Low cost educational video for first year undergraduate students using oscilloscopes

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In this paper, we report the development and application of a multimedia resource designed to complement learning activities in undergraduate engineering and physics laboratories on the setup and operation of a digital storage oscilloscope. The development and design of this resource was kept as simple as possible. Cognitive load theory, in which the learning tool was designed to minimise extraneous cognitive load in students, was used as the guiding design framework. This resource has demonstrated a significant improvement in students' understanding and confidence in the use of the digital storage oscilloscope and associated test equipment. Student feedback has indicated areas of improvement required, such as in text-to-speech quality.

Keywords: Digital storage oscilloscope; cognitive load theory; multimedia.

Introduction

Learning the correct operation and use of an oscilloscope, and more recently, a digital storage oscilloscope (DSO), is one of the most important and daunting skills required of undergraduate students studying engineering and physics at university. The student's ability to master this skill quickly and efficiency can have a significant bearing on their progress through a unit of study with confidence. Additionally, their retention of knowledge in subsequent units of study can be affected by their understanding and ability to review this knowledge and skills. In the School of Engineering at Edith Cowan University (ECU), the method of instruction for the DSO was originally based on a worksheet-style laboratory tutorial that involved a combination of written instructions and time-limited laboratory supervision. As such, there was a perception among teaching staff that this process was not meeting the demands of students. Also, this process was repeated in subsequent laboratory-based units, where the retention of knowledge by students on the operation of the DSO was poor.

Mayer (1997, 2003a) suggested that a single medium explanation (i.e. verbal or written) does not ensure that students understand what has been explained. A search of the literature indicated a lack of multimedia instructional material on the operation of a DSO at a level appropriate for undergraduate students being exposed to this instrument for the first time. Hence, in this study, we developed an audiovisual multimedia resource ("Multimedia Tutorial") on the setup and operation of a DSO and function generator for basic measurements of waveform properties, with specific application to DSO models used in the School of Engineering at ECU. This resource is used to implement a method of instruction that incorporates a multimedia presentation which complements written instructions and supervision of students in the laboratory. The audiovisual demonstration focuses primarily on the setup of a DSO and a function generator, as setting up is normally the hardest part of the laboratory exercise for an inexperienced student. This Multimedia Tutorial is aimed at undergraduate first year students, though it also has use for retraining students in the operation of a DSO in later years. The main purpose of the study is to reduce the complexities of laboratory experiments and increase the retention of knowledge for students who study physics and engineering at ECU. The Multimedia Tutorial can be viewed by students at any time, so that learning activities are not restricted to the laboratory setting.

Cognitive load theory (CLT)

CLT is an instructional design theory, which can assist designers of instructional material to reduce the cognitive load on the learner, when they are faced with poorly designed instructional material (Errey, Ginns & Pitts, 2006). This instructional design approach utilises an information processing model, involving working memory as well as long-term memory. CLT helps instructional designers to understand the processes that are involved as learners respond to different stimuli (the five senses of the human body) from the environment (Eggen & Kauchak, 2007). As we respond to the different stimuli in the environment, our goal is to make sense of the information gathered and try to understand. CLT explains learning in the human mind by focusing on changes in the mental processes and constructs that occur when individuals try to understand. Table 1 provides different principles that many theorists of this form of instructional design agree upon.

Table 1: Overall principles in CLT (adapted from Eggen & Kauchak, 2007)

- People are mentally active in their attempts to understand how the world works.
- Learning and development depend on the learners experiences.
- Learners construct - they do not record - knowledge in an attempt to make sense of these experiences.
- Knowledge that is constructed depends on knowledge that learners already possess.
- Learning is enhanced in a social environment.
- Learning requires practice and feedback.

Learning

We can define *learning* as ‘a change in a learner’s mental structure that inevitably leads to a change in behaviour’ (Eggen & Kauchak, 2007). The mental structures that change include goals, beliefs, expectations, and other components that are in the individual’s mind. For learners to understand the world around them, CLTs are grounded in the belief that learners are always mentally active in trying to understand and make sense of everything they see and feel in their environments. As learners search for new knowledge and information, this helps to answer questions which they have constructed in their mind. In answering these questions, learners will modify their own previous understanding as they acquire this new knowledge. The result is a change of behaviour as they increase their own understanding. This type of theory regards humans as *goal orientated beings* who seek more information. This illustrates that learners are not video cameras that simply record information as it is visualised. Instead, all new information is constructed with previous information and integrated together. To successfully integrate new information with old information requires:

1. Practice: Individuals only learn to do actions properly after multiple practices; this reinforces and helps to properly integrate new knowledge with pre-existing knowledge;
2. Feedback: Is information about prior understanding, which is used to help build upon new or future understanding. Feedback is one of a teacher’s most important roles as an instructor, because it enables a learner to arrive at a more advanced understanding. It is additional knowledge used to enhance learning for an individual.

Information processing

Information processing is a theory, as seen in Figure 1, about how a stimulus that is either viewed or heard enters our memory systems (Eggen & Kauchak, 2007). As it enters our memory system, it is selected and organised into storage, and can be retrieved from the memory system at a later time. This model has three important features. Researchers refer to the three features in combination as *cognitive architecture*: (i) memory stores, (ii) cognitive processes, and (iii) metacognition.

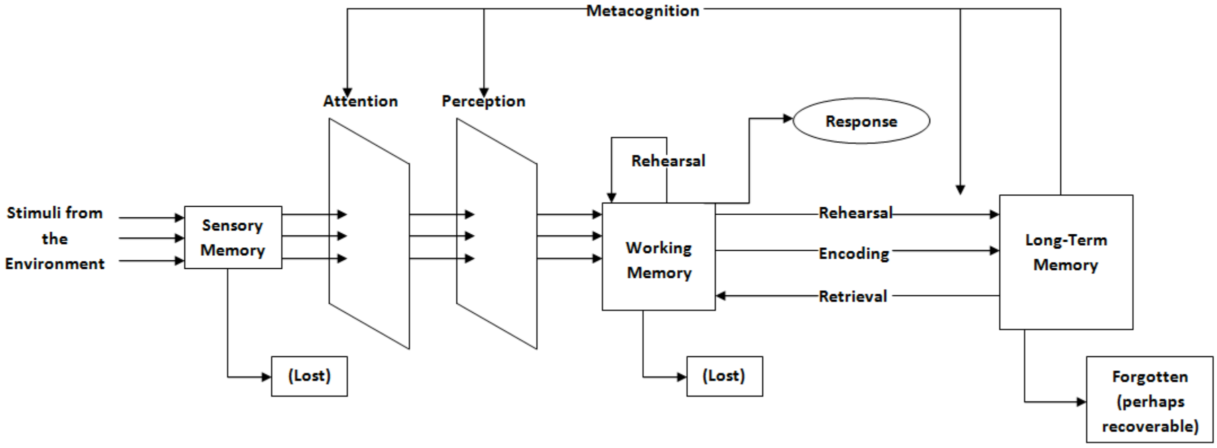

Figure 1: The information processing model (adapted from Eggen & Kauchak, 2007)

Memory stores

These are storage centres for information, and can either be held in sensory, working, or long-term memory areas (Eggen & Kauchak, 2007). Each of these areas defines a part of the information processing model and how the information is integrated together (Errey, Ginns, & Pitts, 2006).

Sensory memory
This area of the memory deals with the stimuli that are processed through our senses (Errey, Ginns, & Pitts, 2006). These particular memories are not held for very long in this area, on average the memory lasts for about half a second for visual information, and three seconds for audio information. This memory area has a virtually unlimited capacity, with the information content constantly being overwritten because of the vast quantity of data that enters this system (Eggen & Kauchak, 2007). If the information is not processed immediately then the information has no meaning and won't be integrated. This last point has repercussions with multimedia learning, because if the image is not held on the screen for an extended period of time, then the learner will not be able to extract any information for processing in the next area. This memory area holds onto information until the learner has attached meaning. Meaning is created when the input information arrives at the working memory for interpretation.

Working memory
This is the system that actively holds multiple pieces of information such as audio and pictures, and makes them available for further information processing (Eggen & Kauchak, 2007). This particular area can only hold about five to nine objects at any given time. It stores and holds the information until it can be processed. It is an integral part of the cognitive processing system, and is the area where deliberate thinking happens. The results of this thinking process can either be placed into long-term memory or goes back into sensory memory (Errey, Ginns, & Pitts, 2006). Information that is stored in the working memory has the potential to be combined with previous information that is stored in long-term memory; this new type of information can be manipulated, interpreted, or recombined with newer knowledge to continue the process again.

Intrinsic + Germane + Extraneous = Total cognitive load

Figure 2: Total cognitive equation
(adapted from Amarasing, 2009)

The most striking feature of this area is its limitations. These limitations are considered quite important by some researchers, because this is the area where the learner makes conscious decisions on how to link new knowledge with prior knowledge. This limitation is commonly referred to as cognitive load, which is defined as the total amount of mental activity that is placed on the working memory at any one time (Amarasing, 2009). There are separate loadings that combine together to make up the total cognitive load; intrinsic, germane, and extraneous. Figure 2 (above) and Table 2 (below) provide details of each of the three cognitive loads.

Table 2: Definitions of each type of cognitive load
(adapted from Amarasing, 2009)

Cognitive load type	Explanation
Intrinsic	This depends on the complexity or the difficulty level of the information. It is the memory required for the thinking task at any given instance. It measures the amount of working memory is used to complete the amount of information that needs to be process. This type of load cannot be modified by instructional design.
Germane	Is the load that is a part of building newer and more complex schema. By doing this a novice learner is able to transition to an expert learner.
Extraneous	Is a resultant of the techniques in which information to be learned is presented in. This type of load does not contribute to the learning process. This type of load can be modified by instructional design methods.

The implications of this include: that when the intrinsic load is low, there may be sufficient mental resources that are remaining to enable the learner to learn information for instructional material even with high extraneous load. The opposite is if the learner has high intrinsic load, and therefore will have high extraneous load, the resultant is learning may fail to occur. Modifying the instructional material may lower the extraneous load, leading to learning (Amarasing, 2009). Figure 3 demonstrates the different scenarios.

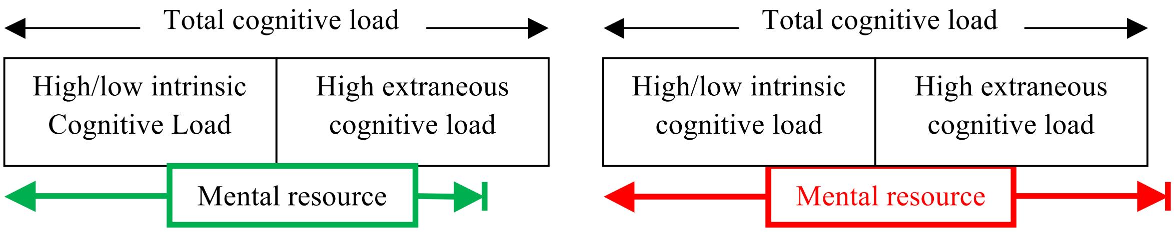

Figure 3: Situations where (a) learning can occur, and (b) learning cannot occur
(adapted from Amarasing, 2009)

Cognitive load multimedia theory

There are two different scenarios that illustrate how an individual learns, where learning does or does not occur. The latter of the two different scenarios is where the learner fails to understand the information because the mental resources required are greater than cognitive load available. In this scenario, there is information overload. This requires the instructional designer to modify the instructions to reduce extraneous loading placed on the learner. In this section, we will analyse methods to reduce the extraneous load when designing multimedia resources.

Reducing cognitive load in multimedia presentations
The issue for instructional designers is to reduce the extraneous cognitive load that is placed on the learner. In this section, we will analyse design principles that have been developed to reduce the cognitive load on students. Table 3 presents a number of different design principles that have been develop by Mayer (2003b) and tested amongst learners. These principles present different methods to reduce the cognitive load that is placed on the learner. Table 4 illustrates different cognitive overload scenarios, and methods to reduce the loading pressures which are placed on the individual (Mayer & Moreno, 2003).

Development

This study is divided into two parts; (i) the development of a rudimentary instructional audio-visual presentation for explaining the basic setup and use of a digital storage oscilloscope (DSO) and a function generator for measuring the key properties of a sine wave signal, and (ii) the implementation of this audio-visual presentation into the learning activities of undergraduate students, including an analysis of the effect of this Multimedia Tutorial on the student's understanding of DSO operation.

Table 3: Design principles for multimedia learning
(adapted from Mayer, 2003b)

Principle	Summary of the principle
Modality	Present the words in narration spoken form.
Contiguity	Synchronise audio and the animation at the same time.
Multimedia	Design a presentation with both words and pictures.
Personalisation	Narration of words should be design presented in conservation style not in a formal style.
Coherence	Avoid using extra and irrelevant information.
Redundancy	When using animation and narration in a multimedia explanation avoid using redundant online text.
Pre-training	When designing multimedia explanation, begin with explanation of the components used in the explanation.
Signalling	Designing multimedia use signalling cues for the learner.
Pacing	Allow the learner to have control over the pace of the presentation.

Table 4: Methods for reducing cognitive loading for different scenarios
(adapted from Mayer & Moreno, 2003)

Type of overload scenario	Load reducing method	Description of research effect
Type 1: Essential processing in visual channel > cognitive capacity of visual channel		
Visual channel is overloaded by essential processing demands.	**Off-loading**: Move some essential processing from visual channel to auditory channel.	**Modality effect**: Better transfer when words are presented as narration rather than as on-screen text.
Type 2: Essential processing (in both channels) > cognitive capacity		
Both channels are overloaded by essential processing demands.	**Segmenting**: Allow time between successive bite-size segments. **Pre-training**: Provide pre-training names and characteristics of components.	**Segmentation effect**: Better transfer when lesson is presented in learner-controlled segments rather than as continuous unit. **Pre-training effect**: Better transfer when students know names and behaviours of system components.
Type 3: Essential processing + incidental processing (caused by extraneous material) > cognitive capacity		
One or both channels overloaded by essential and incidental processing (attributable to extraneous material).	**Weeding**: Eliminate interesting but extraneous material to reduce processing of extraneous material. **Signalling**: Provide cues for how to process the material to reduce processing of extraneous material.	**Coherence effect**: Better transfer when extraneous material is excluded. **Signalling effect**: Better transfer when signals are included.
Type 4: Essential processing + incidental processing (caused by confusing presentation) > cognitive capacity		
One or both channels overloaded by essential and incidental processing (attributable to confusing presentation of essential material).	**Aligning**: Place printed words near corresponding parts of graphics to reduce need for visual scanning. **Eliminating redundancy**: Avoid presenting identical streams of printed and spoken words.	**Spatial contiguity effect**: Better transfer when printed words are placed near corresponding parts of graphics. **Redundancy effect**: Better transfer when words are presented as narration rather than narration and on-screen text.

Type 5: Essential processing + representational holding > cognitive capacity		
One or both channels overloaded by essential processing and representational holding.	**Synchronising**: Present narration and corresponding animation simultaneously to minimise need to hold representations in memory. **Individualising**: Make sure learners possess skill at holding mental representations.	**Temporal contiguity effect**: Better transfer when corresponding animation and narration are presented simultaneously rather than successively. **Spatial ability effect**: High spatial learners benefit more from well-designed instruction than do low spatial learners.

The simplified method we have used to develop the instructional Multimedia Tutorial has additional advantages, particularly in terms of the resources required to modify the current tutorial, so that updated and further instructional multimedia presentations can be developed. The process developed is time efficient and the particular problem of synchronising the audio narration with the visual slides is solved.

Multimedia development

When designing the presentation, there were two objectives in mind:

1. Design and audio-visual presentation that met the principles from Table 2; and
2. Keeping the cost of the design project to a minimum.

To achieve these objectives, we used a variety of different resources. Figure 4 shows an overview of the design method that was taken, and Table 5 illustrates the design principles that were incorporated into each of the stages as well as the benefit and costs of designing the presentation this way. More detailed explanations of the processes that were used to develop these stages have been published elsewhere in the literature (Oswald, Baccini, Hinckley & Wild, 2012; Oswald, Wild & Hinckley, 2012).

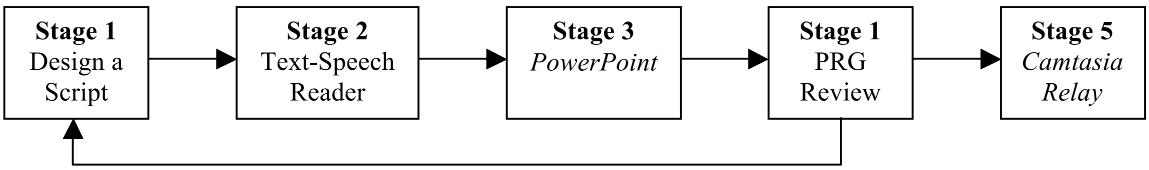

Figure 4: Design overview for the presentation

The Multimedia Tutorial is an explanation of the basic functionality of the DSO and the function generator. The presentation is broken into different sections focusing on the different aspects of the laboratory worksheet that all students traditionally use. Figure 5 shows a typical slide from the presentation explaining to students how to display a sine wave on the oscilloscope using the function generator.

The first section is an introduction explaining to the students; the outline, goals, and the equipment to be used in the current laboratory session. The next section is an animation on how to connect the function generator to the DSO. The second half of this section explains the function generator and how to utilise it to display a sinusoidal waveform on the DSO screen. We then move onto explaining how to use the oscilloscope, with the key focus of avoiding using the Auto-Scale button, as this can set the DSO to incorrect default setting, and ingrain poor habits in students. The third section involves how to measure different features of the waveform on the oscilloscope. The final section is a summary of the Multimedia Tutorial. The Multimedia Presentation operates for a total of 6 minutes and 30 seconds. For someone to create a similar multimedia presentation, only requires some knowledge of how to use Microsoft *PowerPoint* in the ability to draw, animate, and synchronise animations with audio files. While this first presentation requires a longer design timeframe (up to 10 hours for stages 1 to 3), further presentations may only take 2-3 hours to complete the first three stages of Figure 4.

Table 5: Principles, benefits, and costs associated with each of these stages

Stage	Mayer's principle	Benefits	Cost
1	• Pre-training	• Easy to update • Acts as a storyboard for how the presentation proceeds in a logical manner	• No costs
2	• Modality • Personalisation • Coherence • Pacing	• The ability to use different languages to meet the demands of international students	• Free - $51.99 on the Apple *App Store* • Trial versions available for Mac and Windows operating systems to be able purchase later on
3	• Contiguity • Multimedia • Redundancy • Signalling	• Easy to change and update • Works with *Camtasia Relay*	• Already licensed by the University for everyone to use
4	• Coherence • Signalling	• Members with wide ranging experience using DSO • Not all members a part of the design process, who can offer improvements where oversights or omissions that have occurred	• No costs
5	• Pacing	• Small MP4 file • Easily placed on sites like *Blackboard* without taking up too much server memory • Can be viewed by students on either smart phones or devices before a laboratory session • Works well with Microsoft *PowerPoint*	• Already licensed by the University for use by lecturers

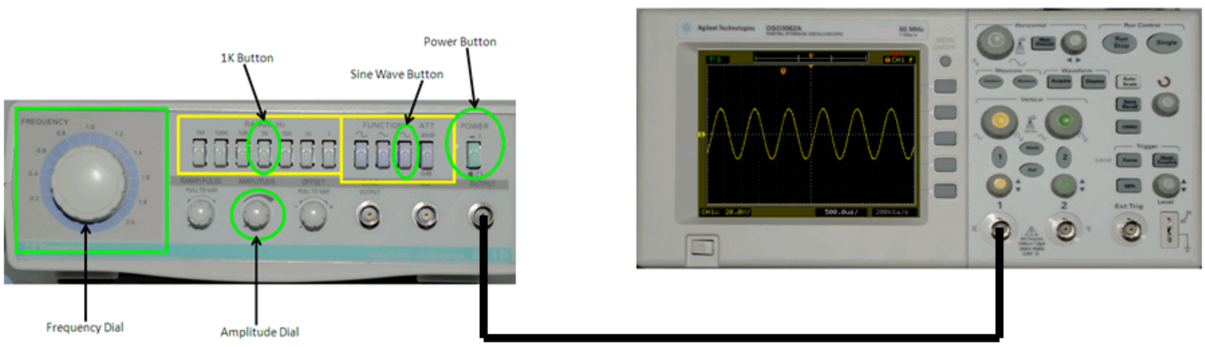

Figure 5: Slide showing students how to use the function generator to display a waveform on the DSO

The Multimedia Tutorial was created using the following processes (Oswald, Baccini, Hinckley & Wild, 2012; Oswald, Wild & Hinckley, 2012). High resolution images were created with a digital camera, which were then imported into Microsoft *PowerPoint*. Animations were created using the *PowerPoint* animation feature. A script was developed, and audio files created using a text-to-speech software package. A text speed of 180 words per minute was eventually selected. One audio file was created for each animation in *Powerpoint*. *Camtasia Relay* was used to create the Multimedia Tutorial in the form of an MP4 file.

Implementation

The participants of the two studies were students at ECU from different Physics units. The first study involved 75 students who had not covered year 12 physics and required some form of knowledge of physics for their degrees. Most of these students were first year engineering students, although the cohort also included students studying physics, education, aviation, and sports science. This study compared the two instructional designs (traditional method gathering the information from a laboratory worksheet, and the new method where we designed this Multimedia Tutorial) using the oscilloscope.

The second study involved 20 students who had completed year 12 physics, or completed at least one other physics unit in their degree. This study involved investigating students' preferences on how these multimedia presentations should be designed. These experiments were conducted in scheduled laboratory classes with no academic penalty to their grades for students not participating in the study.

Results

Results from previous research (Oswald, Baccini, Hinckley & Wild, 2012; Oswald, Wild & Hinckley, 2012), indicated that there was a statistically significant difference. There was an effect size of 1.53 for the pre-lab test and 0.73 for the post-lab test, between the original method and new method explaining how to utilise the DSO at an introductory level. This indicates a large practical difference for both groups. The results indicate that we have successfully modified the instructions overall, from the original method to the new method, and this has resulted in students achieving better marks for those who utilise the new method. These results analysed the macro differences between the two groups.

In this section, we will first analyse the average of students' performance for each of the questions in the pre-lab and post-lab tests. In the pre-lab test, there were nine questions, with the two groups answering questions 1-3 and 7-9 (which were worth 1 mark each) and questions 4-6 (which were worth 2 marks each). The first group (31 participants) only had access to the laboratory worksheet and there were 31 participants in this group. The second group (44 participants) had access to both the Multimedia Tutorial and laboratory worksheet. This test simply asks the students how to connect the oscilloscope to the function generator and what functions some of the buttons perform. Table 6 displays the percentages of how each group performed on each question in the pre-lab test.

The results from Table 6 indicate that explanations from the Multimedia Tutorial aided the students in completing the pre-laboratory test. The results show that the laboratory worksheet is either not totally clear in its explanation, or students are not able to easily infer what the instructions were implying to answer these questions. This can be easily seen as the group without the multimedia only achieved marks over 50% for two of the questions in the pre-lab test.

Table 6: The percentage of marks achieved by the students, as a whole, for the pre-test questions

	No multimedia	With multimedia
Q1 What type of cable is used to connect the function generator to the DSO?	74.2	91.3
Q2 Which of the outputs do you connect the cable for the Function Generator?	29.0	100
Q3 Which of the inputs do you insert the cable to the DSO?	54.8	93.5
Q4 Which two buttons on the function generator, excluding the power button, do you need to utilise?	0	82.60
Q5 What values do you set the frequency dial and amplitude dial to?	48.4	96.7
Q6 What does the horizontal and vertical axes represent on the DSO screen?	50.0	93.5
Q7 How do the horizontal and vertical scale dials alter the waveform on the DSO screen?	12.9	60.9
Q8 How do the Positional Dials alter the waveform on the DSO screen?	38.7	47.8
Q9 When should you use the Auto-Scale Button?	0	56.5

On the other hand, the results for the group with the multimedia showed that, for all but one of the questions, the students achieve greater than 50% of the obtainable marks. The most concerning feature for the results is that for questions 7 to 9, the achieved marks dropped below 80% for the multimedia group. This would indicate that the explanations in this section are not clear, and that the explanations of the questions in these sections need to be improved.

The second part of this first study was a post-lab test analysing how students would measure the waveform they were asked to produce from the laboratory worksheet. There were three questions to this section, each worth one mark. Table 7 displays the average percentages for each group for each question.

These results were taken after the experiment was completed. The results indicate that, for the first two questions, the group using the Multimedia Tutorial performed significantly better than the group without the multimedia presentation. The most surprising result was the third question, where the group without the Multimedia Tutorial performed significantly better than the group with the Multimedia Tutorial. One reason for this could be that the explanation on how to perform this instruction was not as clear as it could be in the Multimedia Tutorial. Another reason might be that there was confusion in the instructions from the laboratory demonstrator, and the instructions given in the multimedia, if students were asked questions to perform this task.

Table 7: The percentage of marks achieved by the students, as a whole, for the post-test questions

	No multimedia	With multimedia
Q1 For Channel 1 on the DSO, what setting should the coupling be set to?	71.0	84.8
Q2 When taking your measurements, what multiplier was Channel 1 probe input set to?	48.4	82.6
Q3 When displaying relevant data about the waveform, which button did you utilise?	64.5	52.2

In summary, by modifying the original instructional design and creating the new multimedia instructional design using the principles in Table 5, we have successfully shown that student results did improve, and in some cases there was significant improvement over the old instructional method. By modifying the instructional design, we were able to reduce the extraneous load on students, freeing up more of the students mental resources to learn the material (as shown in Figure 3). Overall, the results in Tables 7 and 8 indicate that work is still required to improve the presentation. We still need to modify the instructional design of the Multimedia Tutorial, to make clearer and greater emphasis on key points where the students are still struggling. Work still needs to be completed on the last three questions of the pre-lab test and the last question of the post-lab test, while we still need to refine the overall presentation.

Student feedback

A second survey was commissioned for a sample of 20 students who utilised the DSO in a unit that assumes students had prior knowledge using this equipment. We proposed a hypothetical question to the students; that if they had access to the resource when they were completing the experiment, would any difficulties that were experienced have been reduced. Figure 6 indicates that students overwhelmingly believe that having access to the Multimedia Tutorial would have reduced the problems that they may have encountered. This is also consistent with the results from the effect size (Oswald, Baccini, Hinckley and Wild, 2012; Oswald, Wild and Hinckley, 2012), with these results demonstrating a significant difference and a practical difference between those students who have access to the Multimedia Tutorial than those who did not have access to the Multimedia Tutorial.

Another part to the survey asked the students, if further Multimedia Tutorial were to be created, what aspects of DSO operation students would want to have included. For this survey, we generated multiple options and gave the students the option to provide relevant feedback. The options offered to the students were: explaining oscilloscope functions, explaining how to use the function generator, how to measure on the oscilloscope, and how to connect the oscilloscope to other devices. The results for these questions are displayed in Figure 7.

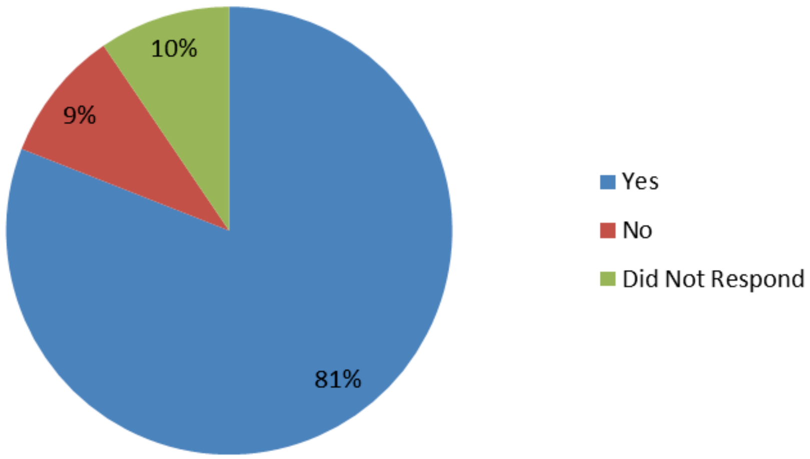

Figure 6: Respondents views to whether having access to the multimedia tutorial would reduce issues that hampered their ability to complete the laboratory experiment.

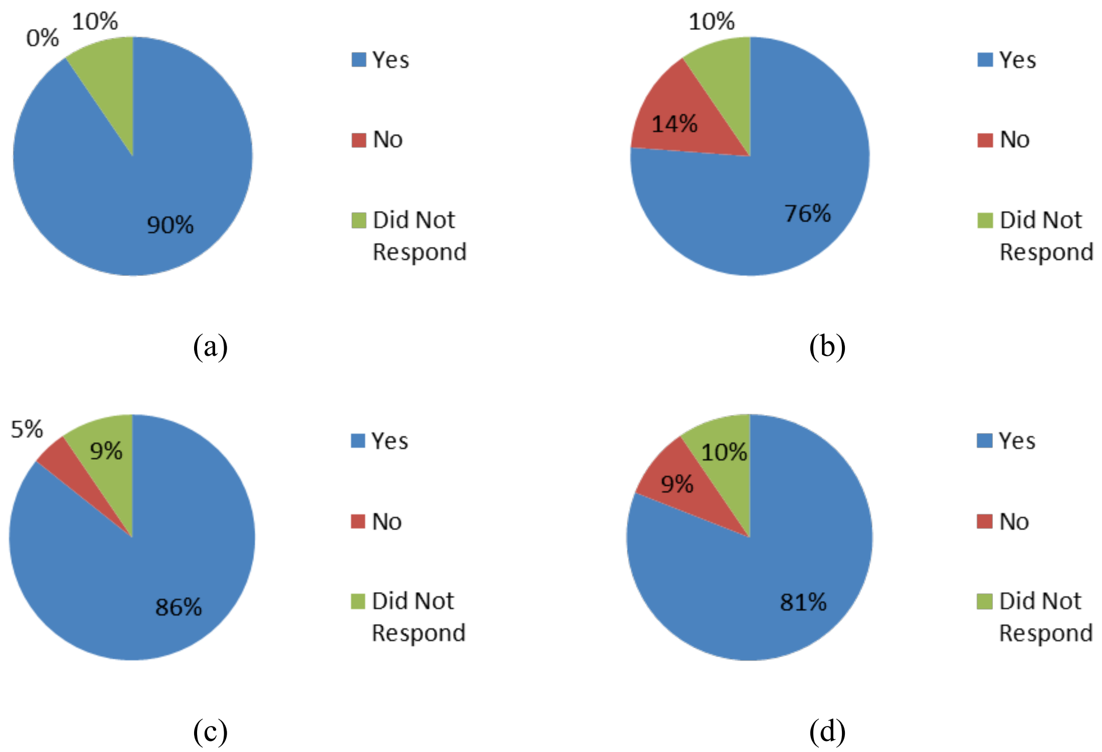

Figure 7: Student feedback for additional multimedia functionality, explaining (a) oscilloscope functions, (b) how to use the function generator, (c) how to measure on the oscilloscope, and (d) how to connect the oscilloscope to other devices.

The results from student feedback were: “the computer generated voice to talk slower”, “voice could be slightly smoother”, “voice more natural”, “voice is disjointed”, and “use a normal voice”. These results illustrate that more effort needs to be spent on developing better text-to-speech conversion, that can provide a more realistically-voiced narration for the students, and can still provide the same benefits that the current software can achieve.

Benefits

The benefits of designing a multimedia presentation of this type are wide-ranging. One of the aims of this project was to make the multimedia development as cost effective as possible (Institute of Physics, 2010; Powell, Anderson, van der Spiegel & Pope, 2003). Much of the software and technology that is used was either already owned or licensed by the University for use by staff and students. This project used readily available equipment and technology found at any University to a positive effect on student learning. It is also possible to quickly and simply modify a presentation, and create new presentations.

A secondary benefit is that the presentation demonstrates the specific test equipment that students will be exposed to in Physics and Engineering laboratory sessions in the School of Engineering. Our experiences have shown that students want instruction on the specific instruments they will use in the laboratory program, not a general presentation on an instrument that does not have the same controls (located in the same positions) as those used in the lab. The purpose of our project is to design a presentation for the students that relates to equipment that is utilised at ECU. Transferability of knowledge, in that we would also want students to develop generic skills that allow them to use any type and model of DSO, is also important. However, at this early stage of implementation of this Multimedia Tutorial, student confidence is considered more important that transferability, as this will allow students to quickly and efficiently develop fundamental operational skills for these specific DSOs. This aspect will be investigated in future studies.

Finally, the availability of relevant instructional multimedia allows students to easily access these learning tools online, both during and outside scheduled classes. This is useful, not only for initial instruction in the use and operations of a DSO (and function generator), but can also aid knowledge retention for future units of study, where it is assumed that students have already mastered the operation of a DSO.

Future work

Experience has shown that student retention of this knowledge is poor for current teaching methods. The issues that we will examine in future studies include:

- Comparison between the old and new methods in a first year units to investigate which method helps students retain more knowledge over time.
- Incorporating these multimedia resources into second and third year units where DSO use is assumed, and compare these results back to the first year unit where the students are assumed to have no knowledge of oscilloscopes.
- Continual study over time to investigate if students understanding has increase from unit to unit where oscilloscope knowledge is assumed.
- Develop additional Multimedia Tutorials to cover other DSOs and equipment. For example, advanced engineering units covering communications principles currently use the *Agilent 600* series DSO.

Also, from the results of the student feedback survey, a better text-to-speech conversion needs to be implemented, to produce a more realistic narration. We will also need to investigate the benefits of language options that these text-to-speech readers incorporate. We need to analyse if international students would benefit more from the Multimedia Tutorial being in their native language or are current settings suitable. Finally, our original Multimedia Tutorial needs refining, and new tutorials need developing that focus on different aspects of the oscilloscope and how it is utilised in Physics and Engineering units.

Conclusions

We have designed and developed an educational audio-visual resource on how to utilise the basic functions of the DSO. This resource is currently targeted at undergraduate first year students, although it is also useful as a review tool for students in second and third years. This paper illustrates that a significant improvement is obtained to students understanding of DSO operation by the utilisation of a Multimedia Tutorial in a laboratory exercise. We believe this to be the case as the Multimedia Tutorial offers clear and consistent instructions if the students chose to replay the multimedia. Added benefits in the use of a multimedia tutorial of this kind is that it reduces strains placed on the laboratory demonstrator, as students are more capable of completing parts of the laboratory exercise by themselves without the aid of the demonstrator.

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