The Benefits of Using Instructor-Developed Screencasts to Support College Students' Learning ofMaths: Insights from an Irish Case Study

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Abstract
This article reports on a case study undertaken to explore college students' views of the benefits of screencasts in enhancing their Maths learning experience at an Irish institute of technology. A total of 47 screencasts, developed for 14 topics for Year 1, Year 2 and Year 3 mandatory Algebra and Calculus courses taught by one instructor, were uploaded onto the college's Moodle site for students to access. An open-response survey asking about the benefits of the screencasts and how they helped students to learn the course content was administered online. Out of the total population of 266 students taking the courses, 138 responded to the survey constituting a response rate of about 52%. The data were analysed using an inductive thematic content analysis, in which student feedback was scrutinized and categorized according to the central ideas they shared. Themes that represented different types of screencast use and benefits were generated from this clustering of feedback. Consistent with previous studies, the findings show that a vast majority of students (88.4%) used the screencasts for many different purposes and viewed the videos as an extremely useful tool that enhanced their Maths learning experience, stating that they were*"very helpful," "very informative," "easy to follow," "very practical,"* and *"a brilliant asset to have."*The narrative data pointed to ten primary benefits of screencasts, which included supporting flexible and personalized learning, supplementing lectures and enhancing understanding of keyskills, delivering a vicarious learning experience, facilitatingexam revision and material review, providing multimodal support for Maths learning, helping students to keep track with Maths modules, filling up gaps in notes, serving as a memory aid, providing a tighter match with course content, and making Maths learning more enjoyable. The findings have positive implications for screencasts as a promising tool for Maths learning in future decades.

Introduction

The rapid and widespread adoption of virtual learning environments (VLEs) in higher education has enabled Web 2.0 tools, such as screencasts, to be used innovatively to support and enhancetraditional teaching and learning. Screencasts are video tutorials that capture the activity on a computer screen with concurrent audio commentary. Theycan be watched on a PC or any

mobile device with video playback capabilities. Screencastshave been identified as a very useful tool in enhancing students' learning of skills-based subjects, particularly Mathematics as they allow the recording of handwritten step-by-step solutions of problems including specialist mathematical notation (Jordan, Loch, Lowe, Mestel, &Wilkins, 2012).Once generated, they can be recycled annually by the course instructor and shared with others in the same discipline, so they become a reusable learning object (RLO) (Seery, 2010).

In terms of learning principles, thereis a distinct characteristic of screencasts that renders them especially beneficial; and that is the fusion of visual and audio elements together to support the way the human brain learns, which is by making meaningful associations between what is being seen (visual stimuli) and heard (auditory stimuli). This nature of screencasts that combines visual stimuli (images, handwriting, and on-screen movements) and audio stimuli (sound, narration, and voice-over description of steps and movements) fits well theoretically with Mayer's principles of multimedia learning, which state that people learn better from a combination of words and graphics rather than from words alone (multimedia principle); when graphics are presented with narration rather than with printed text (modality principle); when corresponding words (narration) and pictures are presented at the same time rather than in succession(temporal contiguity principle); when the words are spoken in a conversational style rather than a formal style (personalization principle); and when the words are spoken by a friendly human voice rather than a machine voice (voice principle)(Mayer, 2005).

Drawing from these principles, Math screencasts that demonstrate how to solve problems in a well-paced, step-by-step procedure backed by the friendly and familiar voice of the instructor should function to optimize Math learning and enhance the student experience. Such screencasts have an additive effect that improves Math learning, and are in keeping with Paivio's (1986) dual coding theory, which posits that meaningful learning occurs when students process information simultaneously through two discrete input channels, i.e. the visual and auditory channels.Screencast features that allow for infinite pausing and replaying also help students to handle, at their own pace, the cognitive load present in typical mathematical narratives such as that shown in Figure 1 below:

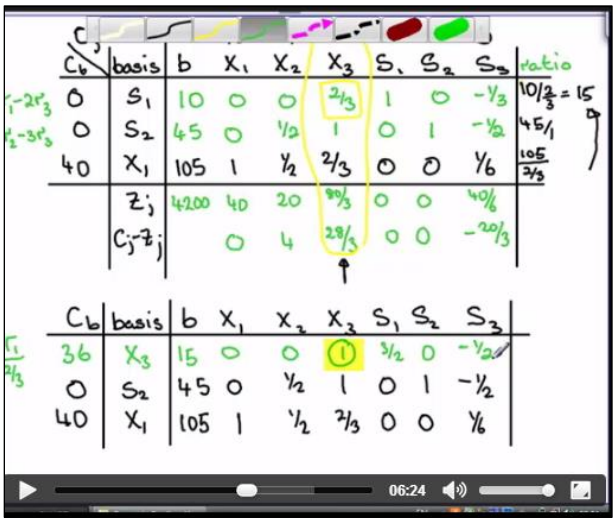

*Figure 1.*Many Maths problem solving steps, for example the Simplex Method, contain heavy cognitive load

Viewed from this perspective of learning, screencasts have an advantage over podcasts, which are basically digital audio content that students can listen to. A major limitation of podcasts is that they are linear and unidimensioal in nature (Usluel & Mazman, 2009).Learners using podcasts rely entirely on the auditory channel to process and acquire information, which may prove a little harder to do than if some visual stimuli are provided to aid the presentation of audio content. Based on this premise, therefore, podcasts would be more suitable for lecture-based materials of a theoretical nature than for step-by-step demonstrationsthat require the presence of visual aspects related to the content.

In this case study, we explored college students' views on the benefits of a set of instructor-developed screencasts for Maths learning. The students were working towards a degree in mechanical and renewable engineering (MRE), computer network management (CNM), electronic and computer engineering (ECE), and sports and nutrition science (SNS) at an Irish institute of technology. In these degree programmes, Algebra and Calculus were a mandatory component. The screencasts demonstrated the keyskills that students needed to acquire for successful completion of the courses and for advanced study in engineering and related fields.The videos were created by the second author of this articlefollowing students' feedback that they could answer a question in class but when working on Math problems later at home, they could not remember some aspect of the solution. Thistype of learning predicament is likely to be greater for students with poor note-taking skills, and for non-native speakers of English learning Maths in an English-speaking institution. It was felt that the provision of short screencasts uploaded onto the courses' Math Moodle pages would cater to these students' needs, enable them to see how typical problems are solved in a pace that suits their learning ability, and hence overcome this stumbling block.

Description of the Maths Screencasts

The screencasts were created using Camtasia Studio8.0 and SMART Notebook for first year through third year mandatory Algebra and Calculus courses. They ranged between 1:49 minutes and 11:20 minutes in length. A total of 22 screencasts were created for the Year 1 class group, 14 for the second year group, and 11 for the third years. The specific topics covered in the screencasts are shown in Table 1.

Table1 *Summary of Screencasts Developed for the Algebra and CalculusCourses*

Year	Topics	Screencast Duration (minutes)	No of Screencasts
1	Algebra, Trigonometry, Differentiation, Series, Integration, and Complex Numbers	1:49 to 11:20	22
2	Matrices, Numerical Methods, Differential Equations and Laplace Transforms, Series and Partial Differentiation	2:18 to 8:01	14
3	Calculus, Fourier Series and Fourier Transforms, Laplace Transforms and Double Integrals	1:59 to 10:27	11
		Total Number of Screencasts	47

Each screencast focused on only one specific content or keyskill, and had the following features: a clear descriptive title, a statement of purposestating the problem to be solved and explaining what students will see in the demonstration, a problem solved by the instructor in a clear, step-by-step fashion, the instructor's voice-over description of the steps and results, and a brief conclusion.Some screencasts contained annotations to help students understand the steps more clearly. Screenshots of some of the screencasts are shown below (Figures 2 to 6).

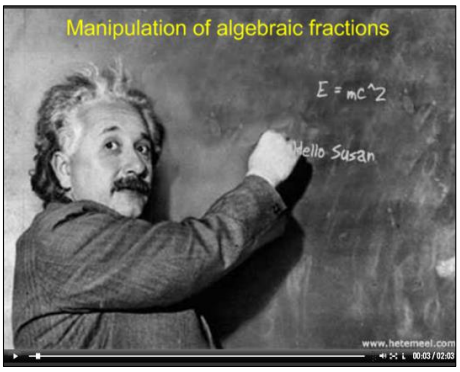

Figure 2. The title was stated clearly at the beginning of the screencast with an interesting visual stimulus

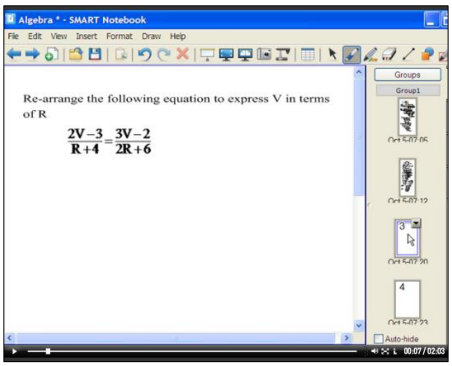

Figure 3. A statement of purpose explaining what students will see was given after the title

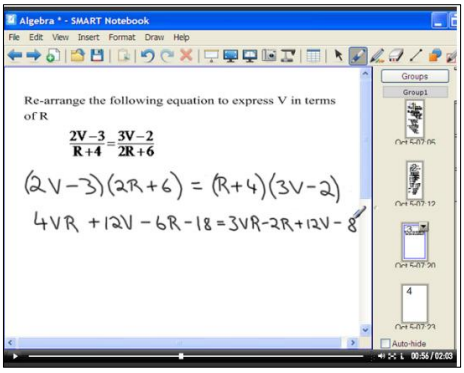

Figure 4. A step-by-step solution of the problem was demonstrated with a voice-over description

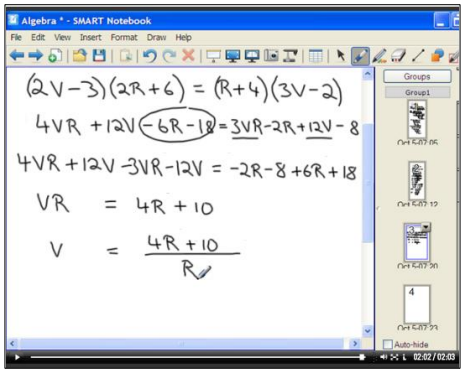

Figure 5. A brief conclusion summarizing the results was given at the end

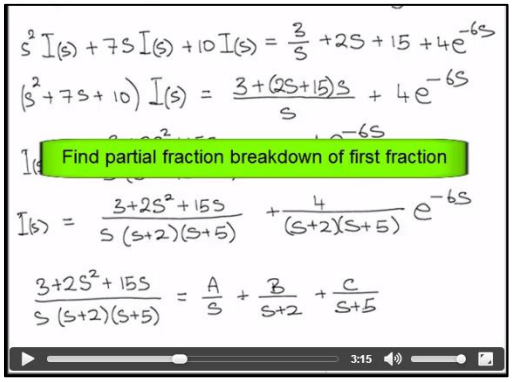

Figure 6. Some of the screencasts contained annotations

Research Objectives

Our case study was conducted to address the following objectives:

1. To determine the percentage of students who used the screencasts to support their Maths learning needs;
2. To explore users' perceptions of the Maths screencasts;
3. To determine the ways in which the screencasts had benefited students, and addressed their learning needs.
4. To determine the reasons for non-use of the screencasts.

Literature Review

Research has shown that screencasts offer multiple benefits for students, particularly in subjects dealing with abstract thinking, complex concepts and extensive problem solving such as engineering, computer studies, science and mathematics. These courses tend to have significant amounts of cognitive load which can easily overwhelm students, most of whom are limited in their ability to absorb new and abstract concepts by attending a single lecture. Therefore, technology-enhanced learning using screencasts helps them to handle the vast amount of complex information and reduce the problem of cognitive overload, a condition that results when there is a poor match between an instructor's pace of instruction and learners' cognitive capacities (Merkt, Weigand, Heier, & Schwan, 2011).Screencasts provide an effective means of dealing with cognitive overload by giving students control over the rate of information being conveyed to them at one time.

O'Malley (2010) encourages a widespread adoption of screencasting as a pedagogical tool, seeing its immense benefits to both students and lecturers. He demonstrates thatwhat benefits students the most about screencast use is the flexibility of learning afforded by the technology, where students can infinitely pause and replay at difficult segments of a lesson, decide to listen to the lecture again anytime they want, and catch up with missed lectures. For most students, the luxury of being able to view lecture material at their convenience and in their own timeis a welcoming change. The same benefits were recorded inother studies. For example in Comiskey and McCartan (2011),students used screencasts *"in their own time to reinforce what had been covered in class"* (p. 33), while those that had missed a particular lecture said the videos were *"an excellent resource as they could catch up at home before the next week's session"* (p. 33). They felt the video resources were an ideal learning medium, and used them mostly for revision purposesto supplement text-based notes. This pattern of learning is seen as an important shift towards student-centered pedagogy, where the instructional medium *"gives students greater autonomy and control over choice of subject matter, learning methods and pace of study"* (Gibbs, 1992, as cited in Comiskey&McCartan, 2011). Similarly, Boffey, Gerrans, and Kennedy (2006) note that students particularly liked having access to lecture content outside of the classroom andflexibility in watching lectures at their own pace.

Pinder-Grover, Millunchick, and Bierwert (2008) experimented with "muddiest point" screencasts – where they asked students to identify the muddiest points in every topic taught in an engineering courseand later created screencasts to explain the points – and found that students did well in the exam on the topics associated with the screencasts. Students felt the "muddiest point" screencasts were helpful in influencng their learning outcomes in the course, and reported using the videos to clarify misunderstandings, supplement the lecture material, and review for exams.Similarlyin Green, Pinder-Grover, and Millunchick (2012), students perceivedscreencasts

as a valuable learning tool that was instrumental in raising their competency with particular topics, and most often used them as a study resource, particularly for exams. The authors also discovered that students tend to watch a screencast in its entirety from start to finish if it was a short presentation, and that those who watched the screencasts completely tend to report gaining a significantly deeper understanding of the material. The finding was corroborated by Wilkes (2012) where students reported being able to grasp mathematical concepts more clearly with the help of screencasts, finding them easy to use and follow, and especially useful for revision.

In a large lecture environment, screencasting technology is an effective way to reach a large number of students (Educause, 2006; Falconer, Nicodemus, DeGrazia, & Medlin, 2012), and has a huge potential for addressing theirmyriad academic needs, which are impossible to be addressed by a single lecturer. The efficacy of screencasts in fulfilling these diverse needs was demonstrated by Pinder-Grover, Green, and Millunchick (2011), who documented the strategic use of screencasts in a large introductory Materials Science and Engineering course, and examined their impact on student usage and course performance. Students in the course perceived the screencasts to be helpful and tend to use the resources as a study supplement. Their usage of the screencasts wasalso positively and significantly correlated with course performance as indicated by the final grade, with the most substantial gains found for students with the least amount of prior knowledge in the course material. At the James Cook University in the U.S., screencasts have been used successfully to supplement lecturesin large mathematicsand engineering classes, deliver mini-lectures that explained topics identified by students as unclear, and give feedback on homework and quizzes (Mullamphy, Higgins, Belward, & Ward, 2009). For education programmes where students are remote from the instructor, screencasts provide a simple yet effective means to deliver rich content to distance students to support various types of learning, as shown in Peterson (2007).

Innovative uses of screencasting have been shown to impact learning and student attitudes in the positive direction.Guerrero, Baumgartel, and Zobott (2013) utilized instructor-developed screencasts to transform a traditional Mathematics classroom into a more constructive one. The researchers made the videos available to preservice elementary teachers in advance of class so that face-to-face instructional time could be used for more constructive learning activities, such as working through problems, advancing concepts, and engaging in collaborative learning. The results were interesting. The transformed pedagogy had a positive impact on the preservice teachers' understanding of course content and attitudes toward mathematics. They valued the inverted classroom as the class time was freed up from passive elements of instruction to focus on actually doing the mathematics. The participants also liked that they had more time *"to process and think about course content prior to applying it in class, and that they could watch lectures anywhere, anytime at their own pace"* (p. 186). The latter finding seems to be consistent across studies.

Most studies on screencasts show favorable student perceptions of them as a learning enhancement tool. In addition to improving learning outcomes, students also found the video tutorials engaging and effective in supplementing lecture material. Mullamphy et al. (2009) point out that the presentation format of screencasts is considerably more engaging for students than the use of chalk, PowerPoint or audio-only podcasts. With the instructional benefits of screencasting clearly established, recent trends in the use of the technology are taking a new direction. Of late, screencasts are increasingly being employed to provide feedback to students and promote assessment for learning (e.g. Haxton &McGarvey, 2011; O'Malley, 2011; Séror, 2012; Thompson & Lee, 2012), and to engage them in higher-order metacognitive processes (e.g. McLoughlin & Loch, 2012; Ro, 2011). Extant research suggests that positive learning outcomes associated with screencasts are more likely caused by how they are used as a learning resource,

rather than by the pure technology itself. While there is much empirical evidence documenting the advantages of screencasting, none has approached them from the standpoint of thematic benefits supported by theory. Hence in this case study, we exploredwhat these thematic benefits may be for Irish college studentslearning Maths aided by instructor-developed screencasts.

Method

Data Collection and Instrument

Students' reactions to the instructor-developed screencasts were captured through an open-ended survey that was administered online. The survey was uploaded onto the Maths Moodle site and went live for two and a half months. All studentshad ample time to respond. The questionnaire contained two sections, A and B. Section A asked for demographic details such as age, specialized degree programme, year of study, and first language, as well asoff-campus Moodle accessibilityfrom the students' home locations. This was an important question since the screencasts were only accessible from the Moodle pages. Section B requested students to indicate how the screencasts aided their learning of Mathematics in the said courses. Students were prompted to write as much as they wished about the uses and benefits of the screencasts. The open-response survey format allowed for rich narrative data to be captured from a large number of students. Students would be enabled to provide more focused and elaborate feedback, which would giveus insight into their perceptions of the uses and benefits of the screencasts. Out of the 266 students enrolled in the courses, 138 responded constituting a response rate of about 52%.

Sample

The survey was administered to a total population of 266 students from four different degree programmes, namely Electronic and Computer Engineering (ECE) (n = 78), Computer Network Management (CNM) (n = 46), Mechanical and Renewable Engineering (MRE) (n = 61), and Sports and Nutrition Science (SNS) (n = 81). The students were taught mandatory Calculus and Algebra courses by the same instructor who developed the screencasts. The ECE, CNM and MRE student groups were taking the courses in the semester that our case study was conducted, while the Sports and Nutrition Science group had taken them in the semester before. The sample that responded to the survey consisted of 138 students. Their mean age was 27. Eighty-two percent (n = 113) were native speakers of English, while the remaining 18% (n = 25) were speakers of Arabic, Russian, Slovakian, Romanian, Turkish, Polish, Portugese, Spanish, Urdu, Yoruba, Finnish, Vietnamese, and Thai. Figure 7 shows the sample breakdown by degree programme.

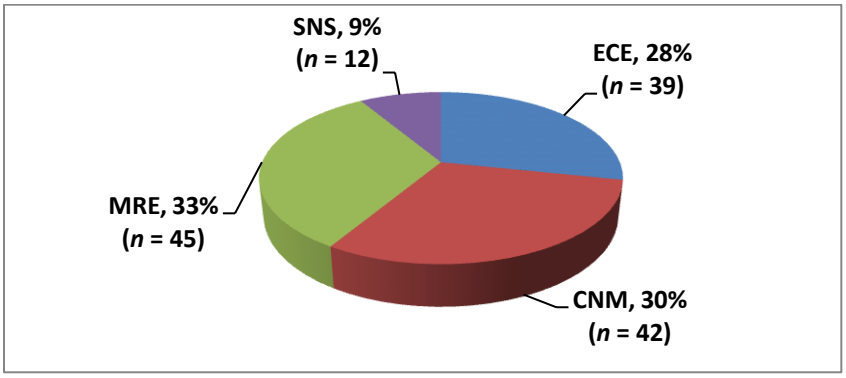

*Figure 7.*Sample breakdown by degree programme

The highest response rate (91.3%) came from the Computer Network Management group, where only 4 students did not respond, followed by Mechanical and Renewable Engineering (73.8%), and Electronic and Computer Engineering (50%). The Sports and Nutrition Science group recorded the lowest response rate (11.1%). In terms of year of study, half of the responses came from the third year students (50%), most likely due to their higher degree of familiarity with the Moodle pages and screencasts. The first and second years each recorded a 25% response rate.

Data Analysis

Descriptive statistics were employed to present student demographics and percentage of screencast use. The narrative data (students' written responses) were analyzed using an inductive thematic content analysis (TCA). The analysisis a descriptive presentation of the narrative data using themes that were generated using a bottom-up approach. Individual student responses were read through, scrutinized for specific key ideas or characteristics, and then categorized according to the similarity of key ideas shared across participants. Appropriate labels were then given to the themes to represent the key benefits of screencast use for college students' Maths learning.

Findings

Reasons for Non-Use of the Screencasts

Only 11.6% of the sample (n = 16) said they never used the screencasts, or rarely used them. Although the Maths Moodle page was very well laid out and systematically organized with clear headings for screencasts and other learning objects (Figure 8), some students were surprisingly unaware of their presence on the page, claiming that they had *"never seen one on the Maths Moodle site"* (3rd year, MRE student).

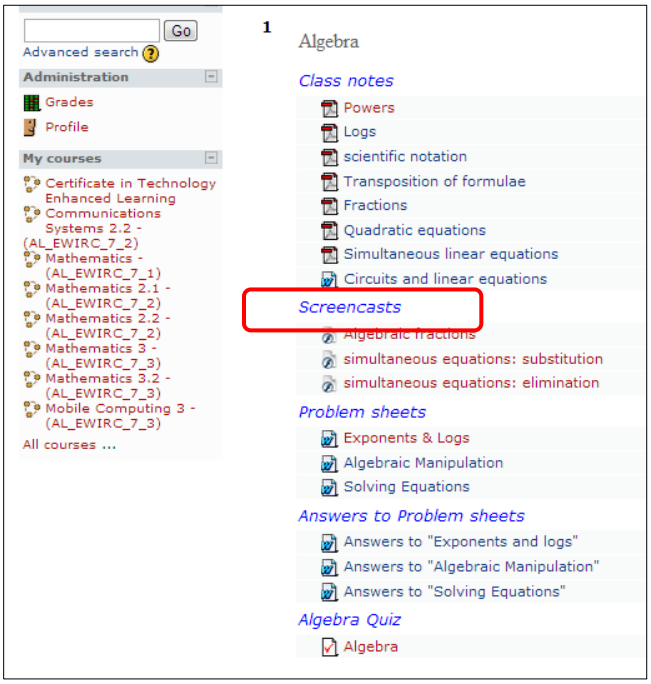

*Figure 8.*The Maths Moodle page was well laid out with a clear heading for screencasts

A few found the videos to be of *"little significance"*(3rdyear, MRE student), most likely because they had already grasped the keyskills from the lectures, and therefore did not need the explanation provided in the screencasts. This was explained by a 44-year old student in his third year of Computer Network Management (CNM):

> The lectures are explained well enough that I don't use them often.

Wilkes (2012) also uncovered the same reason for students' non-use of screencasts in her study, in addition to other causes such as slow Internet connection, difficulty with opening and downloading the videos, and lack of plug-ins. The consistency in the finding suggests that screencasts tend to be used mostly by students needing further instructional support for Mathematical understanding, and less by those who are already quite proficient in the subject and those that learn well from lectures.

Overall Perceptions of the Screencasts

Users of the screencasts were large in number, constituting 88.4% of the sample (n = 122).In general, they responded positively to the videos, proclaiming them to be*"very useful*,"*"extremely helpful," "very informative and legible," "very practical,"* and *"easy to use."*Two students commented:

> It is very helpful to hear the lecturer go through the solutions step by step *(1st year, SNS).*

> These (the videos) have been a huge and continuous help*(1st year, CNM).*

The same student acceptance was reported in Falconer et al. (2012), Green et al. (2012), Pinder-Grover et al. (2008), Pinder-Grover et al. (2011), and Wilkes (2012). In this study, many felt that the videos provided an alternative form of instruction that played a significant role in easing their Maths learning process:

> It (learning from the screencasts)is much easier than looking at questions on paper already done *(3rd year, ECE student).*

> The screencasts are good because they help me learn(*2nd year, CNM student).*

> (They are) very easy to learn from and (provide) good step-by-step procedures *(2nd year, CNM student).*

> I find it very easy to learn using these *(3rd year, ECE student).*

Students used the screencasts for many purposes to accommodate their learning needs, and found them good and useful for these reasons. A fresh high school graduate who was in his first year of Electronic and Computer Engineering (ECE) said the video tutorials helped him to practice and keep up with the Maths module, while a more mature student wrote:

> The screencasts were very helpful indeedas they give a clear example of the work that we are covering in the classroom *(2nd Year, ECE student).*

The positive reactions were likely due to the well-paced and orderly nature of the explanation given in the videos, and the direct connection of the content with what was being covered in the

Maths modules. The comments of four particular students summed up the general views of the student groups:

> The screencasts are great *(2nd Year, ECE student).*
>
> Visual step-by-step examples of the subject materials are very informative and easy to follow *(2nd Year, ECE student).*
>
> The screencasts are a brilliant asset to have *(3rd Year, ECE student).*
>
> The screencasts are definitely the best part of the Maths Moodle page*(3rd Year, ECE student).*

Benefits of Using Screencasts to Support College Students' Learning of Maths

Students'comments provided an overwhelming amount of anecdotal evidence in support of how the screencasts had benefited them. As they had varying Maths learning needs, the precise manner in which they used and benefited from the screencasts also varied according to their needs. From their extensive written comments, we uncovered ten thematic benefits.

Benefit 1: Alloweda Flexible and Personalized Learning

The most number of testimonies came in support of screencasts as a tool that enabledstudents to engage ina flexible, self-paced independent learning mode, a finding consistent withBoffey et al. (2006), Mullamphy et al. (2010), O'Malley (2010),Comiskey and McCartan (2011), Wilkes (2012), and more recently, Guerrero et al. (2013). A major advantage of the screencasts was that they could be remotely accessed, downloaded onto to a PC or a portable player, and viewed offline anytime, anywhere. Therefore, the learning enabled by screencasts extends beyond the classroom and transcends the boundaries of time and space.A mature student in his second year of Computer Network Management mentioned that the videos were *"very helpful if you are stuck on a problem outside class hours"*when the lecturer was not directly accessible for help. Students liked the fact that the screencasts were constantly available on the Moodle page, allowing them to study in the comfort of their own home and move at a pace most well-suited to their ability. This was mentioned repeatedly throughout the comments:

> The screencasts are very helpful for figuring out problems at home *(3rd year, ECE student).*
>
> I find it very easy to learn using these as I can sit in the comfort of my own home and go over them as much as I want *(3rd year, ECE student).*
>
> (The screencasts are) good as you can follow full worked examples at your own pace, pausing and restarting as you go *(3rd year, MRE student).*
>
> These are easy to follow, and allow myself to learn at my own speed *(3rd year, MRE student).*
>
> They are excellent for helping you understand in your own time *(2nd year, ECE student).*

As the Internet was accessible to all the students both on campus and from their home locations, they could watch the video tutorials anytime, anywhere and replay them as many times as they wished until they gained a satisfactory understanding of the Maths keyskills. This particular utility of the screencasts gave them control over their own learning:

> The screencasts allow me to go over in detail the steps involved in a particular question because it is possible to pause the video and play it again until I am satisfied that I understand what is going on*(3rd year, MRE student)*.
>
> I found screencasts the best way of learning at home because you can pause and rewind to figure exactly what is going on *(3rd year, ECE student).*
>
> These help me the most! I can rewind on the bits I'm unsure of (*2nd year, CNM student).*
>
> Screencasts explain things slowly and if you don't understand, you can always rewind *(3rd year, MRE student).*
>
> They can help because you can pause them and look at them as much as you want, unlike class*(3rd year, MRE student).*

Being able to control the screencasts gave students the flexibility and option to learn at their own pace, something a regular classroom cannot always offer or accommodate. With screencasts, students were able to control the rate of information being supplied to them, pausing, restarting and rewinding if it happened to be too fast. This represents a shift towards greater student-centered learning articulated by Gibbs (1992), and was a very critical factor influencing students' ability to adequately understandthe Maths. The screencasts also afforded *"a sort of one-on-one tuition,"*as stated by one male student, a point further illustrated by a first year Computer Network Management student, who found them *"to be the biggest help as it's the same as a private tutor (that allows) you to pause and take notes."*For students with limited notetaking skills, the screencasts would be of tremendous help. In these instances, the screencasts took on the role of a private virtual tutor that is able to accommodate the varied paces of students' understanding, ability, and learning styles.

Benefit 2: Supplemented Lectures and EnhancedUnderstanding of Maths Keyskills

Many students also reported using the screencasts to address the gaps in their understanding of Maths. This wasthe second most recurring usage pattern that emerged from the data, and corroborates the usage pattern found in Pinder-Grover, et al. (2008) and Mullamphy, et al. (2009).The need fordeeper and more thorough understanding of the Mathsarose when for various reasons, students failed to grasp the keyskills from the face-to-face instruction, or when they understood them only partially. An Arabic-speaking student explained how the language barrier sometimes got in the way of her Mathematical understanding:

> Actually I am good in Maths but when the lecturer introduces anew topic like Laplace Transforms or Probabilities, I sometimes can't catch what he is speaking about as I don't know these words in English and need a dictionary to translate them*(2nd year, ECE student).*

Gaps in Mathematical understanding are not uncommon, and students turned to the systematic and clear explanations provided in the screencasts to fulfill this learning need, as explained by a non-regular user of the screencasts:

> I've only used the screencasts once or twice when I needed a more thorough understanding of the material *(3rd Year, CNM student)*.

A 47-year old Electronic and Computer Engineering student valued the explanation as being *"a clear example of the work (covered) in the classroom,"*while another student appreciated that he could *"understand the method (of problem solving) better"* after watching the screencasts. The systematic presentation of the step-by-step solution, coupled with the fact that they could control the screencasts, helped to instill the much needed Mathematical understanding. Turning to the screencastsfor learning assistancewas reiterated again and again by a good number of students:

> (The screencasts are) good for when you want to go over what you did the same day, especially if you didn't quite grasp it the first time *(3rd Year, MRE student)*.
>
> The screencasts are are extremely helpful if you do not understand some of the Maths after the lecture*(2nd year, ECE student)*
>
> Screencasts give a slower narrated explanation of the mathematical problem which is very helpful if not understood in lectures*(3rd Year, MRE student)*.
>
> (The screencasts provide an) extra way of learning if not completely understood in class*(3rd Year, MRE student)*.
>
> They clearly explain in great detail topics I have difficulty understanding *(2nd year, CNM student).*
>
> You see a step-by-step breakdown of the questions which help you to understand the questions better *(3rd year, ECE student).*
>
> I found that I was able to understand the method more clearly and know where each figure/answer came from*(1st year, SNS student).*

Students' testimonies underscore the important role of the videos in supplementing classroom instruction, and in further enhancing their understanding of the Maths.

Benefit 3: Provided a Vicarious Learning Experience

Like many multimedia resources,screencasts can be an effective means for delivering vicarious learning experiences due to their ability to simulate learning in the actual lecture situation. By having an expert model the problem solving just as an instructor would typically do in class, screencasts have the capability to bring the classroom feel to a media presentation. With instructor-developed screencasts, students are more likely to feel a sense of connection with the instructor, and this gives the videosan upper hand over random or generic videos available on the Internet. Two mature ECE and CNM students aptly described the nature of the instructor-developed screencasts posted on the Maths Moodle pages:

> The screencasts are presented in a fashion that is similar to the actual lectures, where the reasons for taking certain steps are clarified*(2nd year, CNM student)*.

> The screencasts are tutorials where the lecturer gives step by step instructions on how to solve various Math problems. The lecturer's commentary explains exactly what is happening at each stage of the problem*(3rd year, ECE student)*.

Hence, it is not surprising that students found them to be pedagogically equivalent to the face-to-face instruction. Threestudents explained how their engagement with the screencasts provided an instruction very closely resembling that of the actual lecture:

> It's like catching the lecture again which can be easily forgotten*(3rd year, MRE student)*.

> It's like attending a lecture. You learn more because you are talked through each stage of the solution. They are very helpful *(2nd year, ECE student)*.

> You're shown the method on how to solve a problem just as you have seen in the classroom *(1st year, CNM student)*.

The close resemblance to actual lectures provided a vicarious learning experience that was of great value, more so because with the screencasts, students had control over the pace of the instruction.Having an expert model the problem solving like real time instruction also means that students can see and master the Maths in their own time. This is also an important aspect of vicarious learning afforded by screencasts.

Benefit 4: Helped Students to Make Up for Missed Lectures and Keep on Track

The availability of the lectures in video forms plays a huge role in helping students to catch up with missed content, thus enabling them to keep on track with the module they were following. An Arabic-speaking, 2nd year ECE student reported relying on the videos for any missed introductory learning episode fundamental to further Mathematical understanding:

> The videos help me when I was absent from lectures to understand the introductory part of a lesson *(2nd year, ECE student)*.

As found by Loch (2010) and O'Malley (2010), a primary benefit of screencasts is that it offers students the opportunity to catch up on missed lectures. Their findings are corroborated in this study:

> I had missed a few lectures. I went through the notes, and the screencasts. It really helped me to cover up what I had missed *(2nd year, ECE student)*.

> (The screencasts allowed) me to see for myself how many classes I missed to keep track (of the Maths module)*(1st year, SNS student)*.

> I'll always have the content even when I miss a day*(1st year, CNM student)*.

> If I miss a class, the screencasts help me catch up*(3rd year, MRE student)*.

> If you can't come to class, you can still follow classes easily*(3rd year, ECE student).*

The efficacy of screencasts in covering lecture material holds a lot of promise as an instructional tool not only for traditional face-to-face programmes as shown by Guerrero et al. (2013), but also for distance education, as indicated by Peterson (2007).

Benefit 5: ProvidedMultimodal Support for Maths Learning

Students do not learn the same way. They have varied learning styles. Some may benefit more from interacting, discussing, and note-taking; others from watching, listening, and doing. In this case study, students expressed a need for the latter form of learning. They pointed to the visual and auditory elements in screencasts as beneficial to their learning:

> In some cases, it is not enough to learn from written materials. Screencasts are better to learn (from) by watching and listening as in class *(2nd year, CNM student).*

> Screencasts are good and useful. The voice and picture together make learning easy*(3rd year, ECE student).*

In the Mathematical context, the visual component and on-screen movements incorporated in screencasts are certainly effective in demonstrating typical multistep problem solving approaches in Maths. Seeing the logical progression of problem solving and how the solution is generated reduces the abstraction level and complexity in Maths, and is critical in assisting students to grasp the keyskills:

> The lecturer gives step by step instructions on how to solve various Math problems. The lecturer's commentary explains exactly what is happening at each stage of the problem. This is useful*(3rd year, ECE student).*

> A question is worked out step by step, which you can watch as often as you like until you are 100% confident in that question*(1styear, CNM student).*

> They are very helpful as you can see how the Maths are done from start to finish *(2nd year, CNM student).*

> They are a great help when you can see the questions being done and explained; you can watch them over and over again*(2nd year, ECE student).*

Maths is known for being abstract and difficult; hence the multimodal support inherent in screencasts renders it more manageable. The support is needed by virtually every student. Students' comments in this study reinforce the ideas articulated in Mayer's multimedia learning principles that graphics and narration presented concurrently aid the understanding and acquisition of complex Mathematical concepts. Some students even regard the multimodal elements as providing a superior form of learning to traditional, didactic methods:

> Seeing how the question is explained is a far better way of learning in my opinion*(1st year, SNS student).*

There were others who declared that the *"visual explanation"*(3rd year, MRE student) had greatly eased their Mathematical understanding, made the Maths *"more straightforward"* (2nd year, CNM student), and was*"much easier (to comprehend) than looking at question on paper already done"* (3rd year, ECE student).

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Benefit 6: FacilitatedExam Review and Revision

Using screencasts for material review and revision purposes was also a common theme throughout students' written comments.A first year CNM student wrote it was *"great to be able to rewatch the Maths and follow along."*Statements such as these and others that described the screencasts as being useful for material review frequently popped up in the anecdotes:

> The screencasts give you a step by step run through sample problems and are very useful for revision*(2nd year, CNM student).*
>
> They are helpful for revision*(3rd year, MRE student; 2nd year CNM student).*
>
> The screencasts are great especially if you would like to go back and review a topic*(1st year, CNM student).*
>
> I find the screencasts very useful when studying for an exam as they are usually based on the more difficult questions*(1st year, CNM student).*
>
> They were a great preparation for the final exam and helped alot*(3rd year, ECE student).*

The evidence is in harmony with the findings of Comiskey and McCartan (2011), Green, et al (2012), and Wilkes (2012), all of which pointed to the important function of screencasts in facilitating review and revision. In this study, students also used the videos in tandem with other learning resources made available on the Moodle site, such as problem sheets and class notes. One student found them of great benefit as they *"provided a good source of revision for problem sheets and exams"*(2nd year, ECE student).These resources were not only useful for exam preparations; but they also helped students to digest complex problem solving methods in greater detail to enable working on the problem sheets. According to a third year student, reviewing course material using the screencasts was especially handy when the lecturer was not available for help:

> I use them during revision weeks leading up to exams when the lecturer is not on hand. It is possible to email the lecturer but I would tend to reserve that for something I was having great difficulty with *(3rd year, CNM student).*

The comments reveal yet another clear advantage of using screencasts, and that is, they release lecturers from the task of having to re-explain concepts, thus freeing up their time for more valuable activities. Lecturers will testify that repeating lectures and re-explaining concepts can be a frustrating and tiresome task. Therefore from this perspective, screencasting is an added benefit both to students and lecturers.

Benefit 7: Helped to Fill Gaps in Class Notes

Due to limitations in the working memory capacity, students sometimes find it hard to listen to the lecture, understand and follow the Mathematical narrative, and take good notes at the same time.For students whose first language is not English, this can be an especially challenging task. Two non-native speakers wrote:

> I am not a native English speaker, so it's quite hard for me to catch up with the instructor in class. I usually have to borrow my friend's book (for notes)*(3rd year, CNM student).*

> If I were learning Maths in my own language, I could write notes and catch up with the lecture. But in English, it's difficult for me. For example, sometimes the teacher does not write on the board and when he speaks, we have to write with him. It's difficult and I don't know what to write in my notes *(3rd year, ECE student).*

However, difficulty with taking good notes is not limited to non-native speakers. An English-speaking student also admitted that he sometimes *"took something down wrong in class"*(1st year, CNM student).Those that found gaps in their notes turned to the screencasts for help:

> I find the screencasts very useful if I can't find what I need in the notes*(2nd year, ECE student).*

> They are very helpful if I missed some of the notes! *(1st year, CNM student).*

Written notes are a necessary means to capture information in a traditional classroom where lectures are ephemeral. Students typically experience limitations in their working memory capacity, often resulting in the inability to hold information long enough to take full, constructive notes from lectures.Screencasts helped students to fill the gaps in their class notes when their notetaking ability sometimes failed them.

Benefit 8: Served as a Memory Aid

Forgetting lectures is not an uncommon occurrence. It is a phenomenon also associated with deficits in the working memory capacity. A third year MRE student professed that the lectures *"can be easily forgotten."*In Maths, students typically forget formulas and steps in solving problems.Fortunately,forgetfulness is a prevalent learning limitation that the screencasts helped students to overcome, as ilustrated by their feedback:

> The videos help me when I forget steps in how to work out the problem *(1st year, CNM student).*

> The screencasts are very useful. Recalling this (how to solve the Maths problems) is (made) easier than looking through textbooks for information*(3rd year, ECE student).*

Another student used the videos to commit formulae to memory:

> The screencasts are very good for helping you memorize equations *(2nd year, ECE student).*

Clearly for some students, the screencasts functioned as a learning tool to overcome memory lapses in rememberinglessons and the lack of ability to take good lecture notes, which are essentially limitations arising from shortcomings of the working memory. Thorne (n.d) suggests that instruction be provided in multiple formats to help students remember content better.The student feedback obtained in this study illustrates the viability of screencasts as an efficient means of providing one of these formats for Maths instruction.

Benefit 9: Provideda Tighter Match withthe Maths Modules

Students expressed a preference for the instructor-developed screencasts to those readily available on the Internet, such as the Maths videos created by the Khan Academy. This is understandable because the content and keyskills addressed in the screencasts were directly relevant to the concepts and keyskills imparted in the Maths modules. A mature student explained the importance of a close match between the screencast content and the Maths modules extensively:

> While there are seemingly endless YouTube videos availabe (Khan academy, etc), they usually have a U.S. or U.K-centered focus (terms and examples used). I find the Maths videos/screencasts to provide a tighter match with the course notes. There have been topics where I have used some of the YouTube videos (i.e. Algebra), but these were to elaborate on specific sub-topics*(1st year, CNM student).*

Thus, having instructor-developed screencasts is a great advantage for students as it definitely saves them the time and trouble of having to scour the Internet for video-based learning resources which might not turn out to be relevant or useful at all. Maths videos such as those provided on the Khan Academy website, for example, athough generally useful for Maths learning are bound to contain variations in their system of explanations and problem solving approaches:

> Having the lecturer create them also means that you're shown the method on how to solve a problem just as you have seen in the classroom, as opposed to watching an external video where another lecturer might have a slight variation on how to solve certain Math problems *(1st year, CNM student).*

Students appreciated the value of the screencasts as they covered the exact topics they were learning in the Maths modules, hence making the video contents closely matched with and directly relevant to their Maths learning needs.

Benefit 10: Made Maths Learning Fun

Finally, the screencasts added motivational values into students' Maths learning experience. Mullamphy et al. (2009) had earlier indicated how students liked the engaging nature of screencasts in contrast to traditional forms of learning from printed material. In this study, we found that studentsliked how the videos made *"the Maths more enjoyable"* (1st year, ECE student). A third year MRE student decided that learning with the screencasts was certainly

"more interesting than reading straight from a word page," while a Polish student in his first year of Computer Network Management commented:

> I like the video materials presented by our Maths instructor. This is an opportunity to comeback to interesting material anytime 24 hours/day and see step by step again how to resolve a problem.

In Maths, it is very important to make the learning enjoyable to sustain students' interest. It is also a factor that influences students' achievement and motivation to succeed in the subject.

Discussion and Conclusion

Screencasts are a great learning resource and an extraordinary supplementary tool to lectures and text-based material. Their advantages to students learning Maths are plentiful, as indicated by our narrative data.The findings of our case study show that they were well-received and viewed favorably by students for their usefulness and ease of use, consistent with the results of other studies on screencasts (e.g. Boffrey, 2006; Green et al., 2012; Mullamphy, 2009; Pinder-Grover et al., 2008, 2011).A vast majority of students found huge benefts in being able to personalize their Maths learning with the screencasts, moving at a pace most well-suited to their ability.They used the screencasts mainly to make up for missed lectures, work on further understanding the Maths, review for exams and prime their memory. They also valued the close match of the video content with the course material and appreciated the presentation format of the videos which rendered Maths more interesting and enjoyable. Although many of these benefits have been documented in previous research, the presentation of the benefits is rather piecemeal. Our findings are an important contribution to the screencast literature as they have presented the advantages as thematic benefits supported by narrative data. It might be useful in the next step of research to confirm these thematic benefits with statistical data using construct-validation procedures such as Factor Analysis or Structural Equation Modeling. In essence, our findings underscore the important role of screencasting as an effective learning and teaching technology for the digital age, not only in Mathematics education but also in other fields as well. Thus, it is really worthwhile to consider screencasting as a content delivery formatand assessment tool for both distance and traditional learning programmes, and train faculty to use it in orderto improve the quality of learning in higher education.

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