BAMS Article

An Interactive Online Course in Climate and Climate Change

Advancing Climate Literacy for Non–Atmospheric Science Majors

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ABSTRACT: Since 2013, the Department of Atmospheric and Oceanic Sciences at the University of Wisconsin–Madison has offered an online course titled "Climate and Climate Change." Students enrolled in this course learn the physical principles governing Earth's climate and climate change within the broader context of societal impacts and global political considerations. Students interact weekly with each other about these topics, and frequent instructor interaction stimulates further learning related to the course goals. The course was delivered through a balanced mix of forum discussions, weekly worksheets, quizzes, and a final project. For this study, student climate literacy was assessed through voluntary pre- and post-course surveys containing student self-assessment questions and a variety of questions directly based on course content. Post-course survey results indicate 99% of students taking this course feel "fairly well informed" or "very well informed" about their physical understanding of Earth's climate and the numerous processes governing climate change. The 2019 cohort observed a statistically significant increase in the percentage of students adopting the viewpoint that climate change is caused primarily by human activities. We present a template for implementation in other Earth science or atmospheric science curricula, which includes discussion forum, quiz, and worksheet examples from this course.

https://doi.org/10.1175/BAMS-D-19-0271.1
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Supplemental material: https://doi.org/10.1175/BAMS-D-19-0271.2
In final form 7 July 2020

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Climate change, or the systematic change in long-term climate elements (e.g., temperature, wind) sustained over several decades or longer (American Meteorological Society 2020), is arguably the most serious humanitarian crisis confronting society in the twenty-first century. Global air temperatures over land have risen by 1.5°C since the Industrial Revolution, with additional warming predicted by the end of the century (American Meteorological Society 2019; IPCC 2019). Increased global temperatures, polar ice melt and subsequent sea level rise, and changes in the frequency of extreme weather events have and will have an especially pronounced impact on Earth's lowest socioeconomic populations, which are humanity's most vulnerable members. Nearly 40% of the world's population lives near continental coastlines, which are especially likely to experience the worst impacts of climate change.

An individual's climate literacy, or general knowledge about the Earth's climate system and physical processes that explain everyday climate phenomenon, is one indicator of a person's likelihood to engage in responsible environmental stewardship and reduce their carbon footprint (Bedford 2016) in an effort to address the growing threats from climate change. Climate literacy can be challenging to instill due to several external factors including, for example, climate change disinformation campaigns (van der Linden et al. 2017), personal political leanings (Bedford 2016), or even biased media coverage (Boykoff and Boykoff 2004). Despite substantial efforts to improve the general public's climate literacy as well as knowledge about the threats of climate change, a large fraction of the U.S. population remains either unconvinced that climate change is a phenomenon that humans should take seriously (Conca 2019; Yale Program on Climate Change Communication 2020) or does not understand the underlying facets explaining climate change (Ungar 2000; Somerville and Hassol 2011; Mittenzwei et al. 2019). Professional societies, including the American Meteorological Society, have to carefully promote scientific debate related to climate literacy and climate change without being perceived as biased or politically motivated (Stenhouse et al. 2017).

The topic of climate literacy and climate change is also a general science literacy problem, where misconceptions and a lack of access to educational resources further complicate matters. A classic example of this is documented by a 1980s YouTube video of Harvard graduates incorrectly explaining why we have seasons. Similarly, a study by Jeffries et al. (2001) found that students believed holes in the ozone layer were responsible for enhancing the greenhouse effect. Clary and Wandersee (2014) investigated how *long* it would take for students to retain facts about climate and climate change. Results from their study found that misconceptions about climate change lingered if the subject was covered for only 3 weeks, and provided evidence that a 6-week or longer course was ideal for content retention. More recently, Bedford (2016) found that an individual's climate literacy was correlated with their level of concern for anthropogenic global warming. Most evidence suggesting climate change education has a long-term effect on individual decision making is anecdotal, which necessitates quantitative and qualitative results to truly assess the impact of climate change education (Anderson 2012).

Another challenge associated with long-term assessments of the impacts of climate change education is associated with accessibility to such courses. For example, in the United States, approximately 1 in 6 college students are likely to take at least one climate change–related course, in part because research universities are more likely to offer more climate change courses compared to liberal arts colleges (Hess and Collins 2018). The bottom line is that climate change is a complicated topic, and educators in the atmospheric sciences have a pressing need to help raise climate literacy across society and to make climate change education more easily accessible to the general population.

Both undergraduate curricula and courses across many United States colleges and universities have been developed to improve science literacy and address misconceptions (Kirk et al. 2014; see Table 1). At Northern Vermont University–Lyndon, all students in the Atmospheric Science program are required to take climate-related coursework regardless of their final career path choice (Hanrahan and Shafer 2019). Recent studies have also highlighted how individual college courses utilize different learning techniques in climate and climate change education. Even role playing games implemented in undergraduate climate change education can be effective (Kluver et al. 2018). While conventional methods for instruction (e.g., using questionnaires) remain important, personal engagement (i.e., direct engagement in traditional settings, or via direct messages in traditional or online settings) in college courses is increasingly necessary to aid in the teaching of climate literacy (Cordero et al. 2008). Furthermore, agnotology, or the study of why ignorance and misconceptions exist, has gained traction as a learning tool for improving climate literacy (Cook et al. 2014). The recent

Table 1. Recent studies surveying climate literacy improvements and/or tangible impacts from undergraduate climate change education.

Authors/study	Objective	Method	Notable result
Cordero et al. (2020): The role of climate change education on individual lifetime carbon emissions	Evaluate the effectiveness of a college course on "promoting lasting responsible environmental behavior."	Students taking COMM 168 were surveyed 5 or more years after taking the course.	"The participants in COMM 168 reduced their per capita (carbon) emissions by 3.54 GT/year."
Hanrahan and Shafer (2019): Improving climate change literacy and promoting outreach in an undergraduate atmospheric sciences program	"Increase the number of scientists who are knowledgeable about climate change … and encourage these experts to engage with non-experts and provide them with adequate resources to do so."	All atmospheric science/meteorology students at Northern Vermont University–Lyndon must take courses related to the "science of human-caused climate change" and then "encouraged to communicate this knowledge to the public."	Students showed a heightened sense of interest in climatology; an increase from 22% to 78% of upper-class students now talk about climate and climate change outside of the university.
Kluver et al. (2018): Role playing a city's response to climate change: Engaging undergraduate geoscience students	Implement a role-playing game within an Earth and atmospheric science course to improve students' understanding of climate change adaptation.	Examine course exam data when implementing project as well as survey students regarding thoughts on effectiveness of role-playing games.	Students improved exam scores through improvement on role playing game content related to questions and exhibited, in general, a positive reception to utilizing the game within the course.
Bedford (2016): Does climate literacy matter? A case study of U.S. students level of concern about anthropogenic warming	Study the relationship between climate literacy and concern for anthropogenic global warming.	Create a survey asking about existing climate literacy and anthropogenic global warming concerns; ~450 responses across a university.	This study found "increased levels of concern with increased levels of climate literacy" but also "overall levels of climate literacy were found to be quite low for many students."

studies on undergraduate climate change education highlights the effectiveness of different teaching methods, but as Andersen (2012) pointed out, quantitative and qualitative studies on climate change education's long-term impacts remain limited.

Motivated by the need to improve student climate literacy as well as the increased emphasis in climate science education within colleges and universities across the United States, the Department of Atmospheric and Oceanic Sciences (AOS) at the University of Wisconsin–Madison (UW) launched an online credit course (AOS 102) titled "Climate and Climate Change" in collaboration with NOAA's Cooperative Institute for Meteorological Satellite Studies (CIMSS) in 2013. After seven years of teaching this course and analysis of course evaluations by students, we have identified a successful mix of learning tools for an online-based climate and climate change class. This paper highlights these learning tools and provides a template for educating students in climate science, especially non-science majors. The next sections of this paper describe our implementation strategy for the course, a sequential list of topics covered, a summary of the core science concepts behind climate and climate change appropriate for a general elective course, and finally pre- and post-course survey results that assess student climate literacy.

Course implementation

Course history. The UW AOS Climate and Climate Change course was the end result of two NASA education grants. The first grant (NNX10AB52A) was awarded to the Cooperative Institute for Meteorological Satellite Studies (CIMSS) to develop an asynchronous online course for middle and high school science teachers conveying foundational science behind the 2007 IPCC Summary for Policymakers (IPCC 2007). After NASA announced funding for community colleges a few years later, a collaboration ensued between CIMSS and Madison Area Technical College (MATC). NASA funded a project (NNX11AL99A) for the development of an introductory college-level climate course at MATC (Lindstrom et al. 2012, 2013; Lynds et al. 2013). CIMSS and MATC collaborated during the development of this course, where course credit earned through this class at MATC could be directly transferable to UW–Madison. Evaluator feedback (e.g., feedback from students, noted areas for improvement) from the MATC course helped the development of the UW AOS Climate and Climate Change course, an online course that debuted in the 2013 spring semester within the Department of Atmospheric and Oceanic Sciences. Many of the activities, originally developed at CIMSS, were adapted from the original online course for grades 6–12 educators (Mooney et al. 2012; Mooney and Ackerman 2014a,b) and remain an integral part of the current AOS 102 course.

Course enrollment and evolution. Online course instruction has developed rapidly over the past decade, with Learning Management Systems (LMS) becoming popular for consolidating and managing online course materials (Naveh et al. 2010). Online instruction came with new challenges during the inaugural offering of AOS 102. Originally developed and offered in Drupal (e.g., Nurminen et al. 2008; Holton 2009), learning was truly a "two-way street" sharing information with students while also identifying tools and strategies for robust online learning. With these challenges in mind, the first Climate and Climate Change class in 2013 had a maximum enrollment of 30 students but capacity was not met. For 2014 and 2015, over 20 students enrolled AOS 102 but capacity again was never reached.

The popularity of AOS 102 increased significantly when it was moved to the summer semester of 2016. The course was reconfigured to fit an 8-week syllabus offered on a platform called "Learn at UW." The 30-student enrollment capacity was met with students participating from numerous locations—including locations outside of the United States. As part of a university-wide mandate, all courses (including AOS 102) migrated to its current cloud-based, learning management system "Canvas" in 2018 (John 2014). Canvas proved easy for both instructors and students to use, with (for example) direct functionality for creating and uploading videos, posting and interacting on discussion forums, and submitting (grading) assignments. In 2018, the College of Letters and Science at UW–Madison reached out to the AOS department, asking if the course instructors (Mooney and Ackerman) would consider increasing enrollment due to an extensive waitlist. From this point, the course enrollment cap was increased from 30 to 75. For both 2018 and 2019, capacity was met with 75 students initially enrolled, with 68 and 66 students (respectively) completing the course.

Course topics, active learning exercises, and assessment

Summary of course topics. The course topics, content, and active learning exercises were identical between the 2018 and 2019 classes (Table 2). Leading into week 1, students reflect on their current state of knowledge, culminating with a discussion forum assignment requiring them to create and upload a short (~2 min) video explaining why they are interested in taking the course. Week 2 content is focused entirely on the physical science of climate change. During this week, students learn about Earth's energy budget, the water and carbon cycles, Milankovitch cycles, and feedback loops. Students are also asked to write a discussion forum post about a region in the United States experiencing higher-than-normal rainfall (this activity is provided as supplemental material). For this assignment, students investigate and discuss resources they would use to determine if natural variability or climate change most likely explained the higher-than-normal rainfall for their location. Making an explicit determination would require extensive research and a knowledge base not yet attainable through this course.

The week 3 module, titled "IPCC Overview and Observations of Climate Change," introduces students to the International Panel on Climate Change (IPCC) reports, with an emphasis on understanding how observational-based datasets convey climate change and thus guide

Table 2. The AOS 102 course syllabus and topic list for 2018 and 2019.

	Topic	Activity
PRE-COURSE	Pre-course knowledge assessment	Students take a survey on course-relevant knowledge prior to Week 1.
Week 1	Introduction to Climate and Climate Change	Students create a video sharing why they took the course. Most students know the climate is changing but are not very clear about why it is important or what they can do about it.
Week 2	The Physical Science of Climate Change	Students learn how the Sun drives the Earth's climate from a physical perspective.
Week 3	The IPCC and AR5 Observations of Climate Change	Students read the most recent IPCC Summary for Policy Makers and learn how policy or law helps protect the environment.
Week 4	Climate Modeling, IPCC Future Scenarios and Climate Mitigation	Students gain a general knowledge of computer models, RCP pathways, and how mitigation efforts are linked to RCPs.
Week 5	Societal Impacts, Risks and Vulnerabilities, and Climate Adaptation	Students learn how climate change impacts humans and society, especially vulnerable populations, and how natural or human systems adjust to the changing environment.
Week 6	The U.S. National Climate Assessment and the 2016 USGCRP Climate and Health Assessment	Students have a better understanding of the impacts of climate change on the United States.
Week 7	Changing Weather and Climate in the Great Lakes Region	Students learn classical weather conditions of the region and current observations of changing climate across the region.
Week 8	Sustainability, Career Considerations, Staying "Climate Smart" and Communicating Climate Change	Students learn about career options before creating a video expressing their own thoughts on climate change.
POST-COURSE	Post-course knowledge assessment	Students take the same survey (i.e., the pre-course survey) on course-relevant knowledge at the end of the course.

the IPCC Summary for Policymakers. Students also learn about how observations of climate change are debated and ultimately synthesized into other related international climate change meetings and reports, including the Kyoto Protocol, Copenhagen Climate Conference, and the Paris Accord. Another integral aspect of this week's content is "communicating uncertainty," because uncertainties in the observational dataset are what continue to guide ongoing climate change research. The week 3 worksheet assignment, an "IPCC Likelihood Activity," requires students to learn the basics of the Student's *t* test, including applying the statistical tool to a (locally relevant) phenomenon: is the "ice-off" date for Lake Mendota (a large lake on the northern border of Madison, WI) occurring earlier? An HTML5 web application was developed to ensure students can compute and compare ice-off data for interpretation.

Weeks 4 and 5 focus on future climate scenarios, mitigation, and adaptation. Students learn the basics of climate modeling and future scenarios discussed in the IPCC report, including the representative concentration pathway (RCP) scenarios and how different mitigation choices link to different RCP pathways. Content from these two weeks distills key climate science into takeaway messages that are emphasized throughout the remainder of the course. In week 4, students are tasked to research an existing law or proposed policy and discuss it in relation to the energy sources in each RCP through the year 2100. For week 5, students watch and comment on "The Story of Solutions," a 2013 video that explores moving our fossil fuel economy in a more sustainable and morally just direction. This assignment is purposely timed to offset the intensity of information the students have been ingesting to this point with examples of proactive community responses to the climate crisis.

The course is rounded out over the remaining three weeks. Week 6 narrows the focus to the United States by sharing content from the National Climate Assessment (NCA; Jardine et al. 2013) and the U.S. Global Change Research Program (USGCRP; National Assessment Synthesis Team 2000; USGCRP 2018) assessment on the public health threat from climate change. One key area we emphasize are the challenges to mental health and well-being, which are shown to impact the entire United States, thus sharing an important message for college students should they too be struggling with the enormity of the topic. Week 7 shifts to the Great Lakes Region where UW–Madison resides, with students learning observed changes in the weather and climate across the region. Finally, week 8 focuses on communicating climate change. After reading the lesson content and viewing several video examples, students are required to create and upload a short "elevator speech" sharing their ideas around climate change based on what they learned in AOS 102.

Course assessment. Students taking AOS 102 complete discussion forum posts, worksheet assignments, and quizzes during each week of the semester. The final project for the course is a research paper describing recent and future climate for an assigned locations. The combination of weekly quizzes, discussion forum posts, worksheet assignments, and a research paper ensures a comprehensive assessment of student learning and that all important course concepts are applied throughout the semester. The breakdown for student assessment and grading is as follows (current as of the 2019 course). Samples of the discussion forum and worksheet assignments, as well as weekly quizzes, are provided as supplemental material. Finally, climate literacy assessment is further measured through voluntary pre- and post-course surveys, which are also included as supplemental material.

Discussion forum. Students' week-to-week grade (25%) is primarily determined from the discussion forum portion of the grade. Each week, the instructor asks a question based on that week's course material, tied to current events whenever possible. A student can earn full credit on their weekly discussion forum post by demonstrating mastery of material learned that week, maintaining scientific integrity (including justifying facts or stances by citing literature, when appropriate), and by responding to another student's discussion forum post during the week. Students must respond with ~1–2 paragraphs for the main discussion prompt to be considered for full credit. Course instructors monitor the discussion forum posts, and often reply to students' posts throughout the week in an effort to stimulate additional discussion.

Worksheets. Students also complete weekly worksheet assignments as part of the overall AOS 102 course assessment (20% of grade). These worksheets focus on a specific topic(s) from the given weekly course material, with the course material serving as an guide for completing the worksheet. These worksheets are generally more rigorous than the discussion forum assignments.

Weekly quizzes. Quizzes round out the week-to-week assignments in AOS 102 (20% of grade). Topics not covered by the worksheet or discussion forum assignments are typically covered in the weekly quizzes. Weekly quizzes, each with 10–20 questions, are the main mode of assessment for knowledge retention from assigned videos and primary learning objectives.

Final project. The final project is the largest component of a student's final grade (35%). Students are required to write an 8–10-page research paper on one of three locations (assigned by last name alphabetically). This final project requires students to demonstrate a comprehensive understanding of the aspects of climate and climate change covered throughout the semester. A grading rubric ensures that students apply aspects from all topics learned throughout the course in their final project paper.

Pre- and post-course surveys. All results presented in this study are based on the pre- and post-course surveys. Student climate literacy gains are measured by comparing the pre- and post-course surveys, which were partially inspired by surveys conducted by the Yale Project on Climate Change Communication when AOS 102 was under development (Leiserowitz et al. 2012). The AOS 102 survey includes three self-assessment questions (two of which are relevant for this study) and 17 fact-based questions pulled directly from course materials developed by the evaluator for the NASA NNX11AL99A grant. Finally, given the voluntary nature of these surveys, we note that the number of respondents for the pre-course (post-course) surveys in 2018 and 2019 was 56 (57) and 49 (38) responses, respectively.

Survey results

Student self-assessment of climate literacy is first measured in question 1, which asks "how well informed do you feel about how Earth's climate system works?" Over 69% of respondents in the 2018 pre-course survey reported being "not very well informed" or "not at all informed" and 61% of 2019 respondents reporting being either "not very well informed" or "not at all informed" (Fig. 1). By the end of the course, 99% of students indicated they considered themselves "fairly well informed" or "very well informed" about how Earth's climate system works via the combined post-course survey results from 2018 and 2019. We tested the statistical significance between the pre- and post-course surveys using a Welch's t test, because the number of responses between the pre- and post-course survey results differed between each year. This result is statistically significant for both years at the 99% confidence level (Table 3).

The second student self-assessment question asked them to "Select the sentence that best describes your views about climate change," which documented a shift in the students attitudes and beliefs regarding climate change (Fig. 2). Although a few students selected "Global climate change is not real, because science theory is not proven fact" and "Global climate change is a hoax" in pre-course surveys, most students by the end of both years (88% in 2018

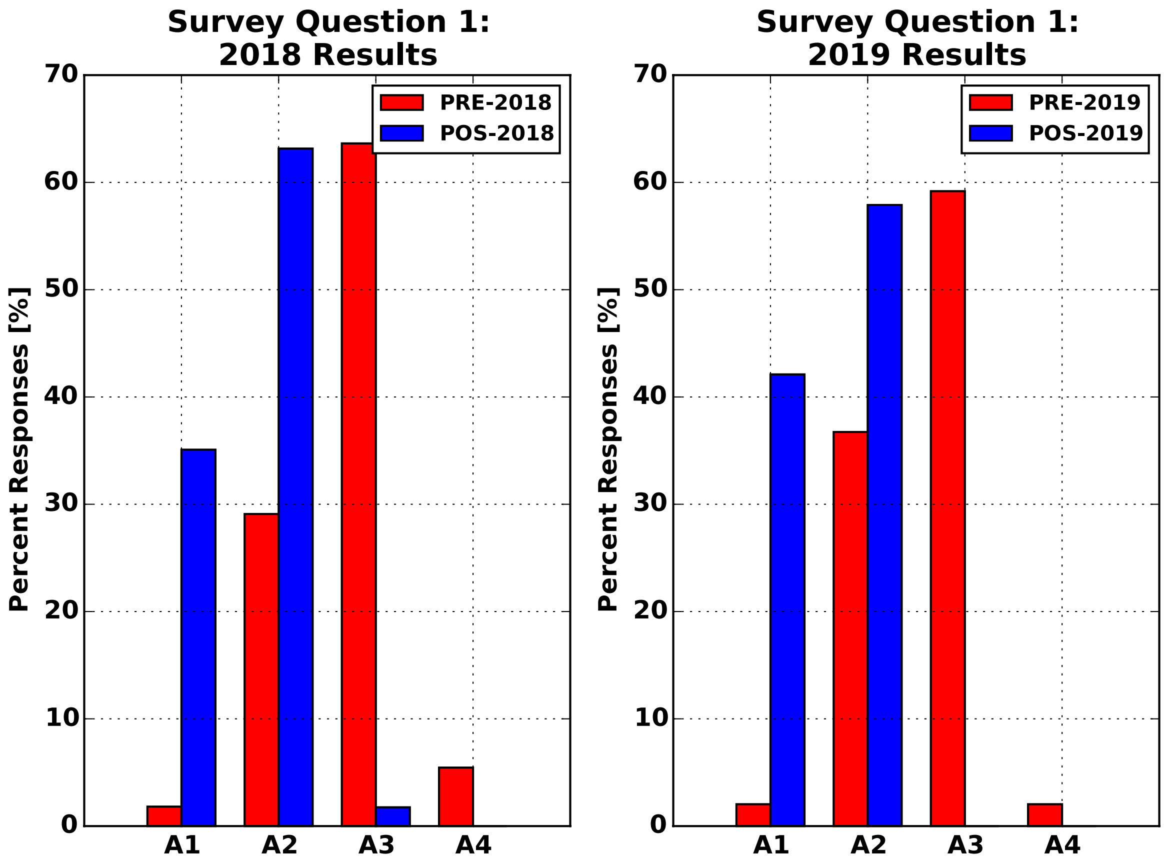

Fig. 1. Question 1 responses from (left) 2018 and (right) 2019 pre- and post-course surveys. The question to this survey was "Personally, how well informed do you feel about how the Earth's 'climate system' works?" The responses indicate "very well informed" (A1), "fairly well informed" (A2), "not very well informed" (A3), and "not at all informed" (A4). Pre-course and post-course survey results are noted in red and blue, respectively.

and 92% in 2019) answered that "global climate change is real, and it is mainly due to anthropogenic factors." This result is statistically significant at the 95% confidence level for 2019. While this result provides some evidence on how opinions regarding climate change coincide with self-assessed climate literacy, a future study relating climate literacy to opinions regarding climate change could be possible with additional questions targeting student opinions.

The remaining survey questions were developed and designed to assess student learning directly from course materials. More students correctly answered every post-course survey question as compared to the pre-course survey, indicating a majority of students attained a basic understanding of many climate and climate change related topics. For example, an improvement in their understanding of greenhouse gases was found with a question asking students "which statement is true about greenhouse gases?" For each class, 74% and 87% (2018 and 2019, respectively) correctly answered that greenhouse gases are transparent to shortwave radiation but absorb longwave radiation. This was an improvement from the pre-course

Table 3. Student's *t* test results comparing the pre- and post-course survey results for the questions "How well informed do you feel about how Earth's climate system works?" and "Select the sentence that best describes your views about climate change." A Welch's *t* test was used, since the number of pre- and post-course survey respondents was different in all cases.

	Q1: How well informed about do you feel how Earth's climate system works?	Q2: Select the sentence that best describes your views about climate change.
2018: *p* value	$\ll 0.01$	0.163
2018: Significance level	99%	Not significant
2019: *p* value	$\ll 0.01$	0.043
2019: Significance level	99%	95%

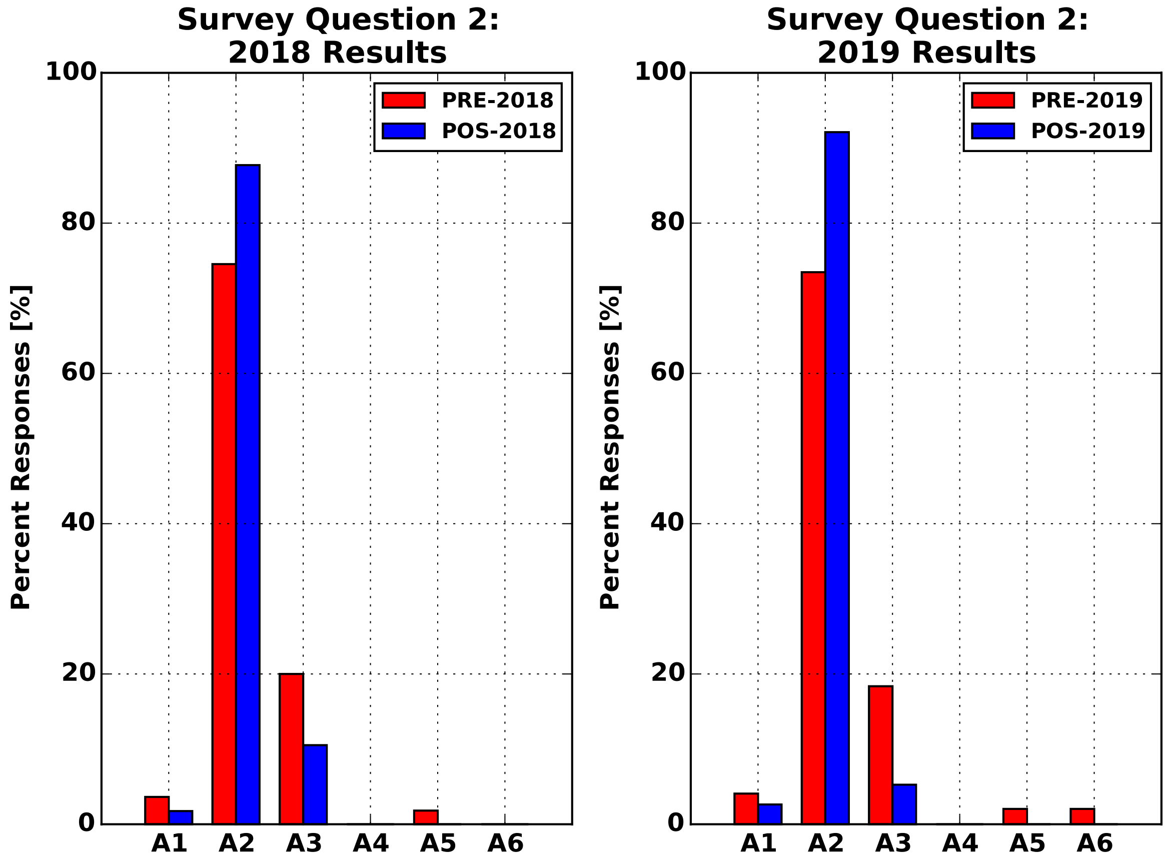

Fig. 2. Question 2 responses from (left) 2018 and (right) 2019 pre- and post-course surveys. The question to this survey was "Select the sentence that best describes your views on global climate change." The responses indicate "global climate change is real, and it is due to natural changes in the atmosphere and ocean" (A1), "global climate change is real, and it is mainly due to anthropogenic factors (i.e., human induced factors)" (A2), "global climate change is real because science has shown the changes to be real" (A3), "global climate change is not real, because science theory is not proven fact" (A4), "global climate change is not real, because I have not observed significant climate change in my lifetime" (A5), and "global climate change is a hoax" (A6). Pre-course and post-course survey results are noted in red and blue, respectively.

surveys, where 64% and 63% of respondents answered correctly. As another example, over 82% of respondents from both the 2018 and 2019 post-course surveys correctly answered that seawater becomes more acidic as it absorbs carbon dioxide.

While students taking this course attained a greater understanding of climate and climate change, results from the post-course surveys indicate room for improvement. For example, the 2018 post-course survey results indicated 47% of respondents think carbon dioxide is the most abundant greenhouse gas (compared to 50% correctly answering water vapor). Results from the same survey given at the conclusion of the 2019 class found a slightly better result: 37% of respondents said carbon dioxide is the most abundant greenhouse gas compared to 53% correctly answering water vapor. This is an improvement from the pre-course survey results (27% correctly answered water vapor in both 2018 and 2019). In the 2019 post-course survey, 43% of respondents incorrectly answered that either oxygen or nitrogen is a gas that is good at trapping heat from Earth's surface (i.e., a greenhouse gas). While the majority of respondents correctly answered these questions, the larger number of incorrect responses on these two basic greenhouse gas questions suggest a need for improving course materials conveying the basic science behind greenhouse gases.

Despite these needed areas of improvement, results from the post-course survey demonstrate that most students (respective to each class) answered a majority (88%, or 15 out of

17) of science-based questions correctly in 2018 and all (100%, or 17 out of 17) science-based questions correctly in 2019, compared to 65% (11/17) for the 2018 and 2019 pre-course surveys. In other words, student comprehension improved by 28% (2018) and 35% (2019) as a result of the AOS 102 course. Based on these results, we conclude that a majority of students leave the class with a fundamental understanding of climate science and a foundation for strong climate literacy. These conclusions are supported by both student self-assessment and instructor assessment of course content-based survey questions.

To summarize our results:

1) Students taking the course feel significantly more informed about how Earth's climate system works.
2) From the most recent 2019 course, most students' views on climate change shifted to "climate change is real, and it is due to mainly anthropogenic factors." This result was also statistically significant.
3) Every fact-based question in both post-course surveys was answered with a 50% or higher correct response rate in 2019, an improvement from 2018 when 15 of the 17 questions were answered with a 50% or higher correct response rate.

Conclusions

The Climate and Climate Change course developed at UW–Madison, originally implemented in 2013, has become one of the most popular online summer elective courses at the UW. This course is structured to actively engage students in learning about the science of climate change and is based on a variety of learning techniques. Students begin the course by uploading a video introduction describing their motivations for taking the course. A foundation of scientific principles is instilled during the first few weeks of the course, which are essential to understanding climate models, the IPCC reports, and the basis of climate-based policy decisions. A key learning device is the weekly discussion forum where students engage with each other while testing their own knowledge. Worksheet assignments push students to deeper learning, and quizzes ensure they complete and comprehend assigned readings. For the last week, students upload an "elevator speech" video explaining climate change to a stranger in less than 2 minutes. A final project research paper supports good writing skills while combining course topics in a real-world scenario.

The AOS 102 course will continue to evolve as new scientific research becomes available, and will also evolve in response to current events and new findings on best practices of climate change education and climate literacy. Future versions of the pre- and post-course surveys will likely seek demographic information and attempt to gauge behavior change around steps taken to adapt to or mitigate climate change (i.e., reduce carbon footprint, political actions, etc.). Expanding the pre- and post-course surveys could provide additional insight into connections between knowledge gains and lifestyle choices as well as the course's effectiveness relative to similar courses in traditional course settings. This body of information is much needed from climate and climate change educators (e.g., Anderson 2012), so that tangible outcomes of climate and climate change education can be assessed throughout society (e.g., Cordero et al. 2020).

In light of the global pandemic beginning in late 2019 and with numerous college courses moving (at least temporarily) to online platforms worldwide, we hope that these lessons learned from AOS 102 can benefit other instructors moving content online, and that educators will share experiences, challenges, and successes with the broader weather and climate community.

We learned, and have demonstrated, that the key to successful online education is a diverse set of resources and activities to engage students, especially a discussion forum. Students completing AOS 102 experienced increased confidence in their understanding of climate science and the Earth–climate system. Although the discussion forums were monitored by course instructors, every student engaged other students at least once a week and freely expressed their own fact-based feedback to one another. By having the majority of the weekly course grade centered around discussion forums and worksheet assignments, complemented with weekly quizzes and an independent final project, the majority of students leave the class with a fundamental understanding of climate science (as evidenced by the course surveys) and with the confidence that they feel well informed about climate change. A few areas for improvement were also revealed by the surveys, and future iterations of this class will continue improving the delivery of the science behind climate and climate change. Culminating with the 2019 class, having a majority of students correctly answer every post-course survey question demonstrates that the AOS 102 class is helping to improve the climate literacy of a general audience.

Acknowledgments. The authors thank two anonymous reviewers for their insightful and helpful comments that improved the quality of this manuscript. The authors would also like to acknowledge all previous teaching assistants throughout all versions of AOS 102: Kyle Griffin, Simran Raju, Jobst Müsse, Ashtin Massie, Kate Abbott, and James Winkelman. Andrew, Yun, and Zachary were also teaching assistants for AOS 102.

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