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The Development of an Online Resource Platform for Mathematics Education as a Means to Increase Student Engagement and Retention

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THE DEVELOPMENT OF AN ONLINE RESOURCE PLATFORM FOR MATHEMATICS EDUCATION AS A MEANS TO INCREASE STUDENT ENGAGEMENT AND RETENTION

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Abstract: There is currently a growing interest in improving the retention levels of undergraduate students on STEM related programmes. Students' prior knowledge of mathematics is a key factor in predicting whether they will succeed in engineering or not. A poor grasp of key mathematical skills typically leads to students failing to achieve the learning outcomes of technical modules. Consequently, mathematics is often the focus of engineering education research. A decline in core mathematical skills; the lowering of entry requirements and the diversity of the student cohort, all contribute to the need for a more comprehensive learning support system. Today's students are immersed in an increasingly technological world and are willing to adapt to new technological advances. In order to increase engagement and retention rates a pedagogical shift from the more traditional hierarchical approach to learning to one that embraces the use of technology as a tool to enhance the student learning experience is required. This paper outlines a study being undertaken in the College of Engineering and Built Environment at the Dublin Institute of Technology to create an on-line platform of resources which allows first year engineering students to consolidate and reinforce the mathematical knowledge required to succeed in engineering. By including the student as co-creator of these resources a deeper learning experience is achieved.

Keywords; engineering mathematics, student engagement, active learning, student learning experience, transferable skills, first year experience

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1. INTRODUCTION

The role played by mathematics in the education of engineers and other STEM (Science, Technology, Engineering and Mathematics) related disciplines is widely acknowledged. The transition from second level to third level education often exposes students with weak mathematical skills leading to problems of engagement and retention (Sheridan, 2013; Russell, 2005; Williamson et al., 2003). Key mathematical competencies evaluated through the use of a standard maths diagnostic test (MDT) have shown that many students entering higher education are lacking in the mathematical skills required to succeed in technical programmes (Marjoram et al., 2013; Carr et al., 2013). These students generally struggle to reach the learning outcomes of technical modules and have a poor learning experience which ultimately can affect engagement in module material and persistence in the programme. In order to enhance the learning experience, especially for students who are making the transition from second-level education, a more wide-ranging learning support system needs to be explored and applied. This paper presents preliminary findings of a study being undertaken in the College of Engineering and Built Environment at the Dublin Institute of Technology to develop an on-line platform of resources to enable first-year engineering students to consolidate and reinforce key mathematical skills required to succeed in engineering and other STEM related programmes.

The use of technology as an aid to teaching and learning is widely documented in research literature. However, almost all examples found document the use of technology by the lecturer to create course content. For example, Loch et al. (2012) look at exploiting emerging technologies to complement mathematics support with online '*MathsCasts*'. The use of screencasts created by the lecturer is explored by McLoughlin and Loch (2012). Kao (2008) looks at using video podcasts to enhance the students' learning experience in engineering. For this study, unlike the references cited earlier, the student will co-create course content, in the form of videos, using graphic tablets.

When the present cohort of third level students first entered the education system, many of the technologies available today did not exist while others were not readily available. Even though the use of technologies such as screencasts, podcasts or tablet PCs is increasing in higher education, and their application as learning tools has been the subject of many scientific studies, numerous challenges have been identified in the implementation and use of new and emergent technologies. These challenges include lack of faculty training and the transitory nature of technological tools amongst others (Johnson et al., 2013).

The use of graphic tablet technology as a teaching and learning tool is encountered in a number of disciplines from architecture to product design. As a teaching tool for mathematics, their use is not readily documented in research literature. However, one example (Carillo, 2013) documents the use of graphic tablets by the lecturer to create course content. Today's students are immersed in a world of technology characterised in the main by a diversity of communication styles and methods. The students' ability to quickly adapt and prosper in a world filled with technology offers new opportunities for the lecturer to exploit technology to facilitate and support new methods of learning.

The traditional approach to learning described by Bovill (2011) which places the '*expert tutor*' in front of '*subordinate learners*' would appear to be no longer suitable to meet the changing needs and expectations of the modern student. In order to engage the student the educator must communicate with a similar set of tools. By shifting from a '*passive*' to an '*active*' learning environment a deeper learning experience can be stimulated. Active learning shifts the focus from content delivery by the educator to active engagement with the material by the student. The role played by active learning in higher education is discussed by Chickering (1987, 1996) within the context of their seven principles of good practice in undergraduate education. Cromack (2008) also make the assertion that where a "*symbiotic relationship exists between technology and learner-centred education*" an improvement in student learning is observed.

2. BACKGROUND

2.1 Rational for Study

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 an Irish perspective, *The National Strategy for Higher Education to 2030* (DES, 2011) emphasises the need for teachers in higher education to "*…stimulate active, not passive learning*".

2.2 Entry to Higher Education in Ireland

The standard route of entry to third-level education in Ireland is through the Central Applications Office[2] (CAO). Course entry is based on a points system which is determined by student demand and the limited number of places available. Points are obtained based on a student's performance in six subjects taken as part of a senior state examination known as the Leaving Certificate (LC) which is held at the end of their final year in secondary school. Mathematics exams can be taken at three levels: higher; ordinary; and foundation. Students who take foundation mathematics are not eligible for direct entry into third level.

[1] http://ec.europa.eu/education/policy/higher-education/bologna-process_en.htm

[2] http://www.cao.ie/

2.3 Awards offered by Dublin Institute of Technology

Qualification across education and training in Ireland are overseen by the National Qualifications of Ireland[3] (NQAI). It oversees a 10-level framework referred to as the National Framework of Qualifications[4] (NFQ) and is based on specified standards of knowledge, skill and competence and ensures that qualifications are of a quality and standard recognised both nationally and internationally.

DIT offers awards from levels 6-10 based on the NFQ. The routes to both level 7 (ordinary) and level 8 (honours) engineering programmes are illustrated in Figure 1. Entry to level 7 engineering programmes requires a minimum of 40% in a lower level mathematics exam whereas entry to a level 8 engineering programme requires a minimum of 55% in a higher level mathematics exam taken as part of the LC. Consequently, students on level 7 programmes typically have a lower academic ability in mathematics.

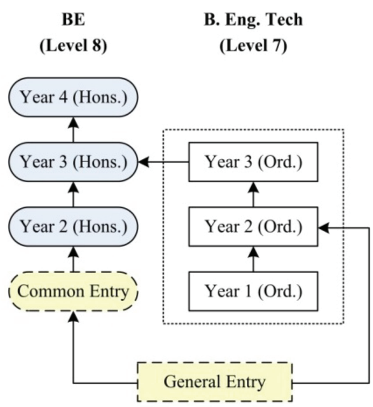

Figure 1: Typical routes to engineering programmes in DIT.

4. METHODOLOGY

4.1 Participants in study

The participants in this study are from a first-year level 7 non-denominated general entry engineering programme (DT097). Of the 37 students enrolled on this programme only 7 (16%) took the higher level mathematics paper in the LC. Nationally, for the academic year 2012-13 from which the majority of this cohort is drawn, 25.6% took the higher level mathematics paper. A breakdown of the grades attained for the participants who took the ordinary level mathematics paper yields the following numbers in a particular category: A (i.e. 85%-100%) = 2; B (i.e. 70%-84%) = 14; C (i.e. 55%-69%) = 4; and D (i.e. 40%-54%) = 10. These results indicate that a significant proportion of the students have a poor understanding of fundamental mathematical concepts.

4.2 Approach taken to study

The approach taken for this study follows the design based approach described by Reeves et al. (2004) and is illustrated in Figure 2. The four stages of the design based approach may be broken down as follows:

- **Stage 1:** Core mathematical concepts which are proving difficult to understand are focused on. These may be initially identified using a standard MDT.
- **Stage 2:** A set of online quizzes is developed by the lecturer and includes feedback videos created by the student covering various topics. The students' disseminate knowledge on a mathematical concept.
- **Stage 3:** Evaluation of student performance through online quizzes. Students are encouraged to give feedback at regular intervals and demonstrate active performance.

[3] http://www.nqai.ie/

[4] http://www.nfq.ie/nfq/en/FanDiagram/nqai_nfq_08.html

- **Stage 4:** Outputs 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 can also be analysed

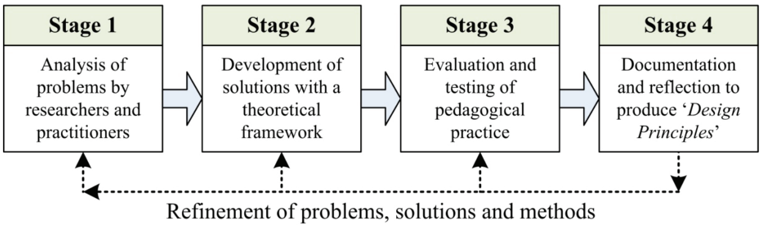

Figure 2: Design based approach undertaken.

4.3 Creating the solution to mathematical problems

As part of the active learning constructivist approach, the students create solutions to mathematical problems using graphic-tablet technology and video creation software (see Figure 3). Working collaboratively, in groups of two or three, a script for the video is prepared prior to recording (see Figure 4) which includes some background theory and a description of how the problem was solved. This requires the students to synthesise knowledge from various sources and to engage with the underlying concepts at a deeper level as they are required to explain the process, concepts and theory behind the solution.

Figure 3: Students using a graphics tablet to record a video.

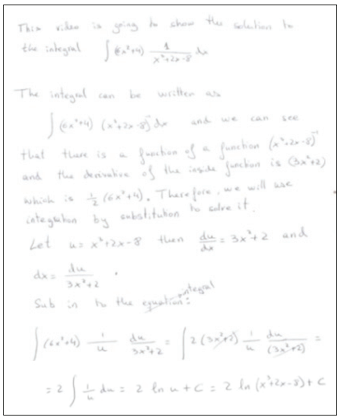

Figure 4: Extract from a typical student-created script.

4.4 Creating the online quizzes

The Learning Management System (LMS) used by DIT is webcourses (Blackboard). Wondershare QuizCreator which is integrated as a SCORM (Shareable Content Object Reference Model) quiz package into webcourses is used to create the online quizzes. Its run-time environment (RTE) is illustrated in Figure 5. The principal function of the SCORM is to allow reusability and interoperability of learning resources across different LMS. This is achieved through a common means of '*launching*' learning resources. Resources communicate with the LMS through an Application Programming Interface (API). A programming language such as JavaScript is used to implement RTE API function calls to the LMS.

The SCORM objects (SCOs) consist of the quiz questions and feedback videos. The LMS loads the SCOs and delivers them according to the instructions which detail the order and number of questions to be answered. Branching can be incorporated so that different paths can be taken depending on the answers chosen by the student (see Figure 6). 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.

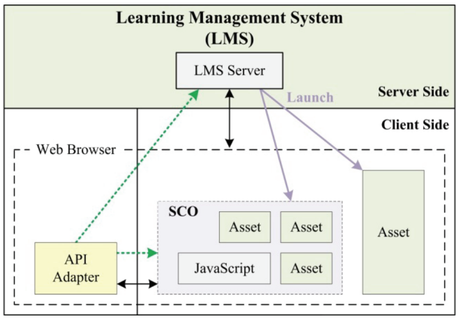

Figure 5: The SCORM run-time environment.

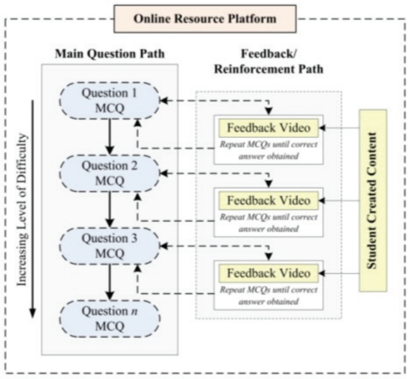

Figure 6: Main question and feedback/reinforcement paths.

A typical question from the MQP and its associated FRP are illustrated in Fig. 7 and Fig. 8 respectively.

Question (Main Question Path)	
Find the primitive of the function: $$(6x^2+4)\frac{1}{x^3+2x-8}$$	
Possible Solutions	
(a)	$\frac{6x^3}{3}+4x+x^{-2}+2x-8x+C$
(b)	$2\ln(x^3+2x-8)+C$
(c)	$(2x^3+4x)\left(\frac{x^{-2}}{-2}+2\ln(x)-8x\right)+C$
(d)	$12x\frac{1}{3x^2+2}+C$

Figure 7: Sample quiz question from MQP.

Question (Feedback/Reinforcement Path)	
What is the value of the following integral? $$\int (\mathbf{2x+1})(\mathbf{x^2+x+1})^{\mathbf{2}}\,\mathbf{dx}$$	
Possible Solutions	
(a)	$(x^2+x)\left(\frac{x^3}{3}+\frac{x^2}{2}+x\right)+C$
(b)	$4\,(x^2+x+1)+C$
(c)	$\ln(x^2+x+1)+C$
(d)	$\frac{(x^2+x+1)^3}{3}+C$

Figure 8: Sample quiz question from FRP.

5. RESULTS

5.1 Maths Diagnostic Test

The results from the maths diagnostic test (MDT) provided an initial insight into the mathematical capabilities of the participants. To ensure the inclusivity of all students i.e. standard and non-standard CAO applicants, MDT scores were chosen rather than LC scores to measure mathematical capabilities. From Figure 9, it is evident that there are a high proportion of students with a poor understanding of key mathematical concepts. Based on these results two subgroups were identified based on performance i.e. students with a score ≥50% and students with a score <50%.

5.2 Student Survey

A survey in the form of a series of statements was given to the students. Responses were based on a five-point Likert scale (1-Strongly Disagree, 2-Disagree, 3-Neither Agree/Disagree, 4-Agree, 5-Strongly Agree). The average responses to five of the statements are given in Table 1.

	Statement	**Average Response**
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 1: Selected survey questions including average responses.

The responses received from the survey are illustrated in Figures 10-14. Students were also presented with the statement '*If you could rewrite the maths module, you would remove the video component'* with the responses based on the same five-point scale. Figure 15 illustrates the results based on the sub-groups identified earlier. When the results are divided into the responses of the two sub-groups, the lower scores sub-group tends to prefer 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 (see Figure 16).

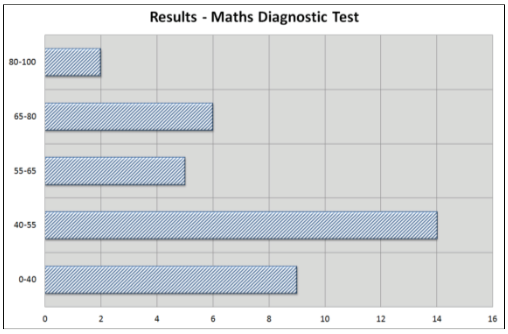

Figure 9: Results from MDT.

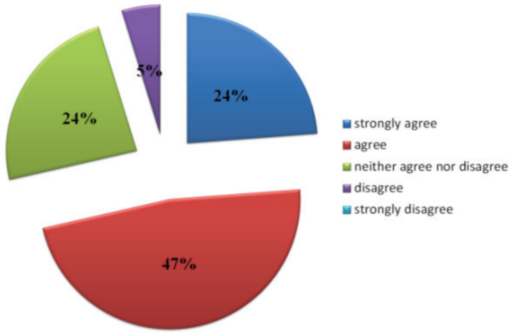

Figure 10: Statement 1 responses.

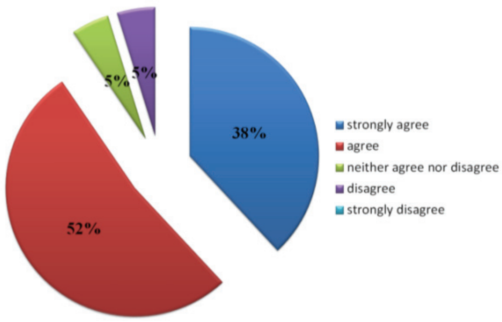

Figure 11: Statement 2 responses.

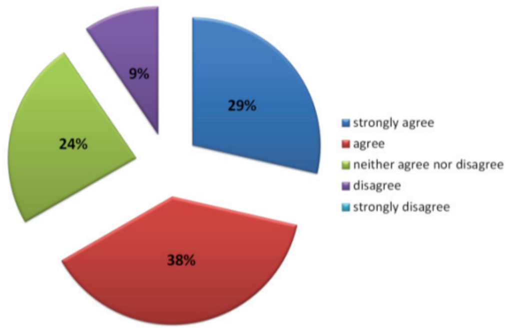

Figure 12: Statement 3 responses.

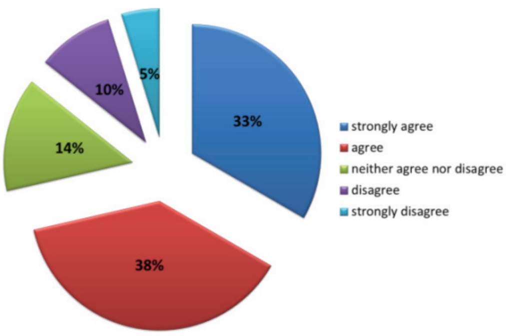

Figure 13: Statement 4 responses.

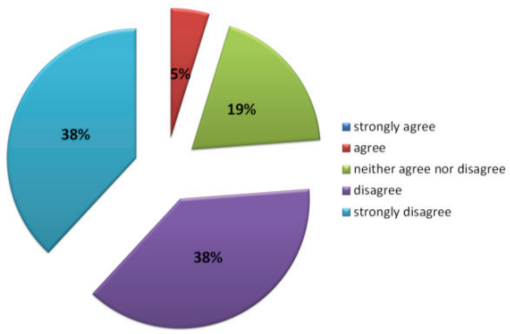

Figure 14: Statement 5 responses.

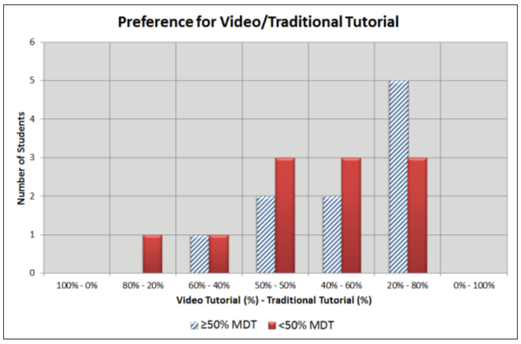

Figure 15: Student preference for video / traditional tutorial..

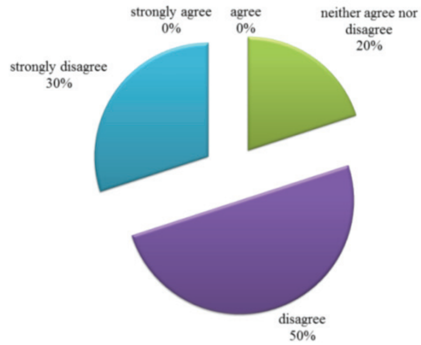

Figure 16: Statement: "*If you could rewrite the maths module, you would remove the video component*."

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.

6. DISCUSSION & CONCLUSIONS

This paper outlines the findings of the first stage of a longitudinal study examining the development of an online resource platform for mathematics education for the purpose of increasing student engagement and retention. One of its main aims is to minimise the range in prior knowledge in mathematics commonly found in first-year students taking STEM related programmes. By including the student as co-creator of module content they are actively involved in synthesising knowledge from various sources to solve mathematical problems and disseminating their solution to their peers via videos which form part of the online platform. Students are provided with a multimedia tool created mainly by students for the benefit of other students.

The results show that the students adapt to the new methodology and the use of technology is perceived as a positive addition to their learning experience. The students with lower mathematical skills show more interest in using the technology which can be explained by the ease of access and self-study capabilities of the videos and quizzes. As the range of abilities in the student cohort covered a broad spectrum, the fact that students at the upper end of the spectrum (≥50%) showed less inclination towards the use of the methodology emphasises the need to adjust the content of the quizzes and videos to the mathematical level of the students. Both groups of students reacted more positively to the creation of videos that posed a challenge to them. A difference in the perceived level of the challenge may explain the different responses from students in the upper and lower spectrum of abilities. The results from both groups show an increase in student motivation and engagement with the subject matter and students become more empowered by the experience.

7. FUTURE WORK

This paper outlines the first stage of a longitudinal study which will be extended over time building up an archive of quiz questions and videos across diverse topics in mathematics. The platform will grow as more and improved resources are added and its extension to other technical subjects will be explored.

8. ACKNOWLEDGEMENTS

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8. REFERENCES

Carrillo, A., Cejudo, J. M., Dominquez, F. and Rodriguez, E., 2013. Graphics tablet technology in second year thermal engineering teaching. *Journal of Technology and Science Education*, 3(3), 102-112.

Bovill, C., Cook-Sather, A., and Felten, P. 2011. Students as co-creators of teaching approaches, course design, and curricula: implications for academic developers. *International Journal for Academic Development*, 16(2), 133-145.

Carr, M., Fidalgo C., de Almeida, E. B., Brance, J. R., and Santos, V., 2013. Maths diagnostic testing in engineering: Dublin Institute of Technology and Coimbra Institute of Engineering, *1st International Conference of the Portuguese Society for Engineering Education (CIPSEE)*, Porto, Portugal. 31st Oct. - 1st Nov. 2013.

Chickering, A. W. AND Gamson, Z. F., 1987. Seven principles for good practice in undergraduate education. *AAHE bulletin*, 3(7).

Chickering, A. W. and Ehrmann, S. C., 1996. Implementing the seven principles: Technology as lever. *AAHE bulletin*, 49, 3-6.

Cromack, J. 2008. Technology and learning-centred education: Research-based support for how the tablet PC embodies the Seven Principles of Good Practice in Undergraduate Education. *38th Annual Frontiers in Education Conference*. Saratoga Springs, NY. 22-25 October 2008.

Department of Education and Skills (DES) 2011. *National Strategy for Higher Education to 2030, Report to the Strategy Group*, 52-53.
Available online at:
http://www.hea.ie/sites/default/files/national_strategy_for_higher_education_2030.pdf
Accessed: 14 February 2014

Johnson, L., Adams Becker, S., Cummins, M., Estrada, V., Freeman, A., and Ludgate, H., 2013. NMC *Horizon Report: 2013 Higher Education Edition*. Austin, Texas: The New Media Consortium
Available online at: http://www.nmc.org/publications/2013-horizon-report-higher-ed
Accessed: 10 June 2014

Kao, I., 2008. Using video podcast to enhance students' learning experience in engineering, *Proceedings of 115th Annual ASEE Conference and Exposition*, Pittsburg, PA. 22-25 June 2008.

Loch, B., Gill, O. and Croft A., 2012. Complementing mathematics support with online MathsCasts. *ANZIAM J.*, 53 (EMAC 2011), C561-C575.

Marjoram, M., Robinson P., O'Sullivan, C. and Carr M., 2013. Improving the key skills of engineering students in mathematics, *41st SEFI Conference*, Leuven, Belgium. 16-20 September 2013

McLoughlin, C. and Loch, B., 2012. Engaging students in cognitive and metacognitive processes using screencasts. *Proceedings of the 2012 World Conference on Educational Multimedia, Hypermedia and Telecommunications* (EDMEDIA 2012), Denver, CO. 26 June 2012.

Reeves, T. C., Herrington, J. and Oliver, R., 2004. A development research agenda for online collaborative learning. *Educational Technology Research and Development*, 52(4), 53-65.

Russell, M., 2005. Academic success, failure and withdrawal among first year engineering students: was poor mathematical knowledge a critical factor? *Level 3*, 3.

Sheridan, B., 2013. How much do our incoming first year students know? Diagnostic testing in mathematics at third level, *Irish Journal of Academic Practice*, 2(1).

Williamson, S., Hirst C., Bishop P. and Croft T., 2003. Supporting mathematics education in UK engineering departments, *International Conference on Engineering Education*, Valencia, Spain, July 2003.