicates some agency for attributing uncertainty to natural phenomena.



Line 1, 0, Candy	*Okay,* (reading the prompt) *Which line best shows what you think will happen in the future?*
Line 2, 3.2, Debbi	*Okay, it completely depends. It'll do this or this if we can clean up our act. It will do this if we can't, which I feel like this is more likely. Numeral A.*
Line 3, 21.2	(off topic)
Line 4, 29.6, Candy	*I would say actually B* (points with cursor), *because we're going to clean up our act.*

Figure 2. The Temperature Trend Task and Student Talk

Uncertainty in The Temperature Trend Task: Can We Clean Up our Act?

This next short episode has been chosen to illustrate an additional sense of uncertainty students may identify. The graph in Figure 2 indicates three potential future trends, all seen in comparison to the (known and established) trend up to 2008. As with the graph from the earlier episode, the uncertainty involved in year-to-year fluctuations is managed by means of a running trend. But there is a new form of uncertainty here about things yet to happen. Prior to Line 1, Debbi had already asserted that outcome A was more likely while Candy expressed doubt about this. Then, In Line 1, Candy rereads verbatim from the prompt. In Line 2, Debbi indicates two possibilities, both involving the intervention of humans, finding the more pessimistic one more likely. Here she explicitly mentions likelihood as a feature of her argument. In Line 4, Candy asserts a contrary and more optimistic option in response to this likelihood assertion. As they continued with their discussion beyond Line 4, Candy's more optimistic view prevails. Later, after Line 4 they typed in their written response: "We think that by then, green technology will be advanced enough to help stabilized temperatures and greenhouse gas levels." Candy was initially tentative about how to characterize future uncertainty, but eventually adopted Debbi's sense that it depends on human actions. Upon doing so, she then convinced Debbi to reverse her view as to how human intervention will likely transpire. In making this explanation they grappled with how to manage uncertainties in projections about future events. So, they progressed from discussions of possibilities (A or B) to criteria for choosing (which is more likely) to some explanation as to why this would be so (green technology). In so doing their attributions of uncertainty became more grounded in explanation of phenomena (external) while the uncertainty itself become progressively delimited.

Discussion

Under ordinary circumstances textual responses are the only traces of activity preserved for teachers or for researchers. The screencasts help to make visible the various ways students do discursive work toward achieving agreement. This work is largely lost in the textual responses. Student progress in both episodes appears to have been facilitated by the teacher's organizational decision to assign students to collaborate and discuss in pairs—consistent with recommendations of the online lesson providers. The speech we witness occurs because the two students have been given the task of formulating a consensus before submitting a textual response. This underscores the value of having students collaborate as they work on online lessons such as these.

Previous research has shown that students can engage to some extent in climate change lessons that make uncertainty an explicit aspect of scientific practice (Pallant & Lee, 2015). As students grapple with uncertainty they tend to either attribute uncertainty to what Pallant and Lee (2015) describe as "personal" sources or to "scientific" ones. That is, students locate uncertainty either in their own limitations or in aspects of real world phenomena, as expressed in data from graphs and model-simulations. Those who attribute uncertainty to scientific sources are much more likely to make "correct" or normative claims about climate change phenomena. Though preliminary in scope, this analysis sheds some light on the means by which students can migrate from an internalized to externalized (scientific) sense of uncertainty.

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