

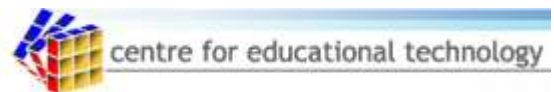


## Case Study 8

### Custom-designed virtual experiment in fracture mechanics in Mechanical Engineering

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*November 2008*



Title: Case Study 8: Custom-designed virtual experiment in fracture mechanics in Mechanical Engineering

November 2008

Report of the Opening Scholarship Project funded by the Shuttleworth Foundation

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Published by the Centre of Educational Technology, University of Cape Town, Private Bag x3, Rondebosch, Cape Town, 7701.

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## Acronyms and abbreviations

CET	Centre for Educational Technology
CREE	Centre for Research in Engineering Education
ICT	Information and communication technologies
LMS	Learning management system
NDE	non-destructive evaluation
OER	Open educational resource
UCT	University of Cape Town

## Introduction

This case study describes the development and use of a custom-designed virtual experiment in Mechanical Engineering which partially simulates the concept of metal fatigue to help student engage with a complex practical application. It then explores some of the enabling or constraining structures, policies and practices at a national, institutional and personal level that appear to have an impact on making such a simulation available as an Open educational resource (OER).

According to Nickerson, Corter, Esche and Chassapis, 'economic pressures on universities and the emergence of new technologies have spurred the creation of new systems for delivering engineering laboratories in education, in particular simulations and remote-access laboratory systems' (2007: 708). There is still some debate around the relative benefits of performing mechanical engineering experiments hands-on in a physical laboratory or in some type of remote laboratory (Greene, Issa, Smyth, Brabazon and McLoughlin 2007). However, there are studies that present some evidence that

performing a laboratory experiment as an observer (non-hands-on), such as conducted in a distance education context, can be as effective a learning tool as personally performing the experiment in a laboratory. (Abdel-Salam and Kauffman 2006: 747)

Li, Aziz, Esche and Chassapis observe that 'while the operation of online laboratories is very effective compared with traditional, on-site laboratories, their development demands vast financial, temporal and personnel resources' (2007: F3G-1). These financial and resource constraints certainly influence the extent to which ICTs are adopted for teaching and learning activities in Mechanical Engineering, but may provide a compelling reason for sharing developed resources with others in the discipline.

This case study investigates how a lecturer collaborated with a team of educational technologists from the Centre for Educational Technology (CET) at the University of Cape Town (UCT) to develop a custom-designed virtual experiment for a Mechanical Engineering lecturer to use as a virtual practical. It briefly provides the reasoning behind the selection of this virtual experiment as a case study and reviews the research methodology adopted, before describing the pedagogical reasons behind its development. It then explores some of the enabling and constraining issues that influence making this virtual experiment available as an OER.

## Selection of this case study

Selection of this case study was based on the lecturer's prior application for a Teaching with Technology Grant,<sup>1</sup> offered each year by CET, and reported success of the implementation of the funds by the fund co-ordinator in CET. It was specially selected, as it dealt with a curriculum topic that, as a digital resource, is potentially sharable among other Mechanical Engineering students beyond the confines of UCT.

## Research methodology

This case study used a range of methods to investigate the use of a custom-designed physical simulation in Mechanical Engineering. These included document analysis of existing resources (a proposal for funding, prior publications and presentations) and follow-up interviews with the lecturer and educational technologists concerned.

## Custom-designed virtual experiment in Mechanical Engineering

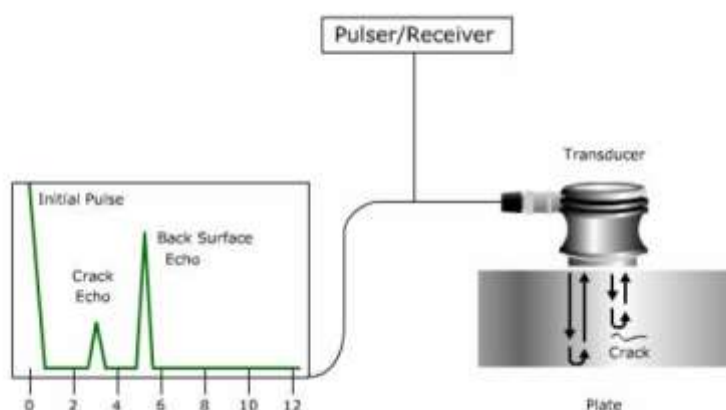
### Curriculum context

In his presentation,<sup>2</sup> the Mechanical Engineering lecturer described the rise of the discipline of fracture mechanics which enables engineers to predict whether a flaw in an object might result in a critical failure under a specific load. One way in which these tests are conducted is through the use of ultrasonic non-destructive evaluation (NDE). He further explained how ultrasonic testing uses high frequency sound waves directed into some type of material to locate changes in the properties of this material. He noted that the most common approach of such ultrasonic testing is that of a 'pulse-echo' where sound is introduced to the material and reflections (echoes) are returned to a receiver from internal imperfection. The reflected wave signal is transformed into an electrical signal by a transducer (Figure 1).

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<sup>1</sup> <http://www.cet.uct.ac.za/collaborate#grants>

<sup>2</sup> <http://teaching.cet.uct.ac.za/articles/view/23>



**Figure 1: Process of ultrasonic testing**

(from Reed, Deacon & Jaffer 2006: 20)

### Pedagogical challenges

In a short article the lecturer and the educational technologist explain that the third-year Mechanical Engineering students who need to understand ultrasonic NDE ‘needed to experience a practical application of the theory before many things would start making sense’ (Reed, Deacon and Jaffer 2006: 20). In order to fully engage with the complex theory, students need to have opportunities to explore materials and relate their findings back to the theory. The lecturer explained that the key challenge that this poses is that there is ‘no way of doing actual ultrasonic testing in the lab’ as the ‘cost of ultrasonic probes is prohibitive and the difficulties in designing an experiment with “interesting” flaws for students to find are almost insurmountable’ (Reed *et al.* 2006: 20). Moreover, the time allocated to this section of the curriculum is quite restricted and the practical tutorial session is only one hour long.

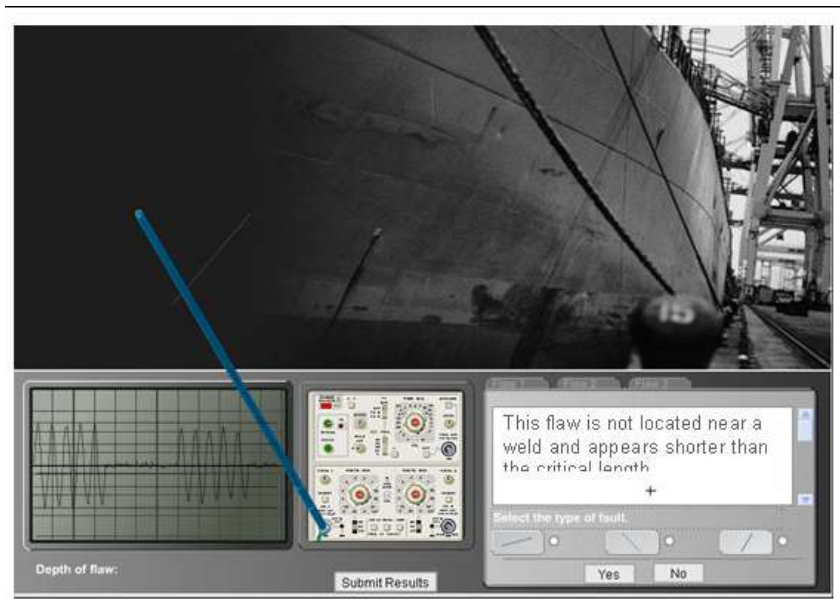
These challenges and the opportunity provided by CET to support lecturers to develop digital course materials resulted in the development of a computer-based tutorial that requires students to engage with a simulation of an ultrasonic probe and use this information along with the theory to make judgements about the nature of flaws detected in specific materials.

### The virtual experiment

The lecturer and the educational technologists from CET devised a three-part virtual experiment for third-year Mechanical Engineering students using a combination of Adobe Flash, MExcel and MSWord. The virtual experiment was contextualised within a real-life situation – the sinking of the Alexandros 7, the 299-metre bulk carrier, about 300 nautical miles off the Eastern Cape Coast of South Africa. Students are required to undertake three associated tasks as the ship’s engineer:

1. Use the ultrasonic probe to locate the flaw in the hull of the ship.
2. Process the data collected with an oscilloscope.
3. Write a report on an assessment of the flaws and recommend whether the ship should be repaired immediately or be allowed to sail.

In the first part of the virtual experiment, students are required to move the virtual ultrasonic probe across the hull of the ship and note the representation of the output of what a real oscilloscope reading would have shown. As the educational technologist created a set of randomly generated flaws (within set parameters), each student has their own 'flaw' of different length and orientation to detect, thereby ensuring that each student has a 'unique' problem. The students move the virtual probe over the hull of the ship and note the oscilloscope outputs when the flaw is detected (Figure 3).

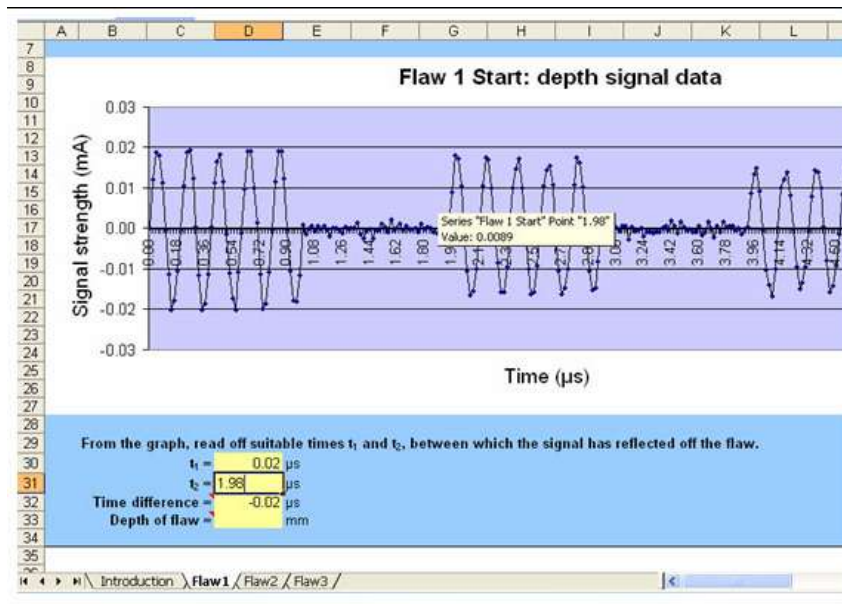


**Figure 2: Hull of the ship with virtual probe and associated oscilloscope outputs<sup>3</sup>**

Once the 'flaw' is detected, the information is then exported to an MS Excel spreadsheet. Each student is presented with a personalised spreadsheet and is then required to calculate the depth, length and orientation of the flaw (Figure 3).

<sup>3</sup> From <http://teaching.cet.uct.ac.za/articles/view/23>.

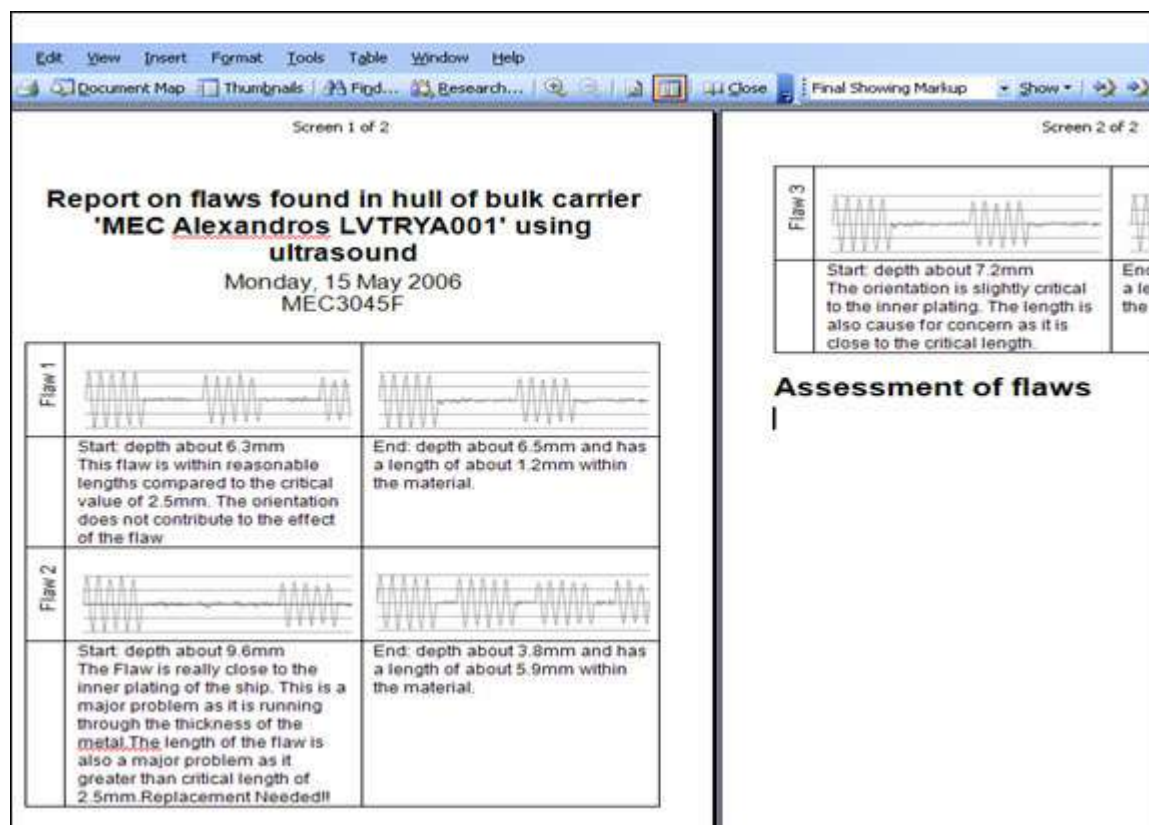




**Figure 3: Simulated oscilloscope outputs<sup>4</sup>**

Having completed the analysis on the spreadsheet, students are then required to open up a MSWord document that has assembled their earlier calculations and interpretations in a report form (Figure 4). The students are then asked to justify their assessment and make a recommendation to the captain of the ship. This exercise requires students to make a qualitative judgment from a series of quantitative data that draws on the underlying theory of fracture mechanics.

<sup>4</sup> From <http://teaching.cet.uct.ac.za/articles/view/23>.



**Figure 4: Report on flaws found in hull of bulk carrier<sup>5</sup>**

The lecturer's assessment focused on 'the accuracy of the analysis of the data as well as the quality of the interpretation made as to whether the ship could continue in active service or not' (Reed *et al.* 2006: 20).

### Value of the simulation: Lecturers' views

The lecturer reported that the online tutorial conducted in a computer lab was successful in providing students with the intended experience. In particular he notes that: 'much of the educational technology developed was to enable the students to complete the tutorial within an hour when I was available to discuss the conceptual issues ... students finalised the reports in their own time'. He plans to run the tutorial with some minor changes for the next cohort of students.

The lecturer expressed his intention to write up his experience of using this virtual practical and the students' response to it, but this is not a priority at the moment, given the precedence of disciplinary-based research dissemination over pedagogical papers within his discipline.

This innovative virtual practical was clearly inspired by a lecturer who has a concern to make learning as engaging for his students as possible. Although he and some of his colleagues

<sup>5</sup> From <http://teaching.cet.uct.ac.za/articles/view/23>.

are committed to innovative teaching strategies, he reports that this sentiment is not shared by the entire department.

### Potential as an open education resource

When the lecturer was approached by the interviewer and later by colleagues from CET about the possibility of making this simulation available as an OER, he was very receptive to the idea. However, as he did not initially intend this virtual practical to be used outside of this specific course, the lecturer explained it was not originally designed as a stand-alone simulation and would need further development to make it one. When asked whether he would be prepared to undertake this development with CET, he was slightly reluctant as the existing simulation seems to suit his current needs.

### Institutional policies, structures and practices constraining or enabling OER

In terms of institutional policies or structures that tend to constrain the lecturer using or producing potential OER, the precedence of research over teaching clearly has an impact on the time the lecturer devotes to preparing teaching resources. This is compounded by his perception that within his department disciplinary-based research dissemination is still valued more than pedagogical research and its dissemination, despite the existence of the Centre for Research in Engineering Education (CREE).<sup>6</sup>

Fortunately the lecturer has found some support from colleagues in his department who are supportive of pedagogical deliberation and he has been able to benefit from this collegial back-up as well of the technical and financial support from CET (in the form of the Teaching with Technology grant).

While there are a number of constraints and a few enablements to publishing this resource as an OER, the ultrasonic probe tutorial highlights some possibilities towards opening up resources not originally intended to be used beyond the particular context.

### National policies, structures and practices constraining or enabling OER

In terms of national structures that tend to constrain the lecturer using or producing potential OER, the only slightly implicit constraint alluded to was the time that it took to develop these materials, which reduces the amount of time spent on other activities such as research – a key requirement stipulated by the national Policy and Procedures for measuring the research output of public higher education institutions (Ministry of Education South Africa 2003). Although the lecturer has plans to formally publish his reflections on the use of this virtual

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<sup>6</sup> The aim of CREE is to establish and promote engineering education as a research field both at UCT and in the broader academic community. (See <http://www.cree.uct.ac.za/>.)

experiment, he has published initial reflections in CREE (Reed, Deacon & Jaffer 2006), and either he or members of CET have reported on his simulation in a range of presentations to colleagues at UCT and elsewhere. Moreover, he has also presented his reflections on his use of this simulation at the CET's Show and Tell seminars.<sup>7,8</sup>

At the moment there are no obvious national structures that deliberately enable the development of OER in general or for mechanical engineering materials in particular.

## Degrees of openness

Hodgkinson-Williams and Gray (2008) describe four of the attributes associated with the concept of 'openness': social openness – 'the willingness to make materials available beyond the confines of the classroom'; technological openness – 'the presence and use of interoperability standards and functionality'; legal openness – 'a range of flexible licenses'; and financial openness – 'affordability to the user'.

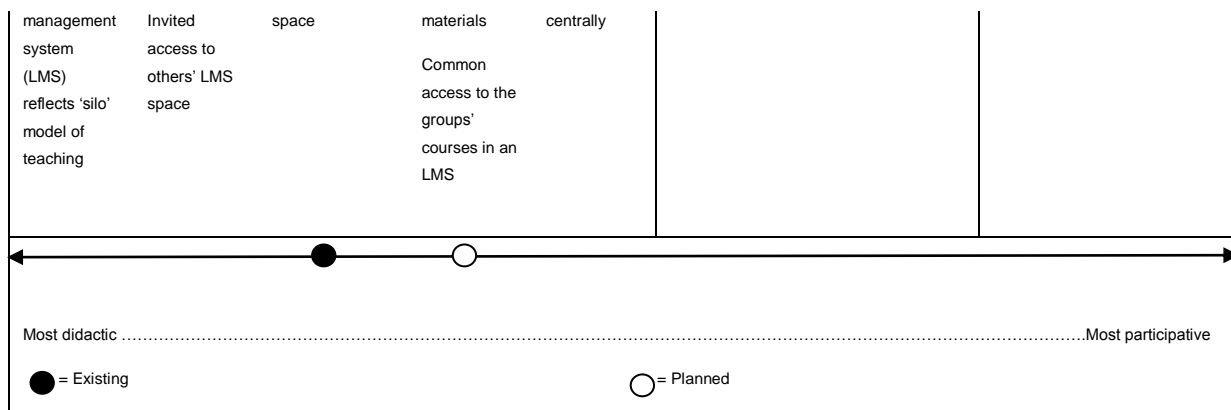
## Social openness

On the scale of social openness (Figure 5), the ultrasonic probe practical currently falls on the lecturer-centred use continuum, as this simulation was intended to be a demonstration tool for the lecturer. As the lecturer and the educational technology team from CET developed the simulation together, it can probably be construed as 'co-ordinating' use. For this simulation to move along the continuum of social openness, it would need to include as a minimum additional teaching notes to describe its intended use. The lecturer is willing to share this resource, but may need some financial or technical support in the development of the accompanying notes to make it immediately useful to others.

Social openness								
Lecturer-centred					Student-centred		Student, lecturer and broader community	
USE					CONTRIBUTE		SHARE	
Traditional	Distributing	Coordinating	Organising	Managing	Participating	Contributing	Exchanging	Collaborating
Individual lecturer designs, uses and manages own materials for specific context Learning	Individual lecturer designs, uses and manages own materials for specific context, but shares some	More coordinated curriculum design More sharing and reuse Partial access to others' LMS	Clear aims for working together Group design procedures More organised local	Courses designed, developed and managed by multi-disciplinary teams Materials managed	Participate in forums or chats within LMS spaces	Contribute opinions on content and processes in blogs	Sharing content and processes with peers and lecturers using wikis	Collaborating with peers, lecturers and others (e.g. professionals in the field in virtual communities)

<sup>7</sup> <http://teaching.cet.uct.ac.za/articles/view/23>

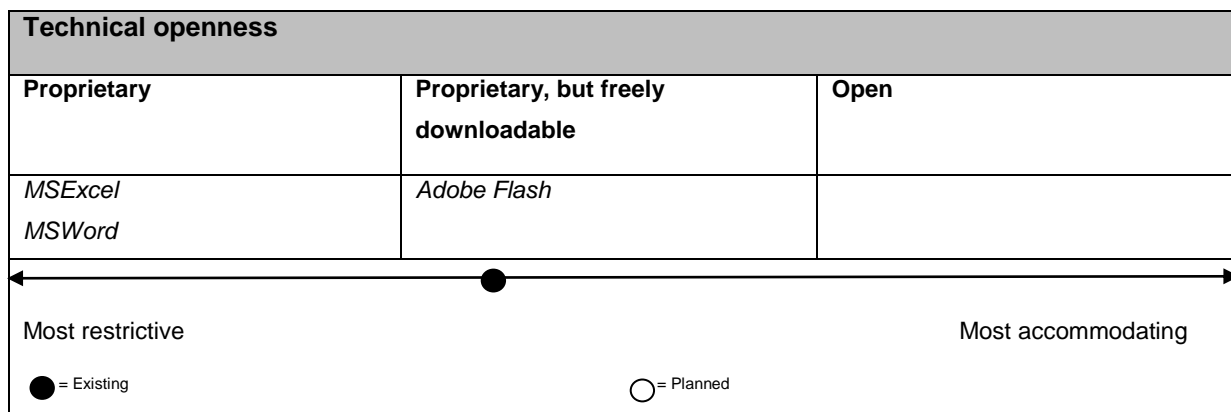
<sup>8</sup> <http://www.cet.uct.ac.za/BrandonReed>



**Figure 5: Degrees of social openness: Ultrasonic probe virtual practical**

### Technical openness

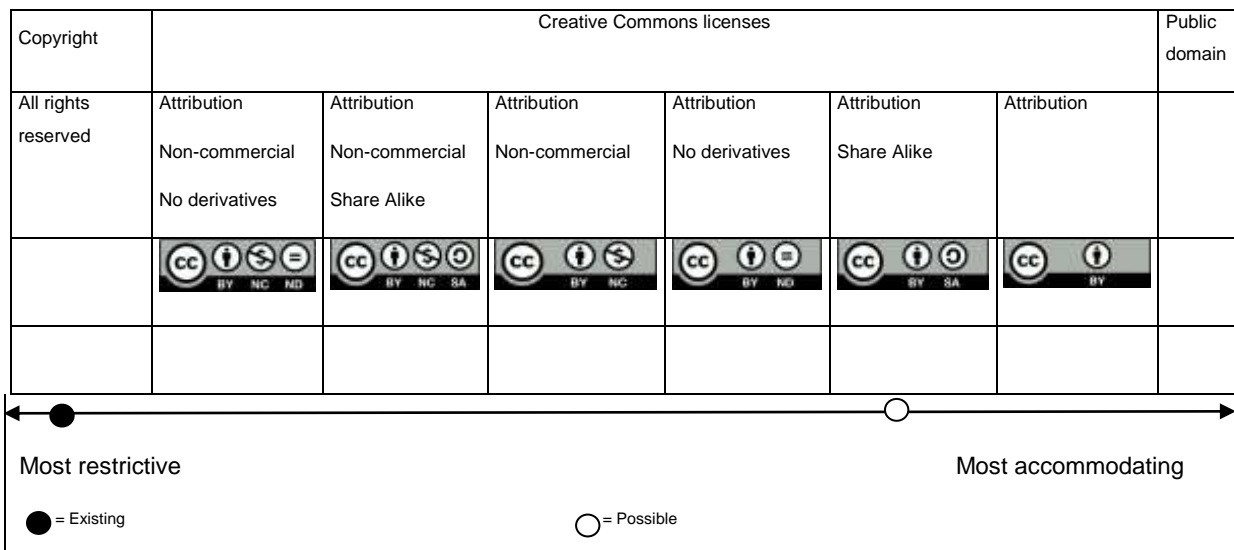
As the ultrasonic probe virtual tutorial is written in Adobe Flash, a proprietary, but freely downloadable animation tool, it is technically 'partially open'. If the lecturer and educational technology team make the product available, others could theoretically make adaptations to the code as well as reconfigure the MSExcel and MSWord files (Figure 6).



**Figure 6: Degrees of technical openness: Ultrasonic probe virtual practical**

### Legal openness

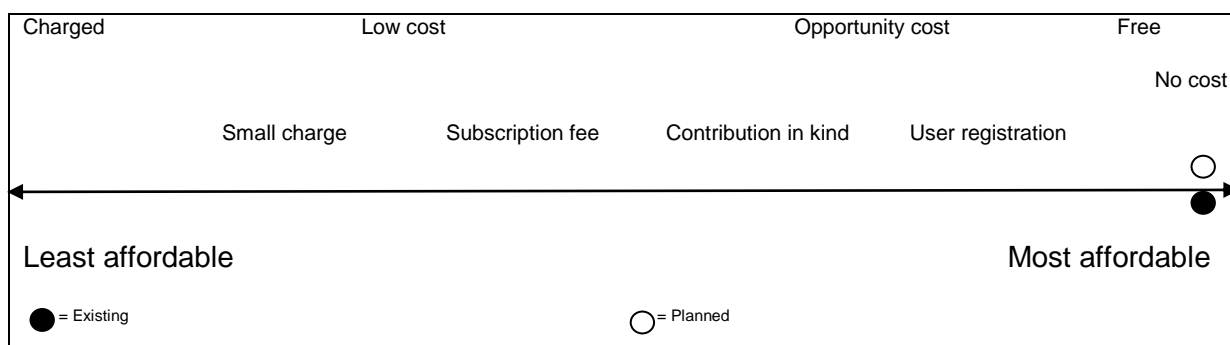
At the moment the virtual ultrasonic probe practical is assumed to have the lecturer's copyright as this is the default copyright, but he has indicated that he is prepared to share it as Creative Commons Attribution/Share-Alike license (Figure 7). The extent of the sharing still needs to be determined.



**Figure 7: Degrees of legal openness: Ultrasonic probe virtual practical**

### Financial openness

At the moment the development of this virtual ultrasonic probe tutorial was sponsored by a Teaching with Technology grant. The grant is not awarded with the intention to recover costs, so theoretically the tutorial can be shared at no cost (Figure 8).



**Figure 8: Degrees of financial openness: Ultrasonic probe virtual practical**

## Lessons learned

The key lessons learned and key recommendations are as follows:

*Lesson 1: The original intention of the use of digital learning materials is an important indicator of how easily existing digital learning materials can be made available as OER.*

As the lecturer's original intention was to create a simulation to demonstrate the practical application of a concept and not as a stand-alone simulation, its deployment as an OER is not possible without further development.

### *Ways forward*

- Include additional programming to make it a stand-alone simulation.
- Develop additional teaching notes to explain how it is used to support the curriculum.

*Lesson 2: Partnerships between lecturers and educational technology specialists can result in the development of quite sophisticated digital learning materials.*

This case illustrates the value of team development with the lecturer actively involved in the scoping of the design of the digital learning material and the technical development allocated to a learning designer and a programmer. While this current version only demonstrates the relationship between identifying the potential point of metal fatigue and the readings on the oscilloscope, with additional funding and motivation for extended use, this simulation could be developed as a stand-alone simulation.

*Lesson 3: A cost benefit analysis needs to indicate the potential value of the digital learning material*

While it might be ideal to have sophisticated digital learning materials to support the teaching and learning processes, a cost benefit analysis needs to be undertaken to ensure that the particular digital learning materials warrant the level of investment required.

*Ways forward*

- Investigate whether there are other similar materials available and if not, investigate whether a similar course at another higher education institution or professional association might be willing to invest in the development and reuse of the materials.
- Decide that this will be an OER and therefore include the key notes that make it usable without excessive redevelopment.



## Conclusion

This virtual experiment used ICTs to create a learning environment that would have been difficult to achieve in a one-hour tutorial in a traditional setting. While the virtual experiment was not originally intended to be used beyond the third-year Mechanical Engineering group at UCT, with some additional programming or additional teaching notes, it could be shared more widely as an OER. The key issue to be resolved is the time required to do this, as the lecturer is satisfied with its current state. Funding or other incentives would need to be provided to create additional programming or teaching notes.

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