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How videos are used in secondary school physics teaching

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Abstract

Short videos are widely used in secondary level physics classes, part of a portfolio of strategies for teaching and learning. However, research into how they are used, why they are used and the optimum design for learning is in its infancy. This paper seeks to examine how videos are used in UK physics classrooms for the communication of physics ideas and for practical work. It features the results of a small survey of physics teachers and the results of a search through the relevant literature.

Introduction

Videos are part of the modern classroom. Live TV programmes in the 60s and 70s were gradually superseded by videos and DVDs but videos became a more frequent part of lessons when access to networked computers and video sharing sites such as YouTube became ubiquitous. Teachers began accumulating collections of favourite videos as soon as the technology made this possible but, until video sharing sites, these collections were tied to hardware such as computer hard drives or VHS tapes. When a teacher moved school, these collections were often lost.

Videos are commonly used to reiterate the ideas of a lesson, to generate interest in a topic and to bring real world examples of the applications of physics into the classroom. Used well, they are an enjoyable and powerful learning tool but there is little research into how they are used in classrooms and still less on their impact on learning. Current journal articles tend to concentrate on innovative uses for videos, there is little reporting of how videos are used in practice and the impact that this has on students' understanding, learning and enjoyment of physics.

This paper reports on parts of a literature search for papers describing the use of videos in secondary school physics teaching and a wide ranging survey of how physics teachers are using videos in real life. Most of the responses to this small, targeted survey were drawn from teachers working in a UK setting. The uses identified by the survey are compared to suggestions from the literature.

Typical UK sixth form physics specifications are a dry collection of relationships, equations and laws, they need teachers to tell stories and put the ideas into context. Good physics teaching videos offer engaging content that is not dependent on the charisma of a teacher.

The author of this paper has built a website, physicstube.org as a source of videos with correct physics, a resource for stuck sixth form students away from a teacher, friend or family member to turn to for help. This site is built to a proof of concept stage, to progress further, evidence of the need for the site is required, hence this investigation. This paper covers the use of videos throughout secondary school physics teaching, its scope goes beyond the physicstube.org target audience.

The literature search that forms the basis of this paper began informally, following leads from useful articles in the Times Education Supplement. This was complimented with a systematic search of the e-journals available to the University of Cambridge library using the string 'physics AND video AND (teach∗ OR Learn∗ OR educat∗)' which produced 66 187 results. This set was filtered to include only papers in peer-reviewed journals published between 2014 and 2019. They had to be in English and include 'physics' and 'secondary education'. This reduced the results set to 71 articles. Examination of the titles and abstracts of these journals further reduced this number to 28 that were relevant to this study and read in full. This small number reflects the sparseness of the literature on this subject, papers published before the usual five-year history of a topic are included because of this paucity. The most useful of these papers feature in this paper.

Work on how videos are used in secondary physics teaching can be divided into two broad categories; videos are used to support the teaching of physics ideas and as a data capture tool for practical activities. This paper considers these categories separately.

Use of videos to support the teaching and learning of physics ideas

Literature findings

In their guidance on the use of digital technology, 'Using Digital Technology to Improve Learning' (Stringer *et al* (2019)), the Education Endowment Foundation (EEF) state that 'to date, technology has been most effective when it is used to supplement or enhance teaching, rather than to replace it. In studies with the largest recorded impacts, technology typically provides access to additional resources and opportunities for additional learning time'. The EEF states that users should consider what technology replaces when attempting to assess its impact. 'The best judgment of a new technology comes from asking "has it had a greater positive impact than the alternative?' rather than just 'has it had an impact?"'.

In a study of 94 students at a Singaporean girls' school, Yap and Chew (2014) found that 'for both the express and normal streams, attitudes towards the learning of physics improved significantly with the use of demonstrations supported by the appropriate use of ICT tools'. In this study, ICT tools meant a mixture of dataloggers, animations and video clips. These provided an interactive style of teaching that contrasted with the chalk'n'talk that students were used to. Although attitudes to physics were improved, this study makes no comment on academic attainment.

Objective research on the impact of videos on academic outcomes is less reported in the literature. Faulconer *et al* (2018) compared outcomes for a group of 1909 first year physics undergraduates studying at Embry-Riddle Aeronautical University, FL. This unusual student body has an average age of 34 and 50% are serving in the US military. The University offers its courses by a choice of traditional face-to-face instruction, synchronous video instruction, and online classes. Retention was better for face to face and video synchronous instruction but people who stuck with online videos were more likely to get an A. The dropout rate for the online programme was much higher than for the other modes of instruction.

Berk (2009) sets out the main uses of video clips, TV and YouTube in college classrooms. These can be summarised as improving engagement with the lesson, controlling the mood in a classroom and acting as a stimulus to imagination or discussion.

Survey results

All students like watching videos. 'Do your students enjoy watching videos as part of a lesson?' is the only question in my survey where 100% of a sample of 51 agreed. Teachers find watching online videos useful too. 53% of a sample of 51 teachers use videos to help review a topic before they teach it.

67% of a total of 52 survey respondents put links to relevant videos onto their school's moodle site or equivalent virtual learning environment. Teachers posting video links for their students were asked if their students watch them. 33 people responded, of these 94% said the videos were watched.

Videos in physics lessons are used in keeping with the EEF's recommendations. They are not replacing traditional teaching methods; they are used by students in tandem with traditional sources of knowledge. 79% of a sample of 47 teachers report that their students use textbooks out of class. 60% of students work with their friends and 40% get help from their families. These were the most popular support strategies adopted by students. On average teachers ticked 3.4 out of class learning techniques from a list of 7 possibilities.

Using videos to reiterate an idea that has just been taught is a popular use of videos in physics classes; 96% of 56 teachers are doing this. 95% of a sample of 43 teachers use videos to generate interest in a topic among their students while 88% of teachers from a sample of 42 are using videos as attention grabbers. Using videos as lesson starters is slightly less popular, 73% of a sample of 59 teachers are doing this.

Asking students to complete worksheets as they watch videos is a use suggested by Berk. 71% of a sample of 56 teachers do this. Of these, 13 use them across key stages 3, 4 and 5, that is 11 to 18-year olds. A further 11 deploy worksheets for key stages 3 and 4 only, 11 to 16-year olds and 5 use worksheets for key stages 4 and 5, 14 to 18-year olds. Four survey respondents use worksheets for 1 key stage only, with roughly equal numbers for each key stage.

Videos of model solutions to problems provide an opportunity to animate textbook worked examples and supplement writing, diagrams and equations with narration. However, concerns about inconsistent notation put some teachers off. Only 44% of a sample of 55 respondents have used these.

Spaced repetition of an idea is an evidence-based technique of reviewing information at gradually increasing intervals, a way to implement Berk's suggestion of using videos to increase the memory of content. 60% of a sample of 55 teachers attempt to use videos in this way. Using videos as plenaries is slightly less popular, only 58% of a sample of 55 teachers have used videos to summarise their lessons at the end.

Use of videos to support the teaching and learning of practical physics

Literature findings

An area well represented in the literature but not so common in the classrooms of survey respondents is the use of videos to capture and analyse experimental data. Videos are used to capture phenomena that happen too fast to see in real life, to capture things that happen too slowly and, in conjunction with software, as a data source for quantitative analysis. Some uses are a combination of both capture of fast events and subsequent use of software to understand the mathematics.

Varieschi (2006) used video to capture evidence for his detailed algebra of a loop the loop track. He used the images to show that the normal rules of projectile motion apply to an object on a circular track.

Heck and Vonk (2009) used video to slow down the motion of a row of coins pushed in an arc by a stick parallel to their centres. The motion was analysed using COACH software, paid for video analysis software produced by a Dutch university spin out. The combination of video plus software made detailed analysis of the motion available to secondary school students. Heck used COACH again with high school students to investigate the changing mass of a bungee jumper in flight and so resolve a debate that ran through Dutch journals at the time. Repeating this investigation would make a neat EPQ project (Heck *et al* 2010).

Bryan (2010) reported on attempts to use a VCR for data capture in the early 90s but was stymied by the poor recording quality. By 2010 he could write 'video analysis now provides a cost-effective, yet sophisticated method in which energy conservation may be examined and verified'. He says that using video for data capture is cheaper and less cumbersome than using motion sensors, more than 1 object can be followed and an object can be followed in 2D. Video became feasible in Bryan's 25 years of attempting to use it but he points out that students only actually learn from technology if their interactions with the technology and each other are designed to facilitate learning.

Carroll and Hughes (2013) used a smartphone camera with focus locks and software that could convert angles to heights to track a shadow across a nearby tall building and hence determine the radius of the Earth. This is a traditional physics experiment, with considerable of sources of uncertainty, smartphone technology enabled capture of data too slow to watch in real life.

Ng and Chan (2015) used a consumer grade high speed digital camera to slow mechanical waves. Video is more effective for teaching this topic because it captures movement, something a textbook illustration cannot hope to achieve. Ng and Chan describe how they overcame the lighting requirements for short-exposure photography and how they used regular speed video to overcome the problem of everyone in a class of 30 students getting a good view of a small ripple tank demonstration. In addition, they note that 'because the video can be paused or rewound, teachers can easily prompt students to observe, describe, explain, or predict the refraction phenomenon'.

Wee *et al* (2015) used TRACKER, a free video analysis software package, to support kinematics learning for a group of 123 15 year-old students. They used tests before and after the teaching intervention to assess the learning gain but confess that their results may have been slightly confounded by students discussing their answers to the pre-test. Overall, they conclude 'the evidence suggests the students learned kinematics concepts more effectively than they would have with traditional passive, non-interactive lessons'.

Videos sourced from the internet can be used for teaching, missing out the step of data capture, which may be difficult for some experiments. Dias *et al* (2016) describe using the free software Audacity to obtain frequency data from YouTube clips of cars passing the camera. From the change of pitch in the engine note, the authors calculate the speed of the car.

Heck and Van Buuren (2017) used video capture with smartphones to lead students through an investigation of blocks sliding on ramps. The combination of video and COACH software reduced the measurement and maths burden on the students who engaged with the concepts under investigation more directly. The students engaged with advanced ideas about friction that were beyond the expectations of students of their age.

Bonato *et al* (2017) describe their set up for making videos of waves in springs and analysing them. They explain how such videos are powerful tools for tackling misconceptions such as the relationship between the speed of the motion of the source of the wave and the speed of propagation of the wave. They shot their video on an iPhone 6, using a frame rate of 240 fps and used the free TRACKER software for analysis. They conclude that 'students should execute personal laboratory measurements with the aim of achieving, by themselves, results eventually contrasting with their own spontaneous understanding of these phenomena'.

Aguilar-Marín *et al* (2018) also used TRACKER software to analyse videos of electromagnetic experiments. Video enabled them to capture transient phenomena difficult to observe by conventional means. For example, using a smartphone video and TRACKER analysis, an aluminium plate falling through the field of some neodymium magnets was shown to reach terminal velocity.

Neto and Souza (2018) used smartphones and TRACKER to capture and analyse data for an activity that aimed to create a mathematical model for the relationship between step length and human walking speed. This activity was considered suitable for all secondary school students but requires the time of 3 to 4 lessons.

Finally, Vollmer and Möllmann (2018) used time-lapse videography to experimentally validate the algebraic model for rates of melting or evaporation that they teach to first year university students. One of their experiments condensed a 7-week evaporation process into a watchable timespan.

Survey results

All this reported activity contrasts with the use of video for data capture in secondary school physics classrooms. 49% of a sample of 55 teachers have used videos to show something that is too slow to watch in real life but only 35% of a sample of 55 teachers have used software, free or otherwise, to analyse data captured by video.

The use of videos to give instructions for practical activities is another less popular use, only 33% of a sample of 55 teachers have tried this. Some excellent videos have been made for the professional development of teachers; for example, Alom Shaha has made series reviewing different methods of doing popular physics practical. These films would make excellent stimulus material for students before they write an evaluation of their work but only 30% of a sample of 54 teachers have used videos in this way.

Physics teachers are using videos to replace demonstrations, 88% of a sample of 55 teachers have done this at some point. More worryingly, 64% of teachers from a sample of 55 have used videos as a substitute for experimental equipment they do not have. No references were found in the literature to these uses of videos.

Conclusions

Videos have arrived in classrooms; they are popular with both students and teachers: they are used in ways that are broadly compliant with the suggestions for the use of digital technology to improve learning made by the Education Endowment Foundation.

Videos contribute to improving the enjoyment of physics for secondary-age students of all abilities. While video-based courses accessed at the convenience of student contribute to achieving the highest grades for some students, the dropout rate is high for this mode of instruction. Students enjoy and benefit from the social interaction of education.

Currently, videos are not a go-to help resource for students, but if they are put onto a school's virtual learning environment, students watch them in their own time.

The literature on the use of videos in secondary physics education contains many descriptions of practical activities but these are not widely implemented in real classrooms. Around half of the teachers surveyed have used videos to speed up slow demonstrations but only a third have used software for the analysis of data captured by video. Less than a third of teachers use videos as stimulus material for the discussion of experiments before students write evaluations. However, videos are widely used to replace demonstrations or experiments, because the equipment required to do the experiment in real life is not available.

Videos are used by secondary school teachers and students, but their full potential is not exploited.

Useful URLs

www.physlets.org/tracker/ TRACKER
https://cma-science.nl/downloads-2/downloads-software COACH
www.audacityteam.org/download/ Audio Editing Program
http://alomshaha.com/film/
www.physicstube.org

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