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Student Media Production to Meet Challenges in Climate Change Science Education

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ABSTRACT

While the need for effective climate change education is growing, this area of geoscience also poses unique educational challenges. These challenges include the politicization of climate change, the psychological and affective responses it elicits, and common misconceptions, which can all create barriers to learning. Here, we present an instructional approach and curriculum materials that combine climate change education with media literacy through student production of public service announcements (PSAs). The purpose of this work was to use student media projects as a means to elicit active, affective, social, and analytic learning of climate change science content, with the goals of increasing engagement and intrinsic motivation and fostering deeper learning about climate change through students' efforts to educate others. These projects also improve video literacy and associated 21st century communication and information technology skills. We incorporated a PSA production project as a culminating assignment in an advanced university course on climate change and developed associated curriculum materials for preproduction (research, planning, script-writing, creating storyboards, etc.), production (filming, creating visual and audio assets), and postproduction (editing, distribution) phases as part of the Climate Education in an Age of Media, or CAM, Project. Student and audience learning outcomes were assessed by a team of external evaluators. Both student producers and viewers showed gains in climate literacy. Qualitative analysis of student experiences revealed high levels of intrinsic motivation and engagement with the project, critical thinking, social learning, an interest in climate change that reached beyond the course, and a sense of empowerment and agency. While our focus was on a university-level course targeted primarily to science majors, our work with other educators has indicated that this approach has the potential to be an effective climate change education tool in a variety of instructional settings, ranging from middle school to informal high school education and graduate school. © *2014 National Association of Geoscience Teachers*. [DOI: 10.5408/13-050.1]

Key words: climate change education, media literacy, youth media production, engagement theory, affective processing

INTRODUCTION

Despite the defining role that climate change will play in the lives of today's young people, their understanding of its causes, its implications, and the scale of action required to address it is inadequate (Leiserowitz et al., 2011). Like many other geoscience areas, educational challenges in climate change include its inherent complexity and dynamic nature, as well as the interdisciplinary perspective needed to understand its drivers and consequences. Perhaps even more importantly, the profound implications of ongoing climate change for human society and energy systems can create unique barriers to learning that demand new pedagogical approaches. These barriers include its politicization in the public discourse, the psychological and affective responses it elicits, and the deeply entrenched misconceptions about climate change that nonexperts frequently hold (Leiserowitz, 2006; Marx et al., 2007; CRED, 2009; Forest and Feder, 2011; Pidgeon and Fischhoff, 2011). Students learning about climate change are often faced with social dissonance when they attempt to reconcile a view of the future that is informed by climate change science with the views of their family and friends. When faced with this dissonance, many people seek and credit information that relieves it, even if doing so reverses gains they have made in climate literacy (Kahan et al., 2012). Together, these responses can impede the formation of robust mental models of the climate and energy systems that are needed to incorporate new information, make effective decisions, and find innovative solutions to address climate change (Engelmann and Huntoon, 2011; Jones et al., 2011). Social science research has made it clear that these barriers are not effectively addressed through the "information deficit model"; i.e., information delivery alone is not an effective means for overcoming misconceptions (Pidgeon and Fischhoff, 2011). Instead, effective approaches that engage active, affective, and social learning pathways are needed to address barriers that stem from these domains. Here, we describe a new approach to climate change education that incorporates media production by students as a means to evoke both analytic and affective processing. This approach can be applied at levels from middle school to graduate school, although we focus on curriculum developed for undergraduate and graduate students who were primarily science majors. Our initial results support the hypothesis that student media production projects provide an opportunity for social learning and affective processing of climate change science content, leading to increased engagement and improved learning outcomes.

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In addition to the analytic processing that is evoked in conventional geoscience pedagogical approaches (e.g., reading, lecture presentations, laboratory reports, exams), video production provides a means by which to engage associative and affective processing (which is automatic, rapid, and influenced by emotion), through storytelling, metaphor, images, and emotion (Graber, 1990). The affective system plays an important role in evaluating uncertainty and risk (such as potential climate change impacts or mitigation), and it is the primary motivator for action (Weber, 2006) and sustained commitment to difficult problems (Pidgeon and Fischhoff, 2011). While the affective system enables rapid responses, analytic reasoning requires us to learn algorithms for decision making and apply them through conscious awareness and control, a process that takes time (Marx et al., 2007). Importantly, these two processing systems work together: analytic reasoning is not effective unless guided by emotion and affect, and, if the responses of the two systems are in conflict, the affective system almost always prevails (Damasio, 1994). Thus, emotion is integral to our thinking, perceptions, and behavior (Pidgeon and Fischhoff, 2011). Challenging students to convey the essence of scientific concepts through media production requires them to engage both analytic and affective processing, opening an opportunity for deeper learning. In addition, video production is inherently collaborative, requiring students to take on various roles during preproduction (e.g., writing, content research, finding images and sets, creating a storyboard), production (e.g., directing, acting, filming), and postproduction (e.g., editing, further research, distribution, and promotion). This collaborative aspect engages social learning and may help students overcome some of the barriers presented by social dissonance (Kahan et al., 2012) that climate change can evoke.

Integrating climate change science with media literacy also provides a means for students to gain an understanding of the medium through which much of societal discourse is carried out. Literacy can be considered the "comprehensive set of skills needed by individuals to learn, work, socially interact and cope with the needs of everyday life" (Mioduser et al., 2008, p. 23). With recent developments in information and communication technologies and their increasing use among young people especially (Jenkins et al., 2009), media education, or the process of teaching and learning about the media (Buckingham, 2003), and its outcome, media literacy, are now considered essential 21st century literacy skills (Mioduser et al., 2008). Video production combines many key literacy skills, including content research, writing, an understanding of the power of images and sounds, the ability to use that power, and the ability to manipulate, transform, and distribute digital media (Ranker, 2008; Jenkins et al., 2009). Through collaboration, reflection, and visual expression of concepts, video production facilitates a deeper understanding of material (Sawyer, 2006).

Young people are increasingly turning to video media as an expressive form, with 27% of American teens having shot and uploaded video to the internet (Lenhart, 2012). Yet, despite its pervasiveness in society and among young people especially, university faculty have been slow to leverage the potential of media production as an educational tool, especially in science. The confluence of falling financial and technological barriers to producing media, the need for innovative approaches to meet climate change education challenges, and the potential for media literacy to empower young people to add their voice to the societal discourse about climate change science creates an ideal setting for bringing this 21st century skill into geoscience education at the university level.

PROGRAM APPROACH AND CURRICULUM

Course Setting and Student Demographics

Video production curriculum was integrated into an upper-level undergraduate- and graduate-level cross-disciplinary course on climate change science and policy titled "Climate Change: Science, Communication, and Solutions." The video production course module was adapted from a workshop originally developed by Randy Olson for doctoral students at Scripps Institution of Oceanography (http://www.randyolsonproductions.com) and involved student production of public service announcements (PSAs). Information about the course, as well as curriculum materials such as slide decks for workshop presentations, assignments associated with the media production project, and exemplars of student work, is provided at our Climate Education in an Age of Media (CAM) Project Web site (http://cleanet.org/cced_media/). Briefly, the course was 13 weeks long, with about 9 weeks of the semester devoted to climate change science, including the physical basis of the greenhouse effect, radiative forcing by natural and anthropogenic processes, the carbon cycle, the use of climate models and paleoclimate proxies to study changing climates, the impacts of climate change on natural and human systems, and ocean acidification. The subsequent 3 weeks of the course were devoted to climate change economics, policy, and social and technological solutions. The PSA project was completed within a 3 d video production workshop followed by a public screening and "meet-the-filmmaker" event held by the students.

Class sizes varied from 16 to 27 students. We have incorporated other media production projects (e.g., "video mash-ups," in which students edit together visual assets that they find online or create without filming, thereby avoiding most of the production phase) into larger classes (up to 44 students), but we believe that the PSA project would be difficult to implement effectively in a large class unless media support and instructional assistants were available. Among the 68 students enrolled in the courses described here, 90% were science majors, and most were seniors (54%) or graduate students (21%). While we do not have ethnic and racial data for students enrolled in the course, 54% were male and 46% were female. The ethnic and racial composition of the general student body at University of Massachusetts–Lowell (UMass–Lowell) consists of 65% white, 8.5% Asian, 6.3% African American or black, and 8.4% Hispanic/Latino (http://nces.ed.gov/globallocator/col_info_popup.asp?ID=166513).

PSAs are short (typically 1 min) pieces delivering a message to raise awareness about an issue that is in the public's interest and to influence or change attitudes and behavior. This format was especially appropriate for a cross-disciplinary course in climate change, in which the relationship between climate change science and broader society was a recurring theme. However, it would also be appropriate in courses that are focused only on science, as long as the instructor has an interest in challenging students to convey frequently complex scientific concepts in ways that are interesting, accessible, and relevant to a general audience. In PSA production, students are challenged to bring metaphor, humor or emotion, and creative storytelling into communication. Other media genres (e.g., person-on-the-street interviews, mini-documentaries, animation) may be a better fit, depending on the media resources available to the instructor, the amount of time available, and the desired learning outcomes. For example, in our experience, simple "paper-mation" videos can be an effective means to convey abstract science concepts or systems, while person-on-the-street interviews can be effective for exploring, and correcting, misconceptions. We are currently developing an online toolkit with lesson plans for integrating different media genres into climate change education curriculum. For PSAs, cameras and video-editing software are needed at a minimum, and production quality can be improved by access to equipment such as microphones, a sound recording room, a green screen, lights, and software for manipulating and creating images (e.g., Adobe Photoshop, Adobe Illustrator). Collaboration between science faculty and a media resource center facilitates implementation of these projects, as it minimizes faculty time and resources needed for purchasing, maintaining, and learning to use media equipment and enables faculty to focus on content and engaging students in critical thinking. In the absence of a media resource center, using easily accessible technologies (e.g., phone cameras and free editing software such as Majisto) can keep media technology learning curves to a minimum.

The video production process is commonly viewed of as having three phases: preproduction, or planning; production, where assets and resources are created and/or gathered; and postproduction, where everything is brought together, integrated, synthesized, assembled, and edited into a single coherent informative and aesthetic piece of communication. Each of these phases offers opportunities for learning and assessment (Tables I and II). During preproduction research and learning, students must reach a degree of mastery of the content in order to convey that information in creative and compelling ways. In our curriculum, students were given a reading assignment about communicating science through storytelling (Olson, 2009) and an assignment to write a one-page script (Table I). Scripts were written with a simple three-act structure: a first act in which the subject is introduced and a source of conflict or tension is established when the question is posed; a second act in which possible solutions of resolving the tension are explored; and a third act in which the question is answered and the tension is released (Olson, 2009). The assignment and an exemplar are provided as supplementary materials (available at http://dx.doi.org/10.5408/13-050s1) and are available on the CAM Project Web site (http://cleanet.org/cced_media/). Students were also asked to prepare a 3 min presentation in which they "pitched" their ideas to the entire class, after which the class voted for the best pitches, with groups of four to five students formed to produce each of the winning PSAs. These assignments involved learning through research, synthesis, and creativity, as well as writing and oral presentation skills (Tables I and II). Our experience was that relying on students to vote for the top projects gave the entire class a sense of agency and ownership of the pieces that were produced, as it was the students, not the instructor, who chose them.

During the workshop, students were given an overview of the PSA format, strategies for effective communication and filming techniques, and information about copyright infringement, informed consent, and media release forms. The UMass–Lowell Media Center, a division of the university libraries, provided equipment and technical assistance for camera, sound, and lighting equipment, as well as editing software (FinalCut Express). In the absence of these resources, any digital camera (including those on phones or other handheld devices) could be used for these projects. Low-cost and free editing software is available for both personal computer (PC) and Mac platforms (e.g., online editors, iMovie for Mac, Microsoft Movie Maker for PC). Tutorials and information about how to use editing software are available online (e.g., http://www.creativecow.net/). A single-page overview for using FinalCut Express or FinalCut Pro is available on our project Web site, and with increasing use of media technology among young people, it is more and more common that students already have familiarity and even expertise with these technologies (Lenhart, 2012).

Simple improvisation games were incorporated into the workshop presentation to help students transition from the technical, detail-oriented communication style of science, to a looser style of creative storytelling in order to convey key concepts to a broad audience (Olson, 2009). Briefly, we used the game "Two Truths and One Lie" (Farmer, 2007), in which one student would make three statements about themselves, two of which were true and one of which was not true. They would then turn to another student, ask them to guess which statement was the lie, and then the next student would make three statements (two truths and a lie) about themselves. The game continues until every student has had a chance to respond. We also created a game we called "Climate Change Point of View" in which pairs of students were asked to take on the point of view of some concept or object related to climate change and act out a skit that showed how they viewed or experienced climate change from that vantage (e.g., objects we used included carbon dioxide, Earth and extreme weather, a bird and a skyscraper, mosquitoes, boats, forest ecosystems, a small child).

Once groups were formed, they began collaborative work of revising the script, contributing ideas on how to effectively execute the project, assigning roles to group members (director, camera person, editor, actor, researcher, etc.), and creating a storyboard (Table I). Storyboards provide a means to plan media production through a sequence of illustrations or images that can be used in conjunction with the script (Cristiano, 2005). Each group then gave a brief oral presentation, in which they explained production plans, including scientific content, message, feasibility of production plans, and media technology needed (Table I). This presentation provided an opportunity for all students to offer ideas and resources and to critique each other's plans. Instructors then met with each team to review and comment on the clarity, feasibility, media technology needed, and scientific accuracy of planned pieces. Students spent the remainder of the first day planning for their shoots and practicing using camera, lighting, and sound equipment. Students began shooting the following morning and were asked to have at least one person editing footage by midday the second day and to have completed shooting footage by the morning of the third day. Instructors were available to

TABLE I: Instructional notes and resources for individual components of media production projects for climate change education.

Component	Instructional Notes	Specific Resources
Preproduction		
Research and content mastery	Highly flexible (e.g., lectures, reading assignments, term paper, homework, etc.).	CAM Project Web site; science resources
Communicating science to nonscientists	Reading assignments, online video, lecture, and/or in-class improvisation games.	CAM Project Web site Olson (2009) Somerville and Hassol (2011)
Script writing	Brief written homework assignment.[1]	CAM Project Web site
Pitch presentations	Brief (e.g., 3 min) oral presentations in class.[2]	PSA assignment on CAM Web site
Storyboard	Matches visual components of media piece to script. Important for planning and successful execution of production.[2]	CAM Project Web site
Group presentation of production plans	Brief oral presentation done by each group in which they explain production plans, including scientific content/message and logistics; opportunity for all students to offer ideas and resources.[2]	PSA assignment on CAM Web site
Production		
Filming, recording narration	In-class workshop or group homework assignment. If available, leverage media center resources.	CAM Project Web site
Finding/creating visual assets	Opportunity for peer-to-peer and student–instructor discussion to create scientifically accurate and compelling pieces.	CAM Project Web site NASA Climate Reel Other climate change science Web sites
Postproduction and distribution		
Editing	Peer-to-peer discussion, revision, media literacy.	
Rough-cut screening	Excellent opportunity for students to critique other groups' work; discuss efficacy and content.[2]	
Final-cut screening and presentation	Opportunity for students to cultivate public speaking and facilitation skills. Encourage students to prepare questions for their audience and to plan a cohesive event. If open to the public or community groups, can serve as a service learning component.	
Online distribution	Opportunities may depend on institutional policies, especially if students are minors.	Vimeo.com, YouTube

[1]Assessment of student work recommended.
[2]Optional opportunity to assess student work.

discuss ideas and troubleshoot with students for about 4 h on both the second and third days.

During the production phase, students learned media and technology literacy skills such as operating cameras, framing a shot, acting or interviewing skills, and capturing audio. They learned how to narrate their script, digitize their footage to a computer, edit the video, and arrange their resources on a time line with recorded audio, images, music, transitions, and text in ways that effectively conveyed and enhanced their message. Other life, career, and social skills, like time management, task delegation, individual responsibility, and leadership are all required for this phase of creative, hands-on, and time-consuming work. Frequently, major project revisions occurred, as students continued to discuss, brainstorm, critique, and make changes to their project. The postproduction phase involved editing their project into a coherent presentation. The iterative process of editing provides an opportunity for learning through continued group discussions and manipulation of images, audio, and timing to deliver their message in a compelling manner. As they created their own piece, they gained insight into the process by which the media they consume is produced and become more sophisticated consumers as result.

We found it helpful to have students view each other's work prior to completion, during a "gallery-style" rough-cut screening in which the class assembles around each computer students are working on, and each group screens their "first draft" on their computer monitor. Having a rough-cut screening deadline a few hours before the end of the workshop helps keep students on task and provides another opportunity for feedback on revisions and scientific accuracy, as well as for planning for distribution of their work beyond the classroom. At this stage, the instructor's focus is often facilitating peer-to-peer discussion and ensuring content accuracy, rather than providing direct feedback.

Several examples of screenshots from PSAs are shown in Fig. 1, and exemplars can be viewed on our Web site (see http://cleanet.org/cced_media/cam_tv/). We found that a 3 d intensive format was an effective means to facilitate student interaction, participation of all members from each group,

TABLE II: Alignment of assignments and learning goals or literacies associated with each component of the PSA project.

Assignment	Description or Topic	Learning Goals/Skills/Literacies
Preproduction		
Script (individual)	Students write a one-page script for their proposed PSA using a three-act structure.	Critical thinking and problem solving
		Research and writing
		Creativity and affective processing
		"Translation" of scientific content into accessible, clear message
Pitch presentation (individual)	Students deliver a 3 min "pitch" describing their proposed PSA and give compelling reasons for why it should be chosen for production.	Communication
		Initiative and self-direction
		Social skills
Storyboard (group)	Students create a sequence that conveys scenes and camera shots associated with each component of the script.	Social skills, collaboration
		Content research
		Time management
Production (group)		
Media technology tutorials	Instructors provide demonstrations on how to use cameras, lights, microphones, and editing software.	Information and communications technology (ICT) literacy
Filming	Students create or find sets and props and shoot film.	Creative thinking
		Problem solving
		ICT literacy
		Social skills
		Leadership
		Writing and revision
Images and audio clips	Students use software (e.g., Adobe Illustrator, Photoshop, Garage Band, Audacity) or find images and audio clips to incorporate into video.	Learning and innovation skills
		ICT literacy
		Social skills
Postproduction (group)		
Editing	Students engage in discussion about images, affect, effectiveness, content, etc.	Problem solving
		ICT literacy
		Creativity
		Collaboration
		Planning, time management
Public screening event	Students present their media piece, give a short oral presentation about the piece and their key message, and engage the audience in a discussion about climate change.	Group collaboration
		Planning
		Oral communication skills
Distribution	Media pieces are posted online, and students decide how to promote and distribute them.	Social skills
		ICT literacy

and access to instructors knowledgeable about climate change and media production. However, if it is not possible to break with conventional class periods, components of the workshop could be offered over the course of roughly 2 weeks of class time, with students assigned components of the preproduction, production, and postproduction work as homework (see Table I).

Student-Produced Media as a Bridge Between Formal and Informal Climate Change Education

Despite the current focus on online dissemination, we have found that face-to-face events in which student pieces are screened and students are given an opportunity to discuss climate change science and communication with a public audience can be both motivating and empowering. Such events provide a means to incorporate service learning into this project, with students serving as educators of others beyond their class, connecting their work back to the "real world." Knowing that they will present their work in a public forum and be given an opportunity to explain the potential, challenges, and pitfalls of communicating climate change through short videos is likely to increase their level of commitment to and engagement in the project (Kearsley and Schneiderman, 1998). Videos are often an effective means for stimulating discussion (Mitra et al., 2010), and the live screening events offered an opportunity for students to both present their pieces and use them as a means to launch discussions with their audiences.

FIGURE 1: Screenshots from several student-produced PSAs (clockwise from upper left: "Rock 'Em Sock 'Em" (a fight between humanity and climate change); "Blinded" (a look at whether we will open our eyes to climate change); "Mr. Mayhem" (a spoof on a commercial that warns us of consequences if we ignore the signs of climate change); and "Inheritance" (a look at intergenerational issues around climate change.) These and other pieces are available at http://cleanet.org/cced_media/.

With the growing ubiquity of video monitors, opportunities for screening student-produced media in informal settings are also growing. For example, at UMass–Lowell, video monitors that stream campus information are mounted above elevators and in hallways around campus. We worked with our Student Affairs Office to have several student-produced PSAs stream continuously on these monitors, showcasing student work and, perhaps, increasing climate change awareness among their peers. Opportunities for broadcasting student work on local cable access television stations are also growing, as many of these stations are in need of content that is relevant to their local communities (in our case, student pieces have been screened on local access stations in both Cambridge and Lowell, Massachusetts). Similarly, student-produced pieces could be readily integrated into museum displays or screenings and shown at community events. Videos produced during this project have been screened at campus-wide events, community events (e.g., Lowell's Sustainability Week), and in other professors' classes.

EVALUATION OF LEARNING OUTCOMES

The course and video production workshop were evaluated for three consecutive years by a team of evaluators (SageFox Consulting Group, LLC). The evaluation included an assessment of climate change science knowledge (drawn in part from the Yale Project on Climate Change Communication; Leiserowitz et al., 2013), attitudes towards and affective responses to climate change, reflections on the video production workshop, and focus group discussions about student experiences and learning outcomes. Using common practice for the evaluation of qualitative data (Taylor-Powell and Renner, 2003), analysis of the students' comments began by reading through all of the open-ended responses to the survey and the comprehensive notes taken during the focus groups. Students were asked to complete surveys both prior to taking the course (pre-surveys) and after completing the course (post-surveys). Each response was then coded based on the main categories of responses that emerged from the data. These were then combined into the key themes, including: intrinsic motivation and engagement with the project; critical thinking and the challenge of communicating climate change; social learning; an interest in climate change that reached beyond the course; learning connected to the real world; and a sense of empowerment and agency.

Findings from surveys and student reflections on their experiences (68 students over three semesters) and focus groups (18 students over three semesters) provided evidence for gains in communication skills, teamwork and interpersonal skills, conceptual and analytical abilities, their understanding of climate change science concepts, and their commitment to addressing climate change (Fig. 2). The version of the survey used in this study, much of which was drawn from Leiserowitz et al. (2013), was determined to have face validity through examination by professors who were experts on both climate change science and teaching at the university and high school level. These experts examined the survey items both to ensure that the content being asked about was relevant to the educational setting being examined and to ensure that the language being used would

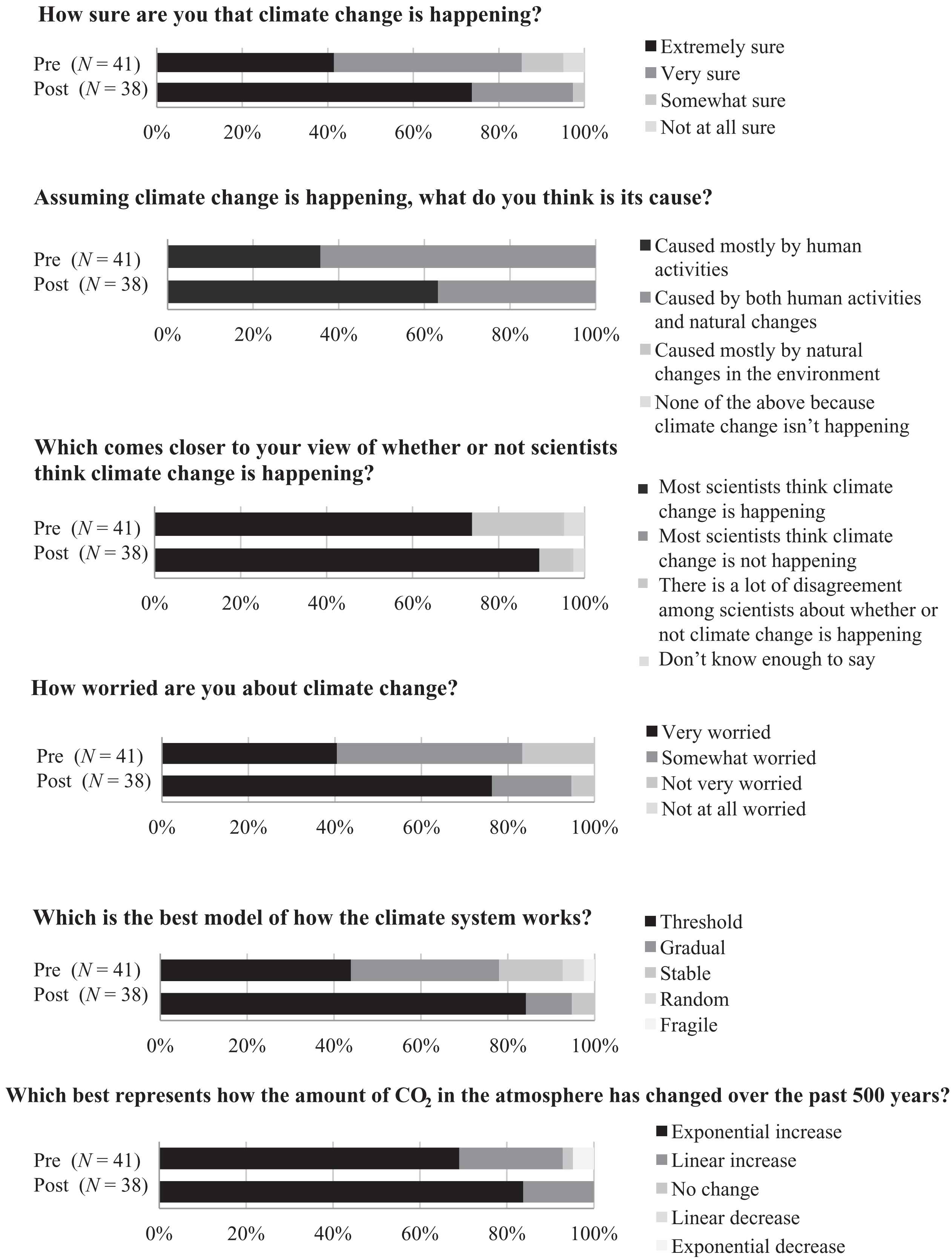

FIGURE 2: Climate literacy learning outcomes for students in the courses that incorporated the media production project ("pre" and "post" results were obtained before and after the 13 week course, respectively.)

be familiar and comprehensible to the target audience. Given that the survey had originally been validated for use with a broad sample of the American population, little modification in the way of wording was necessary in any context. Although several items were removed from the versions of the survey, examination of the responses was conducted on an item-by-item basis rather than in groups, and thus there is reason to believe that the responses to the individual items are comparable to the responses to those same items found by Leiserowitz et al. (2013) for a broad section of the American adult and teen populations. Thus, when we saw that approximately 85% of respondents said they were very or extremely sure that climate change was happening on the presurveys (Fig. 2), we were fairly confident in saying that this was a real difference from the 60% found in Leiserowitz et al.'s (2013) most recent survey results, suggesting that our sample is more accepting of the reality of climate change than the population at large.

While our focus was on learning outcomes for students producing media rather than on the impact of the pieces that they produced on their viewers, we were able to leverage several face-to-face and online screenings of student work to examine audience learning outcomes and responses. Briefly, we conducted pre- and postsurveys of audiences from both face-to-face (61 participants) and online screenings (59 participants) of student-produced videos. Audience members were not enrolled in the course described here and were primarily nonscience major undergraduate students who were offered extra credit for participating in this study. Questions on the surveys addressed both attitudes towards climate change and basic climate change science that the videos addressed, and they were taken primarily from the Yale Project on Climate Change Communication survey (Leiserowitz et al., 2013). Comparison of pre- and postsurvey results indicated substantial gains in the level of concern, interest, and motivation to seek more information about climate change among viewers (Fig. 3).

RESULTS AND DISCUSSION

Video Production Process as a Learning Tool

While video production is rarely incorporated into geoscience education, our findings indicate that it has the potential to meet many of the ''grand challenges of science education,'' including fostering the capacity to work in groups, developing vital communication skills, addressing real-world complex problems, and incorporating active inquiry into science education (Alberts, 2013). Throughout the project, students are required to engage with their peers in a social setting, tackle a topic as a group with an agreed upon common purpose, discuss their understanding, defend their positions, engage in research, define tasks and assignments, and learn to better manage their time.

While the instructional setting described here was limited (i.e., a small- to mid-sized upper-level university course), we have used variations of this approach in other settings and offered professional development workshops to faculty teaching in diverse settings (from informal after-school programs for middle and high school students to graduate students in environmental science and policy). While it is beyond the scope of the current paper to describe learning outcomes obtained in these different settings, we have anecdotal evidence that implementation of the ''CAM approach'' was successful. One high school instructor presented her work using this approach at the National Science Teachers Association meeting (Cochrane, 2014). Instructors from the Alliance for Climate Education (ACE) have used the CAM approach in informal workshops for high school students and reported that, ''In all the workshops we've led using the CAM framework, we've seen inspiring results'' (Brian Stilwell, pers. comm., 3 April 2014). Several of the educators who participated in our professional development workshop planned to implement the CAM approach in additional settings, including middle school science curriculum, general education courses for nonscience majors, and graduate communication courses.

Most of the course examined here focused on scientific content, which was reinforced and explored more deeply during these student projects. Therefore, we do not attribute climate literacy learning outcomes among students enrolled in the course to this project alone. However, we did see evidence for gains in climate literacy when comparing pre- and postcourse survey answers. Results are shown for 2 y of the course (2012 and 2013) for which the same survey questions were used (Fig. 2).

Students consistently ranked the video project as one of the best aspects of the course, viewing it as one of the assignments that promoted the most learning, and most (87%, $n = 55$) recommended that it be included in future offerings of the course. Their major criticism was that the time allotted to it was too short, e.g.:

> *''This exercise would have been more useful if done over a longer period of time. Increase the length of the film and make it a semester-long project.''*

While we agree that the projects themselves would have benefited from additional time, there is so much material to cover in a cross-disciplinary treatment of climate change that we felt a longer video segment could possibly detract from other course components. An alternative approach would be to integrate multiple video projects throughout the semester, with earlier projects focused on specific science content (e.g., an animation of part of the carbon cycle or a feedback loop in the climate system). Such an approach could give students facility with media technology in advance of the PSA project. However, the instructors surmise that an advantage of the short, condensed format for this project is that students have an opportunity to have a clear break with the course routine and are forced into rapid, affective processing during a clearly constrained period that is distinct from the more conventional assignments.

Key themes that emerged from open-ended responses and focus groups included: intrinsic motivation and engagement with the project; critical thinking and the challenge of communicating climate change; social learning; an interest in climate change that reached beyond the course; learning connected to the real world; and a sense of empowerment and agency. There were far too many student comments to include them all here, but a few quotes have been selected that illustrate these learning pathways and outcomes:

- Critical thinking and the challenge of communication:

> *''I think by challenging the class to communicate a subject, especially one as complicated as climate change, in a short*

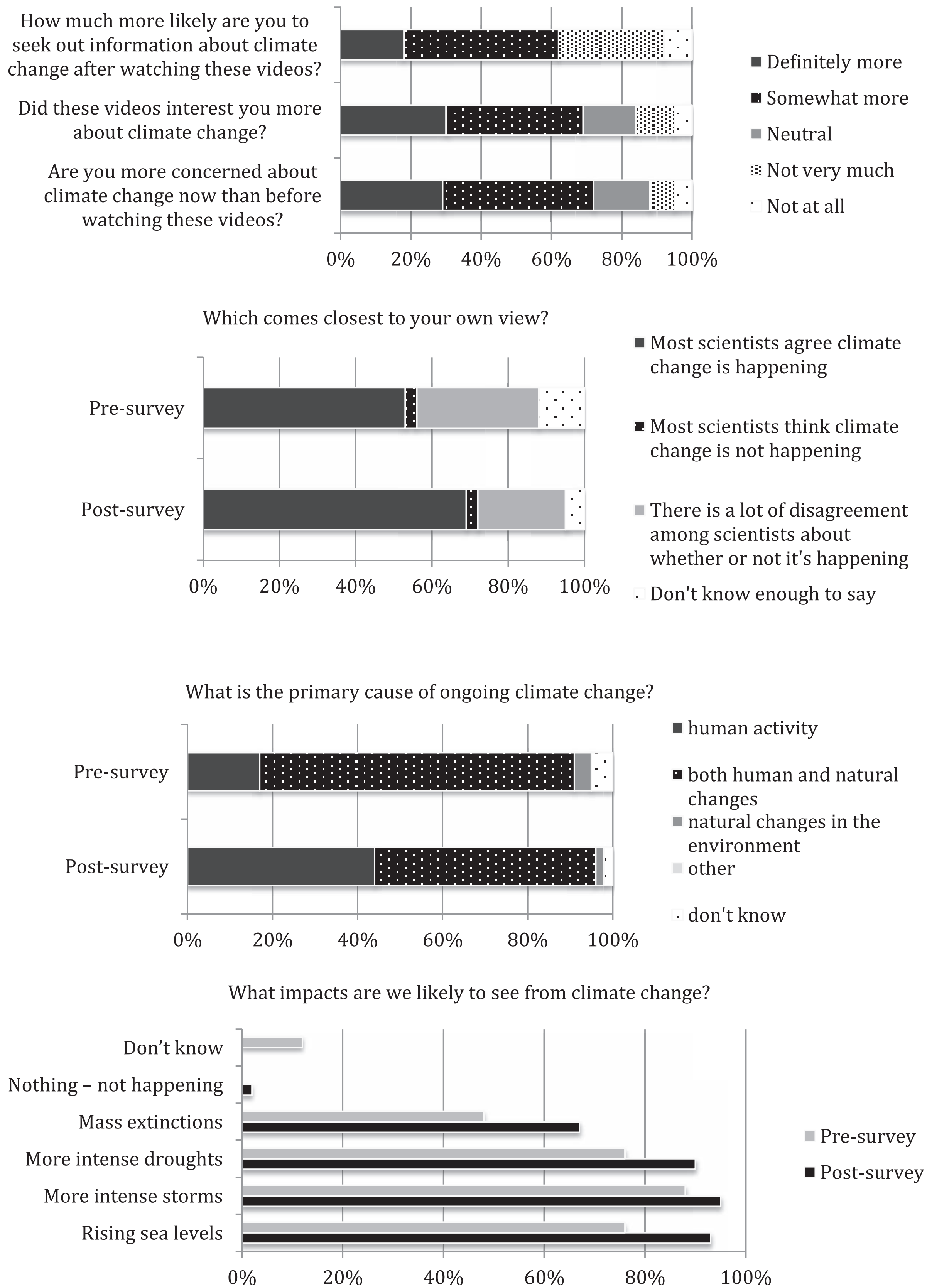

FIGURE 3: Impact of student-produced videos on viewers' concern, interest, and understanding of climate change.

film format, we were forced to show that we had a true understanding of the subject. Creating a video about climate change is much more of a challenge than repeating facts back on a test.''

• Social learning:

''Not only is there more originality in the video production workshop, but there is also more social cohesion, which almost always leads to a deeper understanding of the material usually covered in class.''

''This project required a lot more group activity than a usual class. In group projects (like papers or presentations), usually one or two people end up doing the majority of the work. In the video project, the entire group had to be there every day and participate in every step of the process.''

• Intrinsic motivation and active learning:

''At the emotional level I realized that I really do have a desire to communicate facts about this issue effectively to the public. Throughout making the film, I was very much motivated by these feelings. By making films we were forced to engage actively in the subject, rather than just passively learning about it. Much like the laboratory component of a biology or chemistry class, we were required to take what we had learned in our lectures and apply it.''

''I got so completely immersed in the process, feeling excited and impassioned about my group's ideas, and frustrated when things weren't working the way we wanted them too [sic]. I am incredibly proud of the work we produced.''

• Real-world connection and engagement with the material beyond the classroom:

''Our videos, posters, songs, projects, and other sources of media are going to be the one of the most effective roles in teaching the society we live in.''

• Empowerment and agency:

''We saw that we as a generation matter, and we can make a difference. Absolutely, this workshop got me amped up for climate change action and education. It's something that needs to happen, and it needs to happen fast.''

Each of these themes illustrates the potential of media production to overcome challenges in climate change education. For example, many students' comments about how much they enjoyed the project and how committed they were to its outcome reflected strong intrinsic motivation, which has been linked to sustained commitment and effort in learning (Benware and Deci, 1984; Schunk et al., 2008). Social learning was also critical during this project, providing a means for students to build key 21st century skills such as collaboration and social skills, but also contributing to learning about climate change through group discussion and work (CRED, 2009). In our experience, this project provided students with a social or cultural environment in which they could openly share and discuss their understanding and views on climate change. Because they were doing so with a cohort of peers who had been exposed to the same climate change science content in the earlier part of the semester, students developed a shared understanding that was free of (or at least less constrained by) the cultural conflict with which climate change is often associated (Kahan et al., 2012). This social aspect may further contribute to intrinsic motivation and learning (CRED, 2009) and at least partially counteract detractions from understanding of climate change that can be associated with cultural conflict. Interestingly, several students commented that they used the videos to communicate about climate change with family members and friends with whom they would normally not discuss climate change.

Clearly, our focus was on learning outcomes for students producing media, rather than on the impact of the pieces that they produced on other viewers. However, preliminary results suggest that despite the amateur quality of student-produced pieces, they can be impactful climate change communication tools in informal settings. In addition, most (91%) viewers considered student-produced pieces to have the same or more impact than professionally produced pieces, and several comments reflected that youth were seen as both powerful and trusted messengers; e.g., ''The hard work and research these kids did in order to learn about the subject they were interested in and bring attention to the public ...was very inspirational.'' Lastly, viewers showed gains in their understanding of the level of scientific agreement about climate change, its causes, and its impacts (Fig. 3).

An additional benefit of this project was that it often left students with a sense of empowerment and agency, as well as commitment to addressing climate change beyond the course. Sixty-eight percent of the students we surveyed (n = 34) stated that producing and showing their pieces affected their attitude and opinion about taking action to address climate change, and most who answered that their attitude and opinion were not affected stated that they were already planning to take action on climate change. Sixty-seven percent stated that they gained skills that would make them comfortable enough to consider producing videos in the future. The students clearly recognized the project and the skills it offered as a means to add their voice to the public discourse about climate change and to exert an influence on societal responses to it. This sense of agency and empowerment has been recognized as a goal of climate change education (Forest and Feder, 2011).

CONCLUSIONS

Using student media production as a tool for climate change education offers a promising approach to overcoming some of the challenges associated with climate change education while simultaneously improving media literacy and empowering students to add their voices to the societal discourse about climate change. In particular, unlike many other science topics, the profound implications of climate change, for young people especially, often elicit affective and social responses that present barriers to learning. Media production projects can meet these challenges by engaging analytic, affective, and social learning pathways. These projects challenge students to learn through educating others; to use storytelling, emotion, and metaphor to convey complex content to a general audience; to discuss that content and collaborate with their peers; and to delve into the affective response that they have experienced and that they hope to elicit among their audience. Initial evaluation of this approach indicates that it led to high levels of engagement, intrinsic motivation, and potential to reinforce and expand upon science content learned through conventional pedagogical approaches. It is difficult for us to distinguish student climate literacy outcomes that stemmed specifically from this project, which was a culminating assignment at the end of a semester-long course, from those gained in the rest of the course. However, students and the audiences who viewed their pieces both exhibited improved interest in and understanding of climate change after taking the course or viewing media pieces. Anecdotal evidence from educators who participated in CAM Project professional development workshops indicates that the approach holds promise in a variety of instructional settings, ranging from middle school to graduate students. In support of disseminating this approach, the CAM Project Web site (http://cleanet.org/cced_media/) offers online resources to educators interested in integrating media production and climate change education.

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