Views of the Uncertainties of Climate Change: A Comparison of High School Students and Specialists

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Abstract

Scientific uncertainty permeates the issue of climate change, and public policy decisions must be made in the context of this uncertainty. This article describes interviews with high school students and specialists (scientists and policy analysts) about reasons for scientific disagreement about climate change and whether action is needed now. A comparison of these two groups suggests both pitfalls in the responses of the students and ways in which they effectively made use of non-specialized knowledge or even utilized strategies similar to those of specialists. Educational efforts to prepare students to make judgments about climate change should include not only the science that is certain, but should also address the nature of the uncertainties, reasons for scientific disagreement, and strategies for making decisions given the uncertainties.

Résumé

L'incertitude scientifique entoure l'enjeu du changement climatique. Les décisions en matière de politiques publiques doivent donc être prises dans ce contexte. Cet article décrit des entrevues avec des élèves du secondaire et des spécialistes (scientifiques et analystes des politiques) portant sur le désaccord scientifique à propos du changement climatique et quant à l'opportunité d'agir maintenant. Une comparaison de ces deux groupes révèle des pièges tant dans les réponses des élèves que dans leur façon d'utiliser des connaissances non spécialisées ou même des stratégies semblables à celles des spécialistes. Les efforts pédagogiques en vue de préparer les élèves à exprimer un jugement sur le changement climatique devraient inclure une science certaine. Ils devraient aussi aborder la nature des incertitudes, les raisons du désaccord

scientifique et les stratégies pour prendre des décisions compte tenu des incertitudes.

The publication of the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) signaled a broad agreement among climate scientists that anthropogenic climate change is underway and may pose serious consequences in future decades (Houghton, Meira Filho, Callander, Harris, Kattenburg, & Maskell, 1996). Nonetheless, the thorny questions raised by climate science (e.g., projected regional temperature increases, changes in precipitation patterns, responses of ecosystems) resist certain answers. Although the forthcoming Third Assessment Report of the IPCC reflects recent progress in reducing some uncertainties, considerable uncertainties remain (IPCC, 2001). Meanwhile, reports of the scientific developments in the mass media may tend to amplify uncertainty (e.g., by giving disproportionate attention to extreme scientific views) or even underrepresent uncertainties (e.g., by overemphasizing scientists' "mid-range estimates"). For the public, making an assessment of how to respond to the threat of climate change requires, in part, assessing these uncertainties. This requires that the public understand what scientists are relatively certain about and what they are relatively uncertain about.

Assessing climate change also requires that the public better understand the nature of scientific controversy (McBean & Hengeveld, 2000). One of the most basic policy questions that must be answered is whether action should be taken now or whether more research is needed. If modifications to the human activities that exacerbate climate change are to be taken, a related question concerns how substantial a change is needed. As an educational issue, it is important that high school students graduate with the background to help them make informed judgments about such questions involving uncertainty. This educational goal is especially appropriate considering that today's students are long-term stakeholders in the outcomes of decisions that affect climate change—decisions that may have consequences throughout their lifetimes.

A growing body of research examines how lay persons understand concepts associated with climate change. The lay persons studied have included adults (Bostrom, Morgan, Fischhoff, & Read, 1994; Doble, Richardson, & Danks, 1990; Kempton, Boster, & Hartley, 1995; Read, Bostrom, Morgan, Fischhoff, & Smuts, 1994), high school students (Adams, 1999a, 1999b; Boyes, Chuckran & Stanisstreet, 1993; Gowda, Fox, & Magelkey, 1997), middle school students (Meadows & Wiesenmayer, 1999; Rye, Rubba, &

Wiesenmayer, 1997) and even elementary school students (Francis, Boyes, Qualter, Stanisstreet, 1993). Little research is available regarding how lay persons view uncertainties of climate change, although some questionnaire findings have been reported.

The questionnaire findings are interesting in that they suggest a majority of lay persons agree with the notion that action is needed now on global warming. Kempton, Boster, & Hartley (1995) included a question, "Scientists are just speculating about global climate change. We shouldn't take actions until they have proof" (p. 130) in a questionnaire they administered to 142 United States adults. Their sample was divided among five groups, including two environmental groups (Earth First! and the Sierra Club), a general public group, and two groups who may be disadvantaged by environmental regulations (dry cleaners and saw mill workers). None of the environmental group members agreed with the statement, and interestingly, only 20-22% of the members of each of their other groups agreed with the statement.

In a similar vein, a study by Doble, Richardson, and Danks (1990) found that 60% of their sample (402 adults from four U.S. metropolitan areas) agreed with the statement, "If we wait for more conclusive scientific evidence before taking decisive action to deal with the greenhouse effect, it will be too late" (p. 99). On the other hand, only 29% of their respondents agreed with a converse statement, "Before taking decisive action to deal with the greenhouse effect, we should wait for more conclusive evidence"[1] (p. 99). These findings raise the question: when lay persons evaluate whether the scientific evidence merits taking action about climate change, what kinds of considerations do they use? Interview methods may help illuminate this question.

Other questionnaire research has used high school students but has focused on their views about areas of climate change that are relatively certain. For example, Gowda, Fox, & Magelkey (1997) identified a set of mistakes that high school students made in response to questions about global warming. These mistakes included making estimates of projected temperature changes that exceeded even the upper bounds of scientists' predictions; confusing chlorofluorocarbons, stratospheric ozone depletion, and climate change; focusing on warmer weather as evidence for global warming; blurring unrelated environmental harms with global warming; and confusing weather and climate. Research with students and adults has found similar misconceptions (Boyes et al., 1993; Meadows & Wiesenmayer, 1999; Read et al., 1994; Rye et al., 1997).

Prior questionnaire research has also investigated students' views of the nature of science and scientific disagreement. An important contribution was a questionnaire developed by Aikenhead, Fleming, and Ryan (1987), Views on Science-Technology-Society (VOSTS). The survey was administered to 10,800 Canadian high school students who responded to one of 46 questions, yielding about 236 student responses to each question. A VOSTS question with three versions concerned general reasons for scientific disagreement. Each version of the question shared a common initial stem, as follows:

- 18 When scientists disagree on an issue (e.g., whether or not low-level radiation is harmful), they disagree mostly because:
    - 18.1 one side does not have all the facts,
    - 18.2 of their different moral values, and/or
    - 18.3 of their different personal motives (e.g., pleasing their employers or wanting research grants from the government).

Aikenhead (1987) categorized student responses into 12 types, labeled positions "A" through "L." Listed below are some examples:

> F. Disagreements occur mostly because scientists interpret the facts differently, or they interpret the significance of the facts differently.
> K. Disagreements occur over possible harmful risks or worthwhile benefits.
> L. Scientists are prone to outside influences from companies, business and government, and this explains the disagreements. (p. 474-475)

Other student responses cited issues associated with the moral values or motives of the scientists. Students were much more likely to comment on such factors if cued to do so by the wording of the question. This variability of student responses underscores the issue that identifying the views of lay persons is inherently problematic, particularly when the context created by the experimenter can so strongly influence the outcome (Fischoff, Slovic, & Lichtenstein, 1982).

The present study focuses on a particular scientific controversy, climate change, in order to probe how students respond when given richer contextual information. Findings from earlier questionnaire-based studies have been helpful in framing a set of questions for which a methodology utilizing interviews may be useful. How do students and scientists evaluate scientific disagreement and uncertainty about climate change? How do they evaluate whether action now or more research is needed? The goal of this study is to identify themes and variations in the responses these groups make, rather than to make generalizations about the proportion of students or specialists holding particular views.

This study uses a group of high school students and a group of specialists, including scientists and policy analysts with expertise in climate change. In traditional expert-novice studies, expert subjects serve relatively unproblematically as models of highly competent reasoning (Chi, Glaser, & Farr, 1988; Glaser, 1992). In matters involving risk, the issue is somewhat more complicated (Fischhoff, Slovic, & Lichtenstein, 1982). Educational efforts should provide students the resources to evaluate information and make their own judgments, rather than simply to rely on the judgments of a group of experts. In the present study, experts were included to clarify the different approaches to handling scientific uncertainty that persons with a greater knowledge of climate change might employ. Such a strategy sets the stage for considering questions about whether certain aspects of experts' knowledge base would be useful (or accessible) to high school students.

Method

Sixteen subjects participated in the study, including 10 high school students and 6 specialists. The students were all 17 years old and seniors from a high school in the San Francisco Bay area of California. They were drawn from science classes having students of mixed ability levels. Of the students, 4 were male and 6 were female; 2 were African American, and 1 was Asian American. They were paid $5.75 U.S. per hour.

The 6 specialists, also from California, included 3 scientists, 2 policy analysts, and 1 engineer. The scientists were all actively involved with research connected with climate change. One of the scientists worked on the staff of a major national research laboratory, one was a postdoctoral researcher at a major research university, and one was a doctoral candidate at a major research university. The policy analysts both had experience with policy issues connected with climate change. They were included for their perspectives not as scientists practicing in the area of climate change but as subjects with expertise in interpreting scientific information about climate change. The engineer had studied climate change independently. Except for the post-doctoral researcher, all of the specialist subjects participated on a volunteer basis. The postdoctoral researcher, who participated in subsequent experimental activities, was paid $12.50 U.S. per hour. The ages of the specialists ranged from 27 to 65. One specialist, the doctoral candidate, was a woman and the others were men.

In the recruitment process, specialists were told that the topic of the study concerned global warming, in order to make it clear why their particular expertise would be helpful. However, high school students were not told the topic of the study in order to avoid biasing the sample towards students with particular interests in the topic. The specialists were interviewed in December, 1996, and the students were interviewed in May, 1997.

Procedure

Subjects were given an introduction to the purpose of the study. Next, they were asked to complete a questionnaire about policy responses to global warming. The questionnaire began with two general questions about global warming:

1. Have you heard or read anything about global warming or the greenhouse effect? (a) yes (b) no.
2. Which statement comes closer to your own view? (a) Before taking decisive action to deal with the greenhouse effect, we should wait for more conclusive scientific evidence. (b) If we wait for more conclusive scientific evidence before taking decisive action to deal with the greenhouse effect, it will be too late. (c) Not sure.

The questionnaire also included 15 specific policies proposed to ameliorate global warming (see Appendix 1). For each of these policies, the subject was asked to indicate, "Do it immediately," "Phase it in gradually, over the next 10 years or so," "Don't do it, no matter what," or "Not sure." This question format, and most of the policy questions, were derived from a questionnaire used by Doble Richardson & Danks (1990). In a related questionnaire, subjects rated the stability of their views. The questions about policy options were designed to articulate a framework of possible alternatives for taking action to ameliorate global warming and to illustrate the magnitude of possible policies that might be entertained. Although an analysis of subjects' views of these specific policies is beyond the scope of this paper, Adams (1999a) compares how high school students and specialists viewed policies designed to reduce the environmental impact of automobiles.

Next, the subjects were interviewed about their views of the science of global warming. The interview included questions about the uncertainties of global warming. Table 1 lists these questions.

• How likely do you think it is that human actions have changed global climate?
• How certain are you about what the effects of global warming will be?
• How certain do you think scientists are about the effects of global warming?
• Have you heard about any disagreements among scientists about global warming? Why do you think they disagree?
• Some people say that scientists do not have a clear picture of the problem of global climate change. We should not take action until they have a clearer picture and more convincing evidence. Other people say that scientists have already done enough research and that we should start doing something. What do you think about that?

Table 1. Interview questions.

The interviews were semi-structured. An overall script was used, but the experimenter would ask clarifying questions and/or follow-up questions. The benefit of this approach is increased flexibility and information, but the drawback is reduced experimental consistency. The increased flexibility of a semistructured interview was judged to be a higher priority, given the goals of the study, which were not to attempt to make generalizations about the views of all high school students or scientists, but rather to identify the various kinds of responses made by members of these groups.

The interviews were audiotaped and transcribed. The discussion that follows focuses in the first section on reasons for scientists' disagreement (e.g., responses to the interview questions, "How certain do you think scientists are about the effects of global warming? Have you heard about any disagreements among scientists about global warming? Why do you think they disagree?"). The second section focuses on the issue of "action now versus more research" (e.g., responses to the interview question, "Some people say that scientists do not have a clear picture of the problem of global climate change. We should not take action until they have a clearer picture and more convincing evidence. Other people say that scientists have already done enough research and that we should start doing something. What do you think about that?").

Results: Reasons for Disagreement of Scientists About Global Warming

Specialists

Reasons cited by the specialists for scientific disagreement about global warming included notions of vested interests, scientists' risk tolerance, wanting to be in the limelight, the difficulty of detecting a "signal" in the data, and uncertainties inherent in computer modeling. Mark, the staff scientist, conjectured that scientists may develop a stake in certain perceptions:

> I think some of the scientists, you know, they're—I'm not saying that they're saying what they're saying just because they're getting paid to say it, but I think that they've developed a certain stake in seeing it a certain way. And I think that influences what they're saying.

Ron, the postdoctoral researcher, noted that scientists may differ in their tolerance of risk:

> We all have different criteria where we will say this is a problem. If it's very uncertain, if it's a 50-50 chance, a lot of people will say then it's not a problem. . . . But I would say that is a problem. Right? So, just it's a personal thing about where you will call where the risk becomes a problem.

Ron also suggested that some disagreement is fueled by scientists wanting to be in the limelight:

> I think some of them disagree because they like to be in the limelight. . . . It's easy to find problems with what we're doing. . . . But when you do it, you're the one that gets all of the media attention.

Sue, the doctoral candidate, mentioned the difficulties of detecting a clear signal in the data, although she also noted this argument is waning:

> Well, I think some of the criticisms are based on a few things. One, that we don't understand the data well enough, that the data is, you know, full of noise, and we can't yet separate out, we can't be certain that there's a signal in there. And even if there were, we can't be certain that it's arising from greenhouse gases. That argument has lost its potency more recently as we've gathered more data and understood the system better.

She also cited uncertainties about global climate models (GCMs):

> A lot of people criticize how the global climate models that we use to understand this are developed, that you can't possibly capture the whole climate system with mathematics. And there are still so many uncertainties, or so many processes that we haven't been able to model well enough to put into

> these GCMs, that we can't talk about model predictions with very much confidence. That's where a lot of the heaviest criticisms are aimed. And to a certain extent, some of the criticisms are things that should be listened to, because it is true that GCMs do have a lot of uncertainty, and you can't capture everything in nature with math.

On the other hand, she clarified that climate models are useful in spite of their uncertainties:

> But to a large extent we do, you know, we can trust the models, because they've been tested against, you know, simulating the present climate, and against things that have happened in past climates. So to a certain extent we can understand and trust the models, and the fact that there are different models developed by different groups who tell us similar kinds of things. Maybe the pattern of climate change is different in different models, but the general direction and magnitude is fairly similar.

High School Students

Table 2 summarizes high school students' responses. Like the specialists, high school students discussed inherent difficulties in proving scientific claims associated with global warming, although their specific reasons differed.

• scientists interpret evidence or its significance differently[2]	• it is difficult to prove hypotheses
• some scientists focus on costs, while others emphasize benefits[2]	• it is difficult to conduct controlled experiments
• some scientists are biased[2]	• climate system is complex

Table 2. Views of high school students about reasons for uncertainty of climate change.

Some student responses explained scientific disagreement as rooted in differences in interpretation of evidence or its significance, whether scientists focused on costs or benefits associated with global warming, and bias of scientists due especially to corporate influences. These views are analogous to Aikenhead's (1987) student positions noted earlier—positions F, K, and L, respectively (p. 474-475).

One student made an analogy to how two people could see different things in the same picture:

> It's just, I don't know, the way people look at things. Like for example, I draw a picture of something, right? And we're seeing the same picture? . . . But I could tell you it looks like this, and you could say it looks like something completely different. It's the same thing. (Beth)

Another student suggested that evidence doesn't always point in one direction:

> The evidence doesn't always point in one direction. It's interpretive, so one scientist is gonna say, you know, one thing about the events and another one's gonna say another thing, and they could be opposite poles. (Kyle)

The notion that scientists would weigh evidence differently was also cited:

> Based on how their brain works, they're going to count certain bits of information more valuable than others, and say that other ones were caused by flukes. (Howard)

Another student's response suggested that a source of bias is whether scientists focused on the short-term benefit of not responding to global warming or the long-term costs:

> Well, the pluses and minuses to global warming, I guess. The plus is basically, we live happily for now, conveniently, and the minus is we won't be living too happy in 50 years or so. And so, with these pluses and minuses, I'm sure there are some uncertainties which they have about the facts. (Thomas)

Possible bias of scientists was mentioned, drawing a comparison to scientists in the tobacco industry:

> I mean scientists are biased, a lot of them, and it's not a perfect world. Like for instance, the tobacco industry. It's renowned now, I mean they do tests. I'm sure they get the same results as scientists who aren't in the tobacco industry do, but maybe their minds warp the results, maybe they just, they know outright that they're doing something wrong, but they certainly report different results than the other people do. (Marie)

Other student responses, which did not have direct analogues to those reported by Aikenhead (1987), concerned various reasons why it can be difficult for scientists to develop scientific claims that are certain. A student noted that proving hypotheses can be difficult:

> A lot of science is proof and hypotheses, and to prove your hypotheses you need a lot of evidence. But can you ever really prove your hypotheses, can you ever say it's fact? And the answer most of the time is no. (Kyle)

The difficulty of running controlled laboratory experiments was also cited. (In the example below, the student apparently used the word "lifestyle" to mean something like "ecosystem").

> But you can't really put a real life, lifestyle with eagles and with rabbits and with snakes and with fish in the pond, and mosquito larva or whatever else lives in a pond, and slowly increase the heat one degree every year or whatever, and see what happens. That's why they can't really lab test it, I don't think. Maybe science has gone beyond my knowledge, but if you put, make a huge building, maybe you can do it. (Thomas)

The view that the climate system is complex was also cited:

> I think they're certain about the general things, like the earth is going to warm up and the sea levels will rise, but I think more specific than that, they can't really get because the earth is so huge that it's hard to analyze it. I mean some places haven't changed, some places are still just as cool as they were before, but other places aren't, and I mean it's all one big mess and it's hard to analyze. (Marie)

Results: Action Now vs. Waiting

Specialists

As a group, the specialists expressed views incorporating three overall elements: (a) although there is uncertainty, climate change poses serious risks, (b) the question of responding to climate change is appropriately viewed as an issue of managing risk and uncertainty, (c) we should definitely adopt so-called "no-regrets" policies, which would ameliorate climate change and also have other benefits. Mark, the staff scientist, pointed out that climate change could prove either worse or better than scientists expect:

> And to me, there's clearly room for concern, in the long run. Everybody talks about uncertainty. The uncertainty exists on both sides. . . . And many of the feedbacks are in the direction that would make things worse, the things that aren't that well understood. Some of them might make it better.

He further pointed out there is a tendency to give undue emphasis to mid-range estimates:

> Nobody wants to hear about all the uncertainty. People generally want, whether it's the public or the media or the people in Congress, and they don't want to hear "plus or minus 50%" around the number, they want to hear the number. So everything tends to get focused onto, you know, the middle case. . . and that's not so good either.

He emphasized that instead of focusing on mid-range estimates, it would be more productive to attend to managing uncertainty:

> Because a lot of what it's all about is, how do we manage this uncertainty, and not try to fool ourselves that we do have this certainty, but what's the best actions we can take in this environment where there's some risk involved, and also a lot of uncertainty.

Ned, the engineer, drew an analogy between mitigating the risk of climate change and mitigating the risk of an earthquake:

> One of the closest analogies I can think of is that scientists involved in studying earthquakes, and engineers collectively, are not able to predict when the next big earthquake will happen here on the Hayward Fault. . . . I need to be aware that there is a very serious problem, I need to take some prudent actions to do it. What is that? . . . . I take out earthquake insurance, yes, and also I bolt the house to the foundation and put in some shear walls and whatnot.

Mark a policy analyst drew a parallel between decision making about purchasing insurance and decision making about responses to climate change.

> And you know, as people who sell and buy insurance know, it's hard to say what is too much or isn't too much, it's kind of a matter of how risk averse one wants to be. And you know, that's a social question and political question.

Further, specialists linked this notion of risk mitigation to support for so-called "no regrets" policies—policies that ameliorate global warming and also have other societal benefits. Mike, the other policy analyst, expressed this view as follows:

> The scientific evidence is in fact quite clear. It suggests that, from any reasonable risk mitigation strategy you've gotta deal with, you've gotta deal with the issue as soon as possible. . . . And I think that the so-called "no regrets" approach to this is a particularly convincing one for me personally, with the idea being that the same sets of strategies that we would use to deal with global climate change also have large benefits from a national perspective in terms of reducing foreign energy dependence and in terms of dealing with air quality, in terms of economic efficiency and energy efficiency. . . . So I think those two pieces together, in terms of risk management and in terms of multiple benefits, build a compelling case for dealing with climate change as soon as possible.

High School Students

As a group, the responses of high school students to questioning about "action now versus more research" reflected more variation than did the responses of the specialists. Whereas the specialists unanimously agreed action was needed now, 4 students did not support action now, while 6 students did support action now. Table 3 summarizes students' responses.

More Research	Don't Know	Action Now
• need more information on what scientists know • need to figure out a solution	• you might make things worse • depends on severity of response	• better safe than sorry • the sooner the better • we already know we should change • simple lab experiment confirms global warming • absolute certainty is elusive • we should take actions anyway

Table 3. Views of high school students about "action vs. more" research.

Students not supporting "action now."

The responses of many students who did not support "action now" signaled substantial gaps in their knowledge about the issue of global warming and policy approaches to it. For example, one student who didn't support taking action cited his lack of information about global warming:

> I personally don't have enough information to vote either way. I don't know how much information I could be given by researchers and professors and so on and so forth . . . . I don't know how much the scientific community knows about this, so it would be, it'd be stupid of me to guess either way. (Howard)

The response of another student, who called for research on possible solutions to global warming until an effective solution was found, appeared to reflect a lack of information about remedies that are already possible:

> I mean you gotta figure out what the problem is, and you gotta figure, analyze where it is, and what it does, and then you have to figure out something that'll counteract it. . . that's what we should start immediately on. But then once we have that, an effective means of stopping it, then we should put that into action. (Dan)

Another reason for waiting to take action was a general concern for unforeseen consequences of any actions taken:

> I figure before you can do something you need to know exactly what you're dealing with. Because if you don't know exactly what you're dealing with, you just might mess up, and make things worse than what they already are. (Tara)

Not all the responses of students who didn't support action now were simply a matter of ignorance. A thoughtful response of a student, who, on the questionnaire, "wasn't sure" about taking action now or waiting for more research, clarified in the interview that (1) he was concerned about taking extreme measures prematurely and (2) he thought decisions to undertake actions affecting a large number of people should involve society as a whole:

> Depends what the something is. . . . If it's something like people aren't allowed to drive cars, that's a little, you know, extreme. And, but if it's something, I mean if it's not as severe, then I can see people taking that action as a precaution. But if it's something that's going to affect a large group of people, then the society as a whole is gonna have to decide whether the scientific evidence is substantial or not. (Kyle)

Students supporting "action now."

Some student responses resembled folk aphorisms, e.g., "better safe than sorry" and "the sooner the better":

> I feel, you know, you need to be safe than sorry, you know? (Bonnie)

> Because if it is a big problem, then the sooner you take action, the more likely you are to be able to fix it. (Cindy)

Another student offered a kind of "thought experiment" to justify taking action now:

> I think we should definitely start doing something. I think there's a pretty simple lab test you can perform, where you just shine a light in and see how the greenhouse effect works, with a nice clean jar. And you throw in some pollution up in there, and then shine the same light in, and see if it's a hotter temperature in there, over time. And if that lab test says yes. . . it's hotter inside the jar of pollution, then it's gonna be hotter between the earth and the atmosphere. And I think that's enough already. So yeah, I think scientists have done enough research to do some action. (Thomas)

Another student response noted that scientific certainty is elusive, and therefore scientific uncertainty can not justify inaction:

> You can't start when you know it's absolutely true . . . . I mean, science is kinda that way. It's never as certain as like a math problem is, like two plus two is always gonna equal four. (Beth)

Another student response echoed that of the specialists in calling for "no regrets" policies:

> I think even if scientists aren't sure about everything about global warming, even if they aren't sure if it's happening or not, it doesn't even matter. You should still stop pollution, I mean. There's no drawback to that, except well, maybe losing jobs and things like that. . . . But I mean if global warming is a fact, that it is happening, even if they don't know the particulars, you can at least start trying to do something. I mean there are things that you know will work, like stopping all that pollution. That's going to help even if the details of global warming aren't known. And if global warming isn't a reality, then doing that will still be good. (Marie)

Discussion

As a methodological issue, providing students the context of a specific controversy, the issue of global warming in this case, provides an illuminating perspective for investigating students' views about reasons for scientific disagreement. This study reveals views not captured by methodologies that probe for general reasons for scientific disagreement without the context of a specific issue. Both the high school students and specialists cited a variety of reasons why proving scientific claims may be difficult. The student responses included the view that it can be difficult to prove hypotheses—an issue that is germane to other areas of scientific inquiry besides climate science. Other student views that arose in this study were more directly tied to the specific context of climate science, but also are indicative of more general reasons for scientific disagreement. These include the difficulty of conducting controlled experiments and the inherent complexity of the phenomena being investigated. Reasons for scientific disagreement identified by specialists included the scientist's stake in seeing things a certain way, where a scientist draws the line in viewing a risk as a problem, the difficulty of identifying a "signal" in the data, and limitations of computer models. Further research, with larger samples, could characterize the representativeness or frequency of the views.

Whereas prior research about lay persons' understanding of climate change emphasizes scientific issues that are certain, the present study emphasizes judgments about uncertain aspects of climate change. The responses of specialists serve to highlight the issue of managing uncertainty. Specialists expressed views incorporating three overall elements:

- although there is uncertainty, climate change poses serious risks,
- the question of responding to climate change is appropriately viewed as an issue of managing risk and uncertainty, and
- we should definitely adopt so-called “no-regrets” policies.

The responses of some of the high school students, who supported taking action about climate change, ranged from a less-developed common sense version of this view (“better safe then than sorry”) to directly paralleling the specialists in articulating a “no-regrets” type approach. On the other hand, the responses of some students who did not support action now were evidently rooted in some ignorance of approaches to ameliorating global warming that are already available. Educational approaches that include presenting possible remedies to global warming would be helpful for students in this category.

This study describes, and aims to draw attention to, the responses of scientists and high school students to scientific uncertainty. Learning about reasons for scientific disagreement about climate change could provide a productive route for students to develop more sophisticated views about reasons for scientific disagreement in general. Educational interventions designed to prepare students to make judgments about global warming should include not only the “certain science,” but also reasons for scientific disagreement, and, importantly, strategies for making judgments under conditions of uncertainty.

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Notes

[1] The survey that included this question was preceded by experimental activities including a pretest questionnaire, watching a 20-minute informational video about global warming, and participating in small-group discussions lasting approximately 45 minutes.

[2] These views correspond to positions of high school students about reasons for scientific disagreement reported by Aikenhead (1987).

Notes on Contributor

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Appendix 1 *Policies from Questionnaire*

Note: Policies A-L were derived from Doble, Richardson, & Danks (1990).

A. Increase the miles per gallon standard for new cars to *50* mpg by the year 2007 *even if* that would increase the price of new cars and decrease the performance of full size cars and station wagons.
B. Reimpose and strictly enforce a nationwide speed limit of 55 mph *even if* that would inconvenience truckers and drivers, especially in western states.
C. Raise the gasoline tax by $1.00 U.S. a gallon *even if* that would burden truckers and others who need their cars for work. Impose a tax on "gas guzzlers," cars that get poor gas mileage, *even if* that would sharply increase the cost of full size cars and station wagons.
D. Give more aid to Brazil if they stop destroying the rain forests *even if* this means increasing foreign aid and cutting spending in other areas.

E. Reduce the number of trees that can be cut in the U.S. each year *even if* this would increase the price of paper products and might even put some logging companies out of business.

F. Require businesses to improve fuel efficiency or use less energy, *even if* that would greatly increase their costs and the price of their products.

G. Require utilities to burn less coal by using alternative fuels or increasing efficiency *even if* this means many coal miners would lose their jobs.

H. Encourage industries to increase insulation and energy efficiency *even if* this would mean giving them large tax breaks.

I. Build more nuclear power plants (which do not give off carbon dioxide that contributes to the greenhouse effect) *even if* that means living with the risks posed by that technology.

J. Increase government funding to spur development of solar energy *even if* many scientists doubt it will be a viable alternative in the foreseeable future.

K. Require communities to plant a large number of new trees each year *even if* this would mean a tax increase of about $50 U.S. per year per taxpayer.

L. Sharply increase spending on mass transit in urban areas *even if* that would mean a tax increase of about $50 U.S. per year per taxpayer.

M. Fertilize the oceans with iron to stimulate algae (which will absorb carbon dioxide that contributes to the greenhouse effect) *even if* we aren't certain how that will effect ecosystems.

N. "Fee-rebate" system. Charge people who buy cars with poor gas mileage an additional fee, and use the money to give rebates to people who buy cars with good gas mileage. People who buy cars with good gas mileage would get rebates of up to $1,000 U.S. *even if* people who buy cars with poor gas mileage would be charged fees of up to $1,000 U.S.