Digital video as a resource for teaching physics – A preliminary evaluation of effectiveness and some tips on how to do it better

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Abstract: Recent developments in digital video technologies allow video footage to be captured, edited and presented far more easily than was possible with older analogue techniques (e.g. 35mm film, VCR, etc.), making the widespread use of video in lectures a more viable possibility. Here I will discuss my recent experiences with using digital video to improve the effectiveness of examples and anecdotes in my lectures and to enhance, supplement or replace live physics demonstrations. I will include some tips on how to better use digital video as a teaching tool along with a preliminary evaluation of the success of digital video in lectures based on student feedback. Of particular note, the feedback shows that students almost always prefer live demonstrations to videos, even if the demonstration is unsuccessful or difficult to see, suggesting that digital video is not an effective 'low-cost' substitute for demonstrations in the teaching of physics.

Introduction

Physics combines experimental observations, mathematical descriptions and physical intuition to provide scientifically tested explanations for the various physical phenomena that occur in Nature. The first two aspects are relatively easy to teach and reasonably well catered for by traditional lectures, laboratory classes, and tutorials. The intuitive aspect of physics, however, is more nebulous, and generally comes to a student indirectly via accumulated experience (Kolb 1984), for example, by noting that common skills and techniques can be applied to various physical systems.

One way to facilitate the development of physical intuition and accelerate the process of gaining 'experience' is to provide a strong background context for the technical aspects of the course, either by performing live demonstrations or by presenting relevant examples and anecdotes in class. Although the efficacy of live demonstrations is established (Di Stefano 1996), they tend to become less viable in higher year courses because more sophisticated, expensive and cumbersome equipment is required as the physics becomes more complex. For example, while demonstrations of basic physics are easily performed using simple apparatus such as masses, springs, batteries, water, etc., the same cannot be said for quantum physics, where effects are only observed at the atomic scale and under tightly controlled conditions (e.g. the ultra-high vacuum environment of a scanning tunnelling microscope). Furthermore, the set of useful demonstrations is smaller in higher year courses because the students have already seen many of them (unfortunately, this usually means the better ones) in their first year physics courses. The element of surprise (i.e. of 'not knowing the outcome') is often an important factor in a successful demonstration, which is lost when a demonstration is repeated. Hence, the onus tends to fall back on examples and anecdotes or worked problems in higher year courses. However, in my experience as both a student and as a lecturer, examples and anecdotes are often not as effective because they lack the visual dimension and dynamic of live demonstrations.

One route to enhancing the effectiveness and memorability of examples and anecdotes is to use video footage (Zollman and Fuller 1994; Escalada and Zollman 1997; Ellis and Childs 1999; Caspi, Gorskey and Privan 2005; Kirstein and Nordmeier 2007). While video footage has been a possibility for decades now, the old analogue technologies (e.g. photo-slides, 35mm film, VCR, etc.) were quite cumbersome, such that the effort required to produce or obtain video footage suitable for use in lectures outweighed the benefits, effectively eliminating the incentive for the widespread use of video in lectures. However, all this has changed with the advent of digital video technologies. Digital video cameras are now widespread, ranging from dedicated high-quality video recorders with in-built hard-drives for storing hours of footage right through to small cameras and mobile phones capable of obtaining several minutes of lower-resolution video, all of which can make the job of obtaining useful snippets of video footage for use in lectures a quick and easy prospect. Another advantage of

digital video is the ease with which it can be edited or cropped, using for example, software such as *Windows MovieMaker* (free with Windows operating systems) or *iMovie* (for Macs), and then presented as part of a *PowerPoint* presentation in a lecture, particularly given the display technologies now available in most modern lecture theatres. Finally, there is the exciting possibility of creating large digital video archives of useful educational footage, freely accessible via the internet, to provide a wealth of material that could be used in lectures (Micolich, 2008). Ultimately, the digital video revolution offers to shift the balance back in favour of the benefits, such that video footage might finally realise its potential and become widely used, not just in lectures, but in teaching in general.

This paper focuses on my experiences with using digital video to enhance my second year physics courses at the University of New South Wales – PHYS2040 Quantum Physics and PHYS2060 Thermal Physics, but may be useful at a variety of levels including first year. The quantum physics course has an enrolment of approximately 70 students and the thermal physics course has an enrolment of approximately 40 students. In both cases, approximately 25-33% of the students are physics majors, the remainder are science students with other majors, engineering students, nanotechnology students, and a small number of students from more diverse backgrounds (e.g. arts, economics, law or medicine students doing the courses out of interest rather than necessity). These courses have previously been taught in a traditional lecture format, with the inclusion of some live demonstrations, and to better engage the students my aim was to supplement this with video clips. Approximately 50% of the demonstrations in the course were supplemented/replaced with video.

In my courses I have used video to achieve two functions – to provide a visual dimension to enhance presented examples (e.g., showing a beach-ball being bounced around in a cricket stadium to demonstrate the basic concept of Brownian motion) and as a route to enhancing, supplementing, or even replacing the available live physics demonstrations in these courses. There are number of reasons why you might want to do this: firstly it allows you to significantly extend your set of available demonstrations with minimum effort/cost; secondly it allows you to do demonstrations that would be otherwise impossible (e.g. freeze a lake or detonate a nuclear weapon) or very difficult/expensive to perform live (e.g. observing superfluidity in liquid helium); and thirdly it allows a lecturer to provide a much richer experience for students, increasing the relevance of the material being taught and thereby the engagement with the material by the students (Escalada and Zollman 1997). Further examples and inspiration can be found in Micolich 2008, Zollman and Fuller 1994, Kirstein and Nordmeier 2007. In the discussion that follows, I will present some factors that I have found are important in maximising the effectiveness of the use of digital video in lectures as well as some of the feedback that has resulted. The latter will serve as a preliminary evaluation of the effectiveness of using digital video in lectures, which yields some interesting and somewhat unexpected results regarding the interplay of digital video and live physics demonstrations.

Useful tips and important factors to consider in using digital video in lectures

Using digital video in lectures is not quite as simple as just getting a video and showing it to the students. Instead, the results can be quite mixed based on exactly what you show and how you incorporate it into the lecture – digital video can be an effective tool but it can also be a complete disaster, leading either to the distraction and disengagement of the students, or misconceptions and confusions about the material that you are seeking to teach. In experimenting with using digital video in my lectures, I have found that there are a number of important factors to consider:

Videos need to be chosen carefully
It is easy to go overboard using videos, either by having too many or using videos that are only marginally relevant. The most important consideration in choosing a particular video is *intent over*

content – just because a video has useful content doesn't mean that it is necessarily worth showing. Hence, I have started asking myself is 'What is my motivation in showing a video at all?' rather than 'What is in the video that I want my students to see?' The motivations can be quite varied (for some examples – see Micolich, 2008) but it is important that you: a) have one, b) can communicate it to the students so they will see its value and importance, and c) the video that you choose has content that adequately fulfils your intent in showing it.

An ideal way to do this is to have one or two people you can use as a 'test audience' for your videos. While it's not feasible to do this for every video, it is useful for cases that aren't clear-cut, and is particularly important if your intent is humorous rather than serious, both to check that the video is actually funny and not offensive, and to check that the video is not so far off topic that it's funny but irrelevant. The ultimate test audience, however, is the class itself. I find it useful to keep notes on the class' response to the video (make sure you watch the class not your video). I also find it helpful to poll some of the students afterwards, but often if a video works, it will motivate them to come to you to talk about it rather than you having to go to them for comments. Finally, don't be afraid to have no video – if there's nothing worth showing, then don't, we're there to teach not to entertain.

Videos should be cropped to the minimum useful length
It is important to crop your videos down to the bare minimum needed to get the point across. There are two reasons for this. The first and most obvious is that you have very little time in a one hour lecture to waste several minutes on useless footage. The second and more important is that showing a video in a lecture tends to put the students into 'television mode'. After a lifetime of training, their natural response when the television comes on is to watch for a short period (typically 30-90 seconds) and then decide to keep watching, change the channel, or focus their interest elsewhere.

Something similar happens in lectures. You start the video, the students watch for a short period and it either catches their interest and they keep watching, or they switch off, start looking at their notes, chatting, etc. Note, however, that not all chatting during the video is bad, sometimes it indicates very active engagement in the material being shown rather than boredom. Thus the goal in cropping the video is to either get the whole message inside this initial attention-span period, as they do with advertising and news stories, or make sure you at least capture their interest in this period so that they remain focussed for the entire video. I find the former far more effective, and thus it's sometimes better to overcrop a video and lose some interesting content than undercrop it and lose the students' attention. After all, you can always post the video online for the students to see in its entirety later if they're interested (assuming the video is under 10 mins in length, you can even post it to *YouTube*). In fact, posting the entire video online can be a good tactic for getting the students to review the video later, and revisit the associated concepts, improving the chances that they will be remembered.

Don't underestimate the time required for showing a video
Another important consideration is allowing enough time for your video in the lecture. The time you will need depends on exactly what you show, and can be tricky to judge, but it needs to be enough for the video itself, plus what you need to say around it, including any class discussion, and most importantly, time for the students to digest and react to the video itself and then settle back into the lecture. The latter is the easiest to overlook and can be quite important, especially if you plan to show a video likely to elicit a significant response from the students. As a guide, I usually allow double the length of the video as the time it will take to show and discuss, and then modify that based on the expected response. For something that will generate a very significant response (i.e. something really amazing or hilariously funny), I often add some extra time to allow me to show the video twice, just in case students ask to see it again, which does happen occasionally.

Video presentation

An important consideration is how best to incorporate the movie into your lecture presentation. I devote most of my slide to the video to ensure that it appears large enough for viewing throughout the lecture theatre (be careful about the video resolution here, if the resolution is low, it's better to make the video window smaller rather than larger). The ideal way to do this is to use the 'insert movie' command in *PowerPoint* rather than have the video spawn its own viewer, this way the movie appears seamlessly in the presentation. I usually choose for the movie to play only when clicked as it gives you more control over when it plays and allows you to introduce the video before it is played.

Prior preparation prevents poor performance – The value of pre-lecture testing

A *PowerPoint* presentation with video can work perfectly in your office and when you transfer it to the lecture theatre fail spectacularly. This typically occurs because *PowerPoint*'s internal link to the location of the video file is no longer correct once the files have been moved to another computer. Having been caught by this a few times, I now always quickly run through the whole presentation and check that the videos load and play properly immediately before each lecture. Sometimes this means you need to reinsert some movies into *PowerPoint* on the computer from which it is being displayed. I also find it very helpful to run the movies from the hard drive on the lecture theatre computer rather than a USB memory stick, the videos load faster and give fewer problems this way.

Copyright

An important issue regarding the use of video in lectures is copyright, and this depends on the origin of the material and your local copyright legislation. The easiest option is to film the material yourself, in which case you are the copyright owner and you have permission to do as you please with the video. If you aren't the copyright owner, it is your responsibility to either get the copyright owner's permission for its use, or comply with any special licences (e.g. the Part VA/VB educational licences in the Australian Copyright Act) that allow you to use material without permission.

Student feedback and preliminary evaluation of using digital video in lectures

There are three areas of evaluation that demonstrate the effectiveness of using digital videos in lectures: student responses during the course, formal student feedback after the course, and my experience in using the technique. Addressing these individually:

Student response during the course

The student response during the courses was generally positive, but varied from video to video. The better videos are very effective in stimulating discussion amongst the students during the class (sometimes to the point where you need to show the video again as they were too busy discussing the video to concentrate on it the first time), and often result in significant discussion after the lectures, both between the students, and between the students and myself. The latter is extremely useful as it opens a channel to get even more detailed feedback on the video and its effectiveness. The poorer videos tend to produce one of two outcomes, either no response at all – the ultimate failure in a video – or the students come and say how bad it was, and in some cases suggest ways of improving the video or are motivated to find better examples themselves on web sites such as *YouTube*.

Feedback/Course evaluation

To better evaluate my use of digital video in my courses I conducted a written survey with a subset of the students who had attended the PHYS2060 course (approximately 18% of the students enrolled) in the asking some specific questions on this approach. The questions were:

1. Did you find the various videos included in the course useful? Would you have more/less?
2. Given a live demonstration in class and an equivalent demonstration on video, which would you say is more effective? Is the fact that live demos sometimes fail a plus or a minus?

Question 1 – The usefulness of digital video: Of the seven respondents to this survey, six found the videos useful, with comments ranging from: 'Yes, gives focus and relevance to concepts' to 'They were more entertaining and interesting if anything, but I would still recommend keeping them in.' to 'Didn't find the videos too useful, maybe less of them but then again its good to have breaks from strict lecturing'. The mixed set of responses aren't surprising; different students learn in different ways (Gardner 1983, Honey and Mumford 1986) and thus find the videos helpful to differing extents. It should be noted that students' definitions of 'useful' tend to vary, ranging from 'did it directly help increase my course mark?' to 'did it make the course better as a whole?'. It is interesting to note that even in the comments that suggested that the approach wasn't 'useful' *per se*, there was clear evidence of a positive effect, which is that it made the course more interesting and made it easier to maintain focus in the lectures. Some students might not see this directly as useful, but in a subject as technical as physics, any 'sugar that helps the medicine go down' can definitely be a good thing.

Question 2 – The possibility of replacing live demonstrations with digital video: While the responses to the first question were expected, the responses to the second question are surprising, giving a strong warning regarding the relationship between demonstrations and videos. I expected that the students would find the failure of a demonstration to be a bad thing, and anticipated responses such as 'The video is more effective, your demonstrations rarely work and even when they do, they're hard to see'. After all, as a lecturer, nothing is more frustrating than when a demo fails – it's distracting, diminishes the effectiveness of your point, and can be embarrassing.

Instead I found the exact opposite; all seven responses were strongly in favour of videos not being a substitute for live demonstrations, despite the higher than average failure rate of the demonstrations in that year's course. Comments included 'Live demos more exciting even when they don't work, but good to have video as a back-up' and 'In class, nothing beats watching physics live. The fact that sometimes demos fail is probably a plus…'. In light of this, *I now never replace a demo with a video no matter how bad the demo is or how likely it is to fail*, but where possible I do keep a pre-recorded video of the demonstration available as a back-up, just in case the demonstration does fail. I find this to be an excellent option because it gives you a guarantee that you can always get the point of the demonstration across at least, even if 'Murphy's Law' does manage to ruin the live version. Additionally, video can also be useful to give a closer perspective on a demonstration, especially if it is one that is difficult to see (i.e. the effect or apparatus is small). Given this, it is clear that the role of video relative to live demonstrations should be to supplement rather than to replace.

In light of the student feedback, an interesting question to ask is: Why is video no substitute for a live demonstration? After all, in a video the demonstration is guaranteed to work, the phenomena can generally be shown in more detail and more effectively (e.g. using zoomed views or by slowing down or speeding up the video), and the less useful or more distracting parts of the demonstration (e.g. time spent waiting for things to happen) can be easily removed to make more efficient use of the limited time available in lectures. Video is clearly a better option from a lecturer's perspective, so why not also from a student's perspective? The fact that students still find demonstrations that fail to be useful and engaging, sometimes more so than demonstrations that work, suggests that live demonstrations offer an aspect of reality that video cannot provide. This is an aspect of the relationship between live demonstrations and videos that we hope to investigate further in the future.

An evaluation of my experiences with using video in lectures
I found two very positive aspects to using digital video in lectures that have helped make my job as a lecturer much easier. The first is that it really helped me to explain a number of complex concepts, without having to wave my hands around, hand-draw rather poor sketches in class and hope that the students somehow got my point. Instead, I could show a video and simply narrate it accordingly, pointing out exactly what I mean, as it appears. This has certainly made some of my explanations

clearer to the students, who rather than approaching me afterwards to try and get a better understanding of what I was getting at, were approaching me instead to discuss logical extensions of what I'd been teaching – it was clear that the videos were aiding my clarity of explanation, and this was reflected in student reviews of the courses (e.g. 'clear descriptions', 'the analogies used really brought some of the points home'). The second aspect is that it made it so much easier to keep the students awake and interested. As pointed out in the survey results above, at the very least the videos are good 'breaks from strict lecturing', and a chance to re-energise the class for the next block of technical material that needs to be conveyed (Bain 2004; Taran 2005). The videos also made it much easier to get the students interested in the topic and see the relevance of the technical aspects, not only for engineering and technology, but to everyday life as well.

Conclusion

In concluding this article, I'd like to reiterate the four key tips to consider in adding digital video content to lectures:
- there should be a very clear reason behind each video shown and you must be able to communicate this to the students;
- you should make sure that you have a video with content that lives up to your intent in showing it;
- your video should get to the point very quickly and be as short as possible to be effective, cropping should be done ruthlessly; and
- videos are no substitute for live demonstrations in science courses, but they can be a useful as a fallback if the demonstration fails as a tool for improving the clarity of some demonstrations.

Acknowledgements

References

Bain, K. (2004) *What the best college teachers do*, Cambridge, Mass.: Harvard University Press.

Caspi, A., Gorsky, P. and Privman, M. (2005) Viewing Comprehension: Students' learning preferences and strategies when studying from video. *Instructional Science, 33*, 31–47.

Di Stefano, R. (1996) Preliminary IUPP results: Student reactions for in-class demonstrations and to the presentation of coherent themes. *American Journal of Physics, 64*, 58–68.

Ellis, R. and Childs, M. (1999) The effectiveness of video as a learning tool in on-line multimedia modules. *Journal of Educational Media, 24*, 217–223.

Escalada, L.T. and Zollman, D.A. (1997) An investigation of the effects of using interactive digital video in a physics classroom on student learning and attitudes. *Journal of Research in Science Teaching, 34(5)*, 467–489.

Gardner, H. (1983) *Frames of Mind: The Theory of Multiple Intelligences*, New York: Basic Books.

Honey, A. and Mumford, P. (1986) *The Manual of Learning Styles*, Berkshire Peter Honey: Maidenhead.

Kirstein, J. and Nordmeier, V. (2007) Multimedia representation of experiments in physics. *European Journal of Physics, 28*, S115–S126.

Kolb, D.A. (1984) *Experiential Learning*, Englewood Cliffs, New Jersey: Prentice Hall.

Micolich, A.P. (2008) The unrealised potential of *YouTube* – Will it become the 21st Century Lecturer's Film Archive?, In press for *CAL-laborate* (Oct 2008 issue).

Taran, C. (2005). Motivation Techniques in eLearning, *Proceedings of the Fifth IEEE International Conference on Advanced Learning Technologies (ICALT'05)*.

Zollman, D.A. and Fuller, R.G. (1994) Teaching and learning physics with interactive video. *Physics Today, 47*(4), 41–47.