Video Presentations in Engineering-Physics Practicals to Increase the Efficiency of Teaching and Learning

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BACKGROUND

Engineering physics is an essential subject in any undergraduate engineering course. Practicals are a key component of teaching physics, especially to engineers. The “prac” session normally begins with a demonstrator giving the class a short description of the purpose and theory of the exercise, followed by instructions on how to perform the experiment. In recent years, the practical sessions in our first-year physics course have come under increasing pressure to operate more efficiently and effectively. At the same time, it is common knowledge that the younger generation of students are increasingly looking to video presentations to learn how to complete specific tasks.

PURPOSE

The goal of the work was to produce video resources that would help students learn the fundamental theory and operation of the lab experiments before arriving at the practical session, saving valuable class time and reducing pressure on demonstrators.

METHOD

The video series was produced by the teaching and video-production teams after reviewing the content of the lab experiments. Once ready, in semester one 2014, the videos were released to all students (on-campus and off-campus) via the unit web-site. Students were instructed to watch each video prior to attending their respective lab session. Students completed the experiments and submitted standard lab reports on each. The average report marks were compared between 2014 and prior to 2014. At the end of the semester, students were asked to complete an on-line survey to collect their thoughts on the effectiveness of the video presentations.

RESULTS

We produced 10 video presentations for eight experiments. Our observations in the classes and results from the student survey indicate that the students were happy with the content and quality of the videos. Average marks of the lab reports indicated an improvement in average on-campus report scores from 2013 to 2014, and no change in the average scores of the off-campus students. Efficiencies in teaching were gained because the number of demonstrators per class in 2014 was half that in previous years.

CONCLUSIONS

We observed increased efficiency in students performing the experiments, reduced demonstrator costs, and no reduction in students’ academic performance. Students welcomed the videos as a new learning resource.

KEY WORDS

Engineering practicals, flipping the classroom, cloud teaching, video teaching.

Introduction

One of the essential aspects of any course in engineering is teaching practical skills. In many ways, the practical skills a student gains are of equal importance as the theoretical knowledge learned (Feisel & Rosa, 2005). In an earlier paper, we noted five benefits from including practical work in an engineering course (Long, Stannard *et al.*, 2012):

- Practical work links the real word with the theory of the subject taught.
- It allows students to physically experience at least some of the engineering content taught in the course.
- It teaches and allows the students to practice essential technical skills required by all engineers.
- It supports student learning in experimental design and measurement.
- It gives the students experience in experimental record keeping.

Two developments in education have made a significant impact on how we teach engineering. First is the continuing slow decline in funding available to run practical classes, coupled with the increase in the cost of providing education. Second is the rapidly expanding use of pre-recorded video in teaching and learning. In our experience, the largest expense in running practical classes is the cost of hiring paid demonstrators. Even though the work of the demonstrator is very valuable, we have seen a gradual net decrease in funding available to hire them. Ten to fifteen years ago, a lab class of 16 students would routinely be taught by two paid demonstrators. More recently we have seen lab classes of up to 20 students being taught by only one demonstrator. Thus there is always financial pressure to decrease demonstrator costs, or at least keep them from rising.

The other significant development is the increased use of video recordings in teaching and learning. Anecdotally, there has been an increased demand from our students to provide video-recorded lectures in engineering and science subjects. When these videos are not available, the students often seek out videos related to the subject material on the Internet, often YouTube. The amount of academic lecture content available on YouTube increases all the time. When faced with learning a new skill, more often than not we find our students performing a Google search on the topic before studying their own textbooks or course materials. We also know that academics are increasingly using video presentations in their teaching (Jackson, Quinn *et al.*, 2013). Recent examples in science include the *PHYSclip* project at UNSW (Wolfe & Hatsidimitris, 2012), and the *Work-it-Out* series from Murdoch University (Creagh, 2013). In Engineering, recent learning resources via video presentation have been given at Griffith University (Gilbert, Guan *et al.*, 2013), Unitec Institute NZ (H. Wilson, 2013), MIT in the USA (Shah, French *et al.*, 2013), Purdue University in the USA (Rhoads, Nauman *et al.*, 2014), and in our own school (Joordens, Chandran, & Stojcevski, 2012). The use of video presentations in teaching has also entered the undergraduate science laboratory, such as video presentations in experimental biology (Maldarelli, Hartmann *et al.*, 2009; Samarawickrema, Prescott *et al.*, 2013).

In this work, we have prepared a series of ten short video presentations to help students prepare for their practicals in a first-year Engineering Physics unit. We present the videos and student feedback on the videos. We first released the videos to students in semester-one 2014. We compare lab-report marks from before the videos were introduced and afterwards.

SEP101 Engineering Physics

At Deakin University, all first-year engineering students enrol in Engineering Physics. We have taught this unit since 1996; and it runs both on-campus and off-campus (Long, 2013). On-campus students attend six three-hour practical classes during the semester. Off-campus students generally perform their experiments in a single day on a Saturday or at a residential school. From 2013, the practical program was updated to include a number of new experiments, some of which employ data-loggers (PASCO-Scientific) for collecting data, and thus favour computer-generated graphs. Presently there are eight experiments (table 1) in the unit. Students perform six of these. Students write their experiments up in a laboratory notebook and submit them for assessment.

Table 1: Lab experiments assigned in first-year engineering physics

Experiment	Title	Source/Reference
1	Introduction to Microsoft Excel and measurement uncertainties	(Bloch, 2000; J.D. Wilson, 1998)
2	The simple pendulum and Hooke's law	(Loyd, 1997)
3	One-dimensional motion and the inclined plane	(PASCO-Scientific)
4	Projectile motion	(PASCO-Scientific)
5	Friction	(PASCO-Scientific)
6	Collisions	(PASCO-Scientific)
7	Rotational inertia of a flywheel	(Worsnop & Flint, 1951)
8	Standing waves on a wire	(Halliday, Resnick, & Walker, 2008)

Method

Each video introduces the experiment, shows what equipment is used, gives a brief outline of the theory behind the experiment, then shows step-by-step how the experiment is to be performed. When the experiment requires a data-logger, a step-by-step illustration on how to operate the data-logger is given within the context of the experiment. We also produced a brief introductory video presented by the lecturer.

The production of each video followed a nine-step process:

1. The experiment's procedure was reviewed by the lecturer and demonstrators.
2. A storyboard (Orr, Golas, & Yao, 1994) was prepared outlining the key elements of the video scene-by-scene and a script was sketched out (figure 1).
3. From the storyboard, a narrator's script was prepared.
4. The mechanics of the experiment were video-recorded (figure 2).
5. The narration was video-recorded in a green-screen studio.
6. Animations and still images of mathematics in the experiment were produced as video elements.

7. The video and audio components were combined by means of Adobe's *Creative-Cloud* software, and then edited.
8. The final video was assembled, rendered, and released on the unit web-site to the students.
9. The videos were imbedded in an on-line version of the laboratory manual.

Students were instructed to view the videos prior to attending the corresponding practical session. The videos were also available on laptops in the laboratory during each session. Thus students had the opportunity to review a video, and play back the sections that they found most helpful while performing the experiment.

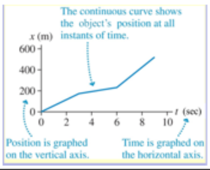
Description	Vision	Dialogue/Sound
Scene 5 Green Screen		First, We will take a look at the theoretical background of one-dimensional motion.
Scene 6 Animation / Document Camera		According to Newton's first law, an object moving without the influence of a net external force maintains a constant velocity. The following equation is used to relate position and time mathematically for an object demonstrating constant velocity (zero acceleration).
Scene 7 Document Camera of Equation	$v = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i} \Rightarrow \frac{dx}{dt}$	In one dimension, velocity is the change in position divided by the change in time: delta-*x* divided by delta-*t*. . When the time interval becomes very small, velocity is the derivative of the position with respect to time.
Scene 8 Animation / Document Camera		For example, we can make a graph of an object's position as a function of time.

Figure 1: Sample storyboard page for the inclined-plane video. The graph at the bottom is taken from a popular physics textbook (Knight, Jones, & Field, 2010).

Figure 2: Video-recording the mechanics of the collisions experiment

At the end of the semester, submitted lab reports were marked by means of a 20-point rubric which assessed the students work on five criteria: aim and introduction; experimental work and results; reporting of results; discussion and uncertainties; and English expression. This rubric was also used in marking lab reports in 2013. We then compared the student's overall marks for laboratory work with the corresponding marks from 2013. Finally, a survey was released to the students seeking their feedback on the videos. The survey was in the form of nine statements. The first statement enquired whether the students was enrolled on-campus or off-campus. The second statement asked when the student viewed the videos: in class, before class, after class, or not at all. Students then gave their opinion on the final seven statements by indicating their agreement or disagreement.

Survey Questions:

1. The videos were useful.
2. The videos assisted me to carry out the experiment in the lab.
3. The videos adequately detailed the use of the data-logger.
4. The theory was adequately explained in the videos.
5. The equipment set up was adequately detailed in the videos.
6. Videos like these would be useful throughout the rest of my course.
7. Using these videos means our prac group could have performed the experiment without the demonstrator.

Results

Table 2 shows the web-addresses of the ten video presentations. A screen shot from one such video is shown in figure 3. Table 3 compares lab-report marks from 2013 (without videos) and 2014 (with videos). Marks data from 2012 (different experiments) are also included for comparison. The uncertainty reported in the marks represents half a standard deviation. We should note that in 2014, the number of demonstrators per class of 20 students was half of that in previous years.

Table 2: Videos for first-year physics practicals at Deakin University

Experiment	Video web-address
Introduction	http://air.deakin.edu.au/public/media/entry_id/0_rlmtfx6e
Measurement uncertainties	http://air.deakin.edu.au/public/media/entry_id/0_m8q8ruwa
Pendulum and Hooke's Law	http://air.deakin.edu.au/public/media/entry_id/0_529fe9kj
Inclined plane	http://air.deakin.edu.au/public/media/entry_id/0_96x2jb0x
Projectiles	http://air.deakin.edu.au/public/media/entry_id/0_g3nvxu43
Friction	http://air.deakin.edu.au/public/media/sep101-friction/0_d9igtn0s
Collisions part 1	http://air.deakin.edu.au/public/media/entry_id/0_o5xuysax
Collisions part 2	http://air.deakin.edu.au/public/media/entry_id/0_9rl9rhrl
Flywheel	http://air.deakin.edu.au/public/media/entry_id/0_d5f171ui
Vibrations on a wire	http://air.deakin.edu.au/public/media/SEP101+-+Vibrations+On+a+Wire/0_0uusm0t9

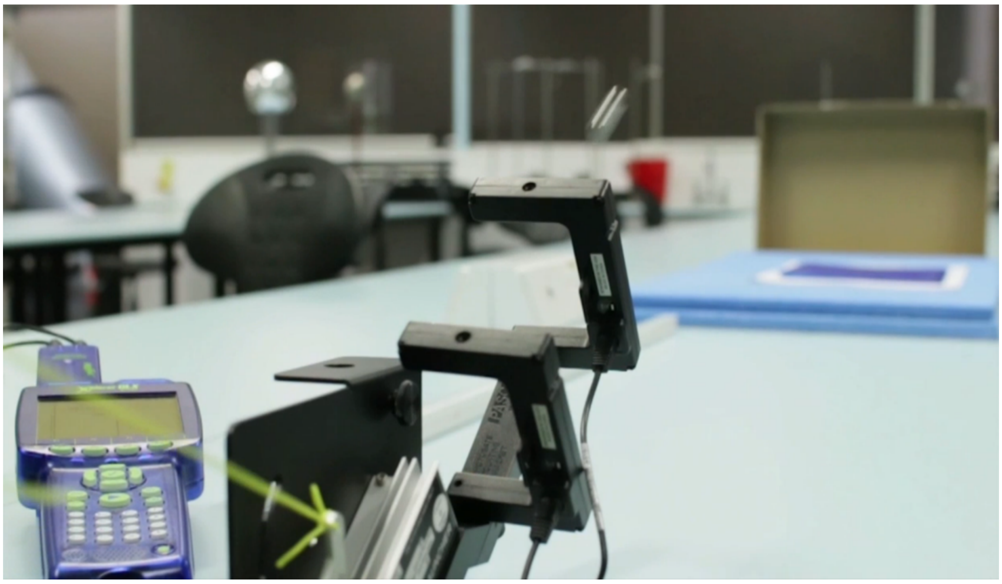


Figure 3: Screen-shot from the video for the projectile-motion experiment

Table 3: Average prac report marks

Year	Total on-campus assessed	Total off-campus assessed	Avg. % marks on-campus	Avg. % marks off-campus	Overall average % marks	Number of demonstrators per 20 students
2012	134	44	67 ± 8	68 ± 10	67± 9	2
2013	138	64	54 ± 7	70 ± 11	59 ± 9	2
2014	117	25	65 ± 9	70 ± 10	66 ± 9	1

The survey results are given in summary in figure 4. We received 21 responses to our survey. Of these, only four students indicated whether they were on-campus (three) or off-campus (one). Of the 21 students, 15 watched the videos before attending lab class, 17 viewed them in class, and one viewed them after class.

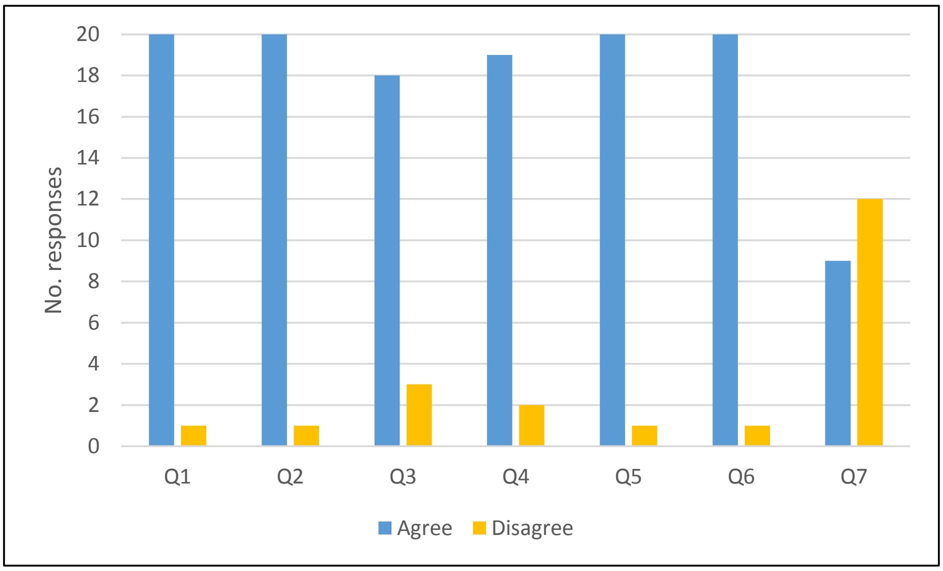


Figure 4: Results to the survey questions investigating student perceptions of the videos

Discussion

Two key results can be gleaned from the results. Firstly, the students who gave us feedback clearly welcomed the videos stepping them through their practical experiments. Secondly, the introduction of the videos enhanced on-campus student learning outcomes as shown by the 10% increase in average practical marks from 2013 to 2014. Off-campus students, while showing no change in average marks from 2013 to 2014, were certainly not worse off by introducing these new learning resources. These preliminary results also indicate that significant cost savings has been achieved by employing half as many demonstrators for this subject without adversely affecting learning outcomes. We also observed that lab classes for off-campus students proceeded more smoothly in 2014 as compared with 2013, because less time was required for the students to learn how to operate the equipment and data-loggers.

Considering that the quality of product for which we were aiming was very high, the videos were produced within the very short time frame of a few months. Other constraints included the necessity to deliver them within a learning-management system (Palmer & Holt, 2010), employing an internal video server similar to YouTube, called “DeakinAir.” Web-browser issues with embedded code caused some issues in terms of access, but in general accessibility was at an acceptable level for the students.

Producing professional videos can be a time-consuming and labour-intensive task requiring large teams and long lead times to adequately prepare for recording. Detailed knowledge of content means that only academics or demonstrators can successfully write and develop storyboards, which require many hours of summarising and editing previously-delivered information over longer class-presentation times. Development also included sourcing additional resources, including photographs and images, and the production of animations and three-dimensional objects. Presenters were filmed in a professional green-screen studio for presentation and voiceovers.

Physics experiments include a large amount of mathematical theory. Presenting equations can prove difficult to translate into video format. Varying methods were attempted to present these equations, using both animation and document cameras to address this issue. There is no doubt, however, that the inclusion of 3-D animations and well-sourced images to demonstrate particular theories has enhanced the traditional delivery of experiments by demonstrators.

Conclusion

To improve student learning and increase the efficiency of teaching in undergraduate engineering-physics laboratory classes, we produced a series of 10 video presentations, explaining how to setup and perform eight experiments. The videos were professionally recorded and edited, then released to the students via the course learning management system. Students viewed the videos prior to and during the lab classes. For the same experiments, we observed an overall increase in average student marks for lab reports from 2013, when there were no videos, to 2014, when the videos were introduced. This was in spite of a 50% reduction in lab demonstrators from 2013 to 2014. Students welcomed the new teaching resources in the subject, and the videos will be used in this subject for a number of years.

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