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An Inconvenient Truth—Is It Still Effective at Familiarizing Students with Global Warming?

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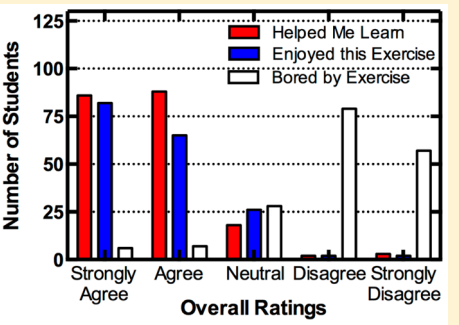
Supporting Information

ABSTRACT: Chemistry courses for nonscience majors emphasize chemical concepts and the relationship of chemical knowledge to everyday life while teaching the utility of quantitative analysis. As an introduction to the topic of global warming, the first half of *An Inconvenient Truth*, released in 2006, has been shown annually since 2008 in the chemistry course for nonscience majors at a large public university. The initial goal of the current study was to determine the effectiveness of this introduction. Even though the results indicate that the percentage of students who have watched this documentary has declined over the years, nearly all students enjoy learning from this relatively jargon-free, broad overview. The documentary causes students to formulate questions about the data presented and to want to learn what has been done about this issue since the documentary was released and whether the trends have continued. All of these are then addressed in subsequent lectures. By collecting the data about the documentary's effectiveness over a period of years, it became possible to address the question whether it remains effective at familiarizing students with global warming ten years after its debut.



KEYWORDS: *High School/Introductory Chemistry, First-Year Undergraduate/General, Atmospheric Chemistry, Enrichment/Review Materials, Environmental Chemistry, Geochemistry, Multimedia-Based Learning, Nonmajor Courses, Water/Water Chemistry*

Chemistry courses for nonscience majors emphasize chemical concepts and the relationship of chemical knowledge to everyday life while teaching the utility of quantitative analysis. The most common goal of such courses is to develop informed and chemically literate citizens. As such, the majority of such courses include a unit on climate science because it is an important topic and it has been growing in significance.[1,2] Chemistry is needed to understand such key aspects as atmospheric gas composition, measuring atmospheric temperature, measuring carbon dioxide levels, and the greenhouse effect, whereby gases with more than three atoms are able to absorb long-wave infrared energy in the form of increased tumbling motion (and then release it).[3,4] Climate science also makes connections between activities in the atmosphere, hydrosphere, and lithosphere to provide students with a broad view of Earth's natural systems, how they interact, and how they are being perturbed. Another desirable feature is the opportunity to describe long-term data collection projects and to have students examine the data and to extrapolate into the near future.

There are a number of challenges to teaching climate science, including the multidisciplinarity of the material, the evidence that students enter chemistry courses with confusion about the nature and relationships between the greenhouse effect, global warming, and the ozone layer,[4] and the politicization of the public's views about climate change.[5] These challenges are present despite a long history of suggestions for effective ways to communicate environmental science to students and to the public by focusing on knowledge, attitudes, and behavior.[5−12] To assist in meeting these challenges, there are simple but effective demonstrations[13,14] and a wide range of materials developed by prominent scientific organizations, including the American Chemical Society,[15] the Environmental Protection Agency,[16] the U.S. National Aeronautics and Space Administration,[17] and the U.S. National Oceanic and Atmospheric Administration.[18] A few leading educators have used the richness of this topic as a strength and developed courses or course materials as the prelude to delving deeply into the proactive topics of green chemistry and sustainability. For instance, at Creighton University, an honors seminar course was developed on Green Chemistry and Sustainability for upper-level students.[19] Likewise, a consortium of chemical education researchers has developed materials for Visualizing the Chemistry of Climate Change for use in General Chemistry courses to help students understand why sustainability initiatives are critical.[20]

It is an advantage that most chemistry textbooks for nonscience majors include sections on climate change and ozone depletion. These important societal topics set the stage for the exploration of the underlying scientific principles. A

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notable success in this area is the *Chemistry in Context* textbook published by the American Chemical Society, now in its eighth edition.[21] However, most of these textbooks provide a quick overview of the context. While doing so may justifiably avoid overwhelming the student with nonchemical information, our experience indicates that the complexity of global warming and climate change requires a deeper introduction.

An engaging way to introduce multidimensional topics into the classroom is to use movies, television shows, and documentaries that include chemical content.[22] These media are pedagogically useful because they are created by master storytellers and students tend to be familiar with them. With regard to using movie clips, our research has shown that the audience will stay with the instructor even when digging quite deeply into chemical details because they want to know whether the movie got it right.[23,24] Other studies have found it useful to use entire movies and documentaries. For instance, movies based on true stories, such as *Apollo 13*,[25] *October Sky*,[26] and *Lorenzo's Oil*[27] are able to drive discussions about lithium hydroxide carbon dioxide scrubbers, rocket fuel comparisons, and orphan disease patient advocacy, respectively.[28−31] Likewise, we found that General Chemistry students were more motivated to write 600-word reports and did a better job when we used the biographical movie *Dr. Ehrlich's Magic Bullet*[32] or the documentary *Me & Isaac Newton*[33] as source material instead of newspaper articles.[34] The goal of the present study was to determine whether the documentary *An Inconvenient Truth*[35] could meet the challenge of introducing the topic of climate change to students in a nonscience chemistry course.

Since its release to theaters in May 2006, *An Inconvenient Truth*[35] has become the international touchstone for the public's knowledge about global warming. Note that it has since become more common to refer to climate change, which includes both global warming and ocean acidification. This documentary, directed by Davis Guggenheim, is about former U.S. Vice President Al Gore's decades-long commitment to this issue. The specific focus of the documentary is Gore's slideshow presentations that he designed to raise public awareness. Within the first 45 min, Gore describes the evidence that global warming is occurring and the correlation between increasing carbon dioxide and temperatures that are driving the change. The second half of the documentary describes some of the consequences if humankind does not act within the next few decades to reduce greenhouse gas emissions. When it was released, it received a great deal of press coverage for its message that global warming is a "planetary emergency". Despite a few inaccuracies, most of which were taken from peer-reviewed publications,[36] a survey in 2007 of 489 members of the American Meteorological Society and the American Geophysical Union showed that 64% of them believe the documentary is very or somewhat reliable.[37] In the same survey, nearly all members agreed (97%) that global average temperatures have increased in the last 100 years and most agreed (84%) that the warming is due to anthropogenic causes. Awareness of the documentary's message was raised even further when it received the 2007 Academy Award for Best Documentary Feature and again when Gore shared the 2007 Nobel Peace Prize with the United Nation's Intergovernmental Panel on Climate Change.

Since Fall 2008, the first half of *An Inconvenient Truth* has been shown annually in the chemistry course for nonscience majors at the University of Nebraska—Lincoln, a large public university. The first half of the documentary was chosen because it provides a succinct and comprehensive summary of the wide-ranging evidence that global warming and climate change are occurring. The initial goal of the current study was to learn whether the documentary served as an effective introduction to these topics. By collecting the data about the documentary's effectiveness over a period of years, it became possible to address the question whether it remains effective at familiarizing students with global warming ten years after its debut.

METHODS

As students watch the first half of *An Inconvenient Truth* during one class period, they complete a Likert survey in which they enter their reactions to 28 scenes (Table 1). Specifically, the survey asked students to choose very favorable, favorable, neutral, unfavorable, or very unfavorable. Each scene was categorized as "Gore", indicating "about Gore's life"; "Background", indicating "related to background or contextual information"; and "Data", indicating "related to data showing evidence for global warming". There was an additional scene categorized as "Comic Relief".[38] The Fall 2015 survey asked students for their comments about a total of 14 different scenes. This was achieved by circulating three forms of the survey, with some scenes appearing on more than one survey. Survey form A had comment rows following scenes 5, 8, 14, 19, and 25. Survey form B had comment rows following scenes 5, 11, 15, 20, and 24. Survey form C had comment rows following scenes 7, 9, 13, 18, and 28.

RESULTS

The first half of the documentary *An Inconvenient Truth* was shown in the chemistry for nonscience majors course at University of Nebraska—Lincoln beginning in Fall 2008 to serve as an introduction to the topic of global warming. Prior to 2008, it was apparent that most students did not understand the context for the two lectures about greenhouse gases, molecular vibrational modes, global temperature increases, and how the historical global measurements of carbon dioxide and temperature were determined. This documentary was chosen for the reasons stated in the introduction. By 2009, however, there was widely reported controversy in the U.S. Congress about the meaning and importance of global warming.[39] The controversy was driven in large part by the economic concern that reducing carbon dioxide emissions would be much more costly than any possible benefits because it would disrupt our petroleum-based economy. While preparing for the Fall 2009 semester, therefore, we searched for ways to learn whether the Congressional controversy was having an influence on student learning about global warming. We found that Marcus and Stoddard proposed a variety of ways to teach social issues using documentaries that deal with controversial issues.[40] One suggestion was to have students report their affective responses about what they've seen and to follow that with an open class discussion about their comments. To determine whether any scenes in *An Inconvenient Truth* were overly distracting, a Likert survey was created (see Methods) in which students were asked to rate each scene from "very favorable" to "very unfavorable". By doing the same survey every Fall semester, we have gained insight into the rhythm of student feelings during the movie. The results show that students are highly engaged with the material.

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Table 1. Scenes Surveyed by Category from the First Half of *An Inconvenient Truth*

Scene[a]	Scene Category[b]	Short Description
1	Gore	"...used to be the next President..."
2	Background	Earthrise photo, from Apollo 8 in 1968
3	Background	Blue Marble photo, from Apollo 17 in 1972
4	Background	Rotating Earth movie, from Galileo space probe (released to the public in 2007)
5	Background	Cloud-free view of Earth's surface, by Tom Van Sant in 1990
6	Gore	Grade school continental drift story
7	Background	The atmosphere is a thin varnish on Earth's surface photo
8	Data	Global warming theory
9	Comic Relief	"Global Warming" scene from the 2002 "Crimes of the Hot" episode of Futurama
10	Gore	Inspired by Professor Roger Revelle
11	Data	Keeling curve of rising CO_2 levels at Mauna Loa since 1958
12	Data	Retreat of glaciers around the world over past 80 years
13	Data	Surface temperatures determined from glacier ice cores cover the past 1000 years
14	Data	Global CO_2 levels and temperatures from Antarctic ice cores cover the past 650,000 years
15	Gore	Inspired by son's accident
16	Data	Surface temperature records since 1880 showing that last 14 years were hottest
17	Data	Heat waves around the world in 2005 (the year before the documentary was filmed)
18	Data	Ocean temperature over past 60 years, predicted versus actual
19	Data	Number of hurricanes and tornados
20	Data	Hurricanes are gaining intensity because higher temperatures lead to higher water temperatures, higher wind velocities, and more air moisture
21	Background	Hurricane Katrina disaster
22	Gore	Inspired to give this presentation by his loss of the presidential election
23	Data	Severe weather events
24	Data	Higher temperatures also lead to more droughts.
25	Gore	Son of senator and "Breeder of the Month"
26	Data	Melting of the Arctic ice shelf and permafrost
27	Data	Number of days/year it is possible to drive on the Arctic tundra over the past 30 years
28	Data	Arctic sea ice thickness over the past century
29	Data	Sunlight heat absorption of ice versus water

[a]Students were asked to rate each scene from *An Inconvenient Truth*[19] on a scale of 1 to 5 for very favorable to very unfavorable, respectively. The 29 scenes were labeled using the scene number, scene category, and a short description. [b]The categories indicated whether they were about Al Gore's life (Gore), contextual information presented with minimal numerical data (Background), numerical data concerning the change in some parameter over a specific period of time (Data), and one scene of comic relief (see ref 38).

Feelings about Individual Scenes

In Fall 2010 and 2011, students gave an overall favorable response to the first half of the documentary (Figure 1). The strongest positive feelings were for the four images of the Earth—the "Earthrise" photo taken during the *Apollo 8* mission in 1968,[41] the "Blue Marble photo taken during the *Apollo 17* mission in 1972,[42] the "Rotating Earth" movie sent from the Galileo space probe and released to the public in 2007,[43] and a cloud-free map of Earth's surface stitched together from satellite photos by Tom Van Sant in 1990.[44] These images encapsulate powerful concepts about life's unity and the finite nature of the Earth. The next strongest positive responses were for data that are coincidentally presented in classroom lectures—the monthly CO_2 levels at the Mauna Loa observatory since 1958, global surface temperatures since 1880, and Antarctic CO_2 levels over the past 650,000 years. These scenes also happen to be the material that students know is most likely to become the subject of questions on an exam.

When the average rating for each scene is plotted versus scene number (Figure 2), the rhythm of student feelings follows the same pattern from year to year. The average student response is neutral for the first scene, in which Gore says he "used to be the next President", and then becomes significantly more favorable when viewing the four scenes of Earth. The average rating for the remaining scenes falls at the border between favorable and neutral. In general, the data and background scenes are received more favorably than the scenes about Gore's life. One of the surprises was the borderline neutral response to the comic relief animation "Some Like It Hot", taken from an episode of *Futurama* from 2002.[38] The last joke in the animation is that politicians solve global warming by dropping ever-larger ice cubes into the ocean. Although the segment certainly makes the students laugh, such mirth apparently does not automatically translate into a strongly favorable feeling. The average scores were quite reproducible from year to year, except for 2012, when they were more neutral than usual, and 2015, when they were more favorable than usual. It is perhaps significant that 2012 was an election year in which global climate change was discussed by both political parties. The Discussion section presents several possible reasons for the greater favorability in 2015.

Effects of Prior Exposure and Perceived Utility

Although the majority of students were reacting favorably to most of the documentary's scenes, it was not clear what students were thinking when they gave those ratings. The first attempt to obtain this information was an open field at the end of the Fall 2012 survey with the heading "Other Comments and Thoughts about the Documentary". In 2012, 23% of the surveys included responses in this field (Figure 3). The percentage of surveys with final comments has risen every year, although the nature and distribution of comments has been similar. In a further effort to ensure that students felt the documentary was providing them with useful information, several more items were added to the survey in Fall 2014. The first question asked whether they had seen the documentary before and, if so, how many times. The data from 2014 and 2015 suggested that the percentage of students who have seen the video is dropping quickly (Figure 3). This was a surprise because a show of hands a few years earlier indicated that about one-third to one-half of the students had seen all or part of the documentary.

Three summative statements were added to the survey in 2014: "This documentary helped me learn"; "I enjoyed this exercise"; and "I was bored by this exercise". An analysis of the Likert responses indicated that over 80% of the students chose "strongly agree" or "agree" to the question about "helped me learn" (Figure 3). This percentage increased even more in 2015 and was coupled with an increase in the percentage of students who submitted their responses and a decrease in the percentage of students who have seen the documentary before. These are interesting correlations. For instance, it may indicate that, in earlier years, the students who had seen the documentary may

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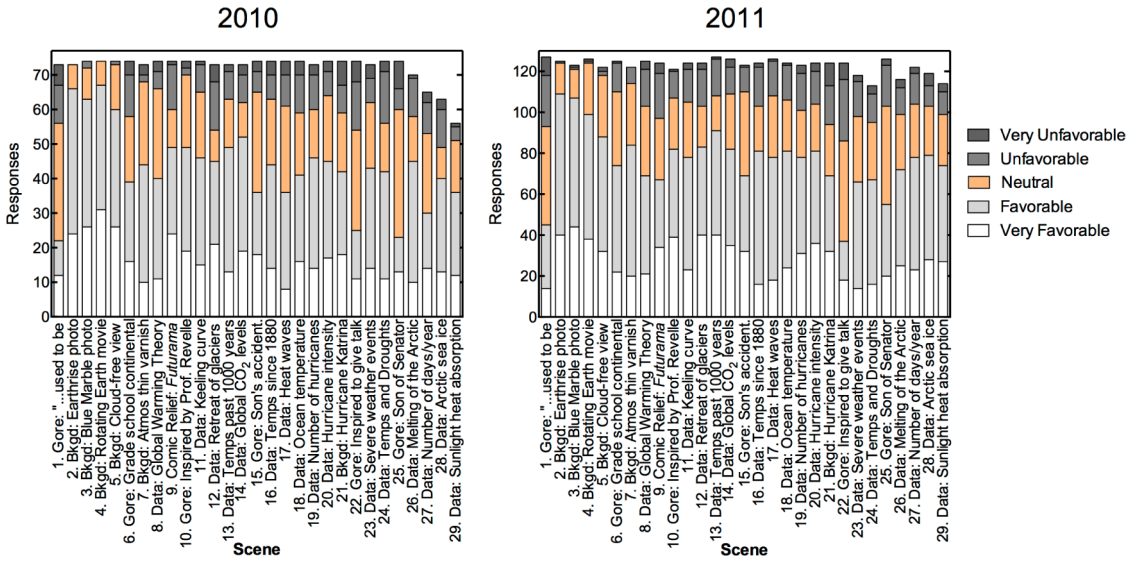

Figure 1. Student reactions to the scenes from the first half of *An Inconvenient Truth*[19] during Fall 2010 (N = 73) and Fall 2011 (N = 123). Students rated each scene using a Likert scale with responses ranging from "very unfavorable" to "very favorable".

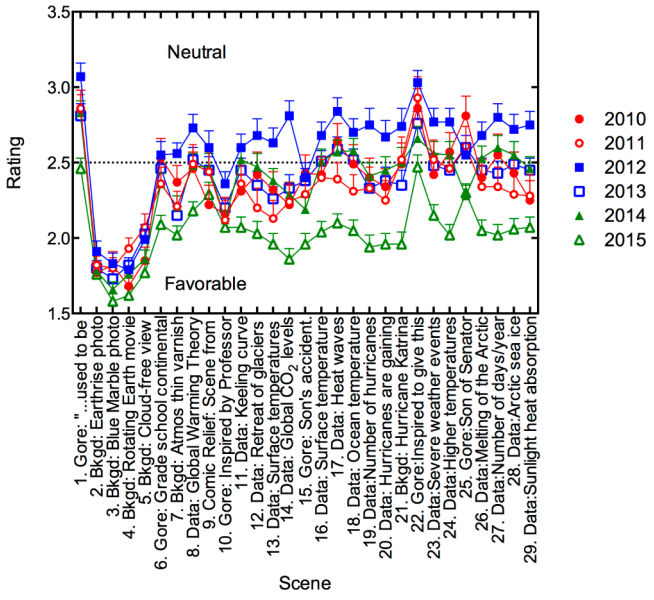

Figure 2. Average student reactions to the scenes from the first half of *An Inconvenient Truth*[19] from Fall 2010 to Fall 2015. The student ratings were converted to numbers 1 to 5 and then averaged to arrive at mean scores and standard errors of the mean.

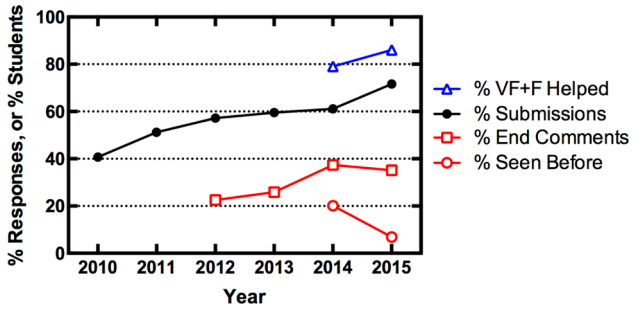

Figure 3. Statistics for the "Inconvenient" surveys collected from Fall 2010 to 2015. The "% Submissions" (closed circles) means the percentage of students who submitted their completed survey sheets. This percentage has increased even as the number of students in the course has increased from 182 students in 2010 to the room capacity of 282 ± 3 from 2013 to 2015. The "% Final Comments" (open squares) means the percentage of surveys with responses to the "Other Comments and Thoughts about the Documentary" field that was added in Fall 2012. The "% Seen Before" (open circles) is how many have seen the documentary before. The "% SA + A Helped" (open triangles) was the percentage of students who answered strongly agree or agree to the statement "This documentary helped me learn".

have preferentially chosen not to attend the class period in which we watched the documentary. No matter the underlying reasons, it is clear that more students are encountering the documentary for the first time in our chemistry course and that they find it to be a valuable introduction.

It was possible to gain insight into the increasingly favorable scores by sorting the scenes according to categories (Figure 4). For instance, student feelings toward the scenes concerning Al Gore's life and his reasons for developing his slide show have become more favorable over the years (Figure 4A). An example is the response to opening scene 1, in which Gore says, "He used to be the next President", which typically receives the most neutral response. The ratings show a trend from neutral/unfavorable to neutral between 2010 and 2015. The exception was 2012, when all scenes were rated less favorably. A different trend was observed for the scenes concerning the data in support of global warming (Figure 4B). The average responses for all these scenes are very close to neutral every year except 2012, when they were less favorable, and 2015, when they became significantly more favorable. The Comic Relief scene showed the most unusual trend, in that it was rated more favorably the first two years but then neutrally starting in 2012 (Figure 4C). The perennially most favorably rated scenes have been the opening scenes of Earth from space (Figure 4C), and these feelings have become increasingly favorable over time. Therefore, the strongly positive overall ratings in 2015 are because student feelings toward Gore's life and motivations have improved incrementally every year while student feelings toward the data has improved a great deal only in the past year.

Comments about Specific Scenes

To learn what the student ratings meant, every student was asked to comment on five scenes. Since there were three

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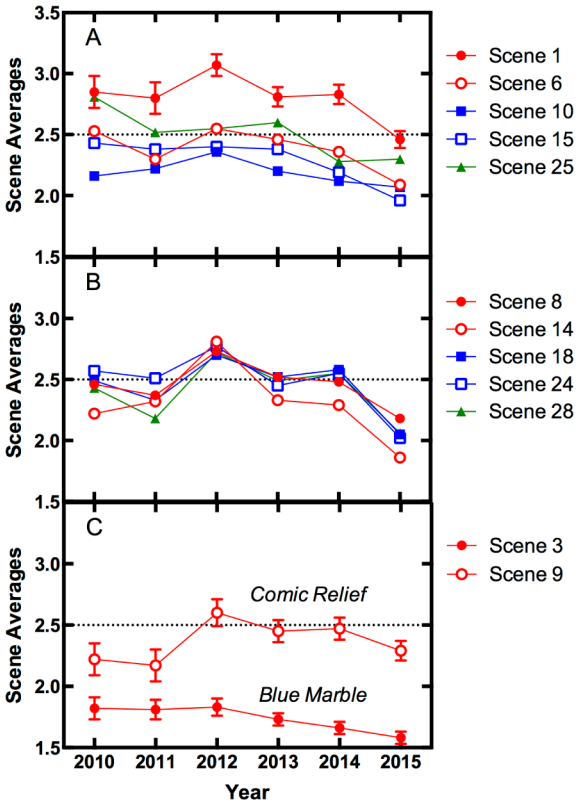

Figure 4. Evolution of mean scores clustered according to scene category: A: Gore's life; B: Data offered in support of global warming; and C: The Blue Marble Earth photo and Comic Relief cartoon.[26] Representative standard errors of the mean are shown for scenes 1, 3, and 9.

versions of the survey form in Fall 2015, each asking for comments on a slightly overlapping set of scenes, we obtained comments on a total of 14 scenes during that year. A summary of responses is provided in the Supporting Information.

Overall Ratings and the Students' Final Comments

There are typically 5 min of class remaining when the last scene ends, which gives students time to rate three summative statements and to offer their final comments. In Fall 2015, nearly all (98%) students rated the summative statements but only 35% gave final comments (Figure 3). Among the 44% of students who strongly agreed that "This documentary helped me learn" (Figure 5), 74% also strongly agreed with "I enjoyed this exercise", and 94% disagreed or strongly disagreed with "I was bored by this exercise". This group of highly engaged students offered final comments such as these:

I learned so much about this topic that I did not know; I truly enjoyed watching this film.

I would be interested to see these same charts and facts for today; 10 years later. Has everything continued to go up? Has is come down at all?

I learned a lot and enjoyed all the topics talked about; Putting his personal life into the video kept me even more interested.

These students were aware they were watching a 10-year-old documentary about one person's efforts to raise awareness about global warming and are primed for an update during subsequent lectures.

Among the 45% of students who agreed that the documentary helped them learn, 88% agreed that they "enjoyed" the experience and 67% disagreed or strongly disagreed they were "bored". This group was slightly less engaged than the previous group, and they were the least likely to offer final comments (25% of them). Among the 22 students who offered final comments, one remained agnostic: "I'm still unsure [of] my views or the support behind the data." The other students offered final comments that were shorter but similar to those in the highly engaged category. In general, these students welcomed this accessible introduction to a complex topic.

The remaining students' responses to "helped me learn" were 9% neutral, 1% disagreed, and 1% strongly disagreed. Among these students, one-third of them strongly agreed or agreed that they "enjoyed" the exercise and were not "bored", suggesting that they welcomed the relief from the usual lectures, demonstrations, and classroom discussions even though it did not help them learn. Based on their comments, however, about half of these same students indicated they were enthusiastic about learning more while the other half professed skepticism about Gore's motives, as in these examples: "I think Al has valid points, also I think he is just trying to get attention" or "I do not agree with Al Gore". These latter students were focused on Gore and his motives more than the topic of global warming.

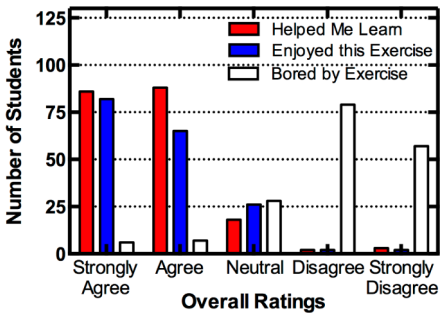

Figure 5. Overall ratings. Students were asked to respond to three statements at the end of the survey: "This documentary helped me learn" (left bar in each category); "I enjoyed this exercise" (middle bar); and "I was bored by this exercise" (right bar).

DISCUSSION

The goal of this project was to learn what students were thinking as they watched the documentary *An Inconvenient Truth*.[35] The results showed that it helps students clarify that the ozone layer does not play a role in global warming (see the comments about Scene 8 in the Supporting Information), that global warming is taking place, and that there is a complex relationship between rising temperatures and the atmosphere, hydrosphere, and lithosphere. It also provokes students to wonder whether the globe has continued to warm since the documentary was released in 2006. What the first half of the documentary does not clarify are the key components that students learn in a chemistry course, namely the atmospheric gas composition, how atmospheric temperature is measured, how carbon dioxide levels are measured, and the chemical basis for the greenhouse effect. All of these topics are introduced during lecture. Therefore, *An Inconvenient Truth* provides a succinct overview but is not a substitute for chemistry instruction on this topic. In subsequent lectures, we revisit two data sets from the documentary (Supporting Information Table 1) so students can see how these parameters have changed—global average annual temperatures since 1880[45] and

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the Mauna Loa carbon dioxide measurements since 1958.[46] Another lecture period is devoted to a discussion about recently published newspaper articles on Nebraska's future environmental challenges (Supporting Information Table 2). The discussions are structured so that students ask pertinent questions about the material and other students answer them.

The survey responses indicate that most students (89% of them) are concerned about the evidence put forward in the documentary. Even the small proportions of students (about 5%) who are not fully convinced by the evidence in the documentary are respectfully skeptical and not dismissive. This percentage of skeptics is much smaller than in the public at large, where one poll found that one-fourth of adults are skeptical of climate change.[47] The discrepancy between the percent skeptics in the chemistry classroom versus the polled U.S. adults could be due to education levels, to polling methods that generate broad results that are simple to interpret and explain, or to both.

The results of our classroom survey indicate that student feelings toward *An Inconvenient Truth* were the most neutral in 2012 and the most favorable in 2015. The variations observed in these two years are actually representative of national concern about climate change among U.S. adults, which happens to be intermixed with the broader conversation about *An Inconvenient Truth* because it is such a touchstone. For instance, the Pew Research Group created a time series of aggregated public opinions from various polls to develop a Climate Change Threat Index for the period between January 2002 and December 2010.[48] The results showed that the average U.S. citizen's concern about the threat of climate change was just below average at the beginning of 2005, rose throughout 2006, reached a peak in mid-2007, but was back to earlier levels by early 2010. An empirical analysis of the factors affecting these opinions indicated that the news reports about the release of *An Inconvenient Truth* and its subsequent Academy Award were the primary factor that caused the rise of concern after 2005. The decline after mid-2007 was correlated with U.S. Congressional Republican votes against environmental bills followed by the economic disaster of 2008.

Of perhaps greater importance for curriculum development was the Gallup poll analysis about global warming.[49] Analysis found three categories of respondents based on their answers to four questions:

1. How much [do you] personally worry about global warming?
2. Seriousness of global warming in the news?
3. Cause of the rise in Earth's temperatures?
4. Will global warming pose a serious threat to your way of life in your lifetime?

Among the "Cool Skeptics" who say they worry "only a little" or "not at all", 100% believe the news is exaggerated, 100% believe in natural causes, and 100% do not feel climate change poses a threat. This group doubled from 12% of respondents in 2001 to 25% in 2014. If students are like-minded, it suggests a strong need to address the time scale for natural causes of climate change in the classroom. The group labeled "Concerned Believers" has remained fairly steady at 39 ± 4% between 2001 and 2014. They worry either "a great deal" or "a fair amount", they believe the news is "underestimated" or "correct", 100% believe it is caused by "human activities", and 65% believe it will pose a threat during their lifetime. The third and final category is "Mixed Middle", with its self-explanatory title. This group has dropped from 49% in 2001 to 36% in 2014, in accordance with the rise of the "Cool Skeptics". The Mixed Middle is the group that would benefit most from instruction about the mechanisms of climate change.

Finally, there are two likely reasons that the student response to the documentary was significantly more favorable in 2015 than in previous years. First, Pope Francis released the *Laudato Si': On Care for Our Common Home* encyclical[50] in May 2015, stating that global warming is real, that it is caused by human actions, and that there is a moral imperative to act because the negative effects will disproportionately affect the world's poor, who contributed the least to the problem. A survey by the University of Michigan and Muhlenberg College published in November 2015 found that 15% of Americans were "more convinced that global warming is happening and we should act" as a result of the Pope's statement.[51] The second-most-likely contributing factor was the release of the Nebraska climate change report prepared by the University of Nebraska—Lincoln.[52] The report brought together a variety of previously published data to show that change had already occurred in the state over the past century. Awareness of this report was heightened by our in-class discussion about the report (see Supporting Information).

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.6b00321.

Further results and discussion; summary of comments about 14 specific scenes; list of the curricular material that follow-up on some data shown in the documentary—global average annual temperatures and carbon dioxide trends; in-class discussion material that allows students to ask and answer questions about environmental issues, including climate change (PDF, DOCX)

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Notes

The authors declare no competing financial interest.

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■ REFERENCES

(1) U.S. Environmental Protection Agency. *Climate Change: Basic Information*; http://www.epa.gov/climatechange/basics (accessed Apr 2016).

(2) U.S. Global Change Research Program. Climate Change Impacts in the United States, 2014. http://www.globalchange.gov (accessed Apr 2016).

(3) Grassian, V. H.; Stone, E. A. Chemistry's Contributions to Our Understanding of Atmospheric Science and Climate. *J. Chem. Educ.* **2015**, *92*, 595−597.

(4) Versprille, A. N.; Towns, M. H. Chemistry Students' Understanding of Climate Change and the Chemistry Related to Climate Change. *J. Chem. Educ.* **2015**, *92*, 603−609.

DOI: 10.1021/acs.jchemed.6b00321
J. Chem. Educ. XXXX, XXX, XXX−XXX

(5) McCright, A. M.; Dunlap, R. E. The Politicization of Climate Change: Political Polarization in the American Public's Views of Global Warming. *Soc. Quart.* **2011**, *52*, 155−194.
(6) Hofstein, A.; Kempa, R. F. Motivating Strategies in Science Education: Attempt at an Analysis. *Eur. J. Sci. Educ.* **1985**, *7*, 221−229.
(7) Sherwood, R. D.; Kinzer, C. K.; Bransford, J. D.; Franks, J. J. Some Benefits of Creating Macro-Contexts for Science Instruction: Initial Findings. *J. Res. Sci. Teach.* **1987**, *24*, 417−435.
(8) Staats, H. J.; Wit, A. P.; Midden, C. Y. H. Communicating the Greenhouse Effect to the Public: Evolution of a Mass Media Campaign from a Social Dilemma Perspective. *J. Environ. Manage.* **1996**, *46*, 189−203.
(9) Pooley, J. A.; O'Connor, M. Environmental Education and Attitudes: Emotions and Beliefs Are What Is Needed. *Environ. Behav.* **2000**, *32*, 711−723.
(10) Dirkx, J. M. The Power of Feelings: Emotion, Imagination, and the Construction of Meaning in Adult Learning. *New Direct. Adult Contin. Educ.* **2001**, *89*, 63−72.
(11) Carlson, R.; Chandler, P.; Sweller, J. Learning and Understanding Science Instructional Material. *J. Educ. Psych.* **2003**, *95*, 629−640.
(12) Shwartz, Y.; Ben-Zvi, R.; Hofstein, A. Chemical Literacy: What Does This Mean to Scientists and School Teachers. *J. Chem. Educ.* **2006**, *83*, 1557−1561.
(13) Elrod, M. J. Greenhouse Warming Potentials from the Infrared Spectroscopy of Atmospheric Gases. *J. Chem. Educ.* **1999**, *76*, 1702−3.
(14) Shallcross, D.; Harrison, T. Practical Demonstrations to Augment Climate Change Lessons. *Sci. School* **2008**, *9*, 46−50.
(15) American Chemical Society. ACS Climate Science Toolkit. http://www.acs.org/content/acs/en/climatescience.html (accessed Jul 2016).
(16) U.S. Environmental Protection Agency. Student's Guide to Global Climate Change. http://www.epa.gov/climatestudents/index.html (accessed Jul 2016).
(17) U.S. National Aeronautics and Space Administration. Transition Region and Coronal Explorer (TrACE). http://science.nasa.gov/missions/trace/ (accessed Jul 2016).
(18) U.S. National Oceanic and Atmospheric Administration. Teaching Resources. http://www.climate.gov/teaching (accessed Jul 2016).
(19) Gross, E. M. Green Chemistry and Sustainability: An Undergraduate Course for Science and Nonscience Majors. *J. Chem. Educ.* **2013**, *90*, 429−431.
(20) Mahaffy, P. G.; Martin, B. E.; Kirchhoff, M.; McKenzie, L.; Holme, T.; Versprille, A.; Towns, M. Infusing Sustainability Science Literacy through Chemistry Education: Climate Science as a Rich Context for Learning Chemistry. *ACS Sustainable Chem. Eng.* **2014**, *2*, 2488−2494.
(21) Middlecamp, C. H.; Mury, M. T.; Anderson, K. L.; Bentley, A. K.; Cann, M. C.; Ellis, J. P.; Purvis-Roberts, K. L. *Chemistry in Context: Applying Chemistry to Society*, 8th ed.; McGraw Hill: New York, NY, 2015.
(22) Clauss, A. Using Popular Culture to Teach Chemistry. *J. Chem. Educ.* **2009**, *86*, 1223.
(23) Frey, C. A.; Mikasen, M. L.; Griep, M. A. Put Some Movie Wow! in Your Chemistry Teaching. *J. Chem. Educ.* **2012**, *89*, 1138−1143.
(24) Griep, M. A.; Mikasen, M. L. Using Movie Clips to Teach Chemistry Formally and Informally. In *Hollywood Chemistry*; Nelson, D., Grazier, K. R., Paglia, J., Perkowitz, S., Eds.; American Chemical Society: Washington, DC,2013; pp 199−213.
(25) *Apollo 13*, 35 mm, 140 min; Imagine Entertainment, Universal Pictures: Universal City, CA, 1995.
(26) *October Sky*, 35 mm, 109 min; Universal Studios, Universal Pictures: Universal City, CA, 1999.
(27) *Lorenzo's Oil*, 35 mm, 129 min, Kennedy Miller; Universal Pictures: Universal City, CA, 1992.
(28) Goll, J. G.; Woods, B. J. Teaching Chemistry Using the Movie *Apollo 13*. *J. Chem. Educ.* **1999**, *76*, 506−508.
(29) Goll, J. G.; Wilkinson, L. J.; Snell, D. M. Teaching Chemistry Using. *J. Chem. Educ.* **2009**, *86*, 177−180.
(30) Ticich, T. M. Carbon Dioxide Absorbers: An Engaging Experiment for the General Chemistry Laboratory. *J. Chem. Educ.* **2011**, *88*, 189−191.
(31) Wink, D. Lorenzo's Oil as a Vehicle for Teaching Chemistry Content, Processes of Science, and Sociology of Science in a General Education Chemistry Classroom. *J. Chem. Educ.* **2011**, *88*, 1380−1384.
(32) *Ehrlich's Magic Bullet*, 35 mm, 103 min; Warner Bros. Pictures: Burbank, CA, 1940.
(33) *Me & Isaac Newton*, DVD, 110 min; Clear Blue Sky Productions, Home Vision Entertainment: Chatsworth, CA, 1999.
(34) Griep, M. A.; Mikasen, M. L. Based on a True Story: Using Movies as Source Material for General Chemistry Reports. *J. Chem. Educ.* **2005**, *82*, 1501−1503.
(35) *An Inconvenient Truth*, 35 mm, 95 min; Paramount Classics and Participant Productions, Paramount Pictures Corporation: Hollywood, CA, 2006.
(36) Brahic, C. Al Gore's *An Inconvenient Truth:* Unscientific? *New Scientist Environment Blog*, 2007. http://www.newscientist.com/blog/environment/2007/10/al-gores-inconvenient-truth.html (accessed Jul 2016).
(37) Farnsworth, S. J.; Lichter, S. R. Scientific Assessments of Climate Change Information in News and Environment Media. *Sci. Commun.* **2011**, *34*, 435−459.
(38) *Futurama*, "Crimes of the Hot" (episode number 62); Written by Aaron Ehasz, directed by Peter Avanzino. First broadcast November 2002 on Fox. https://en.wikipedia.org/wiki/Crimes_of_the_Hot (accessed Jul 2016).
(39) Kohut, A.; Doherty, C.; Dimock, M.; Keeter, S. *More Say There Is Solid Evidence of Global Warming*, 2012. http://www.people-press.org/2012/10/15/more-say-there-is-solid-evidence-of-global-warming/ (accessed Jul 2016).
(40) Marcus, A. S.; Stoddard, J. D. The Inconvenient Truth about Teaching History with Documentary Film: Strategies for Presenting Multiple Perspectives and Teaching Controversial Issues. *Soc. Studies*, **2009**, *Nov./Dec., 100*, 279−284.10.1080/00377990903283957
(41) Wikipedia. Earthrise. https://en.wikipedia.org/wiki/Earthrise (accessed Jul 2016).
(42) Wikipedia. The Blue Marble. https://en.wikipedia.org/wiki/The_Blue_Marble (accessed Jul 2016).
(43) NASA/Goddard Space Flight Center Scientific Visualization Studio. Galileo Earth Views, 2004. https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=2971 (accessed Jul 2016).
(44) Field, K. MapCarte 342/365: Satellite Map of Earth by Tom Van Sant, 1990. http://mapdesign.icaci.org/2014/12/mapcarte-342365-satellite-map-of-earth-by-tom-van-sant-1990/ (accessed Jul 2016).
(45) National Aeronautic and Space Administration. NASA Global Mean Surface Temp (GHCN-v3 1880−03/2016). See http://climate.nasa.gov/vital-signs/global-temperature/ (accessed Jul 2016).
(46) Keeling, F.; Piper, S. C.; Bollenbacher, A. F.; Walker, S. J. *Atmospheric CO_2 Concentrations (ppm) Derived from in situ Air Measurements at Mauna Loa*, 2016. ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_mm_mlo.txt (accessed Jul 2016).
(47) Saad, L. *One in Four in U.S. Are Solidly Skeptical of Global Warming*, 2014. http://www.gallup.com/poll/168620/one-four-solidly-skeptical-global-warming.aspx (accessed Jul 2016).
(48) Brulle, R. J.; Carmichael, J.; Jenkins, J. C. Shifting Public Opinion on Climate Change: An Empirical Assessment of Factors Influencing Concern over Climate Change in the U.S., 2002−2010. *Clim. Change* **2012**, *114*, 169−188.
(49) Borick, C.; Rabe, B. G.; Mills, S. B. *Acceptance of Global Warming among Americans Reaches Highest Level since 2008*; The Center for Local, State, and Urban Policy at the Gerald R. Ford School of Public Policy, University of Michigan: Ann Arbor, MI, 2015. http://closup.umich.edu/issues-in-energy-and-environmental-policy/25/acceptance-of-global-warming-among-americans-reaches-highest-level-since-2008/ (accessed Jul 2016).

DOI: 10.1021/acs.jchemed.6b00321
J. Chem. Educ. XXXX, XXX, XXX−XXX

(50) Pope Francis. *Laudato Si': On Care for Our Common Home*. Encyclical, May 2015. https://en.wikipedia.org/wiki/Laudato_si%27 (accessed Jul 2015).
(51) Mills, S.; Rabe, B.; Borick, C. *The Francis Effect on the Greenhouse Effect*; The Brooking Institute, 2015. http://www.brookings.edu/blogs/fixgov/posts/2015/11/2-pope-francis-climate-mills-rabe-borick (accessed Jul 2016).
(52) Bathke, D. J.; Oglesby, R. J.; Rowe, C. M.; Wilhite, D. A. *Understanding and Assessing Climate Change: Implications for Nebraska*; University of Nebraska–Lincoln: Lincoln, NE, 2014. http://snr.unl.edu/download/research/projects/climateimpacts/2014ClimateChange.pdf (accessed Jul 2016).

DOI: 10.1021/acs.jchemed.6b00321
J. Chem. Educ. XXXX, XXX, XXX–XXX