Developing Educational YouTube Videos as a Tool to Learn and Teach Physics

Cite as: Phys. Teach. **58**, 488 (2020); https://doi.org/10.1119/10.0002068
Published Online: 23 September 2020

Andrés Aragoneses, and Rebecca Messer

Developing Educational YouTube Videos as a Tool to Learn and Teach Physics

Andrés Aragoneses, Eastern Washington University, Cheney, WA, and Carleton College, Northfield, MN
Rebecca Messer, Northfield High School, Northfield, MN

Introductory physics courses can be a challenge for some college students, especially those that have not taken Advanced Placement (AP) physics courses in high school. Even some classical mechanics concepts, such as energy, power, or the laws of Newton, can be non-intuitive and hard to grasp. When it comes to evaluating the learning outcome of our students, some of the aspects we evaluate are their abilities to solve numerical problems. By solving problems the students show how well they understood the concepts and the problem-solving methods. But students can practice enough and learn how to solve related numerical exercises without a deep understanding of the physical concepts. When asked more conceptual questions, some students struggle and lack confidence.

One educational tool that has shown to be efficient in teaching abstract concepts is the so-called learning by teaching,[1,2] where students need to present and teach peers or younger students the concepts they have been studying. This methodology also helps students develop communication skills[3] so necessary in any science-related job, be it by writing scientific papers, presenting results at a conference, or presenting projects to a company.

Also, current technology provides many tools that help convey abstract concepts. One of these tools is short videos, which are becoming more and more popular in social networks such as YouTube, where it is easy to find YouTubers who generate interesting content to teach and disseminate physics.[4-6]

Some physics instructors already have their students create short videos, either to present their homework, or to present their laboratory results, or to present research projects.[7-10] The content of these videos is graded either by the instructor or by their peers, but the videos are not widely viewed outside the college environment.

In this paper we present the results of a project where students from an introductory physics course (most of them first-year college students) develop and create a short YouTube video explaining a particular concept in physics, and then they present the video to junior and senior students from the local high school. The goal of the project is to improve the learning of classical mechanics and special relativity among first-year college students, while developing their team and communication skills, but also to help high school students learn physics, offering them an alternative approach.

Because current students are very familiar and actively engaged in social media platforms, such as Facebook, Instagram, Twitter, or YouTube, the concepts are presented in short videos (less than five minutes) that are uploaded to YouTube, so they are freely accessible at any time.

In order to make this project successful, coordination is required between the college instructor and the high school teacher. Even though, from our experience, high school teachers are very open to this kind of collaboration, this might require more or less effort depending on the institution and the geographic area where it is located. But most universities and colleges have an office for community and civic engagement (CCE) that works to make these connections between the institution and the larger community possible. To overcome possible coordination issues, we highly recommend to locate and use the expertise of this office.

In the project we present here, one of the authors, aware of the interest in teaching innovation of the other author, reached out to start conversations towards a collaboration. The intervention of the CCE office helped to work out coordination and transportation aspects. Having previous satisfactory experience in another institution with a different project involving college and high school collaborations[3] encouraged starting this one.

Creating a YouTube video as an assignment

The students that developed the educational videos were from two different years of the same introductory physics course (Introductory Physics: Newtonian Mechanics and Special Relativity) with the same instructor. More than 90% of the students were first-year college students. Of both sets of students, about half of them had not taken AP Physics in high school. As for the high school students, at the moment of their participation in the project they had already covered classical mechanics and had been introduced to some qualitative special relativity.

The video was one of the graded assignments of the course, with a weight of 15% of the total grade of the course. Grading of the video was focused on the physics, but also on the efficiency and clarity of the presentation of the physics in the video. Previous to the design of their video, an expert from our college's Information Technology Services (ITS) came for 30 minutes to the classroom to give advice and explain the main aspects of a good educational video and how to generate one. Most universities and colleges have ITS but, in case that service is not available, there are many videos online[11-13] that give basic suggestions on how to do a decent short video, and how to avoid basic mistakes. Also, some practical suggestions to make homemade YouTube videos in the classroom can be found in Abbott et al.[10] Coates et al.[14] also describe in detail a course where they introduce students to film-making. For our project, students were offered to use the digital cameras available from ITS, but some decided to use their own smartphones (some tips on how to use a smartphone to create a good short video can be found in Refs. 10 and 13).

The teams were formed of two or three students, so they needed to discuss as a group what physics concept they wanted to present, but also how they wanted to present it, and what is the most efficient, clear, and appealing way of presenting

 DOI: 10.1119/10.0002068

1. Duration (5pts)
- ☐ 3-5 minutes

2. Video content (20pts)
- ☐ Self-introduction. 1-2 sentences [10-15 secs.]
- ☐ Provide general preview of the topic/desired learning outcome [15-20 secs.]
- ☐ Deliver your lesson [2-4min.]
- ☐ Review/summarize your lesson. Provide direction for student application of lesson.

3. Pre and post-production (20pts)
- ☐ Script.
- ☐ Framing, color & luminosity.
- ☐ Vocal delivery & audio levels.
- ☐ Titles.

4. Physics (55pts)
- ☐ The statement of the problem to solve and the concept to explain is clear.
- ☐ The images used help understand the physics.
- ☐ The equations used are the correct ones.
- ☐ The graphs/plots are meaningful, complete and labeled.
- ☐ Numbers are correct and with proper units.
- ☐ The equations used are well explained.
- ☐ The numerical problem is clearly explained.
- ☐ The solution to the numerical problem is correct.
- ☐ The explanation of the concept is clear and rigorous.
- ☐ The explanation is self-sustained. The audience does not need additional knowledge to follow the video.
- ☐ The explanation is addressed to the target audience.

Fig. 1. Rubric used to evaluate the YouTube videos created by the students.

Table I. Sample questions that were asked to the high school students before and after watching the video. Each video had two associated questions.

	Before		After	
	True	False	True	False
In parabolic motion, if you double the initial velocity, would the object reach twice as far?				
An object following parabolic motion on the Moon would reach six times further than on Earth (gravity on Earth is six times that on the Moon).				
If we drop a bottle filled with water and the same bottle filled with iron marbles from a certain height, both would fall at the same rate.				

it, keeping in mind the target audience. To design a self-contained video, we would argue that one must include the explanation of a particular concept and then an application with an example, in a manner as engaging as possible.

One of the two classes developed videos on Newtonian mechanics (kinematics, dynamics, energy, etc.) and the other class on special relativity (time dilation, length contraction, paradoxes, etc.). The videos generated are uploaded to YouTube and are collected at a website, Pills of Physics,[15] developed for the project.

As with any other assignment given to students, the creation of the video has its associated rubric (see Fig. 1). This helps the students to focus into the key aspects that are going to be relevant in their grade, which are also going to help them create a better video. The rubric was generated taking into account the physics learning goals and the key aspects of video-making emphasized during the ITS presentation in the classroom.

College students assess the impact of their videos on high school students

To assess the impact of their videos on the high school students, college students in the second run were asked to accompany them with some related questions for high schoolers to answer before and after they watch the videos. Because they had already covered the physics presented in the videos in their current physics course (AP or non-AP), their answers indicated to us how well they understood those concepts in their course lectures, and the effect that watching the videos had on their answers. There are two true/false questions in each video. Table I shows examples of some of the questions for the videos on classical mechanics.

The project was run with two sections of the same introductory physics course, in two consecutive years. The students in the first run created videos on special relativity and students in the second run created videos on classical mechanics. In this second run we wanted to get a more detailed feedback of the impact of the videos on the high school students, and, in addition to the videos, college students were asked to generate related questions for each of their videos.

College students visited the high school students in their regular lecture period. The videos were distributed at different stations throughout the classroom with one laptop each. Then each station showed repeatedly the same educational video to different groups of high school students. They were watched in small groups (three to four high school students) together with the college students that developed each video. High school students moved to the different stations to watch the different videos. As they got to a new station, high school students answered the true/false questions before watching the related video, then watched the video and answered the same questions again, without interacting with the college students. After that there was a discussion time where questions were clarified. Then they moved to a different station to watch another video on a different topic.

Discussion and conclusions

With this project we intend to have college students reflect on the role of teaching and how that can benefit their own learning. In the process of developing the video, they were required to solve a particular problem in physics, but also to explain it to a person with less background in physics than they have. This makes the students structure their ideas and find an efficient way to address them, using analogies and examples. This requires the additional effort to comprehend the abstract concepts they are presenting. They are also asked to show their draft video to friends and family before editing the final version. By doing this they realize which aspects are unclear to their audience, which could be because of the way they present their topic in some cases, but also because they did not have a clear idea of the physics in other cases.

Figure 2 shows the distribution of correct answers before and after watching the videos. We observe an improvement of the answers, suggesting that the videos, in general, did help clarify the physics. A closer look at the distribution of answers shows that most of the answers that were correct in the first

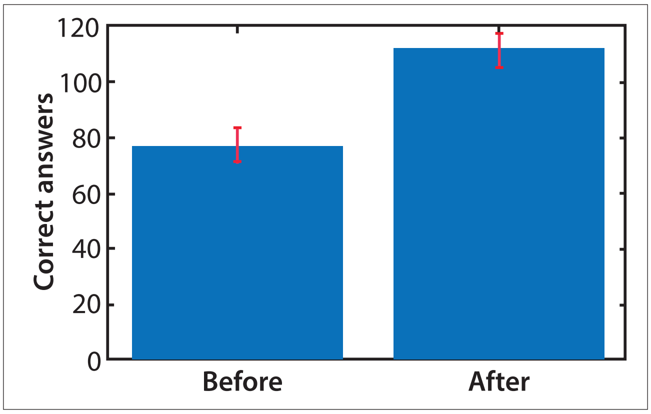

Fig. 2. Probabilities of correct answers before (56.2% out of 137) and after (81.5%) watching the videos. The error bars represent the confidence interval computed with a binomial test.[16]

round stay correct in the second round, and very few are changed to wrong answers. This indicates that the videos are not misleading, they do not introduce incorrect ideas to the students, and they help highlight those concepts that require more focusing or an improvement of the video (moment of inertia and Doppler effect in our case).

Overall, we observe an improvement in the answers from the high school students at the end of the project. We think this is positive and shows the beneficial impact we were anticipating. We are cautious though as, in part, this improvement could be influenced by the fact that they are going over concepts covered previously in class, and watching the video works as a reminder. In addition, there could be an effect on their answers caused by the fact that they answer the true/false questions right after watching the videos, when its message is still fresh in their minds. A more ambitious project will do a follow-up of their understanding after a gap time of more than one day between watching the videos and the second round of questions. Also, we will compare these students to a control group that spends the same amount of time just reviewing their own class notes instead of watching the videos. But what makes this approach different is that, on one hand, we offer the high school students a novel approach in an up-to-date format that is more attractive to them as it is YouTube, and, on the other hand, college students get to experience and reflect on the teaching of physics, and also to work in a more novel platform that is familiar and attractive to them.

On a side note, it is worth mentioning that this learning by teaching project that links high school with college can be easily extended to other age groups, in particular in the same institution, reducing the coordination issues that might arise when two institutions are involved (schedules, semester vs. trimester system, mobility of students, etc.). High school students could develop educational videos for middle school students, or senior students could do the same for sophomore students.

Acknowledgments

Andrés Aragoneses thanks the Center for Community and Civic Engagement (CCCE) from Carleton College for their support and help coordinating the activity with Northfield High School.

References

1. Stanley Frager and Carolyn Stern, "Learning by teaching," *Reading Teach.* **23** (5), 403–405 (1970).
2. David Duran and Keith Topping, *Learning by Teaching: Evidence-Based Strategies to Enhance Learning in the Classroom* (Routledge, 2017).
3. Andrés Aragoneses, Nuria Salán, and Antonio Hernández-Fernández, "Disclosure day on relativity: A science activity beyond the classroom," *World J. Educ. Technol. Curr. Issues* **9** (2), 59–66 (2017).
4. See minutephysics, YouTube, https://www.youtube.com/user/minutephysics.
5. See DrPhysicsA, YouTube, https://www.youtube.com/user/drphysicsa.
6. See Veritasium, YouTube, https://www.youtube.com/user/1veritasium.
7. Scott S. Douglas, John M. Aiken, Shih-Yin Lin, Edwin F. Greco, Emily Alicia-Muñoz, and Michael F. Schatz, "Peer assessment of student-produced mechanics lab report videos," *Phys. Rev. Phys. Educ. Res.* **13**, 020126 (2017).
8. Shih-Yin Lin, Scott S. Douglas, John M. Aiken, Chien-Lin Liu, Edwin F. Greco, Brian D. Thoms, Marcos D. Caballero, and Michael F. Schatz, "Peer evaluation of video lab reports in an introductory physics MOOC," arXiv, https://arxiv.org/pdf/1407.4714.pdf.
9. Shih-Yin Lin, John M. Aiken, Daniel T. Seaton, Scott S. Douglas, Edwin F. Greco, Brian D. Thoms, and Michael F. Schatz, "Exploring physics students' engagement with online instructional videos in an introductory mechanics course," *Phys. Rev. Phys. Educ. Res.* **13**, 020138 (2017).
10. David Abbott, Andrew Roberts, Dan MacIsaac, Kathleen Falconer, Florian Genz, Stefan Hoffmann, André Bresges, and Jeremias Weber, "Adding student video projects to physics courses," *Phys. Teach.* **57**, 224 (April 2019).
11. See Thing Media, YouTube, https://www.youtube.com/user/thinkmediatv.
12. "How to Make YouTube Videos on Your Phone (Beginners Tutorial)," YouTube, https://www.youtube.com/watch?v=am-7kaAerVCQ.
13. "How to Make A YouTube Video," YouTube, https://www.youtube.com/watch?v=Jb6YbvuhUgQ.
14. Rebecca L. Coates, Alvina Kuhai, Laurence Z. J. Turlej, Tom Rivlin, and Laura K. McKemmish, "Phys filmmakers: Teaching science students how to make YouTube-style videos," *Eur. J. Phys.* **39**, 015706 (2018).
15. Pills of Physics, https://aragonesesandres.wixsite.com/pillsof-physics.
16. John R. Taylor, *An Introduction to Error Analysis* (University Science Books, Sausalito, CA, 1992).

Department of Physics, Eastern Washington University, Cheney, WA 99004; aaragoneses@ewu.edu