Engaging students through online video homework assignments: A case study in a large-enrollment ecology and evolution course

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Abstract

Online educational videos have the potential to enhance undergraduate biology learning, for example by showcasing contemporary scientific research and providing content coverage. Here, we describe the integration of nine videos into a large-enrollment introductory evolution and ecology course via weekly homework assignments. We predicted that videos that feature research stories from contemporary scientists could reinforce topics introduced in lecture and provide students with novel insights into the nature of scientific research. Using qualitative analysis of open-ended written feedback from the students on each video assigned throughout the term (n=133-229 responses per video), we identified ten common themes in student perspectives. On the whole, the video homework assignments received more positive than negative comments and all videos received comments suggesting that they were engaging and contributed to learning goals. We discuss opportunities and challenges for the use of online educational videos in teaching ecology and evolution, and we provide guidelines instructors can use to integrate them into their courses.

Introduction

Video has been used in education for decades, and there are expanding audiovisual resources for higher education (Moussiades 2017; Brame 2016; Duffy 2008; Betrancourt 2018). These resources have become essential during the COVID-19 pandemic, as educators worldwide are forced to move their courses online with little preparation. In particular, free online videos - such as those on YouTube, or from online education platforms such as *iBiology* or *HHMI BioInteractive* - provide biology educators with a wealth of curated educational content that is easy to share with their students remotely.

Unlike lecture capture, online videos from external resources can provide unique perspectives on topics and concepts, and they can also showcase broad representations of scientists and their research (Schinske 2016). In addition, videos are amenable to a flipped approach, which frees up valuable synchronous class time for discussion and feedback between educators and students (Gross et al. 2015; Herreid & Schiller 2013; Bishop & Verleger 2013; Sletten 2017). The use of online videos in STEM higher education has been described previously (Dupuis 2013; Cox 2011; Barry 2015; Rajan & Veguilla 2018; Schinske 2016) and at least one study reports an association between online videos and higher exam scores, particularly for students with lower grade point averages (Dupuis 2013). To our knowledge, the use of online videos for teaching undergraduate ecology and evolution has not been reported, nor has this use been evaluated at any level.

Many educators forced online by the COVID-19 pandemic are unable to create their own videos for remote teaching. Now more than ever, educators are likely searching for existing content (e.g., on YouTube) to share with their students online. It is important that educators identify quality video content that can support their student learning goals and which students will find engaging. In this case study, we report the use of nine free online educational videos for teaching concepts and competencies in evolution and ecology in a large-enrollment introductory biology course. The videos were integrated into the curriculum via weekly homework assignments in a traditional (in-person) course. We collected student feedback on each video and performed a qualitative analysis to identify the strengths and opportunities of this approach. We share the results of our case study, and provide guidance for the use of online videos in teaching evolution and ecology remotely.

Materials & Methods

Course Overview

This study was performed in one section of a large-enrollment (1,300 students per quarter) gateway majors introductory biology course focused on evolutionary and ecological concepts at a large research university in the western United States. The course is the first in the introductory series and is a prerequisite for a large number of upper division courses in a wide variety of STEM majors. Enrollment is split across 2-3 sections, ranging in size from 200-500 students. The course consists of the following weekly meetings: three 50-minute lectures (full enrollment), one 50-minute 'discussion' (full enrollment, often treated as a fourth lecture), and one 180-minute laboratory (24 students per lab section). The campus is a Research-1 land-grant Hispanic-serving institution of over 30,000 undergraduate students and structures its academic year into three 10-week sessions. The course covers introductory content in evolution and ecology, including concepts relating to species interactions, functional diversity, population genetics, and natural selection, as well as skill-based content such as hypothesis testing and data interpretation. It meets the campus literacy requirements for instruction in visual literacy, scientific literacy, and quantitative literacy.

The course learning objectives (CLOs) are:

1. Explain what climate is, what causes it, how it is changing, and how it influences the distribution and abundance of organisms.
2. Explain what biodiversity is and describe how it is measured.
3. Predict how human activities such as overharvesting, habitat destruction, and pollution will affect the diversity and composition of ecological communities and the evolutionary trajectory of species.
4. Describe the concept of a tradeoff and give examples, explaining how specific tradeoffs relate to the maintenance of species diversity in nature.
5. Use the fundamental principles of inheritance to explain the relationship between genotype and phenotype in parents and offspring.
6. Distinguish the processes that lead to limited and unlimited population growth and give examples of factors that limit growth for natural populations.
7. Predict the direction, magnitude and outcomes of natural selection given a set of biological starting conditions.
8. Describe the contributions that different forms of natural and other forms of selection and genetic drift make to evolutionary change.
9. Use data from population genetics, natural selection, biogeography, and phylogenetics to explain how new species arise.
10. Explain how competition, predation and mutualism each influence the distribution and abundance of species over time and space.
11. Develop a conceptual framework for global carbon cycling that integrates photosynthesis, primary production, herbivory, decomposition, and the burning of fossil fuels.
12. Interpret graphs and data to evaluate scientific hypotheses, models and theory for any of the content-based objectives above (1-11).

Historically, the discussion sessions have been treated as an additional lecture and do not differ from the structure and style of the formal lecture sessions. They include the full course enrollment and so are not a true discussion format (e.g. as described in White & Kolber 1978). The lead author (LMG) joined the course instructional team in the fall of 2017 and has taught the course 6 times to over 1,800 students. In

2018, LMG instituted a course redesign in which the discussion sessions transitioned into flipped case-studies of campus faculty research relevant to the course. The goals of the redesigned discussion sessions were to 1) practice the scientific method (predicting/interpreting results, accepting/rejecting hypotheses, etc); 2) introduce students to current scientists and active research programs relevant to course content, with a focus on diverse representation*; and 3) illustrate to students the 'cutting edge' of research. The redesigned discussion sessions include weekly homework assignments intended to introduce students to how scientists study the topic to be discussed that week. The homework assignments also serve to restructure point values for the course to include more low-stakes formative assessments, which has been shown to reduce or remove achievement gaps in introductory biology courses (Eddy & Hogan 2014; Haak et al. 2011).

**Both the video homeworks described in this case study and the discussion session activities highlighted individual scientists' research programs. The discussion session activities were structured around campus researchers whose work related to course content. Diverse representation was more pronounced in the discussion activity scientist profiles than in the video homework speakers.*

Structure and Goals of the Homework Assignments

The weekly homework assignments acted as a precursor to the weekly discussion activity. Homework assignments were intended to prepare students for the discussion activities by reinforcing concepts covered in class, linking course topics together, refreshing foundational concepts covered in previous biology courses and/or illustrating research applications of course topics. While the video homeworks and in-class discussion activities focused on different scientists and different research programs, they highlighted research on the same general topic (ex: trade offs). Prior to the term included in this study, the homework assignments consisted of multiple choice quizzes on course topics but did not include online video.

In the fall 2019 term, students enrolled in the course (n = 356) were given weekly homework assignments consisting of viewing one or two online educational videos and responding to 7-8 multiple choice questions relating to the video(s), which were accessed through the course management system. **Table 1** summarizes the demographics of students enrolled in the course while **Table 2** summarizes the online videos used in the homework assignments. Videos were selected from three common open-access sources for biology education: iBiology, HHMI BioInteractive, and Bozeman Science. Because this was the first term in which online video was incorporated into the weekly homework assignments for the course, we sought to understand the student perspective on the use of videos for learning ecology and evolution. To that end, open-ended student feedback on the homework assignments was gathered in two ways:

- Each homework assignment included the following voluntary, ungraded, open-ended question: *In the space below, please provide any feedback you have on the video [title]. The more specific you can be in your comments, the more helpful they will be for us. While your answer is not anonymous, I value your honest feedback and both I and the creators of the videos will use your comments to improve the quality of educational videos produced and their integration into courses like [name of course].*
- The anonymous end-of-quarter course evaluations included the following voluntary, open-ended question: *The video homework assignments were a new component of the course this quarter. Please comment on your opinion of these assignments (whether positive or negative), being as specific as possible.*

Description of coding methods

Student comments on individual videos were coded in two ways, by a single coder (LMG): 1) Overall Attitude: neutral, positive, negative (a comment could be categorized as positive and negative if it included statements of both types), or irrelevant (containing comments not pertaining to the assignment or video); and 2) Specific Comments: including specific types of positive, negative, or neutral statements. A comment receiving a code of 'positive' in the Overall Attitude was then also coded with at least one specific positive code. Similarly, a 'negative' Overall Attitude comment was coded to at least one specific negative code. A comment that was marked as both positive and negative overall received at least one specific negative code and at least one specific positive code. Comments were marked as neutral if they included statements such as "It was ok" or

"The video was fine" without any clarifying detail. Neutral specific comments largely corresponded to how students used the video. These comments related to the speed at which the video was watched, how many times the video was watched, whether a transcript or captions were utilized, etc. While these comments were often associated with positive or negative statements (ex. "It was really confusing, I wouldn't have understood all the jargon without the captions.") they are not themselves positive or negative and so were coded separately. **Table 3** summarizes the coding schema for evaluation of student comments.

Student comments on the video homework structure were also solicited on the anonymous end-of-quarter course evaluations. These comments were coded in a similar manner as the individual video comments, including both an Overall Attitude code and specific positive, negative, and neutral codes. Since the nature of the comments differed, the specific comment codes also differed, though many were similar to those for the individual video comments (**Table 3**).

IRB/Campus review statement

This case study was determined to be exempt from the UC Davis Institutional Review Board review process based on U.S. Department of Health and Human Services guidelines. It falls under the Quality Assurance/Quality Improvement activities exception as it pertains to assessing or improving a program (in the case, the course) and is not experimental in nature. Additionally, the manuscript was reviewed by representatives of the following campus offices to ensure compliance with student data and privacy guidelines: Center for Educational Effectiveness, Office of Information and Educational Technology, and the University Registrar (the campus FERPA officer).

Results

Student Feedback on Individual Homework Assignments

Open-ended feedback on the homework assignments was voluntary and solicited anywhere from 133-229 individual responses representing 37-64% of the enrolled students (**Table 4**). All videos received more positive than negative comments (**Fig 1a**). In general, the proportion of negative comments was higher for lecture-style videos (such as those from iBiology and Bozeman Science) than for documentary-style videos (such as those from HHMI BioInteractive) (**Fig 1a**). The number of comments varied widely between videos and generally declined throughout the quarter (**Fig 1b**).

Common Patterns in Student Responses

Across all homework assignments, the 10 most common response categories included nine positive categories and one negative category (**Fig 2**). Interestingly, the negative category related not to the videos themselves, but to the homework questions developed in association with the videos. This category's appearance in the top 10 was primarily driven by Homework 3, which accounted for nearly 60% of the comments in this category. Four of the top 10 categories were general positive statements describing the student's response to the video overall (clear, interesting, enjoyable, etc). The rest included positive comments about the speaker as an individual, students' enjoyment of the study organism or system discussed, and the figures and graphics presented.

Usage Patterns

With the exception of the first video, comments on usage patterns were uncommon. Of the usage comments, the most common were that students watched the video multiple times and at faster than 1x speed. With the exception of the first video, few technical issues with accessing videos and homework were reported (**Fig 3**).

Video Length

Individual videos varied in length from 8:24 minutes to 36:12 minutes and averaged approximately 18:02 minutes. Two homework assignments incorporated multiple videos, so the average watch time per homework assignment was approximately 23:11 minutes. Across all homeworks, 9.2% of student comments mentioned video length (n=113). Of these comments, 61.9% found the videos too long and the remaining 38.1% found the videos of appropriate length. No homework assignment received zero comments on video length. We observed that the homework assignment with the longest watch time received 46 negative comments and no positive comments on length, while the homework assignment with the shortest watch time received 18 positive comments and no negative comments on length (**Fig 4**). Interestingly, the two homeworks with the longest watch times (Homework 4, 36:12; and Homework 7, 35:23) received markedly different comments regarding length. Homework 4 received the most negative comments on length of any video (n=46), as would be predicted by its longest watch time; however, Homework 7, which was only 49 seconds shorter, received not only far fewer negative comments on length (n=2), but also some positive comments (n=5).

Feedback on Homework Questions

All videos received both positive and negative comments on the associated homework questions, with the exception of "Finding *Tiktaalik* " which received only positive comments. The frequency of comments related to homework questions varied little across videos and were generally uncommon (4-11 positive and negative comments per video), with the exception of Homework 3, specifically in regards to mathematical questions relating to Hardy-Weinberg Equilibrium (**Fig 5**).

Feedback Related to Assignment Goals

All videos received comments suggesting that students engaged with them academically, including connecting video content to course content, real-world events, or the process of science, or advancing their understanding of course material (**Fig 6a**). The balance between these categories varied widely across videos. Student emotional engagement and interest (**Fig 6b**) also varied widely across videos and was generally, though not always, correlated with reports of academic engagement.

Student Feedback From End-of-Quarter Evaluations

Approximately 60% of the anonymous comments from the end-of-quarter evaluations were positive (**Fig 7**). The 10 most common categories included 6 positive and 4 negative categories. Interestingly, common positive and negative categories were often opposing perspectives. For instance "Interesting", "Engaging", and "Boring" were all in the top 10. Similarly, "Links to Course Content" was the most common student response, but "Not Relevant to Class" was tied for 10th.

Discussion

Does Length Matter?

Previous research has suggested that optimal video length for online activities should fall in the 6-9 minute range (Risko et al 2012; Guo et al 2014). Only one of the videos selected for this class was this short and the longest video was four times this recommended length. Comments on length tended to be uncommon in the feedback on each individual video (**Fig 4**), but the comment that homework assignments generally were too lengthy and time consuming was in the top 10 response categories on the end-of-quarter feedback (**Fig 7**). It is possible that the end-of-quarter surveys are a more accurate reflection of student perception given their anonymity; however, even in this format, complaints about length appeared in less than 12% of comments (n = 29/243).

Homework 3 is an interesting case on this point. It included two videos that totalled nearly 19 minutes and which were rated lowest among all videos in terms of academic engagement (**Fig 6a**) and emotional engagement (**Fig 6b**) and for which the homework assignments received more than 5 times the number of complaints as any other homework. Yet this assignment received no negative, and two positive, comments about length (**Fig 4**). Both of the homework assignments that included two videos received fewer complaints about length than their total run time would predict compared to other videos (**Fig 4**), suggesting that multiple short videos were more palatable to students than one video of the same total length.

Homework 4 is also an interesting case. This was the longest video assigned, and was also rather advanced in terms of content and terminology. This video received the most negative comments about length, but was on par with or lower than other videos for other negative comments. Additionally, this video was the second highest rated in terms of positive comments on the presenter and tied for third-highest taxon of interest. Consequently, even a long lecture-style video on a complex topic can be interesting to students if paired with an engaging speaker and a charismatic organism.

Writing Good(?) Questions Around Videos

Including questions with videos is recommended in order to shift videos away from a passive and toward an active learning experience (Brame 2016). Questions associated with the homework assignments were focused primarily around the process of science and linking concepts discussed in the video with other course topics. Common question styles included interpretation of a data figure shown in the video (or found in related publications), evaluation of a hypothesis proposed in the researcher's study, explanation of an outcome reported in the study, and consideration of which related course topics were illustrated or applicable to the video content (though not explicitly stated in the video). Homework 3 received 5-15 times more negative comments about the homework questions than any other assignment (**Fig 5**). This homework assignment was the only one that required calculations and also went the furthest beyond just the content presented in the video, asking students to extrapolate the concepts in the video to a fictitious scenario without a worked example. Interestingly, this assignment received a similar number of *positive* comments about the homework questions as other assignments.

In an introductory course of over 300 students, preparedness and background knowledge on course concepts varies considerably between students. Homework 3 contained 7 questions which varied in difficulty and included two challenging questions to prepare students for possible exam questions. Just two challenging questions led to extreme student frustration with the assignment, which in retrospect, could have been alleviated by either explicitly framing the difficulty for the students before hand (see Importance of Framing section) and/or providing a small hint within the assignment to put students on the correct logical 'path.'

Student Access and Logistical Issues

With the exception of the first video, few comments reported technical issues with accessing the videos and associated homework questions (**Fig 3**). This likely reflects the learning curve on a new style of assignment, as well as the fact that the first video (unlike the others) only required the students to watch the second half, which was confusing for many students to know where to begin the video. All videos had captions and/or transcripts available, though several students requested captions on the first video, apparently unaware of how to access them. Consequently, the instructor showed the students in class how to access captions on YouTube videos and these responses were reduced in subsequent videos.

All videos received comments that students watched the video several times (**Fig 3**). These comments were most numerous in the videos deemed by students to be the most difficult (HW1, HW3 and HW4) and likely reflect students rewatching sections of the video that related to the homework questions. Use of captions and transcripts was also higher in these videos for presumably the same reason. Interestingly, a small number of students noted that they watched the videos from Homework 7 (Finding *Tiktaalik* and The Origin of Birds) multiple times for their own enjoyment and to share with friends or relatives.

Choosing Videos: What do students find most engaging?

Videos were initially chosen based on conceptual links to course material and illustration of the process of science (how scientists develop, test, and evaluate a hypothesis) (**Table 2**). One of the purposes of requesting feedback from students on each video was to gain an understanding of what components of the videos were most important to the students. Not surprisingly, students identified clarity of content, interest and engagement with the topic, and narration by a charismatic speaker as important traits for videos. These comments are consistent with evidence-based suggestions that videos should reduce cognitive load and promote student engagement for highest learning success (Brame 2016).

Interestingly, with one exception, all videos that focused on a particular taxon or habitat of study received positive comments specifically about the taxon or region. The exception was the Virus Adaptation video, which may not have been considered by students to be a 'taxon' of study. This effect was enhanced when the video focused heavily on the organism itself, including many photos or videos of the organism. It should be noted that the taxon effect could be reversed if the video highlights an organism commonly feared by students (ex: spiders).

Generally, students preferred documentary-style videos to lecture-style videos; however, even lecture-style videos received numerous positive responses when they featured a charismatic speaker (ex: Finding *Tiktaalik*) and when they related directly to current environmental issues (ex: Consequences of Amazon Deforestation). In addition to enjoying the 'feel' of documentary-style videos, students also responded positively to seeing the scientists 'at work' gathering data in the field and seeing organisms of study in the wild. These components could be incorporated into lecture-style videos via photographs or embedded videos of field work and study organisms.

The Great Elephant Census hit nearly all of these points - it is a short, documentary-style video, focusing on an extremely charismatic species, whose conservation importance is well-known to students. Additionally, this video illustrated the use of transect and quadrat sampling methods, which the students had recently used in their laboratory activity. Amusingly, several student comments seemed surprised that the methods they learned in lab were a real data-gathering technique. Consequently, this video was consistently highly rated across most of the positive categories.

The Importance of Framing

It is important for educators to promote student engagement with videos by clearly stating why the material was selected for a given course with the given students in mind (Brame 2016). As the instructor, LMG made a conscious effort to frame the homework assignments for the students throughout the quarter. Prior to students completing the first homework assignment, this framing included:

- Explaining the purpose of the video homework in terms of grading structure (low stakes formative assessments)
- Explaining the purpose of the video homework in terms of learning (supplementing flipped discussion sections, showcasing current research by current scientists)
- Explaining the purpose of the voluntary feedback question
- Explicitly encouraging honest feedback, and instructor openness to negative perspectives

Continued framing throughout the quarter included (italicized bullet points represent framing components that the instructor would, in the future, include prior to the first homework assignment):

- *Showing students how to access captions and transcripts for videos*
- *Encouraging students to look up unfamiliar terminology in their textbook or online*
- Encouraging honest feedback by showing anonymized student comments about videos to highlight different student perspectives on the assignment, explicitly including a variety of negative and positive comments and stating that both are useful for the instructor. As student feedback declined throughout the quarter, this strategy was repeated halfway through the course and student responses increased. This approach also served to normalize the experience for students who struggled with the material.
- Explicitly referencing video and homework content during lecture and discussion
- Continuing to clarify instructor perspective on the videos. For instance, the instructor considered Homework 4 to be the most difficult video and notified students ahead of time that they may need to allocate more time that week to the homework assignment.
- Responding to student frustration on difficult homeworks. Following Homework 3, the instructor provided a worked example of the difficult questions, included extra practice on this topic on the exam study guides, and reminded students that one purpose of homework assignments is to give students practice on difficult concepts when the gradepoint stakes are low, in order to better prepare them for high-stakes exams.
- Explicitly encouraging honest feedback on the end-of-quarter evaluations, including instructor openness to negative perspectives, and ensuring that students understood their responses were entirely

anonymous and not visible to the instructor until after final course grades were submitted to the registrar.

Additional Resources

Many undergraduate biology educators will continue remote teaching into the 2020-2021 academic year, and many will be searching for free online videos to supplement their course material. This case study was performed on video homework assignments as a component of a traditional in-person course. The importance of choosing engaging videos is even greater under scenarios of fully remote instruction, when the students' entire coursework is online. In addition to the resources described in this case study (*Bozeman Science*, *HHMI BioInteractive*, and *iBiology*), we recommend educators search for supplemental videos in other well-known resources including *Ted Ed*, *Kahn Academy*, *JOVE* and *Crash Course*. Although not described in this case study, it may be useful to make associated questions interactive by embedding them within videos (Brame 2016). There are several resources that allow educators to interpolate questions throughout videos, including *EdPuzzle*, *PlayPosit*, *Camtasia*, and *Nearpod*.

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Tables

Table 1. Demographic information of course.

Demographic	**Percent of class** (total enrollment = 356)
First Quarter Freshmen	41%
Females*	73%
First Generation (FG)	46.9%
Transfer	8.1%
Low Income (LI)	28.7%
Under-Represented Minority (URM)	28.7%
International	11.2%
English Language Learners	30.6%
Students Repeating the Course	3.7%
Academically Distressed	3.7%

* Students may decline to state their gender or may specify a non-binary gender. This row reflects a rounded percentage of female students.

Students in the College of Biosciences must transfer to institution with the introductory biology series already completed, which reduces the fraction of transfer students in this course

This row shows the number of students who were in some form of academic distress in the last quarter they were enrolled. Here academic distress means that the student was on probation, dismissed, subject to dismissal, or continuing probation.

Table 2. Summary of videos used in weekly homework assignments. * This video was assigned from 27:40-47:01; therefore, student viewing time was 19:21.

ˆ See full list of CLOs in Materials and Methods section.

Table 3. Coding schema for open-ended student feedback on video homework assignments. *Note* : Codes in bold were detected only in individual homework feedback. Codes in italics were detected only in end-of-quarter feedback.

Parent Code	**Child Code**
Usage	Transcript or Captions[1]
	Watched multiple times

	Altered Speed[2]
	Technical Issues
Positive Comments	General Positive[3]
	Explicit Statement of Learning
	Saw Link to Course Content
	Saw Link to Current Events or Issues
	Process of Science
	Length
	Speaker Specific
	Organism or Region of Study
	Style of Presentation, Graphics
	Homework assignment
	Good Practice or Preparation for Exams
	Appropriately Difficult
	General Assignment Structure
Negative Comments	General Negative[4]
	Length
	Too narrow, Not relevant to course content
	Homework assignment
	Speaker Specific
	Organism or Region of Study
	Style of presentation, Graphics
	General Assignment Structure

1. *Including used or desired transcripts or captions.*
2. *Including watching videos faster or slower.*
3. *Including specific phrases such as "liked," "loved," "good," "great," "informative," "educational," "interesting," "intriguing," "engaging," "enjoyable," "fun," "helpful," "useful," "clear," "easy to understand."*
4. *Including specific phrases such as "disliked," "hard to follow," "difficult to understand," "confusing," "unclear," "jargon," "terminology," "dense," "overwhelming," "boring," "dry."*

Table 4. Counts of student responses, per homework assignment.

Assignment	**Number of Responses**	**Percent of class** (total enrollment = 356)
Homework 1	229	64
Homework 2	182	51
Homework 3	174	49
Homework 4	162	46
Homework 5	205	58
Homework 6	133	37
Homework 7	138	39
End-of-quarter course evaluations	243	68

Figures

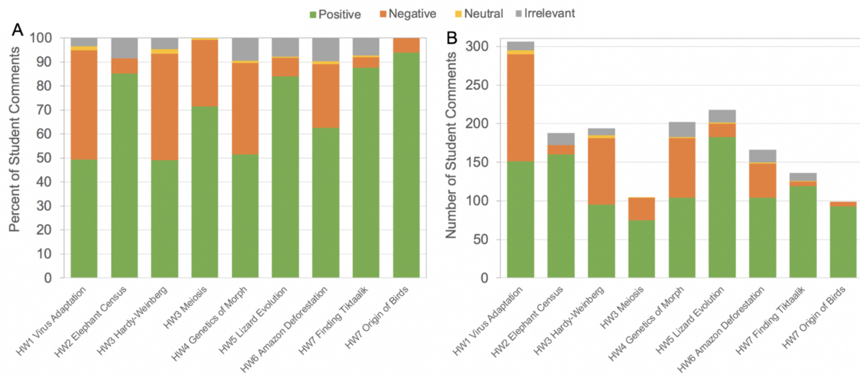

Figure 1: Student attitudes toward nine online educational videos represented by relative (A) and absolute (B) numbers of comment types for each video.

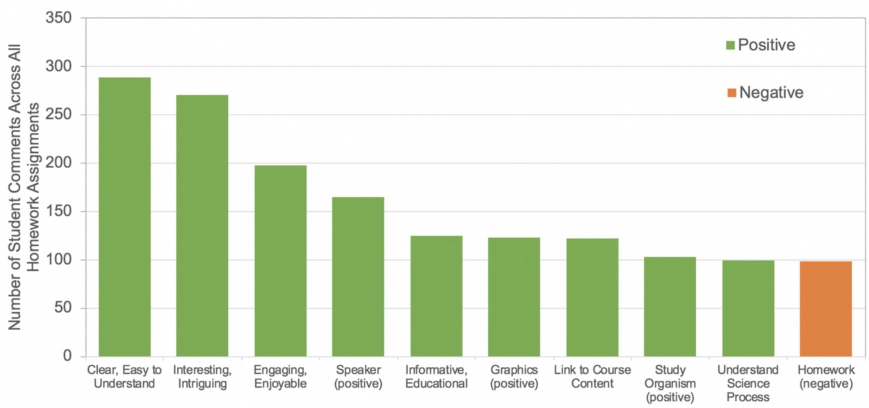

Figure 2: Top themes identified in student feedback on individual videos.

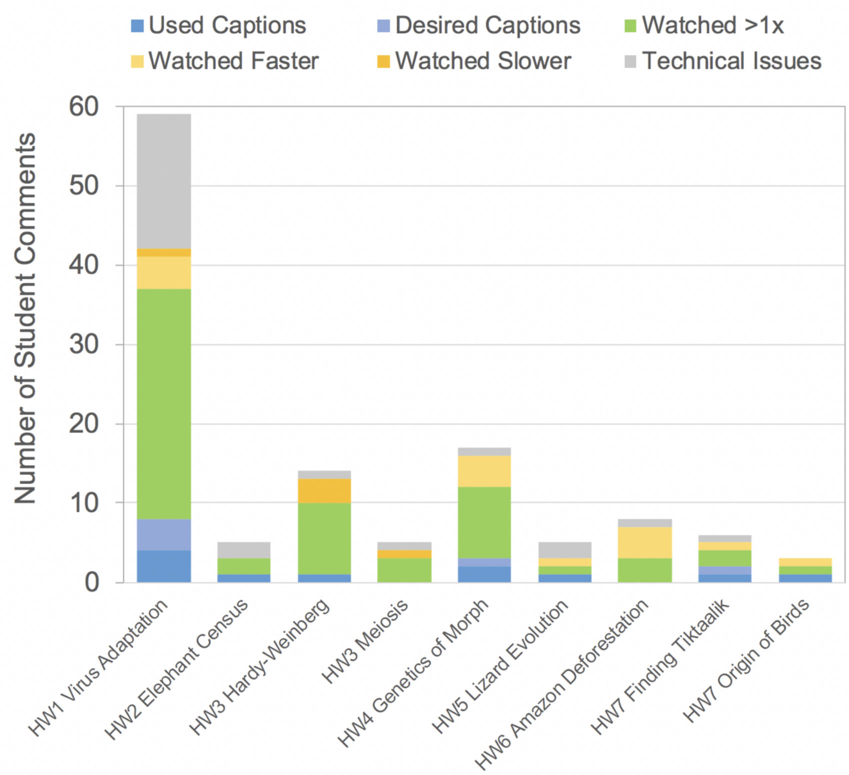

Figure 3: Usage patterns by video, as reported in student comments.

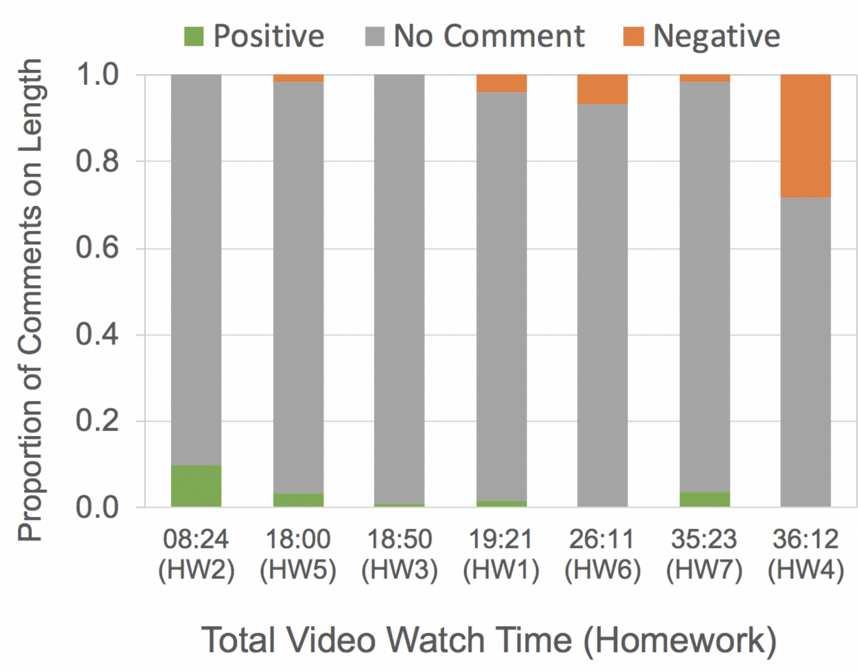

Figure 4: Summary of student comments on video length. Proportion of student comments from individual homework feedback that were positive (green), negative (orange), or did not comment (gray) on length.

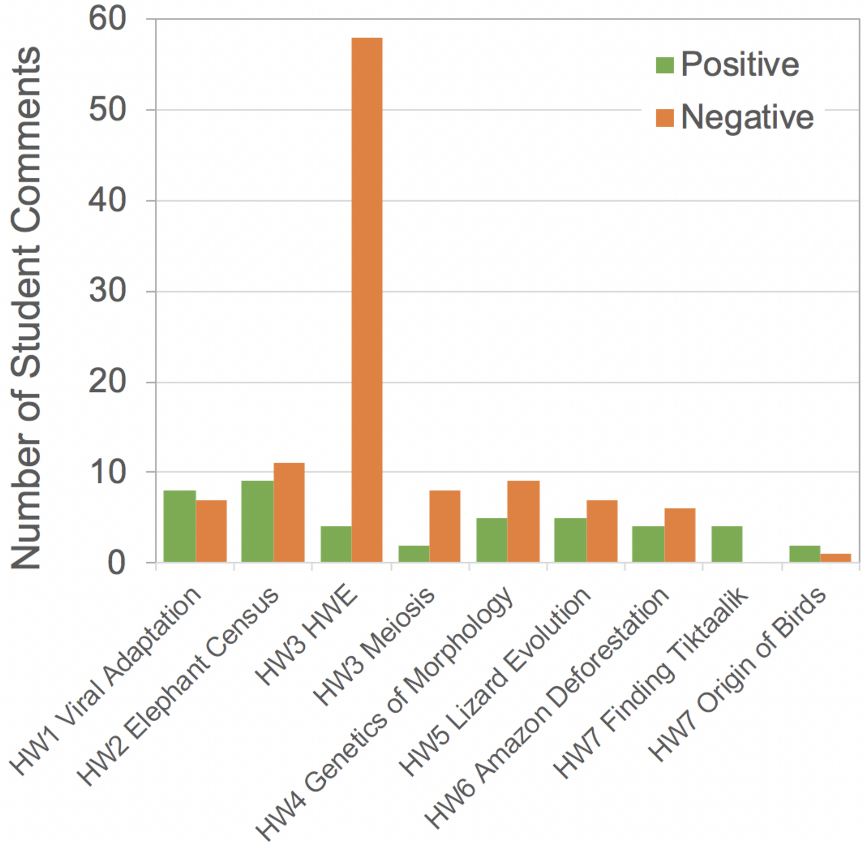

Figure 5: Number of positive (green) and negative (orange) comments about homework questions on each homework assignment.

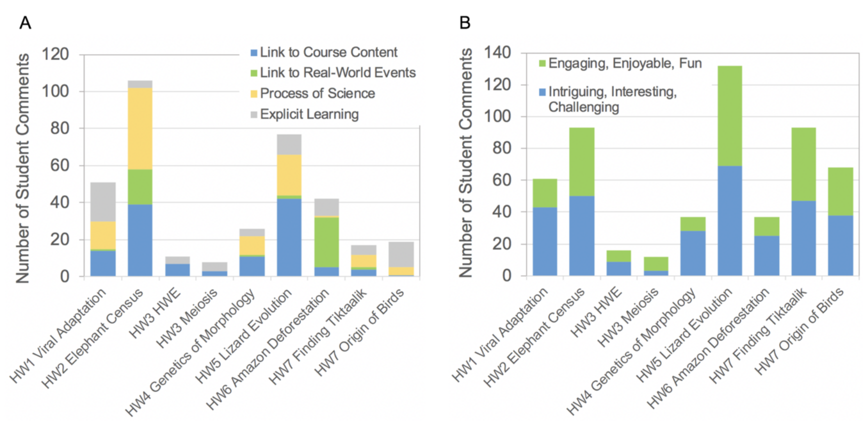

Figure 6: Summary of student comments relating to motivation and engagement. A) Academic engagement in terms of linking video content to course content (blue), real-world events (green), or the process of science (yellow), or explicitly stating that the video contributed to students' understanding of course content (gray). B) Emotional engagement in terms of finding the video interesting, intriguing, or challenging (blue); and engaging, enjoyable, or fun (green).

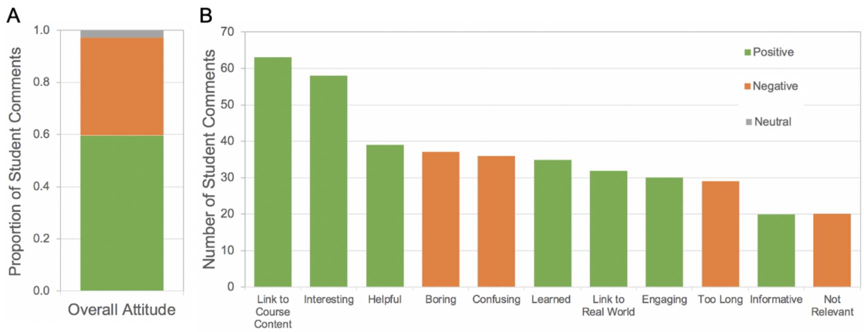

Figure 7: Summary of end-of-quarter student feedback on video homework assignments overall. A) Proportion of student comments that were positive, negative, or neutral. B) Frequency of top themes identified in end-of-quarter feedback.

Data Accessibility Statement

To ensure FERPA (Family Educational Rights and Privacy Act) compliance, the authors will share only aggregated, deidentified data upon request.

Competing Interests Statement

Brittany N. Anderton is an employee of iBiology, a non-profit, open access science education organization.

Author Contributions

Laci M. Gerhart: Conceptualization (equal); Data Curation; Formal Analysis; Investigation; Methodology (lead); Project Administration; Supervision (lead); Visualization (lead); Writing - original draft preparation (equal). Brittany N. Anderton: Conceptualization (equal); Funding Acquisition; Methodology (supporting); Supervision (supporting); Visualization (supporting); Writing - original draft preparation (equal).

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