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Online Resource Platform for Mathematics Education

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Online Resource Platform for Mathematics Education

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Abstract

The aim of this project was to develop and explore the use of a Sharable Content Object Reference Model (SCORM) integrating a web-based platform for the study of mathematics as part of an active learning environment. The platform was designed to provide active support to engineering students especially those in their first year of study. Early use of the platform can identify possible areas of weakness and provide the self-learning environment required for students to become more proficient in areas where they are lacking key skills or are finding the concepts difficult to understand.

The platform consists of a set of tests and applications for the study of engineering mathematics. The tests can adapt and change depending on the answers provided by the student, including video feedback for incorrect answers before the student progresses to the next question. Based on the idea that teaching a concept is the best way to learn that concept, the students become actively involved in the platform as they create the videos that provide feedback to the other users of the platform. This active learning, constructivist approach provides an environment of achievement and ownership that allows students of all levels to enjoy the learning experience.

Keywords: active learning, mathematics education, videos, online quiz, graphic tablets.

"*Tell me and I forget, teach me and I may remember,*
involve me and I learn."
Benjamin Franklin

Outline of Fellowship Project

Introduction

The role of mathematics in the education of engineers and other STEM (Science, Technology, Engineering and Mathematics) related disciplines is widely accepted. Students who possess weak mathematical skills generally struggle to reach the learning outcomes of technical modules, display poor engagement in module content and have issues with retention (Russell 2005; Carr, Bowe and Ni Fhloinn 2010; Sheridan 2013). The use of a standard maths diagnostic test (MDT) to evaluate core competencies has revealed that many students entering higher education do not possess the full suite of mathematical skills required to succeed in technical programmes (Carr et al. 2013; Marjoram et al. 2013).

Using technology as an aid to teaching and learning is widely discussed in research literature (Pinder-Grover, Green and Millunchick 2011; Yoon and Sneddon 2011; Carrillo et al. 2013). In the highly technological world of today communication methods and styles can be quite diverse. Having grown up in this environment the student of today is quicker to embrace technology and adapt to changes as they are introduced. This flexibility presents many opportunities to exploit the diversity of learning and communication styles, and so, in order to engage the student the educator needs to communicate with a similar set of tools.

In the traditional approach to learning outlined by Bovill, Cook-Sather and Felten (2011), the “expert tutor” is placed in front of “subordinate learners”. With the changing needs and expectations of the student a pedagogical shift from a “passive” learning environment to one that embraces “active” learning is required in order to stimulate a deeper learning experience. This approach is supported by a rising interest in research literature which points to students becoming more engaged and empowered when they are employed as agents of their own learning (Kay, Dunne and Hutchinson 2010; Dunne and Zandstra 2011; Green and Crespi 2012). In an active learning environment the focus shifts from content delivery by the lecturer to active engagement with the material by the student. The role played by active learning in higher education is discussed by Chickering and Gamson (1987) and Chickering and Ehrmann (1996) within the context of their seven principles of good practice in undergraduate education. Cromack (2008) also makes the assertion that where a “symbiotic relationship exists between technology and learner-centred education” an improvement in student learning is observed.

Within a European context, the need for a different approach to traditional teaching is supported by the Bologna Process[1] one of the primary objectives of which is the transformation from a *teaching focussed* to a *learning focussed* education system. This involves the adoption of new teaching methodologies which encourage the implementation of active teaching methodologies aimed at improving the student’s core competencies and skills. From a national perspective, “The National Strategy for Higher Education to 2030” (Department of Education and Skills 2011) emphasises the need for teachers in higher education to “stimulate active, not passive learning”. It points to the need to “create a process of active learning by posing problems, challenging student answers, and encouraging

[1] http://www.eurireland.ie/programmes/bologna-process.128.html

(students) to apply the information and concepts". From a DIT perspective, the response of the College of Engineering and Built Environment (Conlon 2013) to the DIT strategy on student engagement (DIT 2011) highlights, among other things, the use of modern technology to support student learning as well as increasing the diversity of the learning experience.

Participants

The students who participated in this study are drawn from a first year level 7 general entry engineering programme (DT097). A comparison of CAO entry points for DT097 with two other denominated level 7 programmes (DT004: Civil Engineering; DT006: Mechanical Engineering) as well as a first year common entry level 8 Engineering programme (DT025) is provided in Table 1. The figure in brackets represents the mid-point entry CAO points. Based on CAO entry points, students from the level 7 DT097 programme compare favourably in their academic achievements with those on the level 8 programme (DT025).

Academic Year	***Level 7***			***Level 8***
	DT097	DT004	DT006	DT025
2010-11	---	220 (365)	230 (385)	340 (390)
2011-12	320 (430)	220 (360)	230 (365)	365 (430)
2012-13	360 (460)	240 (335)	300 (385)	350 (415)

Table 1: Selected programme CAO entry points.

Of the 37 students enrolled on DT097 only 7 (16%) took the higher level mathematics paper in the Leaving Certificate. Nationally, 25.6% took the higher level paper in 2012-13. The distribution of grades among the participants in this study who took the ordinary level mathematics paper is: A (85%-100%) = 2; B (70%-84%) = 14; C (55%-69%) = 4; and D (40%-54%) = 10.

Approach taken to study

Figure 1 illustrates the approach employed for this study. It follows the design-based approach described by Reeves, Herrington and Oliver (2004), the foundations of which lie in developmental research (Van den Akker 1999).

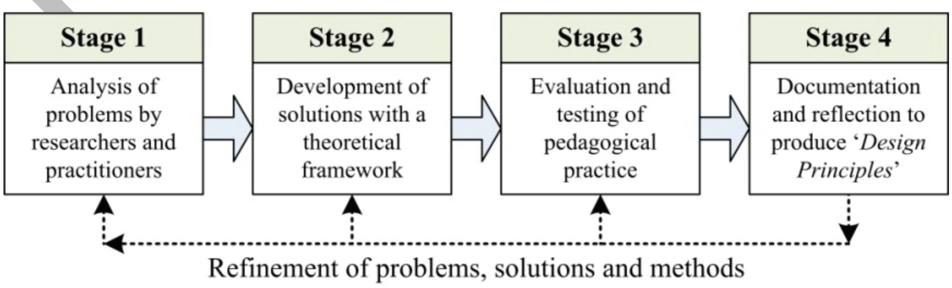

Figure 1: Design based research stages.

Design based research stages

The four stages illustrated in Figure 1 comprise an interactive cycle with an iterative sequence of *analysis*, *design*, *evaluation* and *revision*. A cycle of successive approximations continues until a balance between the initial ideals and the actual realisation of the study are achieved. This approach is particularly beneficial to research aimed at "exploring and exploiting the potential of information and communication technologies in education" (Reeves et al. 2004).

The four stages are broken down as follows:

- **Stage 1:** The focus is on core mathematical concepts which are proving difficult to understand. These are initially identified using either a standard maths diagnostic test (MDT) or through a student survey.
- **Stage 2:** A set of online resources consisting of quizzes created by the lecturer and feedback videos created by the student are developed. The feedback videos allow students to synthesise and disseminate knowledge from various sources on a given mathematical topic.
- **Stage 3:** Evaluation of student performance is carried out using the online quizzes. Students are encouraged to give feedback at regular intervals and demonstrate active performance.
- **Stage 4:** Outputs are in the form of knowledge (student learning) and products (quizzes and videos). Feedback is obtained from students through surveys and focus groups. Usage data and scores from the online quizzes are analysed.

The Learning Management System (LMS) used by DIT is webcourses (Blackboard). The online quizzes are created using Wondershare QuizCreator®[2] which can be integrated as a SCORM (Shareable Content Object Reference Model) quiz package into webcourses.

Phase 1: Students as co-creators

Solutions to mathematical problems are created by the student using graphic tablet technology (Wacom® Intuos Pen & Touch Medium[3]) and video creation software (HyperCam 2[4]). Students work collaboratively in groups of two/three to create a solution. Once a solution is obtained, a script for the video (see Figure 2) is prepared and the graphic tablets are used to create the video with accompanying commentary (see Figure 3). As part of the development of the solution the students gather knowledge from various sources and engage with the concepts at a deeper level as they are required to explain the process, concepts and theory behind it. This helps to promote a deeper learning experience rather than the more shallow approach characterised by rote learning.

[2] http://www.wondershare.com/pro/quizcreator.html
[3] http://www.wacom.com/en/gb/
[4] http://www.hyperionics.com/hc/

Phase 2: Online content for self-study

The SCORM run-time environment (RTE) is illustrated in Figure 4 (adapted from 'ADL SCORM Run-Time Environment - Overview'[5]). Reusability and interoperability of learning resources across different LMS is achieved through a common means of '*launching*' resources. These resources communicate with the LMS through an Application Programming Interface (API) using a language such as JavaScript to implement RTE API function calls to the LMS.

The SCORM objects (SCOs) are made up of quiz questions and feedback videos which are assembled into packages with delivery instructions. The LMS loads the SCOs and delivers them according to the instructions which detail the order and number of questions to be answered. This can be tailored to manage the different paths that can be taken depending on the answers provided by the student. Quiz questions are accessed in ascending order of difficulty as illustrated in Figure 5.

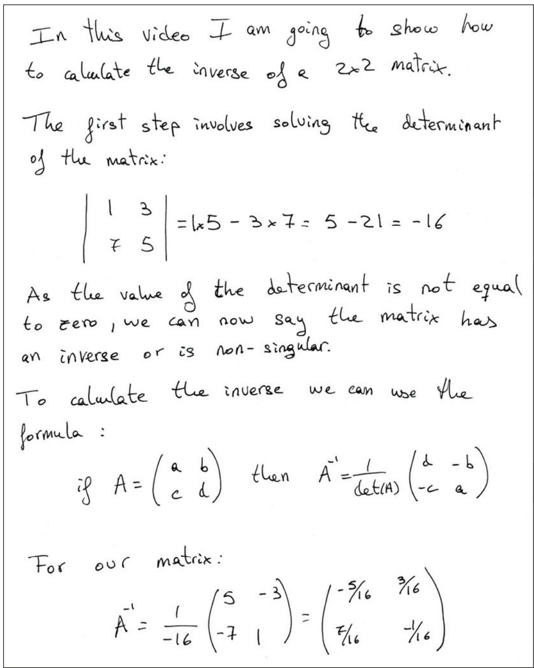

Figure 2: Extract from a typical student-created script.

Figure 3: Students use a graphics tablet to write the solution which is captured as video.

An incorrect answer will cause the student to be re-directed from the *main question path* (MQP) to the *feedback/reinforcement path* (FRP). From here the student may view videos created by their peers to help reinforce the concept being examined by the quiz question. On successful completion of a question the student is re-directed back to the MQP where they can proceed to the next question. A typical question from the MQP and its associated feedback path are illustrated in Figures 6 and 7 respectively.

[5] http://www.cen-ltso.net/main.aspx?put=242

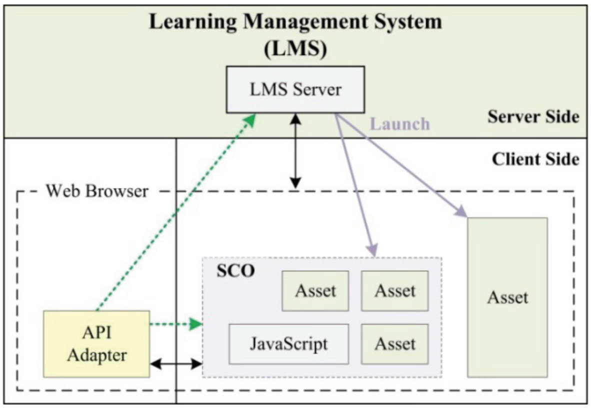

Figure 4: The SCORM run time environment.

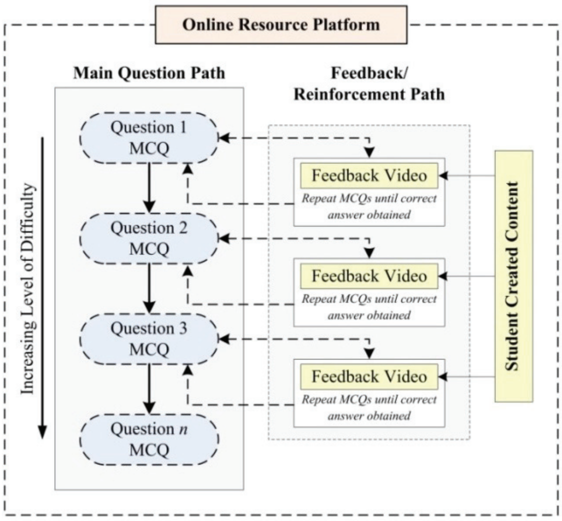

Figure 5: Main question and feedback/reinforcement paths.

Question (Main Question Path)	
Which of the following matrices is singular? $\boldsymbol{A} = \begin{pmatrix} \mathbf{1} & \mathbf{8} \\ \mathbf{2} & \mathbf{16} \end{pmatrix}$ $\boldsymbol{B} = \begin{pmatrix} \mathbf{3} & \mathbf{8} \\ \mathbf{2} & \mathbf{6} \end{pmatrix}$	
Possible Solutions	
(a)	A is singular because its inverse doesn't exist.
(b)	B is singular because its inverse exits.
(c)	Both A and B are singular because their values are not equal to zero.
(d)	None of the two matrices are singular.

Figure 6: Sample quiz question from MQP.

Question (Feedback/Reinforcement Path)	
Find the inverse of… $\boldsymbol{A} = \begin{pmatrix} \mathbf{5} & \mathbf{2} \\ \mathbf{2} & \mathbf{6} \end{pmatrix}$	
Possible Solutions	
(a)	A has no inverse
(b)	$A^{-1} = \begin{pmatrix} 6 & 2 \\ 2 & 5 \end{pmatrix}$
(c)	$A^{-1} = \begin{pmatrix} 6 & -2 \\ -2 & 5 \end{pmatrix}$
(d)	$A^{-1} = \begin{pmatrix} 6/26 & -2/26 \\ -2/26 & 5/26 \end{pmatrix}$

Figure 7: Sample quiz question from FRP.

Evaluation and Conclusions

Maths Diagnostic Test

The mathematical capabilities of the students were measured at the start of the study using a standard MDT (Carr et al. 2013). A breakdown of the results is illustrated in Figure 8. The MDT was chosen over Leaving Certificate mathematics results as it allows all non-standard applicants, who may have taken an alternative route into the programme, as well standard CAO applicants to be included. The results from the MDT show a greater proportion of grades in the lower half (<50%) of the range suggesting a poor understanding of core mathematical concepts. Following the MDT, two sub-groups were identified based on performance i.e. students with a score ≥50% and students with scores <50%.

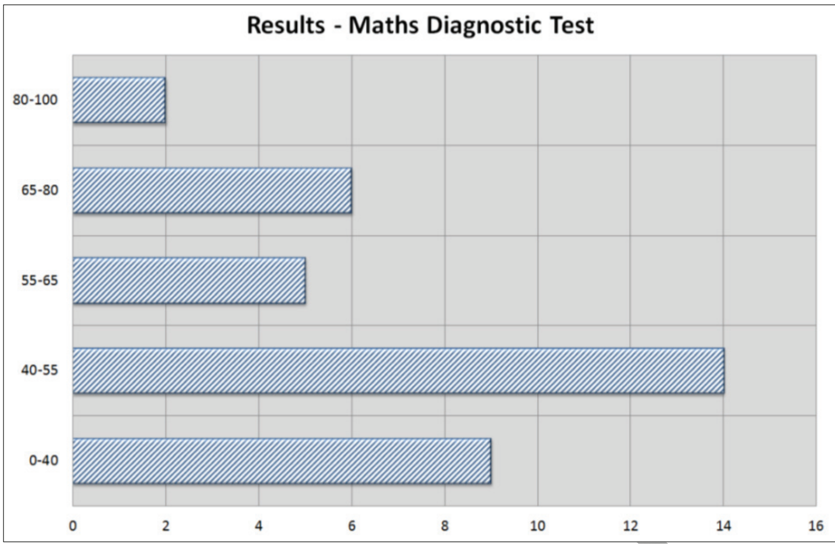

Figure 8: Results from the maths diagnostic test.

Student Survey

A survey was conducted amongst those students who participated with responses based on a five-point Likert scale (*1-Strongly Disagree, 2-Disagree, 3-Neither Agree/Disagree, 4-Agree, 5-Strongly Agree*). Average responses are listed in Table 2 (*n* = 21). The responses received from the survey are illustrated in Figures 9 to 13.

			Average Response
Statements	**1.**	Creating the videos was a very useful tool for learning.	3.90
	2.	Recording the videos allowed me to practice what I learned in the lecture and reinforce the core concepts outlined.	4.24
	3.	I am planning to use all the on-line resources (quizzes and videos) for revision in preparation for my module exam.	3.74
	4.	I would recommend creating videos for other subjects.	3.86
	5.	If you could rewrite the maths module, you would remove the video component.	1.90

Table 2: Selected student survey responses.

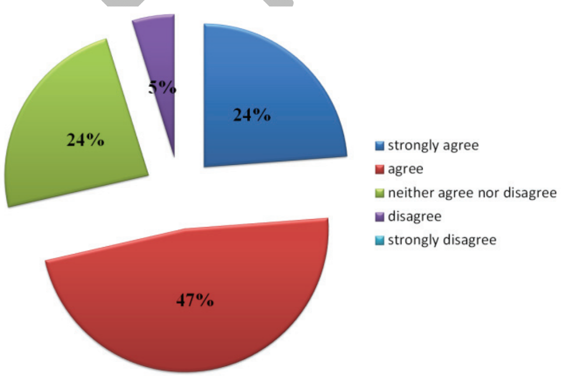

Figure 9: Statement 1 responses.

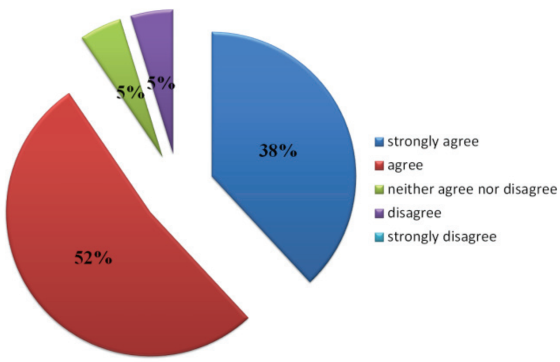

Figure 10: Statement 2 responses.

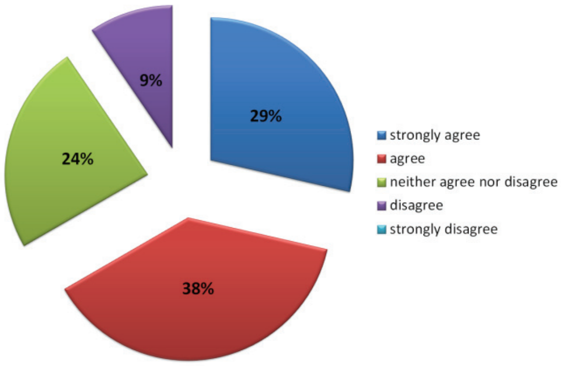

Figure 11: Statement 3 responses.

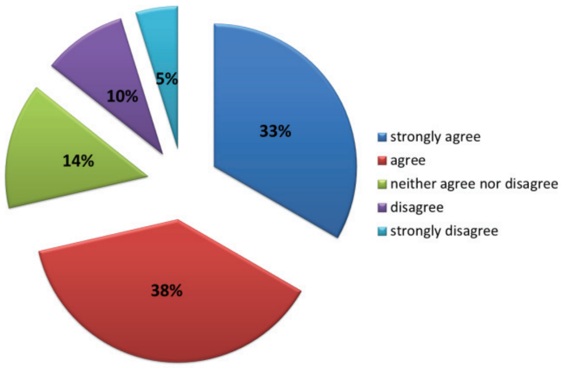

Figure 12: Statement 4 responses.

A question was also posed about student preference for the amount of time spent on tutorial sessions where videos were created as part of an active learning environment to those which took the form of a traditional tutorial session. Figure 14 shows the responses broken down into two categories i.e. those who obtained ≥50% in the MDT and those who achieved <50%.

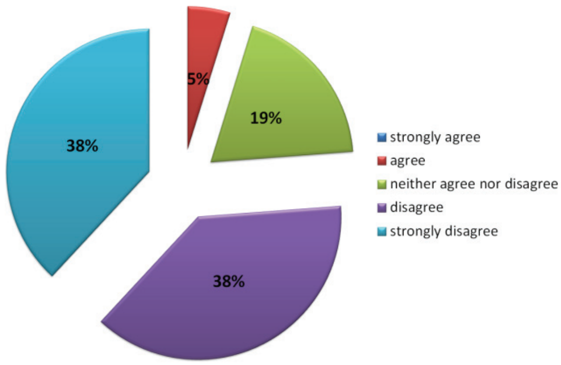

Figure 13: Statement 5 responses.

When the results are divided into the responses of the two sub-groups, the lower scoring sub-group prefers a higher percentage of tutorials creating videos than the sub-group with higher scores. This result is also evident where the students were asked if they would re-write the module to eliminate the video tutorial sessions and replace them with traditional tutorials. The students with a MDT score <50% either disagree or strongly disagree with eliminating the video tutorials are 80%, with 20% neither agreeing nor disagreeing. Comparison between Figure 13 and Figure 15 confirms the trend evidenced in Figure 14 in that students with lower MDT scores (<50%) prefer that the module includes the creation of videos.

The students' responses show a general preference for a mix of traditional and video tutorial sessions. A point to note is that no student showed a preference for a 100% session using one or the other method. This study stems from an initial pilot study carried out by Llorens (2013) into the use of online videos for mathematics peer instruction. Results from that study showed that the active learner approach to online videos, where the students solve a problem and disseminate that solution to their peers via online videos, increases student engagement, encourages deeper thought, increases motivation and provides confidence for weaker students.

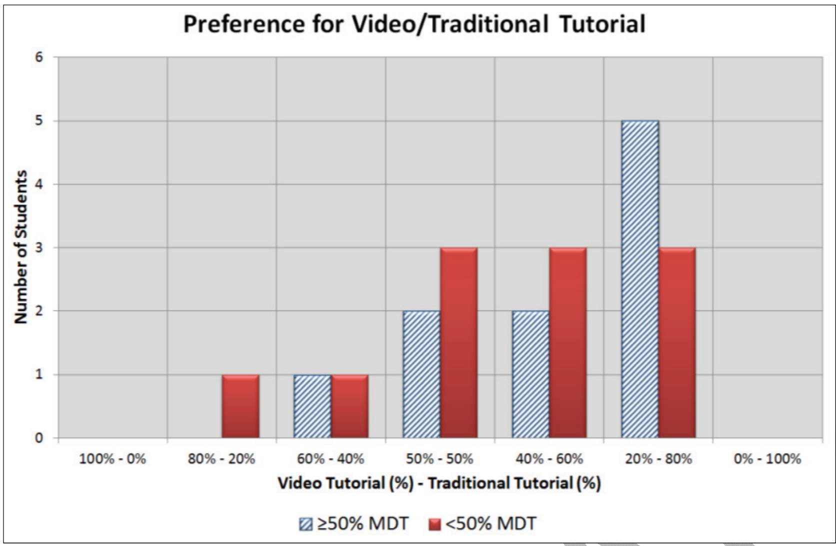

Figure 14: Student preference for video / traditional tutorials.

For this study the pedagogical potential of using graphic tablet technology as an effective learning tool in an active learning constructivist environment was explored. The online platform which consists of the student-created videos and the lecturer-created quizzes is intended to reinforce core concepts and provide students with a multimedia tool created mainly by students for the benefit of other students. As well as strengthening their core competencies in mathematics, they have developed a set of transferrable skills that will benefit them beyond the confines of their studies: teamwork; communication; planning; and technical literacy.

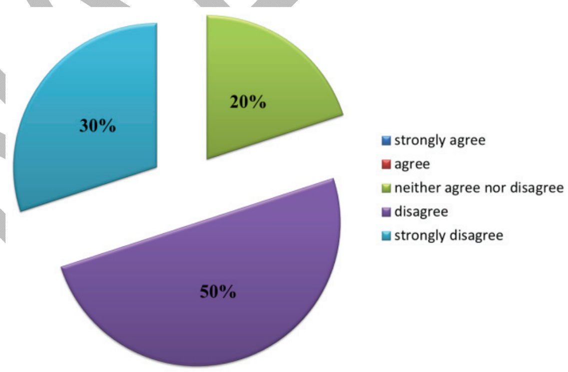

Figure 15: Statement: 'If you could rewrite the maths module, you would remove the video component.'

The general perception amongst the students was that the videos were a useful and enjoyable way of learning. However, the preferred method for tutorial sessions was a mix between traditional sessions and video sessions. Of the students surveyed no one preferred 100% traditional or 100% video sessions. The results show a preference amongst weaker students (based on MDT scores) for non-traditional tutorials and online content.

Recommendations to DIT

As a result of the work done on this project, the following recommendations can be made:

- Increase the use of technology in first year to complement and enhance the first year learning experience.
- In line with the DIT strategic plan, encourage and develop active learning approaches that put the student at the centre of the learning process.
- The use of graphic tablets that allow students to create and share solutions to problems should be explored further in other technical disciplines.
- Extend the online platform to other modules in first year to create a suite of resources to support weaker students or those who take non-traditional entry routes.
- Extend the project to other level 7 first year mathematics modules.

Proposed Future Work

In this report, we have outlined the development and evaluation of an online resource platform consisting of quizzes and students' videos. The results obtained show that students engage actively with technology. Their experience is enriched by the active learning environment and this is reflected in their perceptions and attitudes towards the discipline. This active learning and constructivist approach provides an environment of achievement and ownership that empowers students of all levels allowing them to benefit more from the learning experience.

This project represents the first stage of a longitudinal study which will work towards expanding the bank of quiz questions and feedback videos. The platform will grow as new and improved resources are added and will be extended to provide similar online resources in other technical modules.

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