

# Scaffolding Conceptual Learning in Mathematics with Technology Enhanced Pedagogy – a Preliminary Evaluation of Student Engagement with Screencasts

Catherine McLoughlin  
Australian Catholic University  
Australia  
catherine.mcloughlin@acu.edu.au

Birgit Loch  
Swinburne University of Technology  
Australia  
bloch@swin.edu.au

**Abstract:** We report on a preliminary evaluation of the delivery of engaging, flexible and learner-centred experiences using screencasting technology. This technological/pedagogical innovation is directed at enabling students to develop deeper understanding of key mathematical concepts in order to equip them to undertake degrees in engineering, sciences and statistics. The methods, issues and outcomes of our research demonstrate the success of the *MathsCasts* that have been designed, but also attest to the merit of long-term design based research. The results presented show the value of visual, interactive screencasts for the teaching of mathematics, and the positive impact that this technology has on student learning. We present initial results from a student survey to identify students' active learning strategies.

## Background to the Study

When learning complex and abstract concepts and problem solving, learner support is often crucial, as it is in the case of mathematical concepts and logical reasoning skills. This has been recognised widely in Australia, where most universities offer mathematics support to their students in the form of face-to-face help from a tutor in a dedicated support space, during certain hours. However, there is growing demand for flexible, self-paced access to learning support as students often study in part-time mode or by distance education. There are also access limitations if many students are seeking the tutor's help at the same time, for example before assignment deadlines or for exam preparation (Loch & McLoughlin 2011).

To provide such more flexible options accessible around the clock and from anywhere with connection to the web, tutors at the Mathematics and Statistics Help (MASH) Centre at Swinburne University of Technology produce short screencasts for students to access online. Topics recorded range from the revision of prerequisites at middle to higher high school level that some students may be missing, up to second year university level mathematics currently taught in engineering mathematics units and that students struggle with regularly. These screencasts of mathematical concepts and skills, labeled "MathsCasts", are produced in an international research collaboration together with the mathematics support centres at The University of Limerick (Ireland) and Loughborough University (UK) (Loch, Gill and Croft 2012). More than 250 MathsCasts are available as open educational resources, carrying a creative commons licence (MathsCasts 2013). MathsCasts are produced in a video format (MP4) that may be played back on a wide variety of devices, including those that do not support the Flash format. This decision impacts on the design of the MathsCasts. They are compressed heavily to produce file sizes that can be downloaded fast on mobile devices, and usually only part of the screen is recorded, acknowledging that a recording from a full screen of high definition may be difficult to see on a small smartphone screen.

While screencasting was originally described by Udell (2005), mathematical screencasts are typically narrated by a lecturer or tutor while handwriting on the screen is being recorded. They are multimedia demonstrations that explain problem solving with examples of often complex equations and thereby accommodate various learning styles (Trail & Hadley 2010). The resulting video can be shared via a link, e-mailed, or uploaded (Yee & Hargis 2010), or as in

the MathsCast case, made available via *iTunes U* and *YouTube* as open educational resources.

By accessing video based instruction that combines multiple media formats, students can choose when and how often to access the MathsCasts, and it is expected that positive learning outcomes will be achieved. Nevertheless, the instructional format of most screencasts has often relied upon a didactic model of pedagogy, and often does not intentionally include scaffolds to ensure the active engagement and participation of the learner. To address this issue, we consider several instructional design models based on self-regulated learning (SRL) theory and threshold concepts in order to foster and enhance students' cognitive and metacognitive skills in understanding complex mathematical concepts. Grasping the threshold concept transforms the students' perception of the subject area, and they are better able to relate the topic to wider fields of study (Meyer & Land 2003). Models of SRL share certain assumptions about learning and metacognition, though they may differ on mechanisms to foster SRL processes (Pintrich and de Groot, 1990; Goldman 2003). Our primary goal has been to support the dynamics of students' cognition and mathematical reasoning as they seek to understand abstract concepts. To achieve optimum results, learners need to be self-motivated, mostly self-guided, and to be supported in learning situations where they are expected to learn abstract concepts individually or collaboratively, mediated by technology. Our research indicates that by using particular instructional design approaches to develop MathsCasts, we can better cater to the needs of a diverse student population while meeting the demand for flexible delivery.

In this paper, we first introduce the method of design based research that has been applied to the development of effective mathematical screencasts. We then show some of the feedback collected for one of the stages of the implementation of the design based approach, from students who have accessed and used MathsCasts. Our objective has been to find out more about students' active learning strategies, their views on the flexibility of the resources, and how students have integrated the MathsCasts into their studies. Our methodology employed qualitative methods that used questionnaires, student interviews and feedback submitted online.

## **Literature Review on Screencasting in Higher Education and in Mathematics Education**

Professionals in the computer and library science fields were early adopters of screencasting, but educators and researchers quickly recognized the potential applications of screencasting to online education (Peterson 2007; Sugar, Brown, and Luterbach 2010). Screencasting and online video tutorials have been developed to teach a wide variety of subjects, including object-oriented programming (Lee, Pradhan, & Dalgarno 2008), mathematical modeling (Ellington & Hardin 2008) and nursing (Phillips & Billings 2007). Generally, the aim of these screencasts and video tutorials has been to instruct learners about a topic and to demonstrate specific actions associated with the particular content area. In addition, screencasts allow instructors to model behaviours and operations and allow learners to view the content multiple times at their own pace and according to their own preferences for location, time and situation (Sugar, Brown, and Luterbach 2010). The uptake of screencasting for instructional purposes has been facilitated by the wide variety of screencasting software available, much of it free (Yee & Hargis 2010), and creating screencasts is fast and easy.

We have already identified a need for more research on how to design mathematical screencasts that focus on student engagement (as opposed to content delivery and training), and the imperative of taking into account best practices in instructional design and pedagogy (Loch & McLoughlin 2011). This paper addresses a gap in the literature by addressing the pedagogical effectiveness of Mathscasts used in a higher education context, whereas extant research in in this context is limited to investigations of student's perceived learning processes and their use of the recordings. While Sugar, Brown and Luterbach (2010) undertake an analysis of common structural elements and instructional strategies in screencasts that demonstrate certain tasks on the computer to support their discussion of the anatomy of a screencast, it is questionable that their findings would be applicable to teaching mathematical problem solving with screencasts. Understanding mathematics concepts requires both procedural and conditional knowledge and therefore the instructional design approach is not simply a compilation of procedures.

## **Pedagogical Design for Screencasting**

The literature on podcasting literature may be found in (Heilesen 2010), suggesting that positive outcomes

may sometimes be achieved not by the technology itself, but when the technology supports approaches such as active learning or revision that are known to improve student learning. He recognises that screencasting “has opened up for new ways of integrating classroom teaching and net-based learning on the basis of pedagogical concerns rather than mere administrative convenience”. Sutton-Brady, Scott, Taylor, Carabetta and Clark (2009) emphasise the need to focus on pedagogical design when producing short screencasts targeting individual topics to distinguish them from a static delivery of a lecture or repeat of lecture content. For example, screencasts may be designed to allow students to personalise their learning, listen at their own pace, and to highlight important information. Oud (2009) provides guidelines for the production of effective online screencasts in a library instruction context and investigates software-walkthrough screencasts that show how to perform searches on the Web. She also argues that screencasts should contain a level of interactivity, e.g. user control over pace such as pausing and fast forwarding. Although research on screencasting in the online environment is still emerging, there is preliminary evidence that screencasts may improve learning (Evans 2011), and also in the mathematical context (Jordan, Loch, Lowe, Mestel and Wilkins 2012). Our research intends to augment what is currently known about the positive impact of screencasting on learning, but also to provide evidence based on the student experience.

In mathematics education, it is important to capture visually the individual steps towards the solution of a problem. Mullanphy, Higgins, Belward and Ward (2009) found screencasts capturing narration and mathematical handwriting development on a computer more engaging than a video recording of writing on a blackboard, a narrated PowerPoint recording or audio-only podcasts. However, there is a dearth of research on instructional design guidelines for development of pedagogically sound screencasts for mathematical skills development (mathscasts).

In addition to the lack of clear guidelines on how to design effective mathematical screencasts, we have also found no evidence of what students are doing with these videos, how often they are watching them, if they watch them in company and what device they are actually watching them from. Of course this information is highly relevant to inform the way these videos are created. There is no doubt that access to flexible learning options may benefit student learning, however we may even ask the question: Do students just say they like the flexibility of screencasts, or is this also reflected in the way they use the videos?

To inform design consideration for MathsCasts, in this paper we provide evidence gained from student feedback to answer some of these questions.

## **Design Based Research for Student Learning with Mathematical Screencasts**

Beyond empowering students to learn complex concepts in a flexible, self-paced manner, the project seeks to develop instructional design models for teaching mathematics via screencasting that will promote self-regulatory skills through learner choice of location, space, method of production and access to a range of screencasts. To achieve this, the project seeks the students’ feedback on all aspects of the learning experience to develop self-regulatory learning skills and metacognition, including articulation of their understanding of concepts and topics. Research has indicated that learning needs are often drivers for learning, and that for learning to be optimally effective it needs to relate to learner interests, goals and self-regulatory processes (Dron 2007). For this reason, it is important that the screencasts made available to students target troublesome concepts that students realise they need to revise in order to advance. In an earlier study of screencasting, we investigated evidence of engagement in metacognition by students who viewed the screencasts, focusing on an assessment of learners’ capacity to reflect on their learning (McLoughlin & Loch 2012).

In our research, we introduced an approach to design of Mathscasts and to researching the impact of screencasts research and then applied a qualitative methodology to study the impact of screencasting on mathematics learning in a higher education context. Developmental research (van den Akker 1999) or design-based research is an interdisciplinary approach that acknowledges the applied nature of educational research. In this approach, researchers work in partnership with educators seeking to enhance theories of learning by designing, studying, and refining theory-based innovations in realistic classroom environments (Reeves, Herrington & Oliver 2004), contributing to both theoretical and practical knowledge.

We adopted the four stages of design based research (Reeves, Herrington & Oliver 2004), to investigate how the design of MathsCast episodes influences student learning and meets student needs for support and flexibility, and how through this iterative method the design can be modified to further improve pedagogical approaches and with that student learning. Figure 1 shows our adaptation of Reeves et al.'s model for the mathematics screencasting project.

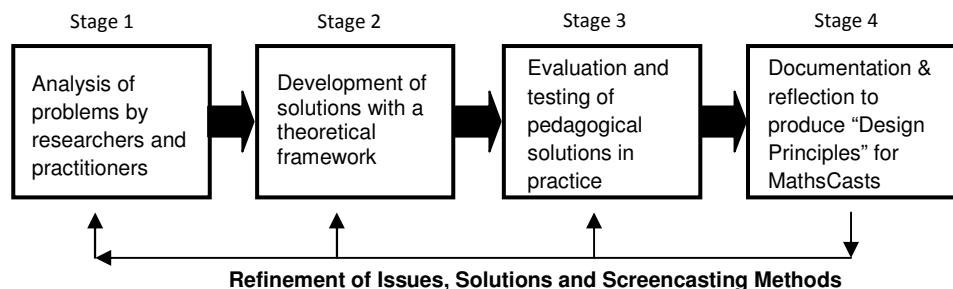


Figure 1: Design Based Research Stages for the Mathematics Screencasting Project. Adapted from Reeves, Herrington & Oliver (2004)

The design based research to develop effective, pedagogically sound MathsCasts proceeds according to these stages:

### **Stage 1: Analysis of practical problems by researchers and tutors/lecturers**

The focus of this stage is on students' needs for flexible, self-paced support in learning certain mathematical concepts which are identified by analysing student visits in the mathematics support centre. Very important considerations are the design and also the effective integration of these screencasts into mathematics learning in order to improve student learning outcomes and self-efficacy in mathematics problems solving. Addressing this issue requires a number of iterations in the design based research process and includes lecturer and student perspectives.

### **Stage 2: Development of solutions using technological innovations within a theoretical framework**

The researchers and lecturers work in partnership to introduce and integrate MathsCasts into formal pedagogies and to enhance existing practices. An overview of approaches taken at the three universities collaborating on the MathsCasts production is described in (Loch et al. 2012).

Strategies to make students aware of the videos have evolved over several iterations at Swinburne University, following very low uptake of MathsCasts in the first semester. Swinburne University of Technology in particular has made MathsCasts available to engineering students for more than two years, which means that students are attuned to the notion of accessing these short screencasts both on and off campus. Feedback obtained shows that students strongly support the initiative to deliver academic material during "downtime" or travel time in order to learn maths concepts in self-paced manner.

### **Stage 3: Iterative cycles of testing and refinement of solutions in practice**

We commenced a series of design stages in order to apply a range of pedagogies in the design of screencasts. These were as follows:

*Phase 1: Screencasts based on worked examples*

*Phase 2: Self-regulated learning approaches*

*Phase 3: Metacognitive approaches to design*

*Phase 4: Use of threshold concepts for design*

Suggestions how to create engaging mathematical screencasts to foster self-regulated learning are described in Loch & McLoughlin (2011). Engaging students in cognitive and metacognitive processes via MathsCasts is discussed in

McLoughlin & Loch (2012). While all MathsCasts by design teach troublesome concepts, some have also been found to address (mini-) threshold concepts (Loch & McLoughlin 2012).

#### **Stage 4: Reflection to produce design principles and to enhance the implementation**

At this stage, the intention is to ensure that the research plan has outputs in the form of both knowledge and products. The impact of the MathsCast pedagogy is assessed by surveying students about their experiences. Following the feedback received, design principles are proposed to scaffold student learning of complex mathematical concepts.

In this paper, we show some of the feedback that students have provided on how, where and when they are watching MathsCasts, providing an evaluation and testing of pedagogical solutions in practice.

### **Evaluation of Student Use of MathsCasts**

Over several semesters, a large bank of MathsCasts has been built across the three collaborating universities. Students enrolled in mathematics units at Swinburne University of Technology have access to more than 250 MathsCasts, sorted into folders representing their respective units on the MASH Centre Blackboard site. An online survey was issued to all students, asking a range of questions relating to MathsCasts. In this paper, we report on how students enrolled in the first two engineering mathematics units have responded to their use of the MathsCasts. Both units have sets of MathsCasts available that cover most topics taught, as well as prerequisite topics that students have struggled with in the past. A total of 43 students filled out the survey, however some skipped questions.

The question reported on in this paper asks about student experiences of active learning strategies adopted while interacting with the videos (e.g., replay or fast forward sections, pause to try themselves).

### **Results: Evidence of Active Learning Strategies**

We have considered elements that would make MathsCasts more engaging and to foster self-regulated learning before (Loch & McLoughlin 2011). Our suggestions included asking students regularly to try to question themselves. In question 14, we asked students “How do you watch MathsCasts?” The student feedback (30 responses) indicates that students indeed use the opportunity to control the video by pausing to think about an explanation (more than a third), but also to rewind and replay a section (more than 50%) and to skip forward to concentrate on sections of most relevance (a third). These intentional actions demonstrate that students are actively engaging with the MathsCasts concepts. While 70% watch the complete video, students appreciate the control over the place, pace and the frequency of their individual use of the MathsCasts. It is encouraging that students also actively do the mathematics while they are watching, with around a quarter of the students responding that they pause the video before watching an explanation, and more than half trying the problem themselves after watching. This shows that MathsCasts are not consumed passively as one would watch TV but are integrated into students’ practice routines, study habits and learning strategies.

### **Conclusions and Future Research**

While there are strong arguments for the provision of screencasts for mathematical support, there is no guarantee that students will either access these or learn from them. It cannot be assumed that all students will have the skills to self-regulate their learning when presented with complex mathematical concepts. In this paper, by applying design-based research, we have shown a number of iterative designs for screencasts that are based on explanations of mathematical problem solving using mathscasts. In our first iteration, where emphasis is on a clear explanation of the problem-solution, to scaffold student understanding of the mathematical thinking involved. To increase learner engagement, we have adopted several iterations in later design stages to produce learner-centred

screencasts and on the development of an instructional design model to enhance active engagement of students with mathematical concepts. Initial evaluation of student feedback indicates that the students who responded to the voluntary survey have the skills to integrate MathsCasts as active support resources into their study strategies.

Our work bears some resemblance to that of Sugar, Brown, and Luterbach (2010) who have begun to develop a framework that identifies the structural components and instructional strategies of screencasts. After an in-depth analysis of thirty-seven different screencasts, they note that the instructional strategies employed in this medium are complex, including elaboration, attention focusing, and concept attainment. Similar to these authors our future research will further explore screencasting instructional strategies, how these strategies are related to an instructor's overall teaching philosophy, and how these strategies affect student learning outcomes. With increased demand for flexible maths support at tertiary level, we are pursuing a research agenda that looks at changes in students' learning outcomes and self-regulated learning strategies, as our current research indicates that students are strategic in their approach and selective in their viewing and use of MathsCasts.

Our research continues to investigate the optimum design principles for MathsCasts that are aimed to increase student understanding of complex mathematical concepts. As part of this investigation, our research seeks to gain an understanding of how students integrate the MathsCasts into their studies (for example, to help with problem solving, assignments, prepare for tests). We also intend to explore whether MathsCasts are suitable in supporting a "flipped classroom" approach, where emphasis in face-to-face contact is on students solving problems, rather than a listening to a lecture. Among other questions we aim to investigate further are students' preferred location for accessing screencasts (for example, off campus, on campus, in the library) and their choice of device used to download and watch the videos from. As the uptake of mobile devices and social media continues among the general population, our students will expect to learn in flexible, interactive and dynamic ways, both on and off campus, and our research agenda is intended to meet present and emerging needs for mathematics learning support using state-of-the-art technologies.

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