Managing for a Changing Climate

A Blended Interdisciplinary Climate Course

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ABSTRACT: We developed a blended (or hybrid) interactive course—*Managing for a Changing Climate*—that provides a holistic view of climate change. The course results from communication with university students and natural and cultural resource managers as well as the need for educational efforts aimed at the public, legislators, and decision-makers. Content includes the components of the physical climate system, natural climate variability, anthropogenic drivers of climate change, climate models and projections, climate assessments, energy economics, environmental policy, vulnerabilities to climate hazards, impacts of climate change, and decision-making related to climate adaptation and mitigation efforts. To convey most of the content, the course-development team created over 50 short videos (3–10 min each) in partnership with experts from a variety of academic, government, and industry institutions. The blended course has been offered as an upper-division, undergraduate course in the Department of Geography and Environmental Sustainability and School of Meteorology (four times) and College of International Studies (in Italy, once) at the University of Oklahoma with over 100 total students. The course has also been presented online-only at no cost to the participants in four fall semesters with over 1,000 total registrations. Videos created for this course are freely available on the YouTube page of the South Central Climate Adaptation Science Center. This course and its associated materials comprise high-quality, formal climate training and education that can be adapted to other formal and informal education settings beyond the walls of the university.

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Anthropogenic climate change is unequivocal [Intergovernmental Panel on Climate Change (IPCC); IPCC 2013] and, even if significant mitigation efforts were to lead to a peaking of global average temperatures at 1.5°C above the preindustrial average, today's postsecondary students will need to deal with climate change impacts during their entire careers (IPCC 2018). Many higher education institutions teach undergraduate courses on climate change science, impacts, decision-making, adaptation, mitigation, policies, and similar topics (e.g., Nieto Ferreira et al. 2012). These courses provide an interdisciplinary foundation of knowledge on global climate change, with students gaining a broad perspective on climate change as a “wicked problem” (e.g., Reed and Lyford 2014; Hanrahan and Shafer 2019). Course content not only provides facts about climate change, but also dispels common misperceptions (e.g., that the ozone hole causes climate change; Cordero et al. 2008).

In the south-central United States, few people discussed global climate change in their jobs prior to the 2010s, when droughts, floods, wildfires, and landfalling hurricanes highlighted the changing extremes in the region (e.g., Riley et al. 2012). Through our work at the U.S. Geological Survey's South Central Climate Adaptation Science Center (South Central CASC) and the University of Oklahoma (OU), we heard both university students and resource managers express discomfort with applying climate science or products (e.g., climate projections) as well as adapting to or mitigating the impacts of climate change on local and regional landscapes without any formal training on the subjects. This hesitancy is despite an increasing number of Americans thinking that global warming is happening and is caused by humans (62% in 2018) (Leiserowitz et al. 2018). This desire for climate change education has been pervasive, with an August 2009 report on stakeholder feedback in the southern Plains and western Gulf Coast listing “educational efforts aimed at public, legislators, and decision-makers” as a high priority (Carter and Hocker 2010).

Those already in the workforce find it difficult to access focused and regionally relevant instruction from a reputable source, especially given their time and funding constraints. Although offering a traditional course would satisfy undergraduate students (the future workforce), it would not address the needs of current local and regional managers. We needed to provide an asynchronous learning environment using web-based technology. Hence, we obtained grants to fund the design and development of a course, *Managing for a Changing Climate*, assuming the upfront and regular maintenance costs of hosting freely available educational modules that were open to the public.

To rigorously test the material and receive qualitative feedback, we concurrently ran the course as a three-credit, cross-listed course in OU's Department of Geography and Environmental Sustainability and its School of Meteorology, offered every fall semester from 2016 to 2019 (and continues to be taught in 2020). We also applied most of the materials in a 4-week, intensive study abroad course in Italy during summer 2019. This article describes the course,

the developed materials, and lessons learned, all of which can enable others to implement similar courses in formal or informal education environments in the future.

Course design and content

Similar to short-courses for professionals across disparate disciplines (e.g., American Geophysical Union 2002), *Managing for a Changing Climate* was designed to provide an integrative understanding of the components of the climate system, external drivers of climate change, impacts of a changing climate on human and physical systems, and adaptation and mitigation policy options. The 16-week, enrolled version (three credits for OU undergraduates) was a blended (or hybrid) course with an average enrollment of 21 students, combining online and once-a-week in-class learning (McGee and Reis 2012). Weekly lecture material that students consumed outside of class was presented in short, online videos, supplemented with readings, quizzes, and discussion boards. See the “Online-only course offering” sidebar for more information about the online-only version of the course. Each week’s 75-min classroom activities included discussions, group work, educational games, or role-playing activities. Instructional content was designed to meet two overarching course goals for all students and a third goal specifically tailored to the enrolled students in the blended course:

- 1) Describe the major concepts, terms, principles, and tools used by climate scientists to interrelate the elements of the physical environment to climate patterns, variability, and trends.
- 2) Describe the major impacts of climate change on society and the environment.
- 3) Apply your scientific knowledge to a simulated policy negotiation using proper terminology and concepts about climate change (enrolled students only).

Online material (videos, readings, and quizzes). Thirty-five speakers, mostly from the south-central United States, presented knowledge in one or two short videos (3–10 min each) on a specific topic congruent with their area of expertise. We wrote and edited 60 scripts (used later for transcripts and closed captioning) and employed a video production company (NextThought Studios in Norman, Oklahoma) to record the videos using a green screen and to design and add graphics in postproduction (Fig. 1). Table 1 lists the 60 videos that cover an introduction to the climate system (weeks 1–3); climate modeling (weeks 4–5); climate assessments (week 6); climate impacts to social, economic, and ecological systems (weeks 7–13); and climate adaptation strategies (week 14). Mitigation was woven into the climate impacts sections, with discussions on low-carbon and no-carbon alternative sources of energy, carbon sequestration, soil health, quality of livestock forage, and coastal and forest restoration, as well as in-class activities and a semester project (see below).

Fig. 1. Example screenshots from short videos on (left) physical impacts to coastal systems and (right) statistical downscaling.

Table 1. Titles of videos created for *Managing for a Changing Climate*. An asterisk indicates videos that were added or rerecorded in 2017 or 2018 based on student feedback.

Weeks	Topic area	Video titles	
1–3	Introduction to the climate system	Welcome to <i>Managing for a Changing Climate</i> Energy and heat transfer Overview of the carbon cycle Human influences on the carbon cycle Measuring our past climate Observing our climate from the ground	Global negotiations on climate change Earth's energy budget Energy budget feedbacks The natural carbon cycle Atmospheric and oceanic circulations Natural climate variability Observing our climate from satellites Observing the carbon cycle
4–5	Climate modeling	Overview of climate projections Scenarios and uncertainty in projections Using GCM output correctly What the projections tell us	Global climate models Statistical downscaling* Dynamical downscaling Using downscaling output correctly
6	Climate assessments	U.S. National Climate Assessment	Intergovernmental Panel on Climate Change
7	Introduction to policy and economics	Overview of public policy Overview of environmental economics	Fundamentals of economics Energy economics*
8–9	Vulnerability and culture	Introduction to vulnerability Impacts to Indigenous peoples Impacts on rural communities* Impacts to land managers*	What is culture? Impacts to island peoples Impacts to urban communities* Impacts to the transportation sector* Vulnerability assessments*
10	Impacts to climate systems	Indicators of a warming world* Empirical evidence of a warming world*	Changes in severe and extreme weather Impacts to polar regions* Changes in hydrologic systems
11	Impacts to coast and marine systems	Impacts on ocean circulations* Impacts on marine systems*	Physical impacts to coastal systems
12	Impacts to ecosystems	Impacts to freshwater aquatic systems Impacts to terrestrial ecosystems	Impacts to wildlife Impacts to crops Impacts to livestock
13	Impacts to human health and security	Climate change and chronic diseases Impacts to national security	Climate change and infectious diseases
14	Adaptation strategies	Decision-making frameworks Sustainable energy*	Adaptation planning* Adaptation in coastal and marine systems*

Speakers included those from early, middle, and late career; faculty and staff; and public, private, and nonprofit sectors, with 19 female and 12 non-White experts (including at least one African American, Asian, Hispanic, and Native American scientist) across a diverse range of disciplines. We reviewed scripts and videos to check for accuracy of content, consistency across the recordings, and clarity in the graphics produced. All videos are freely available through the South Central CASC's YouTube channel (<https://bit.ly/2na4iYv>). They also were hosted on our classroom management software systems (i.e., Janux by NextThought, prior to 2019; Canvas by Instructure, 2019 and later).

In addition to the videos, required and supplemental readings were provided from an array of freely available sources, including the National Climate Assessment and IPCC reports. To evaluate student knowledge of the videos and readings, we administered online quizzes for each section of the course (e.g., physical climate, policy and economics). Each quiz was designed to evaluate specific learning objectives and presented 20 randomly chosen questions

from a question bank that included multiple choice, fill-in-the-blank, and matching question types. Learning objectives were provided to the students as “key takeaways” (supplemental material; <https://doi.org/10.1175/BAMS-D-19-0242.2>) as they progressed through each section and spanned a range of intellectual behavior from recalling information to justifying decisions (Bloom 1956).

In-class activities. One benefit of the blended approach is that in-class periods can be used to apply concepts learned, resulting in students being more engaged and enjoying a course more (e.g., Wanner and Palmer 2015). During the weekly in-class sessions, instructors applied active learning approaches (e.g., Yuretich et al. 2001; Prince 2004; Huguet et al. 2020), such as educational games or role-playing activities, to provide students with relevant hands-on experiences. We adapted some activities from other sources, such as a carbon stabilization wedge game from Princeton University (Hotinski 2015) and “Decisions for the Decades” (Climate and Development Knowledge Network 2014), promoted by the Red Cross and Red Crescent.

Scientists at the South Central CASC created two role-playing activities to demonstrate the complexities of decision-making in a changing climate. Detailed in Rosendahl et al. (2019), one activity focused on interpreting an ensemble of climate projections by dividing into teams with four to five “water resource managers” (i.e., the students) with a “local climate scientist” (e.g., instructor) to query about the projections. We tasked the teams with recommending to the “governor” whether to enter into a long-term contract for water sales to another state, given a list of constraints and maps of future precipitation projections. Another activity assigned each student a job in the local economy of Venice, Italy, and examined policy trade-offs in the face of sea level rise. Students represented the art and history, aquaculture, glassblowing, shipping, tourism, and wastewater industries; they placed a small number of tokens on a game board to vote on the adaptation options they preferred (Fig. 2). After discussions with the other industries, they could move their tokens to see if they could consolidate opinions around a couple preferred methods.

Fig. 2. (left) Game board designed to examine policy trade-offs in the face of sea level rise in Venice, Italy. (right) Students participated in this class activity during the fall 2019 offering of *Managing for a Changing Climate*.

Students also examined the challenges of prioritizing resilience decisions in a city through a shocks-and-stressors game, whereby they rated both the likelihood and the impact of short-term, external pressures (shocks) and long-term negative trends (stressors) related to climate change. Using another in-class activity, students quickly learned that downscaling climate projections was not a straightforward process when they had to estimate temperatures in 36 grid boxes given 9 coarse-resolution values and varying topography along a coastal region. For all activities, students engaged difficult material directly within small groups in a safe environment, where there were no “wrong answers.” We graded the activities based on individual participation in the ensuing discussions to encourage students to become involved in the decision process. The necessity of including course content on vulnerability and culture (e.g., weeks 8–9; Table 1), was evident during the hands-on activities and semester long project (see below) as this was often the material students had been exposed to least. Online asynchronous versions of these activities have not yet been created, but virtual synchronous activities were developed for use in Fall 2020.

Semester projects. Throughout the semester, students worked on a reality-based project that culminated with a mock debate modeled after the United Nations Framework Convention on Climate Change (UNFCCC). These types of experience have been shown to be instrumental in students understanding of climate-related issues and challenges. Nieto Ferreira et al. (2012) demonstrated that exposure to multinational negotiations on climate policies raised student awareness of global issues related to climate change. Negotiations also appeared to be the most important experience that students had in a virtual, collaborative climate change course taught at East Carolina University. A mock environmental summit (similar to the UNFCCC) at the University of California, Santa Barbara, was also shown to facilitate significant learning opportunities and altered student understanding of key concepts, particularly those involving prior misconceptions (Gautier and Rebich 2005; Rebich and Gautier 2005).

At the beginning of the semester, students were assigned a country they would represent at the mock UNFCCC. Countries represented a wide range of interests across the world: oil-based or tourism-based economies, small island nations, religious and secular societies, developed and developing countries, etc. We grouped students into regions (similar to representation at UNFCCC events by Small Island Developing States or the European Union), with two to four students/countries per group and assigned them group work in preparation for the mock UNFCCC. For example, in one year the “Middle East” region included Saudi Arabia, Kuwait, and the United Arab Emirates and the “Central Africa” region included Tanzania, Democratic Republic of Congo, and Uganda. Other regions have been Pacific Islands, South America, Western Europe, Scandinavia, Southeast Asia, Northern Africa, East Asia, and more. We modified countries and regions for each course offering to include countries with timely, high-profile climate-related issues.

Individual writing assignments and group projects were scaffolded to build knowledge and confidence during the semester. Individual papers provided students with a way to prepare for the mock UNFCCC and apply what they learned in the videos by exploring the geography, economics, climate change impacts, ecosystems, and peoples of their assigned country. The students used the content from these papers to create individual, short (<5 min) videos that introduced their country to the class. Students then used content from the papers and videos to collaborate with their group members to develop an in-person presentation about their region that incorporated information about each country. These assignments (papers, video, and presentation) provided them with the background necessary to effectively develop and promote a policy option for the mock UNFCCC debate (Fig. 3). By accumulating and applying knowledge gained throughout the semester, students were able to understand how challenging it is to balance climate change action with actions on other important issues, and why

certain policies may be more attractive than others to certain countries. See the “Mock United Nations Framework Convention on Climate Change” sidebar for more information about the procedures of the mock UNFCCC.

Student feedback

Overall, feedback has been positive, from both the online-only learners (see “Online-only course offering” sidebar) and the OU enrollees. We used this critical feedback each year to modify the course in each

Fig. 3. Students participating in the speech and debate portions of the mock UNFCCC during multiple offerings of *Managing for a Changing Climate*.

Mock United Nations Framework Convention on Climate Change

Each course offering for enrolled OU students included a mock Conference of Parties (COP) for the UNFCCC. Each student represented an assigned country and region (e.g., Costa Rica and Central America), with 7 to 10 regions in total. Teams applied knowledge about their country (gained through individual assignments) to identify climate mitigation and adaptation policy ideas to propose for framework-wide adoption. Example proposals ranged from increases in renewable energy production globally to complex, nation-dependent proposals with progressive carbon taxes, green funds, and aid for lesser-developed countries.

In the first mock COP negotiation of the semester, students gave prepared, 2-min speeches outlining their region’s policy proposal. Moderated and unmoderated debate ensued and, at the end of the first negotiation, each country’s representative voted to advance the top three proposals for the final negotiations at the end of the semester. During the moderated debates, country representatives raised placards to get on the “speaker’s list,” which afforded them up to 60 s of talking time.

In the final negotiations, students gave 5-min, argumentative speeches on why they supported one or more of the three remaining policy options. Student teams generated talking points in preparation for making and rebutting key points during the subsequent debate. Some teams formed coalitions to support each other’s positions. The formality of the mock convention was emphasized by a Chair who presided over the meeting with scripted dialogue and a gavel for ending overly long statements. At the end of the final debate, a second vote was held to determine if consensus could be reached on adopting a UNFCCC-wide policy. Only once (out of five classes) was a policy unanimously voted in favor and only once has any policy failed to receive 50% of the vote. “Winning” proposals have varied in their details each year.

The mock convention was well received by students, with comments including the following:

“I loved the mock-UN style. I cannot state this enough. It was a different aspect to a college course and gave a better understanding of other countries [sic] views on the subject.”

“It felt like we were doing something greater than just the everyday, routine style of learning. In hindsight, I realize this is mildly absurd to say, but it felt like we were actually making a difference by doing this. I left the Thursday of the negotiations, and had two individuals from different countries tell me that they had their minds’ changed by my efforts, and that resulted in a greater feeling than any feeling I have had from school in as long as I can remember.”

Each year, a member of the instructor team attended one week of the UNFCCC COP meeting as a scientific observer. The instructor video conferenced into the classroom and shared real-time observations about the ongoing negotiations. Through this process, students could better understand the climate challenges that people across the world face, build practical skills in collaboration and argumentative debate, and see how their ideas were relevant to decisions made on the global stage.

Online-only course offering

From 2016 to 2019 (and continuing in 2020 and beyond), *Managing for a Changing Climate* was offered online free of charge to provide content to those outside of the university system. We advertised the course through the Climate Adaptation Science Center network that includes universities, federal agencies, Tribal nations, and their partners. Most online learners were either nontraditional students with full-time jobs (including natural or cultural resource managers) or international participants without access to high-quality, local climate education.

The free online course provided the same videos, reading material, quizzes, and discussion boards as the OU enrolled course, but did not engage the students in the hands-on activities, mock UNFCCC, or face-to-face discussions. Online learners could take the quizzes to evaluate their knowledge, but they were not required. As a result, there was no final grade for online-only participants. Those who completed the full set of quizzes received a certificate of completion (Fig. SB1).

The first online offering had over 500 registrants, but fewer than 20 registrants completed the course by taking all the quizzes (Table SB1). Completion rates for online courses vary substantially (0.7%–52.1%), with a median of 12.6% (Jordan 2015). In 2016 and 2017, we offered 16-week courses; their completion rates were at the low end of the range (3%–5%), but consistent with other full-semester massive open online courses (Jordan 2015). To increase the completion rates, we offered the fall 2018 and fall 2019 online course as four short courses. The same material was available as previous years but was segmented into four courses each lasting ~4 weeks, allowing the participants to choose which information was most relevant to their needs. The short courses had the subheadings *Introduction to the Climate System*, *Climate Models and Assessments*, *Societal Impacts*, and *Physical Impacts*.

At the conclusion of the fall 2019 online short courses, we asked participants who had registered for at least one course to provide feedback through an informal evaluation (36 responses). Most respondents who completed at least one course (78%) felt their level of climate knowledge improved as a result of taking these courses. The majority of respondents who had completed coursework (94%) agreed or strongly agreed that the course material added to their knowledge about climate change, and 81% agreed or strongly agreed that the course material prepared them to have in-depth/meaningful conversations about climate change. At the conclusion of their coursework, 95% said they planned to use the material learned in their profession.

Offering the courses as smaller segments improved the completion rates, especially for the introductory (34% in 2018; 45% in 2019) and climate modeling (18% in 2018; 34% in 2019) courses, exceeding the median from Jordan (2015). Participants who signed up for all four courses, however, said the amount of time invested became overwhelming by the time they reached their third short course. In 2020, we plan to host two short courses during the spring and two during the fall to encourage higher completion rates for all short courses.

Fig. SB1. Online learner Sid Sperry with his certificates of completion for all four short courses in fall 2019.

Table SB1. Number of participants who registered and completed the online course in each offering. A course was considered complete if the student took each available quiz.

Course offering	Approximate registrants	Number completed (fraction)
2016	500	16 (3.2%)
2017	200	10 (5%)
2018 Short Course 1: Intro to the climate system	100	33 (33%)
2018 Short Course 2: Climate models and assessments	100	18 (18%)
2018 Short Course 3: Societal impacts	130	14 (11%)
2018 Short Course 4: Physical impacts	120	9 (7.5%)
2019 Short Course 1: Intro to the climate system	209	95 (45.5%)
2019 Short Course 2: Climate models and assessments	223	76 (34.1%)
2019 Short Course 3: Societal impacts	239	50 (20.9%)
2019 Short Course 4: Physical impacts	251	40 (15.9%)

subsequent offering. As a result, student satisfaction scores (including course content and meeting objectives) from the university-administered evaluation system generally increased each time the course was offered.

Constructive student feedback helped us to modify quiz questions to avoid ambiguity and to recognize that we needed to provide additional time in class to discuss the week's videos and readings. Early in the course offerings, students wanted more opportunities to learn about the other countries, leading us to create the regional grouping of countries and the video assignment. We also rerecorded, updated, or added new instructional videos in 2017 and 2018 based on student feedback (Table 1). For example, students found the concepts contained in the statistical downscaling video difficult to understand. We revised the script and recorded a new video to simplify the concepts; the update has been well received.

We also solicited feedback from students in a final reflection paper whereby students described how they engaged in the class, what material was most interesting or most challenging, and how their group dynamics worked. Comments from these papers illustrated the intangible knowledge and experience gained from the course that were not reflected in any evaluation statistics. Quotes from students included the following:

"I have such a different perspective on developing countries and an empathy for their people."

"I have learned a lot about the potential impacts of climate change on cultures and ways of living around the world, especially those of people living in islands and coastal areas that are vulnerable to sea level rise and those of indigenous peoples."

"I knew that mankind was negatively effecting [sic] Earth's environment, but I did not realize the degree to which this was happening until this class."

"I enjoyed the disaster vulnerability activity because it was interesting to see how different people viewed the dangers of specific risks to major areas."

Challenges and looking forward

As we plan for future course offerings at OU and beyond, we identify lessons learned from our challenges. In general, most OU students were familiar with online courses and in-person courses, but the blended environment was new to many. As found in many studies (e.g., Kramarski and Gutman 2006), self-regulation was a critical factor for academic success in the course. We needed to have a thorough introduction to the blended format, including techniques for success, to begin the semester and promote effective patterns of student behavior.

One logistical challenge prior to 2019 was that students needed to learn and use a different course-management platform to watch the videos, upload assignments, take quizzes, and engage in online discussions. Although we overviewed the platform in the first in-person class to show students how to interact with the platform, it was still common for students to miss announcements, not find their grade feedback, or become confused within the online platform throughout the semester. In 2019, we offered the course on OU's standard learning management system; although it did not have some of the more dynamic features of the original platform, the OU students had fewer complaints and less confusion. For those enrolled in the online-only course learning a new platform still remains a challenge, as noted by Tallent-Runnels et al. (2006) and others.

In each offering of the course, we aimed to engage both OU students and external, online-only students in the same discussion boards, providing the OU students new perspectives on management decisions and global issues. The concurrent discussion boards were underutilized, however. OU students needed explicit instructions that a portion of their grade relied

on active engagement in the discussion boards, and the online-only participants typically only used the discussion board to introduce themselves to others. Future offerings of the course need to provide specific discussion prompts that are designed to engage both groups of learners.

Moving forward, we recognize that because some of the course content is based on current events, including outcomes of the UNFCCC Conference of Parties and reports from the IPCC and National Climate Assessment, it is necessary to update the videos, reading materials, and mock UNFCCC activity. Keeping the material and activities relevant to current events is vital to keep the students engaged and motivated.

Summary

Through *Managing for a Changing Climate*, participants were able to learn the basics of climate science, climate change impacts, and climate change adaptation and mitigation without needing to take multiple courses from different programs. The free, online course provided continuing education to a wide array of practitioners in the midst of their careers as well as interested members of the public in the United States and internationally. The videos created for the course were short enough to keep students' attention and still provide the level and range of knowledge that they needed to engage in climate change adaptation, mitigation, policy-making, or other planning and actions. The videos are freely available on the YouTube page of the South Central Climate Adaptation Science Center as a resource to all. They also have been incorporated into other courses at OU and other institutions.

Through the mock UNFCCC and in-class hands-on activities regarding decision-making in the face of a changing climate, OU students also learned how to apply their knowledge to real-world scenarios. These activities gave them practical insights into the complexities of decision-making, the difficulties in international negotiations, and the priorities of countries outside the United States. Importantly, science was delivered in a context that prepared students for the workforce: building oral and written communication skills, discussing and negotiating complex problems, and constructing defensible arguments for various solutions.

Whether they were enrolled in the OU blended course or participated in the online-only portion, learners who engaged with the material felt more confident about their climate knowledge at the conclusion of the course. For those who were enrolled at OU, we noticed significant improvement in the students' writing and verbal communication skills throughout the semester. Additionally, OU students greatly enjoyed learning about the human and physical geography of other countries as related to climate change and what those countries were doing to address this global challenge.

By blending physical, natural, and social sciences with real-world examples, *Managing for a Changing Climate* provides participants with the knowledge and tools to apply what they have learned. In the words of a participant,

"It's interactive and engaging which gets you thinking about real world problems and solutions. If you like that kind of hands-on and using critical thinking skills then it's the class for you."

To receive information about the next course offering, e-mail info@southcentralclimate.org with "MCC" in the subject line.

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