Lens on Climate Change: Making Climate Meaningful Through Student-Produced Videos

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ABSTRACT

Learning about climate change is tangible when it addresses impacts that can be observed close to home. In this program, sixty-four diverse middle and high school students produced videos about locally relevant climate change topics. Graduate and undergraduate students provided mentorship. The program engaged students in research and learning about climate change, and sparked their interest in science careers. Evaluation results showed that students were highly motivated by the experience, developed a genuine interest in their science topic, learned about the scientific process, and developed twenty-first century skills. The program provided a unique and authentic approach to science learning and communication.

Key Words: *climate change, mentoring, active learning, place-based education, video*

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INTRODUCTION

Recent reports from the United Nations Intergovernmental Panel on Climate Change (IPCC) make clear that climate and environmental change will significantly affect future generations and life on Earth (IPCC 2014). Research results unequivocally show that human-induced greenhouse gas emissions cause measurable changes in the climate system and a steady global warming. However, public opinion polls show that only 63 percent of the American public (Leiserowitz *et al.* 2014) and only 54 percent of American teenagers (Leiserowitz, Smith, and Marlon 2011) think that global warming is occurring, while the scientific community broadly agrees that human-induced climate change is happening (IPCC 2013). This discrepancy calls for action to find alternative ways to communicate accepted research findings to the public. Outreach and education activities play a key role in closing this gap between scientist understanding and public perception of this research.

We report here on one such effort to communicate the impact of climate change on a local scale. In the 2013–2014 academic year, sixty-four middle and high school students (typically ages 9–18) from Colorado produced short videos about how climate change affects their lives. Participating students were mentored by geoscience graduate students and most by a video expert, and engaged directly with research scientists to learn about the current state of knowledge around their chosen topic. Through the video-production process, participating students learned about scientists' research findings and translated them into their own words when crafting the message of their videos.

Student-produced videography is an active learning technique that has been used successfully in various educational settings: in preservice teacher education (Hernández-Ramos 2007) and teacher professional development (Calandra, Gurvitch, and Lund 2008); in geography (Kennedy and Lukinbeal 1997; Di Palma 2009; Lukinbeal and Craine 2009); in biology (Harrison-Pitaniello 2013); in chemistry education (Rouda 1973); in climate change education (Rooney-Varga *et al.* 2014); in language education (Gardner 1994; Carney and Foss 2008); in online learning environments (Green 2008); and in informal education (Levin 2011; Vickery 2014). A related genre, student-produced podcasts, has also been used successfully as a learning tool (Armstrong, Tucker, and Massad 2009a, 2009b; Jarvis and Dickie 2010). However, most of these publications provide anecdotal impressions of positive outcomes, and only few have measured the effects of student-produced videos on content-learning gains or a possible effect on students' attitude towards science quantitatively (Wade and Courtney 2014; Rooney-Varga *et al.* 2014) or qualitatively (Vickery 2014). In this article we report qualitative data that measured the program impact.

The need for K–12 students to learn how to communicate about scientific topics is highlighted in the Next Generation Science Standards as one of eight scientific and engineering practices (NGSS Lead States 2013). According to these standards, students from kindergarten to high school will practice science communication while mastering science content. Similarly, the National Research Council (2012) also identified "communicating" and "sharing information using digital technologies" as key twenty-first century skills. Thus, educators are encouraged to teach scientific communication. However, measuring the success of instructional approaches to teach scientific communication in the secondary classroom is still underway (PCAST 2010).

In this article, we report the design and the outcomes of the Lens on Climate Change student-videography program that aimed to increase students' awareness and understanding of how climate change affects their lives. We describe how the student-led production of videos about a climate change topic of local relevance builds communication skills in students while they develop an in-depth understanding of the science content, engage in teamwork, and practice professional interactions. We describe how the program can be adapted as a possible model to use in both secondary and postsecondary classroom settings.

Background

Student-led video production fosters an environment in which learning is shifted from teacher-defined assignments to learning that happens while students deeply research a topic and gather information, develop their own understanding, brainstorm ways to creatively communicate a story or a message, interview stakeholders, and assemble their final product. Thus, video production engages students in authentic learning (Herrington and Oliver 2000) in which they collaboratively work towards a product—the video. This active-learning process leads to strong student engagement and a sense of ownership of the product (Kearney and Schuck 2005, 2006; Hofer and Swan 2008), and thus indirectly to a student-centered learning process (Vickery 2014; Dando and Chadwick 2014). Studies also found that providing students with flexibility and control over their learning results in strong self-esteem and true personal interest in the topic (Kearney and Schuck 2005; Rooney-Varga *et al.* 2014).

Producing films is a rich learning activity. In addition to content learning and the development of videography skills, students learn twenty-first century skills (National Research Council 2012), such as communication and media use. Media literacy is an important skillset for students to develop, especially in a world where digital and networked media play a central role (Hofer and Swan 2008; Horst, Herr-Stephenson, and Robinson 2010; Levin 2010; Ito *et al.* 2010). The many skills developed through video production can be categorized as: (1) conceptual skills; (2) practical video-making skills; (3) communication, presentation, and literacy skills; (4) organizational and team working skills; and (5) higher-order thinking, metacognitive, and affective skills, especially when the student products are celebrated in a meaningful context (Kolka 1967; Kearney and Schuck 2005, 2006; Levin 2011). Many of the tasks required in the video-production process, such as interviewing experts, are unfamiliar and often challenging for students. Once students master these skills, they gain confidence. Preparing for the interviews requires students to develop good content knowledge in order to ask relevant questions. Through the video production process, student learning reaches the highest cognitive level in the Bloom pyramid of learning (*creating*, Bloom *et al.* 1956; Anderson and Krathwohl 2001) and has even been described as transformational (Watkins 2011; Kearney 2011). Engaging students in video production may improve their ability to critically view videos produced by others, an additional aspect of media literacy.

Videos have been used in science classrooms for a long time, mostly as a visual aid or reflection tool (Kearney and Schuck 2005; Dando and Chadwick 2014). The development of simple digital video technology available at an affordable price, such as free video editing software, free online storage or data file tools, and ubiquitous Internet access, has allowed educators to readily incorporate video production as a project-oriented learning approach in classrooms.

A recent Pew Research study shows that the majority of Americans have access to communication technology (Zickuhr and Smith 2012), indicating that the "access gap or digital divide" has narrowed. However, access to technology does not guarantee the participation in the use of this technology. This "participation gap" can only be closed by providing sufficient opportunities and training (Watkins 2011; Vickery 2014). Engaging marginalized students in video production can close a potential participation gap in twenty-first century technology, providing students with access to opportunities, experiences, and skills that prepare them for full participation in a digitized world (Watkins 2011; Vickery 2014). Having students with a diverse set of skills and interests work together on a project provides a powerful opportunity to mix students of different personal backgrounds and academic profiles and builds teams in which the importance of each contributor is apparent.

The National Climate Assessment report (Melillo, Richmond, and Yohe 2014) and the IPCC reports (2013, 2014) show that climate change affects the American public as well as the world on local scales. Climate science is therefore an ideal topic to draw student interest in science and technology since changes can be observed close to home. As David Sobel (2012), a key figure in the development of place-based education theory, states, "learning must begin with the tangible." Having students research a topic of local relevance follows these findings from place-based education in engaging and inspiring students.

Lens On Climate Change Program Design

Eight socioeconomically diverse Colorado middle and high schools (Table 1) participated in the Lens on Climate Change program. Participating students produced short (3–7 minute) documentary-style videos featuring how climate change affects their lives or their community. The topics chosen by the student groups ranged from the Colorado flood of 2013; changes in local snowpack; the shrinking Arapahoe Glacier; drought; an increase in mountain pine beetle occurrence; food security; and agriculture. The overall structure of the program is illustrated in Figure 1. The program explicitly targeted students from groups that are underrepresented in the geosciences (Gonzales and Keane

Table 1. Summary of the socioeconomic and ethnic diversity of participating schools. All values given in percentage, values that are above state average are highlighted in grey. Data from 2011 published by Colorado Department of Education (CDE 2011a, 2011b).

Participating school Type of school School district	Total students	Free and Reduced Lunch	American Indian or Alaskan Native	Asian	Black or African American	Hispanic or Latino	Other or mix ethnicity	White
Alamosa High School, Alamosa RE-IIJ School District	512	56.8%	0.3%	1.2%	0	58.8%	2.8%	38.1%
Arapahoe Ridge Campus, CTE Program, Boulder Valley School District	210	56.7%	2.4%	1.4%	1.0%	53.3%	1.9%	40%
Estes Park Middle School, Park R-3 School District	246	33.3%	0.4%	2.4%	2.0%	20.0%	3.3%	72.0%
Greeley High School, Greeley – 6 School District	1410	56.9%	0.6%	0.6%	1.6%	60.8%	2.8%	33.6%
Manhattan Middle School, Boulder Valley School District	466	27.5%	1.3%	4.7%	1.3%	22.8%	4.7%	65.2%
Nederland Middle/High School, Boulder Valley School District	323	22.0%	1.5%	2.8%	0.3%	6.8%	3.7%	84.8%
Poudre High School, Poudre R-1 School District	1804	35.5%	0.7%	3.7%	1.2%	21.8%	2.3%	70.4%
Whittier K-8, Denver Public Schools	283	82.0%	1.4%	0.7%	43.1%	38.5%	6.7%	9.4%
State Average		**40.9%**	**0.8%**	**3.1%**	**4.8%**	**31.9%**	**3.2%**	**56.1%**

2011). In addition to targeting racial and gender diversity, we also targeted students from rural communities, students from socioeconomically disadvantaged backgrounds, and potential first-generation college students. Each of the participating schools was public and represented urban, suburban, and rural Colorado. The diversity of the school populations was reflected in the participating students. Thirty-six percent of the participating students were female; 64 percent were male. Teachers from the partner schools recruited nine student teams of 6–9 students. The majority of the teachers reported many more students were interested in the program than there were available slots, which required them to select students. Selection was mostly based on short written essays of the students' motivation for participation and a description of the skills they see themselves contributing. Some teachers implemented the program as part of a class (e.g., environmental science; collaboration between video and science class), others implemented the video program outside the formal school day, during lunch period, after school, or as part of an existing environmental club. Some of the teachers offered extra credit for participating students. The teachers received a modest stipend of $150.

The program also was designed to build mentoring capacity among science graduate students and to train them in science communication. The formal mentor-mentee relationship in the LOCC program was accomplished by the assignment of science and video mentors to the student groups. Mentors act as influential role models (Tierney and Grossman 2000) and can increase mentees' academic performance (DuBois *et al.* 2002; Karcher, Davis, and Powell 2002; Diversi and Mecham 2005; Garringer 2010). Benefits of engaging mentors that are only a few years older than the mentees, also referred to as "near-peer mentors," have been described in the literature (Murphey 1998; Evans and Cuffe 2009; Edgcomb 2010). Each student group was paired with both a geoscience graduate student, who conducts research in an environmental science field, to help with the science content and with a professional videographer to support the teams in all technical aspects of video production. The nine student groups were mentored by eleven graduate students and one undergraduate student from geoscience departments, the film school, and two recent graduates. There were slightly more male mentors (54%). The mentors were recruited based on their interest and experience in working with secondary students. They were paired with student groups by matching their scientific expertise and the topics chosen by the student groups.

All mentors completed a two-hour training by CIRES staff, which included the definition of the mentors' role in the program ("be a support but not a friend"), strategies of how to work with middle and high school students, including specific needs and possible challenges like classroom management, and suggestions of how to run the first meeting. All mentors were given a crash course in video production and editing. Specific focus was given to methods for effectively communicating scientific findings. Mentors were encouraged to closely work with the teachers. The wide geographic distribution of schools required some mentors to communicate

Figure 1. Schematic overview of the Lens on Climate Change program structure. (Color figure available online.)

with their student groups remotely. Thus, all mentors were trained in digital communication (Skype, Google Hangout). We provided a $280 mentor stipend and travel reimbursement.

Mentors engaged, on average, five to ten times with their students through face-to-face visits, Skype, or phone meetings, in addition to e-mail correspondence. Face-to-face meetings were the most meaningful interactions. Virtual interactions, including e-mails, were not a reliable communication means. Most mentors reported that they spent a lot of time coordinating meetings with the students and follow-up tasks, in addition to the work directly related to the video production. Mentors of the four nonlocal student groups (>50 miles) described the limited opportunities for face-to-face interactions as challenging.

Another goal of this project was to provide the middle and high school students with exposure to college life, and spark interest in pursuing a college degree. Being mentored by graduate students and interviewing scientists was one avenue for the participating students to interact and build connections with potential role models who have earned a college degree. To further strengthen the connection between the middle and high school and postsecondary students, the LOCC program partnered with an undergraduate course at the University of Colorado—Inside the Greenhouse (ITG)—in which undergraduate students create compositions, including videos, about climate change topics. Thirty-nine undergraduate students participated as part of their class (39% female; 61% male). About one month before the final screening, middle and high school student groups were paired with undergraduate ITG student groups. ITG students were provided with only a one-sentence description of the LOCC student video topic and a hand-drawn sketch (Fig. 2). Based on these prompts the undergraduate students were asked to create a 1–3 minute video response. These response videos were screened back to back with the LOCC student-produced videos at the final screening event. The ITG students overall did less research into the scientific background of the topics than the LOCC students. Their videos displayed an artistic interpretation of the given topic while the LOCC students produced mostly documentary-style videos.

The LOCC video production was divided in the following program phases (Fig. 1, Table 2):

1. **Topic Definition and Script**: During a kickoff meeting, students, mentors, and teachers brainstormed and distilled topic ideas for the video. Supported by the science mentors, students created a concept map of their climate change topic from which they drafted a script for their video, identified expert or stakeholder interviews (e.g., flood victims, park ranger, ranchers), and outlined the footage that was needed with the support of the video mentors.
2. **Filming:** Students filmed interviews with content experts and stakeholders representing diverse viewpoints. The video mentors supported the students in filming both the interviews and footage to intercut with interviews (B-roll). Students planned B-roll filming days by identifying and scouting locations. Science and video mentors helped students find existing footage, audio clips, and still images to supplement their videos.
3. **Editing**: Following the video script, students edited their videos with the help of video mentors and teachers using free software packages (e.g., iMovie, Microsoft Movie Maker). Video mentors guided students with respect to fair use and copyright for music and other licensed materials.
4. **Video Screening**: All videos were presented during an on-campus screening. Before the screening, participating students toured the university campus and the lab spaces of their mentors. During the screening, the students were seated together with the undergraduate students from the Inside the Greenhouse course to provide opportunities for exchange between the groups. University faculty and staff, as well as Boulder community members, parents, and peers, participated in the screening event and served as the jury. The event was well attended with a standing-room-only crowd (150+). A simple scoring rubric with three categories was used to judge the films, and plaques were given out for the best video in each category and the overall winner at each level—middle and high school.

All student videos from the screening are posted on the program Web site.[1] In addition to the official screening, about half the student groups also screened their videos during a school assembly, providing the students with an opportunity to share their accomplishment with peers. The videos were also broadcast on the University of Colorado television channel and some videos were shown on a local school district's educational channel. Newspaper articles and a radio interview raised awareness of the program in the local communities. One group entered their video in a national video contest.

LOCC Program Evaluation

We studied the effectiveness of this project-based learning approach on student learning, student engagement and content knowledge using summative surveys, pre-post surveys and interviews. We also studied the effect of program participation on the mentors. All student mentors completed a nineteen-item online reflection survey after the completion of the program. The survey included questions on the mentor training, interactions with students, science content learning, benefits to students and mentors, challenges, and team support. All participating teachers or teacher teams were interviewed on the phone after the completion of the program. The semistructured interviews followed a seventeen-question script and were recorded

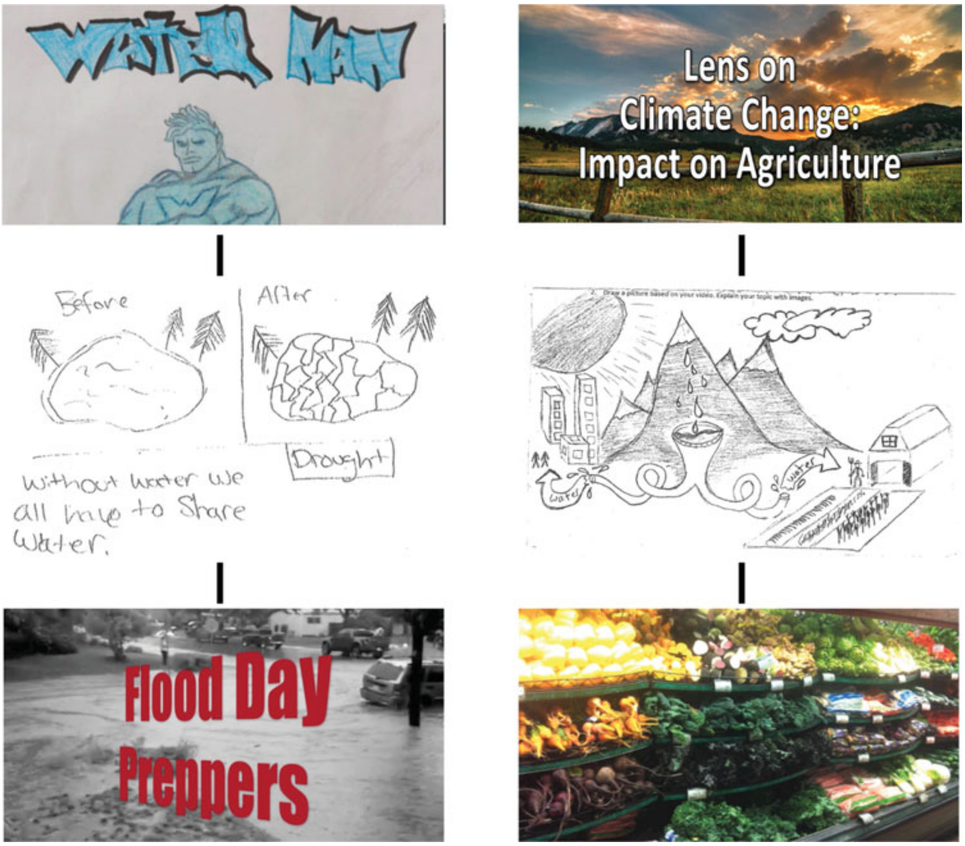

Figure 2. Pairing of secondary and undergraduate videos. Secondary students provided prompts that were hand drawn sketches about their video topic. Undergraduate students produced video responses based on these prompts that were screened back-to-back during the screening event. Top row: Opening frame of secondary student video. Middle row: Provided prompt. Bottom row: Opening frame of undergraduate response video. (Color figure available online.)

for transcription and analysis. During the interview the teachers were asked about recruitment strategies and methods of implementation, impact on students, and how the program could be improved. Teachers shared some secondary student reflection statements and some of the students completed a "Draw a Scientist" test (Chambers 1983; Finson 2002) before and after their participation in the program. Thirty-eight percent of the undergraduate students from the Inside the Greenhouse course completed a six-item online reflection survey, which explored the matching process between the teams, benefits and challenges, and feedback on the screening event.

The survey and interview responses were analyzed using qualitative methods (Patton 2001). Answers were coded and emerging themes were extracted from the open-ended questions and interview transcripts. Exemplary quotes were extracted from the transcripts and surveys. Answers to questions on quantitative scales were analyzed using basic statistical analysis.

Results

Our data show that the program was successful in exposing students and teachers to authentic learning about the local impact of climate and environmental change. All teachers noted that using locally relevant topics enhanced students' interest in the topics and made the learning more meaningful and tangible. Themes that emerged from the teacher interviews around student learning were student understanding of the scientific process and the way scientists derive their data and knowledge. The exposure of students to young graduate students and female scientists, as well as their engagement in understanding the scientific process, led to a more differentiated view of who scientists can be, (e.g., young females, instead of gray-haired elderly men in laboratories). The "Draw a Scientist" exercise, in which students were asked to draw a scientist before and after participating in the program, showed that students' perception of scientists changed over the course of the program.

Asked about the impact on, and the benefits for, the secondary students, the majority of the mentors and teachers pointed out that the middle and high school students developed a genuine interest in their science topic. Mentors attributed this change to the impact of direct interactions with scientists, professionals, and journalists through the student interviews. Another theme that emerged from analyzing the mentor survey responses was that students gained a good understanding and content knowledge of the science behind their climate science topic.

The project-based format of the LOCC program was described as very attractive and meaningful by all participants in the reflection surveys and in the interviews. Teachers agreed strongly that the video program was more engaging for students than traditional approaches to teaching.

> "This was by far one of the most interesting things they've done in their high-school career so far!" [teacher]

When asked about the effects of the program on their students, teachers all reported that the students were enthusiastic about their projects and highly motivated. The

Table 2. Video production schedule broken down into hours based on experience in the Lens on Climate Change program.

Production stage	Notes
Pre-Production • Concept Map (1–2 hours) • Topic Research (2–4 hours) • Script and Interview Questions (1–2 hours) • Shot list (1 hour)	Organization and planning of video early on saves time later during shooting and editing days.
Production • Video Interviews (2–3 hours) • B-Roll Shooting (3–5 hours) • B-Roll Gathering (1–2 hours)	• Times do not include travel time. • B-roll gathering includes finding images and video online for use in video. • Many organizations such as NASA and NOAA have libraries for public use.
Editing • Editing (7–10 hours)	Plan additional time for editing. Editing is a time-consuming task.

thematic analysis of program effects on students showed the following impacts in the order most frequently mentioned by the teachers: (i) students pushed their limits, developed persistence, and were rewarded by a final product; (ii) students developed content knowledge around the chosen science topic; (iii) students were able to practice professional interactions while talking with scientists and leaders in their field of interest; (iv) students built a relationship with their mentor and received a glimpse into college life that many teachers viewed as potentially increasing students' interest in college or even science careers; (v) students learned to communicate about a science topic; and (vi) students developed many new skills around videography, but also teamwork and leadership skills.

> "The project really demanded students to get out of their comfort zone. They had to interview professionals and discuss with experts." [teacher]

> "The most beneficial thing that I got from making the video was that to be confident. Because when we first started making the video I was kind of thinking to drop out of the group and not do it. Then my teacher had a conversation with me that once you start something and you finish it you will feel good about it and it will help me in life. That really helped me because when we got the video done I was really glad that I made something and finished it. It helped me to be confident with myself because I am the kind of person who doesn't have confidence in doing something and finishing it." [sixth-grade student]

For mentors the most important program outcomes for the participants included students working together as a team, enthusiastically taking charge of the content, and completing the product.

> "Students were silly, care-free but serious in their work, and could think of things I couldn't and surprised me." [LOCC mentor]

Participating teachers reported that this video program appealed to students who are not usually engaged in extracurricular activities or high achievers in a traditional academic sense. Two teachers from schools with high racial diversity described that the student group, who consisted of both marginalized and nonmarginalized students, bonded over their participation in the program and sat together over lunch, mixing established social groups.

More than half of the middle and high school students had never been on a college campus or interacted with scientists before. Some of the LOCC students did not have a family member that went to college and who could serve as a role model for such. Both mentors and teachers agreed that pairing the middle and high school students with college student mentors and with undergraduates from the Inside the Greenhouse (ITG) class, as well as bringing them to the University of Colorado campus, were effective means of building students' interest in a college degree or science career.

> "We have noticed that three of the students have really picked up their efforts and have openly talked about going to college. What an amazing contribution ... for our students!" [teacher]

The connection between students and mentors emerged as an important theme in teacher, mentor, and undergraduate student reflections. As described by the teachers, students were excited to engage with real scientists through the program. These interactions with the mentors provided them with insight into college life and graduate school.

The majority of the ITG undergraduate students enjoyed their participation in the program and described the connection with middle and high school students during the screening day as the program highlight. ITG students also enjoyed the creativity of the process in which a simple topic prompt provided a lot of freedom in the interpretation. Some, however, were uncomfortable with the vague assignment and wished for more guidance by the program team. A strong theme that emerged from analyzing our data was that the undergraduate students felt that they would have liked to have more contact with the middle and high school students.

Providing an avenue for science graduate students to engage in science outreach and scientific communication was one of the program goals. We asked the mentors, therefore, to reflect on their personal benefits. Themes that emerged from the mentor reflections, in the order they were most frequently mentioned, were that they saw many benefits to their personal professional development, such as the strengthening of their scientific communication skills and the improvement of mentoring skills. They gained science outreach experience, which some mentors identified as a possible future career direction or a meaningful addition to their work. They also learned how to support and guide students through a transformative experience.

The campus tour and the screening event were well received by all student groups, and the teachers felt the ambiance of the final event added to the students' feeling of accomplishment and importance. Back-to-back screening of the LOCC and the ITG videos was mostly perceived as very enjoyable by the audience based on the analysis of the participant reflections as well as anecdotal reports from people in the audience. The students noticed and were inspired by technical tricks that undergraduate students used in their videos like certain transitions or hooks. The middle and high school students explained that the screening helped them realize they had produced work at the same level as undergraduates, which boosted their confidence about being able to succeed at a college.

> "My students were really nervous when their video was played, sliding down in their chairs, but at the end of the screening event as they were waiting for the jury decision, the students felt confident that their video did well. One of the students said: Remember how you talked about a feeling of accomplishment when you complete a project. Now I know what you meant." [teacher]

The analysis of the reflection surveys brought up challenges and suggestions to improve the program. For example, teachers and mentors struggled with the time commitment that the program demanded and suggested a clear timeline and definition of milestones to decrease the stress during the final program phase. Mentors suggested other ways to improve the mentor preparation, such as offering an option for people who had never mentored to shadow experienced mentors, as well as having regular mentor meetings to discuss challenges. They also suggested offering more training on how to work with middle and high school students. For example, mentors did not know how to encourage participation from every student. Some mentors suggested assigning specific roles to students (e.g., filming, interviewing, editing) to increase personal accountability. While we attempted to pair each student team with a science and a video mentor, we were not able to assign a dedicated video mentor to each of the groups. Therefore, some science mentors supported their teams in the video production and felt that additional training in filming and editing would have been helpful. The video production process, especially the editing, was time-consuming. Both teachers and mentors reported that most groups underestimated the time necessary for the editing process and felt rushed in video production as a result. Teachers and mentors both suggested changes to the jury process. Ideally, videos should be judged by a jury prior to the screening, and the audience would only award a "People's Choice Award."

Discussion

Video production engages students who might not be academically motivated or high achieving by traditional measures (Vickery 2014). Our program results support this published work around student engagement. Students who usually do not engage in academic challenges or afterschool clubs were eager to participate in the video production. Part of the appeal might be that students see peers as their target audience instead of their teachers, creating a powerful draw (Kearney and Schuck 2005; Lange and Ito 2010). Teachers were surprised at the level of dedication that some students who usually are less engaged in school activities showed for the LOCC program. In addition, some of the academically struggling students were able to contribute knowledge and skills they acquired through activities outside of school, such as technology or artistic skills. Thus, these marginalized students played an important role and received unusual peer recognition. The participating students were eager to share their videos on social media platforms with peers and the Web community in addition to the official screenings.

The impact and efficacy of place-based learning has been studied extensively (Sobel 2004; Semken and Freeman 2008; Schweitzer, Davis, and Thompson. 2013). Our program showed that students received a new and extended perspective on locally relevant impacts of climate change. Through the program students learned that climate change is impacting their communities, making it more important to take responsibility in mitigation efforts.

An important component of outlining the video and identifying where students' content understanding is fragmented is the process of developing a script or storyboard (Greenwood 2003; France and Wakefield 2011). Brainstorming connections and feedback effects developed systems thinking skills in the students and identified the relevant components of their video topic. For example, the students who featured drought summarized both the science behind the topic and the implications for the local agriculture. The process of storyboarding was an important reflective process that allowed students to present a complete storyline in their videos.

The near-peer mentoring (Murphey 1998; DuBois *et al.* 2002; Evans and Cuffe 2009) through graduate and undergraduate students was a key element of the program. Near-peer mentors tend to develop a mutual relationship where both sides give and receive support, which might have a high potential for lasting relationships. Through the near-peer mentoring interactions, the college student mentors reflect back on their experiences in middle and high school ("*prolepsis,*" Stone and Wertsch 1984; Cole 1996); through this reflection process, mentors can image a possible pathway for the mentees and provide guidance, both in program completion and also for career goals. Both mentors and mentees reported that their relationship included some of these aspects.

Learning how to be a good mentor is important for science graduate students (Andrews *et al.* 2005). In the program design the teachers were asked to manage scheduling, logistics, and discipline, while the mentors were in charge of the content work. This teacher-supported environment allowed the mentors to grow and develop their mentoring skills and to practice the facilitator role, skills that are often difficult to develop as graduate students.

Strengthening twenty-first century skills is mandated in the existing educational frameworks. Producing videos built or strengthened such skills in the LOCC students. However, students did not just learn practical skills like filming, recording, and editing; they also learned soft skills like the development of interview protocols, communication with professionals, interview techniques, and how to be a good listener. Student learning around professional engagement and interviewing experts was a unique opportunity that is not provided in regular school settings. Students also learned how to research scientific topics and copyright rules both for scientific work and for music used in the videos. Most importantly, the students needed to organize their ideas, provide feedback internally, and each student needed to find their role in the process. They all worked together and developed intergroup cooperation strategies. All these life skills contributed to an important learning process beyond the gain in content knowledge.

Implementing the LOCC Model

Student-produced videos can be incorporated as an engaging assessment or capstone project in both secondary and postsecondary classes even without additional resources. Students can use either electronic or cell phone cameras to shoot footage or record audio. B-roll images can be found online or in archives. Mentors and/or content experts for interviews can be recruited by students for an additional challenge that will build their networking skills, or teachers can reach out to their local community resources. Interviews can be conducted in person or via Skype at little or no expense. Video editing software is available for free online. Partnering between a video or technology class and a science class can help broaden the expertise that students bring to the production. Students could also reach out to scientists or community members for mentoring. Recruitment of mentors by each student group can be an additional challenge that builds students' networking skills. Film screenings can be either done during school assemblies or as part of a final class event. Students may also submit their videos to one of the many student video contests that are offered regionally and nationally.

We find that student-generated videos are powerful learning tools. In the LOCC program, sixty-four students representing a wide range of ethnic and economic groups and geographic locations from eight Colorado middle and high schools produced short videos about local impacts of climate change. Over six months, student video teams worked with their science graduate student mentors and technical experts. Student groups tackled locally relevant topics and through a self-directed, project-based learning approach of producing a documentary video about climate change, they developed in-depth knowledge about a science topic of their choice. The fact that students worked on locally relevant topics expanded students' understanding of their physical environment and made them into experts on a topic they engaged in with their peers and family. In addition to the authentic science learning, students developed many other skills like teamwork and self-directed, goal-oriented work that straddled technology, artistic, and professional interaction. The video production appealed to a diverse group of students and engaged traditionally marginalized students in a project that received considerable peer recognition and attention. Pairing the middle and high school students with graduate and undergraduate mentors built on the strength of near-peer mentoring and exposed secondary students to potential role models. Middle and high school students' exposure to college life was also achieved through the mentor-mentee interactions, partnering with an undergraduate class, interviews of scientists, visitation day on a college campus, and the screening event. In summary, teachers and mentors reported LOCC was a transformational experience.

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Note

1. Student videos may be viewed at http://cires.colorado.edu/education/outreach/LOCC/(accessed February 26, 2015).

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