

# Adding Student Video Projects to Physics Courses

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Physics students have traditionally prepared many kinds of reports—laboratory, activity, project, and even book or article reports. Smartphones and YouTube videos are familiar cultural objects to current students, and our students use smartphone cameras to include photographs of apparatus, phenomena, hand-sketched figures, graphs, and mathematical equations in their physics reports. Here we present basic techniques for physics students to use smartphones and tablets to create short (< 5 min) end-of-semester video projects. Our students mainly use Apple Computer’s iPad<sup>1</sup> tablets, but also other tablets and various smartphones. Finally we discuss appropriate instructor expectations and grading. Similar non-physics student video reporting efforts were reported using video cameras by Kearney,<sup>2</sup> and Hechter and Guy.<sup>3</sup>

## Introducing the limited draft or “proof of concept” video and storyboarding

In class we show physics content and physics learning videos at least weekly, usually from YouTube sources like Veritasium or MinutePhysics.<sup>4</sup> After we introduce the syllabus, video project discussion starts on the first day of classes, when we present an example video<sup>5</sup> and model brief comments. Rather than a polished production, we strongly constrain expectations to a rough draft “proof of concept” video for an audience of class peers, with the topic chosen from an instructor provided list.

The first part of project development is generating an

initial “storyboard” (Fig. 1), which frames the content and scope outcomes. Storyboarding involves creating and refining a comic book-like planned sequence of frames and “shots.” Such frames include introductions (intros) and extros, references, still shots, simple animated sequences, ordinary video, mathematical development, references, etc. Storyboarding templates and lessons are widely available.<sup>6</sup> Bresges<sup>7</sup> posits that student discourse analyzing the physics, and constructing, visualizing, and refining models leading to decisions regarding casting, staging, and continuity leading to a content-rich storyboard is where most of the physics content learning takes place.

We require students present their storyboard as part of their project. The approval process also allows the instructor to identify any safety and apparatus availability concerns, major issues with content-appropriate levels of scope, correctness, and completeness. For instance, we often have students enthusiastically propose to do the impossible, or impractical, and have to redirect their efforts.

## Simple physics whiteboard drawings and animations: “Scribbles”

Simple physics whiteboard animations are perhaps best seen in Henry Reich’s<sup>8</sup> MinutePhysics YouTube videos.

Reich writes equations and does simple sketch animations on a whiteboard, animated by using stop-motion photography, which we call “scribbles.” Others report these as student “slowmation,”<sup>9-11</sup> and instructor-generated<sup>12</sup> scribbles. Scribbles are easily made using simple applications like iMotion, <http://fingerlab.net/portfolio/imotion>, that support stop-motion video production frame by frame. There are iMotion tutorials for and by children on YouTube.

When making scribbles, we use masking tape to lightly fix a modeling physics whiteboard to a tabletop (to avoid accidental sliding), then mount the tablet parallel and above the whiteboard for video recording (Figs. 2-4). Commercial or homemade mounts are possible. Now animate your cartoons, free-body diagrams, calculations, and so forth by drawing one or two lines on the




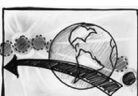

Scene	Shot	Animation	Actors & Objects	Dialogue
1 	<b>Long shot:</b> lecture hall, chalkboard, professor enters room		Professor	“On August 11th, 1999”
2 		<b>outer space:</b> Moon slides past Sun	Sun, Moon	“We observed a total solar eclipse here in Germany.”
3 	<b>Medium shot:</b> Professor puts on glasses		Professor, safety glasses	“Safely observing eclipses without danger to your eyes”
4 		<b>outer space:</b> Moon orbits Earth	Earth, Moon	“requires protective glasses that filter intense ultraviolet radiation.”
5 	<b>Overlay:</b> Animation over real shot, professor shows		Professor, Earth, Moon, Sun	“To better understand solar eclipses we will...”

Fig. 1. An unusually artistic and thorough solar eclipse storyboard by Manuel Wagener.

## Table I: Freshman Physics End-of-Semester “Proof of Concept” Video Project Guidelines.

In groups, students will prepare a three- to five-minute “proof of concept” rough draft video presenting and analyzing a physics phenomenon or idea from a list provided by the instructor, or on a topic negotiated with the instructor. Projects are presented in the last week of classes, and if students wish they may share them privately, semi-privately, or publically online. The grade breakdown follows:

**Proposal (10%)** – A single paragraph emailed to the instructor by week six of the semester. The instructor will negotiate and approve the proposal. Your proposal should include:

- ▶ your working title,
- ▶ the physics subject and scope,
- ▶ a list of team members,
- ▶ identification of possible safety issues,
- ▶ a list of materials, resources and/or access required, and
- ▶ a rough timeline/schedule for project activity.

**Storyboard and references (10%)** – A cartoon-like layout of the first draft of the video, due by week eight of the semester. Also a formatted bibliography of three relevant peer-reviewed physics publications and other appropriate references.

**Proof of concept video (40%)** – This proof of concept rough draft cut of the video is what you present in the last week of class. It must demonstrate multiple representations (ray diagrams, circuit diagrams, free-body diagrams, etc.) of a physics idea or phenomena including:

- ▶ live experimental footage (if possible),
- ▶ mathematics and sample calculations,
- ▶ a scribble (sketches and/or animated drawings original to you),
- ▶ verbal explanation (voiceover), and
- ▶ title, author, and references frames.

**Project paper (40%)** – Five-page double-spaced paper (one-inch margins and page numbers) due last week of class, which should include:

- ▶ abstract (5%)
- ▶ brief overview of the presentation (10%)
- ▶ edited transcript of the video (use text-to-speech, etc.) (5%)
- ▶ discussion of the proof of concept video physics and presentation strengths and weaknesses, and suggestions for creating a new, improved video (15%)
- ▶ conclusions and references (bibliography) (5%)

Note this project does not require or expect a commercial-quality final video – just a proof of concept video that could later guide shooting a higher-quality video. You are required to include a title page in your video with authors’ names, and encouraged (but not required) to include digital rights-free music, etc. You may not include any graphics or stills or music that are not your own product, and must acknowledge by URL any sites or videos that specifically inspired or guided your work.

While you are encouraged to use your own tablets and phones, the physics department also has iPads, headphones, and Snowball microphones that can be signed out or used in the lab room. Technical assistance will also be provided upon request to anyone who desires such, although asking as early as possible is suggested. This project should require roughly 20 hours of effort; ask for help if you get off that timetable.

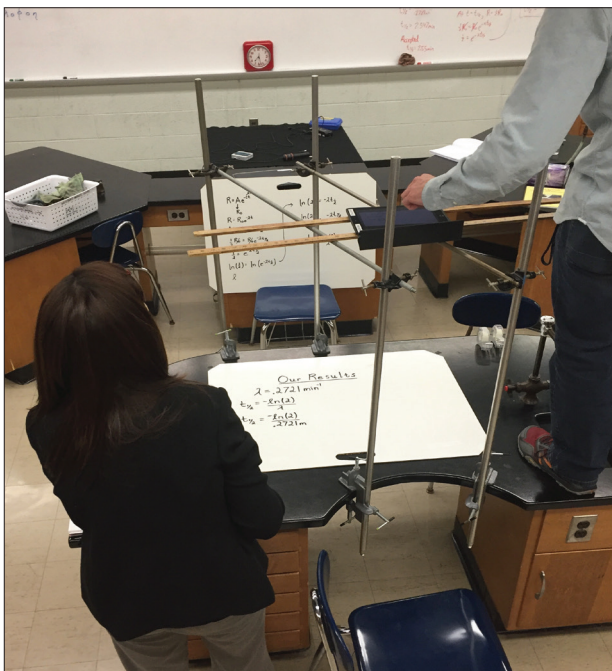


Fig. 2. Two students making an animated “scribble” of half-life calculations with an iPad using iMotion. Note they are working from an out-of-frame guide.

whiteboard, then leaning back out of the frame and either tapping loudly on the table (to acoustically trigger) or manually clicking on the tablet button to record a single frame. Then add a few more lines or characters to the whiteboard and repeat until your scribble sequence is complete. Adjusting playback speed is trivial. Simple animation of objects, paper cut-outs, or images can also be manipulated with or without your hands in view either one frame at a time as described above or by recording 1-10 frames per second and moving slowly—e.g., [tinyurl.com/CartDiver](http://tinyurl.com/CartDiver). We recommend working from a completed whiteboard placed in front of students out of sight of the camera (Fig. 2), and that content (especially math) be checked in advance by instructors. Scribbles may also be generated using software like ExplainEverything, from [explaineverything.com](http://explaineverything.com).

### Reproducibly shooting regular video clips and stills; editing and sound

Shooting non-scribble video clips and single images or “stills” also requires reproducibility and a steady hand—we suggest using an inexpensive commercial mount or improvising camera support (Fig. 3). Framing the picture in the same location with similar lighting is a real issue, and students will almost certainly reshoot and edit images from multiple sessions together. For continuity, the narrator, the human actor

Table II. iPad Tablet software and hardware for creating learner-generated physics videos\*

APP	DEVELOPER (DISTRIBUTION)	PRICE	DESCRIPTION
iMovie	Apple (iTunes store) <i>Often included with Apple Device.</i>	Free or \$4.99	Allows you to shoot, import, piece together, and export video clips with transitions, visual effects, sound effects, music, and voice recording.
iMotion	Fingerlab (iTunes store)	Free	Allows you to film video using stop-motion photography, customize the frame rate, and export the final product.
Video Physics	Vernier (iTunes store)	\$4.99	Allows you to import video, plot the positions of objects frame by frame, set a scale and origin, view the data, export it to Graphical Analysis, and export the video with the motion tracking effect.
Headphones (not really optional)	Sony MDRZX110AP ZX (Amazon)	\$20	Any inexpensive on/over-the-ear headphones (not earbuds) will suffice for mixing sound. We cannot accurately balance sound using iPad speakers alone.
External Microphone (Optional)	Apogee MiC 96k (Amazon)	\$229	Nice high-end desktop microphone.
	Rode smartLav+ Lavalier Mic (Amazon)	\$90	Lavalier mic allows for outside recording if desired.
Adjustable tablet arm / stand-optional	Hercules	\$50	Supports tablet in a wide variety of positions while clamped to table or desk edge.

\* current as of spring 2018



Fig. 3. Commercial, homebrew, and improvised iPad stands on a table for shooting both scribbles and live video.

or actors (“talent”) in the frame should be dressed in a reproducible fashion, e.g., white shirt and black pants, so if reshoots are required, continuity of appearance can be maintained. This continuity of dress often becomes a trademark for professionals (e.g., Derek Muller’s clothing in Veritasium). A simple solution is to have students dress in a standard lab coat kept “on set,” [tinyurl.com/decaycurve](http://tinyurl.com/decaycurve), and we keep a scaffold, single arm, and whiteboard with a lab coat in a corner of the introductory lab away from windows.

Extended editing, titling, etc. can be done on iPad tablets with the free or low-cost Apple iMovie or similar, and our examples were edited in iMovie. Beware that when editing using tablets, iMovie creates and works on a duplicate copy of the video, so students must keep at least 50% free memory to edit (an issue with long videos on tablets). iMovie comes with a library of digital rights-free music and sound effects, and there are online repositories like [FreeMusicsArchive.org](http://FreeMusicsArchive.org). iMovie

supports limited but adequate editing, transitions, voiceover, titling, captioning, and text annotations, though we have had some very few students export movies from tablets and phones for further manipulation, mainly using Apple’s iMovie on a more powerful machine like an iMac, or free online editors like Wondershare’s Filmora, [www.wondershare.com](http://www.wondershare.com).

Due to lower-quality microphones optimized for close face-to-face videoconferencing on tablets, sound is usually the weak link in using tablets and phones to record and edit videos. Tablet-edited movies are often recognizable as such by erratic sound levels due to inaccurately setting levels by listening to the tablet speakers alone—something much improved by external over-the-ear headphones. Professionals use studio monitors in an acoustically controlled mixing studio. While we have used internal and external microphones for tablets’ recorded sound, the simple solution is simply doing a voiceover for the entire video. We expect students to have a complete transcript (readily done with voice-to-text software) included in their final report analyzing and suggesting revisions.

### Appropriate expectations for classroom videos: Process not product

It’s important to restate that the object of this video project activity is *not* to produce professional-quality publicly shared YouTube videos. MinutePhysics, Veritasium, PhysicsGirl, and many other YouTube physics videos are produced by teams of paid, trained, and talented professionals. Physics learners have been producing school-quality lab, book, and project reports as standard classroom practice for over a century, and we recognize that these efforts represent a series of gradual, iterative approximations in which the process, not the product, is of greatest value for promoting student physics learning.<sup>13–15</sup> Hence, we require a proof of concept video, ordinarily not



Fig. 4. A scribble animating wave interference.

shared outside the classroom, as we would student lab reports.

Learning to draw and practicing complex figures, free-body diagrams, motion maps, vector diagrams, circuit diagrams, ray diagrams, pie and bar charts, and other analytic representations are themselves expected and appropriate introductory physics activity. Specific project product expectations may vary widely from student to student, group to group, grade to grade, and course to course and should be entirely determined by the local expert—the teacher.

For our project grading purposes, we require a proposal, storyboard, transcript, proof of concept video, and a *brief analysis* of the video. The analysis requires the identification of strengths and weaknesses each for the physics content, presentation, and video technique. We are not looking for a literary close reading of the video, only something appropriately reflective, mainly about the physics content. A badly flawed video with many in-jokes shared within the class accompanied by a complete, concise report identifying and commenting upon video physics strengths, weaknesses, and appropriate suggestions for reshooting can receive a full score.

### Classroom administration issues

For the final projects, we allow students to self-select teams of three people, and the teams may choose from directly assigned course topics. By restricting the project topics to matters of import to course goals, instructors ensure that the valuable student discourse, reflection, articulation, communication, and conceptual refinement are spent on the most important course content. We intend that improved conceptual learning of critical topics and engagement offset course time lost to the mechanics of videography and production. Video projects in freshman physics courses have replaced an existing course final project worth about one letter grade (10-15% of

the class grade) and students have experienced little difficulty (some arrive with grade school video-making experience). We make limited out-of-class technical video-making help available to students, and do not dedicate regular instructional time to technical help.

Expect the great majority of student video projects will remain private to your classroom and never be publicly viewable. Videos can be shared privately by services such as Google Docs, DropBox, Google Drive, your internally secured school learning management system (LMS), and email. YouTube could still be used privately if desired via settings such as “private” or “unlisted.”

Some concerns: students sometimes overemphasize the visually obvious and compelling surface features of the physics rather than the more important abstract properties and relationships; students have become entangled in self-generated exotic storylines rather than storylines taken from history and nature of science; students have become distracted by technical minutia like effects and music. Instructors should expect to continuously refocus students back onto the physics of the activity.

### Discussion and conclusions: Old wine in a new bottle

The value of project-based learning has been suggested by Etkina in Feder<sup>16</sup> as beneficial “for physics students *even when the approach is a small part of the overall curriculum.*” Physics education and edutainment video making are now recognized as important complex and creative endeavors worthy of formal research and instruction.<sup>17,18</sup>

Video projects exploit our students’ new cultural and entertainment norms by extending the use of many tried-and-true curricular activities. These projects reframe student physics learning via student peer instructional discourse, projects, and presentations into a new media—complementing already well-known small group and whole class discourse, written reports, stand-and-deliver-style PowerPoint presentations, etc. Our preferred focus is on students making presentations to refine their own thoughts—negotiating and clarifying meaning with peers and instructors and presenting their ideas to others in a carefully considered fashion. Planning for this “new” venue of video provides subtly changed yet familiar demands for clarity of student thinking and communication, and we remain focused on that thinking and presentation of physics.

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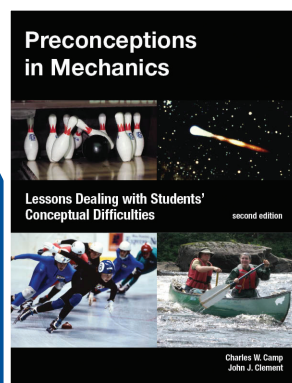
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