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Evaluating the use of problem-based video podcasts to teach mathematics in higher education

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ABSTRACT

Problem-based video podcasts provide short, web-based, audio-visual explanations of how to solve specific procedural problems in subject areas such as mathematics or science. A series of 59 problem-based video podcasts covering five key areas (operations with functions, solving equations, linear functions, exponential and logarithmic functions, and trigonometric functions) were created as self-study tools and used by 288 higher education students to acquire pre-calculus skills over a three week period. The results indicated that a majority of students used the video podcasts frequently, rated them as useful or very useful, viewed them as easy to use, effective learning tools, and reported significant knowledge gains in pre-calculus concepts.

1. Introduction

At least two distinct teaching approaches have been observed regarding the use of video podcasts in education: receptive viewing and problem-based. Receptive viewing of podcasts assumes that learning material in whatever format (e.g., lectures, supporting videos, PowerPoint slides) is to be viewed by students in a relatively passive manner. Problem-based video podcasts, also known as worked examples, provide web-based, audio-visual explanations of specific procedural problems that students may need to solve in a courses such as mathematics or science (Kay, 2012).

Key benefits of using receptive viewing of video podcasts include improved learning and study habits (e.g., Heilesen, 2010; Jarvis & Dickie, 2009; Leijen, Lam, Wildschut, Simons, & Admiraal, 2009; McCombs & Liu, 2007), positive student attitudes towards this medium (e.g., Copley, 2007; Dupagne, Millette, & Grinfeder, 2009; Hill & Nelson, 2011; Vajoczki, Watt, Marquis, & Holshausen, 2010) and increased learning performance (e.g., Crippen & Earl, 2004; Griffin, Mitchell, & Thompson, 2009; Traphagan, Kusera, & Kishi, 2010; Vajoczki et al., 2010).

Limited research, though, has been conducted on problem-based video podcasts (Crippen & Earl, 2004; Loomes, Shafarenko, & Loomes, 2002). The purpose of this paper was to evaluate the effectiveness of problem-based video podcasts designed to improve Calculus readiness for first year university students.

2. Literature review

2.1. Video podcasts in higher education

Video podcasts are audio-visual files that are distributed in a digital format through the Internet using personal computers or mobile devices (McGarr, 2009). They are perhaps best known to students through the YouTube website where over three billon clips are viewed

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daily (Henry, 2011). Since 2006, the use of video podcasts in higher education has grown rapidly (e.g., Heilesen, 2010; McGarr, 2009). Students have described video podcasts as enjoyable to watch (e.g., Green et al., 2003; Winterbottom, 2007), satisfying (e.g., Traphagan et al., 2010; Zhang, Zhou, Briggs, & Nunamaker, 2006), motivating (e.g., Alpay & Gulati, 2010; Hill & Nelson, 2011), intellectually stimulating (e.g., Fernandez, Simo, & Sallan, 2009), useful, helpful, and effective with respect to improving learning (e.g., Bennett & Glover, 2008; Holbrook & Dupont, 2010; Lonn & Teasley, 2009; Pilarski, Johnstone, Pettepher, & Osheroff, 2008). Students particularly enjoy control over when and where they learn (e.g., Hill & Nelson, 2011; Jarvis & Dickie, 2010; Winterbottom, 2007), what they need to learn (e.g., Fill & Ottewill, 2006; Heilesen, 2010), and the pace of learning (e.g., Chester, Buntine, Hammond, & Atkinson, 2011; Fill & Ottewill, 2006; Griffin et al., 2009). In addition, improvements in study habits have been observed including fostering independence (Jarvis & Dickie, 2009), increasing self-reflection (Leijen et al., 2009), more efficient test preparation (McCombs & Liu, 2007), and reviewing material more regularly (Foertsch, Moses, Strikwerda, & Litzkow, 2002; O'Bryan & Hegelheimer, 2007). Regarding learning performance, researchers have reported that the use of video podcasts has resulted in significant gains in skills (e.g., Alpay & Gulati, 2010; So, Pow, & Hung, 2009), test scores (e.g., Crippen & Earl, 2004; Traphagan et al., 2010) and grades (Vajoczki et al., 2010; Wieling & Hofman, 2010). In summary, previous research suggests that video podcasts have a positive impact on student attitudes, behaviour, and learning performance.

2.2. Problem solving and video podcasts

Only two peer-reviewed studies were found examining the use of problem-based or worked example video podcasts. Loomes et al. (2002) discussed the potential benefits of problem-based video podcasts but did not formally study their impact on student attitudes or learning. Crippen and Earl (2004) reported that students had positive attitudes towards the use of video podcasts in an undergraduate chemistry class. Furthermore, there was a significant correlation between the use of problem solving video podcasts and test scores.

The use of problem-based video podcasts in mathematics has not been examined, however, the benefits of using written worked examples are well documented (Atkinson, Derry, Renkl, & Wortham, 2000; Clark & Mayer, 2008; Kirschner, Sweller, & Clark, 2006; Renkl, 2005; Zhu & Simon, 1987). One of the main advantages, particularly for novice learners, is to minimize extraneous cognitive load (engaging in processes that are not beneficial to learning) and optimize germane cognitive load (engaging in processes that help to solve the problem at hand) (Kester, Lehnen, Van Gerven, & Kirschner, 2006; Sweller, 1988; Sweller, van Merriënboer, & Paas, 1998). Clark and Mayer (2008) add that when designing worked examples, teachers should provide clear, step-by-step explanations, ensure that each step is a meaningful and distinct chunk, make connections between the steps articulated and the underlying principles, refrain from reading text on the screen, and, wherever possible, include relevant visuals. It has also been suggested that more experienced or knowledgeable learners may not find worked examples particularly helpful because explanations are too slow and simple (Clark & Mayer, 2008).

In summary, the use of worked examples is a promising teaching approach to assist novice learners in understanding how to solve procedural-based problems, however, research on the use of worked examples presented in video podcasts is limited.

2.3. Student understanding and university level mathematics

In order to be successful in introductory Calculus, students should be comfortable working with functions and performing algebraic manipulations. However, a report by the London Mathematical Society (1995) indicated that higher education mathematics, science, and engineering departments observed a qualitative decline in the mathematical readiness of their first year students. Many students in mathematics courses were hampered because they did not have the essential skills to do algebraic calculations and manipulations fluently and accurately (London Mathematical Society, 1995).

Several international studies have reported that many students have significant difficulty with the range of concepts considered necessary to be successful in university mathematics. Jourdan, Cretchley, and Passmore (2007) reported that students experienced substantial challenges in algebra, functions, and trigonometry. Lawson (2003) noted a significant drop in pre-calculus diagnostic scores from 1991 to 2001. Finally, a Canadian report observed declining student ability in basic algebra, trigonometry, exponents, and logarithms in higher education (Ontario Ministry of Education, 2006).

2.4. Purpose

It is speculated that problem-based video podcasts could provide a reasonable solution for addressing gaps in student pre-calculus knowledge. The purpose of this study was to evaluate the effectiveness of problem-based video podcasts designed to improve student understanding of pre-calculus concepts.

3. Method

3.1. Sample

The student sample, selected from a small university located within a large, metropolitan area of over three million people, consisted of 288 engineering ($n = 140$), science ($n = 121$) or current education ($n = 27$) students (188 males, 100 females) enrolled in a first year undergraduate Calculus course. Students reported high school calculus grades of 60–69 (12%, $n = 35$), 70–79 (37%, $n = 107$), 80–89 (34%, $n = 98$) and 90+ (13.5%, $n = 39$).

3.2. Video podcasts

3.2.1. Development of video podcasts

Under the supervision of the course instructor, a collection of 59 problems and solutions were developed that were deemed important for building an effective foundation to first year Calculus. These problems were then recorded by two female secondary school instructors with advanced knowledge in mathematics using a screen casting program called Camtasia (version 5). Each finished recording took approximately 60–90 min to complete. All video podcasts were then loaded and organized on a course web page. See Kay (2011) for a link to the entire course library of video podcasts.

3.2.2. Content

Five content areas were covered by the video podcasts including operations with functions, solving equations, linear functions, exponential and logarithmic functions, and trigonometric functions. A detailed description of key topics in each content area is provided in Table 1. The length of video podcast clips ranged from 166 s (2:46) to 890 s (14:50) with a mean of 460 s (7:40) and a standard deviation of 143 s (2:23).

3.2.3. Problem format

Each video podcast had the following features: a clear descriptive title, a problem solved by the teacher in a step-by-step fashion (teacher problem) and a corresponding problem to be solved by the student (student problem). The teacher would start by explaining the nature of the problem to be solved and then proceed to discuss the first step. The video podcast would automatically stop so that a student would have time to work through the first step of his/her assigned problem. When the student wished to continue, he/she would click a button and the answer for the first step to the student solution would be presented. The process of explaining a step and pausing the clip to allow the student to complete the corresponding step in his/her assigned problem continued until the full solution was presented. Students could also control the video podcast with a pause, stop, or play button as well as a dragging tool which permitted movement to anywhere in the clip (see http://tiny.cc/calcvp1 for a sample clip).

3.2.4. Design features

When planning and creating the video podcasts for this study, seven key features were followed based on well researched design principles. First, the problem type was selected and segmented into clear steps (e.g., Clark & Mayer, 2008) so that the user was not overwhelmed. Second, the context of the problem was explained and connected where possible to previous mathematical knowledge (Bransford, Brown, & Cocking, 2000). Third, key elements were written down as needed in order to reduce the cognitive load of users (e.g., Chandler & Sweller, 1991; Kester et al., 2006). Fourth, clear visuals were used when necessary to illustrate key aspects of problems (Clark & Mayer, 2008). Fifth, important elements in problems were highlighted in order to focus student attention (e.g., Willingham, 2009). Sixth, teachers were told to use a conversational, relaxed voice to engage users and create the impression that each listener was being addressed personally (e.g., Clark & Mayer, 2008). Finally, the length of each clip was kept to a minimum to address issues of limited attention span (e.g., Medina, 2008; Tapscott, 2009).

3.3. Procedure

Students were sent a link to the video podcasts one week prior to a pre-calculus diagnostic test given during the second week of school. Students were also provided a link to the video podcast web page during the first week of school. After they received their results from the diagnostic test, they were asked to fill in a 10–15 min survey inquiring about their use of and attitudes towards video podcasts. Participation in this study was voluntary, anonymous, and in no way impacted a student's grade. The survey questions about video podcasts are presented in Appendix A.

3.4. Data sources

3.4.1. Background information

Students were asked their gender, program of study, and Calculus grade in high school.

Table 1
Description of problem-based video podcast content.

Content area	Key topics	Range (seconds)	Mean (SD) (seconds)
Operations with functions ($n = 18$ clips)	• Evaluating functions, domain and range, transformations, composition, inverse functions, piecewise functions	257–651	438 (129)
Solving equations ($n = 10$ clips)	• Factoring, rational expressions, inequalities, absolute value, linear systems	264–813	456 (150)
Linear functions ($n = 6$ clips)	• Equation of a line, setting up linear models	274–551	404 (126)
Exponential and logarithmic functions ($n = 12$ clips)	• Exponent and log laws, domain and range, transformations, solving exponential and logarithmic equations, applications	166–683	435 (176)
Trigonometric functions ($n = 13$ clips)	• Radian and degrees, unit circle, transformations, domain and range, setting up models, equations	387–890	544 (115)

3.4.2. Use of video podcast website

The total number of video podcast visits was recorded by a custom designed tracking tool. Students were also asked to estimate how many times they visited the video podcast website and the total time they spent watching clips.

3.4.3. Open-ended response question

Students were asked to explain why they chose to use or not use video podcasts. These qualitative comments were reviewed and categorized by theme. The coding scheme is presented in Appendix B.

3.4.4. Survey data

Students were asked to rate overall usefulness as well as assess nine features of video podcasts (Table 1). The internal reliability of the scale was 0.84. However, all items in the scale were analysed individually in order to gain further insights into the use of problem-based video podcasts.

3.4.5. Performance

Students were asked to assess their pre-calculus knowledge before and after using the video podcasts (operations with functions, solving equations, linear functions, exponential and logarithmic functions, trigonometric functions). This approach to assessing performance, while less precise, was used to preserve anonymity and authenticity of the survey data.

3.5. Research questions

Four key research questions were addressed regarding the use of problem-based video podcasts in the realm of pre-calculus mathematics:

1) Why do students choose to use or not to use video podcasts? (open-ended response);
2) How often are video podcasts used? (tracking data and student feedback);
3) How did students rate the usefulness and quality of video podcasts? (survey data); and
4) Did student understanding of pre-calculus knowledge improve as a result of using video podcasts? (survey questions)

4. Results

4.1. Choosing to use video podcasts

4.1.1. Reasons for using video podcasts

Just over two-thirds of the student sample ($n = 195$) chose to use video podcasts in this study. Eight reasons were cited by students for selecting these tools. The first and most frequent reason for using video podcasts was related to learning benefits ($n = 88$ comments) such as remembering better, reviewing old material, helping to solve and understand problems better, and visualization. The second reason was linked to the quality of video podcast explanations ($n = 64$ comments) and the opportunity to follow clear, step-by-step explanations. The third reason was that students thought, in general, that video podcasts were useful or helpful ($n = 23$ comments). The fourth reason offered was based on the design features of video podcasts ($n = 20$ comments) such as ease of use, variety of examples, and pace of teaching. The fifth reason for students using video podcasts was the interactivity provided by trying to solve the student-based problem ($n = 17$ comments). The sixth reason was that video podcasts were perceived as being a better option than problems presented in a written format ($n = 13$ comments). The final two reasons were student curiosity about video podcasts ($n = 6$ comments) and perceived control over the pace of learning ($n = 5$ comments). See Table 2 for sample comments of reasons for using video podcasts.

Table 2
Sample reasons cited for using video podcasts.

Category	Sample comments
Learning	"The video podcasts helped to remember operations."
	"I have been out of high school for 7 years, and I haven't done [Calculus] since then. So it really ... helped me improve."
	"I used the video clips to help me solve the questions."
	"I used the mini clips to help me understand how the solution came about."
	"They helped a lot to visualize and understand what was happening."
Good explanations	"Seeing a question actually written out step by step in front of you really helps."
	"I used them because they go through all the examples making sure to go through all the simple and complex math."
General comments	"I ... found them helpful."
	"The video podcasts [were] useful and informative."
Design	"Very detailed, interesting, and helpful. Good pace."
	"[There were] some good examples."
Interactivity	"From basic to more complex topics, the mini clips provided an interactive opportunity to learn about and try problems out on your own."
	"I liked these because you actually got to try the problems with someone there helping you along."
Better than written	"Its easier to understand when you see it being done than when you look at a already finished solution."
Curious	"[I was] interested to see what the video podcasts had to offer."
Control	"The video podcasts clips were ... useful as you could go at your own pace."

4.1.2. Reasons for not using video podcasts

Just under one third of the student sample ($n = 95$) chose not to use video podcasts. Five reasons were offered to explain why these students did not select this medium to learn. The first reason was that students felt they did not need the help ($n = 15$ comments). The second reason was that some students, in spite of being sent emails, did not know that video podcasts were available ($n = 14$ comments). The third reason was that students said they did not have time to watch the video podcasts ($n = 13$ comments). The fourth reason for not using video podcasts was based on technology-related problems such as hardware malfunctions or download speed ($n = 7$ comments). The final reason was that students were satisfied with written materials ($n = 5$ comments). See Table 3 for sample comments of reasons not to use video podcasts.

4.2. Use of video podcasts

During the 21 day period that the video podcasts were available, 4675 visits were recorded by the tracking program. The mean number of visits per day was 223 (SD = 151). The number of video podcasts viewed per visit ranged from 1 to 59, with a mean of 5 (SD = 5.4). The mean time spent on a video podcast visit was 358 s (SD = 444 s) with a range of 0–3501 s.

The 21 day time period can be divided up into three distinct sections. The first nine days represent video podcast use prior to and during the first week of class (first week). The next five days represent video podcast use when the diagnostic test was conducted (diagnostic test). The final seven days represents video podcast use after the diagnostic test was taken. Percent of total visits (49%), number of video podcasts viewed per day ($n = 457$), and mean time per visit ($n = 374$ s) were considerably higher when students were preparing for the diagnostic test (Table 4). Post-test video podcast use was similar to first week use (Table 4).

4.3. Ratings of video podcast usefulness and quality

Overall, 87% of the 190 students who used video podcasts rated them as useful ($n = 68$; 36%) or very useful ($n = 98$; 52%). Students rated the problem-based video podcasts highly (Likert scale from 1 to 5) with an average item score of 4.2 (SD = 0.80). The highest rated features of video podcasts were quality of explanations, control over when to study, and writing quality. Other aspects that students liked about video podcasts were improvement over using a textbook, helping to understand problems better, useful tips, and working on the student problem. A summary of the video podcasts ratings is provided in Table 5.

4.4. Impact of video podcasts on understanding

While a formal pre-post test analysis was not completed, students self-assessed five areas of pre-calculus knowledge before and after using the video podcasts. Paired *t*-tests revealed significant gains in all five pre-calculus knowledge categories assessed (Table 6). The effect sizes (based on Cohen's d) ranged from 0.30 to 0.53 and are considered to be moderate ($r = 0.30$) to large ($r = 0.50$) (Cohen, 1988, 1992).

Correlations between self-reported use of video podcasts and self-reported changes in pre-calculus knowledge were positive and significant for all five pre-calculus concepts including basic functions ($r = 0.25$, $p < 0.001$, $n = 190$), solving equations ($r = 0.20$, $p < 0.01$, $n = 190$), linear functions ($r = 0.21$, $p < 0.005$, $n = 190$), exponential and logarithmic functions ($r = 0.24$, $p < 0.005$, $n = 190$), and trigonometric functions ($r = 0.20$, $p < 0.01$, $n = 190$).

5. Discussion

5.1. Choosing to use video podcasts

Two-thirds of the student population in this study elected to use problem-based video podcasts for similar reasons reported in previous research, namely improved learning (e.g., Bennett & Glover, 2008; Holbrook & Dupont, 2010; Lonn & Teasley, 2009) and control over when, where, and how they learned (e.g., Fill & Ottewill, 2006; Griffin et al., 2009; Hill & Nelson, 2011).

A new finding specific to problem-based video podcasts suggests that students benefitted from the step-by-step explanations. The clear presentation of distinct steps was considered especially valuable by students. This result was predicted by cognitive load theory (e.g., Kester et al., 2006; Sweller, 1988) and Clark and Mayer's (2008) detailed suggestions regarding the presentation of meaningful chunks when explaining problems.

Table 3
Sample reasons cited for not using video podcasts.

Category	Sample comments
Did not need help	"I did not use them because I figured I could do it on my own."
	"[I was] already comfortable with the material."
Did not know	"I did not know about them."
	"Actually, I don't know we have video podcasts on the web site."
No time	"I have not found the time as of yet."
	"Haven't had a chance yet."
Technology problem	"They wouldn't work at the time."
	"[The] video podcasts played slowly and required more time than to do the problems themselves."
Used other method	"The .pdfs contained enough information to refresh my memory."
	"I did not need more review than the text provided."

Table 4
Use of problem-based video podcasts.

Characteristic	First week	Diagnostic test week	After diagnostic test
Number of days	9	5	7
Total number of visits	1214	2286	1175
Percent of total visits	26%	49%	25%
Visits per day	135	457	168
Mean time per visit (seconds)	345	374	333

Students also noted a preference for the dynamic visualization of a problem as opposed to the static presentation of a text-based format. This observation supports the speculation by Clark and Mayer (2008) that clear visuals are advantageous in problem solving video podcasts. Another unique finding was the reported gain of completing the interactive student problem. Both survey data and open-ended comments suggested that a number of students found it beneficial to work through the student problem as the video podcast was being presented. This approach to designing worked examples in a video podcast format is new and may prove to be a valuable teaching strategy.

It is important to acknowledge that one third of the students in this study choose not to use video podcasts. The majority of the reasons given were based on tangential issues such as not knowing video podcasts were available, not having enough time to use them, or miscellaneous technical problems. The main direct reason for not using video podcasts was that some students felt they already knew the material. This finding is consistent with Clark and Mayer's (2008) claim that worked examples may not be useful for more experienced or knowledgeable learners.

5.2. Use of video podcasts

The students in this study actively used the problem-based video podcasts provided. During the first week of classes, students viewed over 1200 clips in the span of 10 days, the equivalent of 121 visits per day. Use nearly quadrupled during the diagnostic test week rising to 457 video podcasts viewed daily, supporting previous research suggesting that students use these learning aids as a just-in-time resource before being assessed (e.g., Chester et al., 2011; Crippen & Earl, 2004; Fernandez et al., 2009). This high frequency use is even more impressive considering the concepts covered were not being directly evaluated for marks. Somewhat surprisingly, students used the video podcasts after the diagnostic test almost 170 times per day. Since the testing period was over, it is speculated that some students needed further review to prepare themselves for the upcoming Calculus course.

Also interesting, was the relative consistency of time spent per visit throughout the study. While the number of visits increased during the testing period, then decreased afterwards, the mean amount of time spent viewing video podcasts was five to six minutes. It is tempting to conclude that most students looked at one or two video podcasts per visit, however, the time range (0–59 min) indicates that there was considerable variability in viewing behaviour. Future research should consider monitoring user behaviour more closely and directly asking students how they used the video podcasts.

Finally, it is challenging to compare frequency of use in this study with previous research because past metrics used were so diverse and included number of downloads per term (e.g., Crippen & Earl, 2004; Shantikumar, 2010), views per week (e.g., Moss, O'Connor, & White, 2010), percent of video podcasts viewed (e.g., Dupagne et al., 2009), percent of students who viewed podcasts (e.g., Winterbottom, 2007), and student ratings of use based on a Likert Scale (Pilarski et al., 2008). The current study employed three new measurements (visits per day, mean time per visit, and pattern of visits over time) in order to expand understanding of how students use video podcasts. It is argued that future research should assess frequency in a consistent fashion using multiple measures to build understanding about viewing behaviours and patterns.

5.3. Ratings of video podcast usefulness and quality

Almost 90% of the students who used problem-based video podcasts rated them as useful or very useful. This result is consistent with comments that video podcasts supported learning, provided clear, step-by-step explanations, control over the pace of learning, and helpful visual aids.

Table 5
Summary of ratings for problem-based video podcasts.

Item	*n*	Mean	SD
The video podcasts were easy to follow.	189	4.46	0.68
The clips were helpful because I could do them on my own time.	187	4.40	0.76
The math problems were well explained in the video podcasts.	188	4.31	0.74
The writing in the video podcasts was easy to read.	188	4.30	0.75
I liked using the video podcasts better that using a textbook to work through problems.	188	4.17	0.99
The video podcasts helped me understand math concepts better.	189	4.16	0.77
Good tips were provided in the video podcasts to help me understand the problem.	188	4.10	0.76
I liked doing the "student problem" in the video podcasts.	182	3.87	1.02

Table 6
Pre vs. post ratings of pre-calculus knowledge ($n = 195$).

Topic	Pre video podcasts mean (SD)	Post video podcast mean (SD)	Significance t value	Cohen's d
Operations with functions	3.32 (0.93)	3.68 (0.79)	−6.38**	0.42
Solving equations	3.59 (0.94)	3.80 (0.80)	−3.36*	0.24
Linear functions	3.50 (1.00)	3.77 (0.79)	−4.35**	0.30
Exp. and log functions	2.87 (0.96)	3.31 (0.81)	−6.87**	0.50
Trigonometric functions	2.87 (1.02)	3.37 (0.87)	−7.81**	0.53

*$p < 0.005$.
**$p < 0.001$.

Students also rated all aspects of the video podcasts highly, averaging four or more on a five-point Likert scale. The highest rated features were easy to follow, high quality explanations and the ability to view video podcasts when desired. These results are consistent with previous studies on the key design components of video podcasts (e.g., Clark & Mayer, 2008) and students enjoying control over the learning process (e.g., Hill & Nelson, 2011; Jarvis & Dickie, 2010; Winterbottom, 2007). Two new important features, yet to be examined in previous research, were the readability of writing in the video clips and problem solving tips offered to students. This kind of detailed information may be important to practitioners who wish to design this type of video podcast. Future research on characteristics of problem-based video podcasts might focus on evaluating video podcast qualities by probing students specifically, perhaps through the use of interview or focus group data. Another option might be to use a think-aloud protocol technique, where a student provides a running commentary while actually watching and using a video podcast.

5.4. Impact of video podcasts on understanding

Indirect evidence, based on student self-reports, suggests that understanding of pre-calculus concepts increased significantly as a result of using video podcasts. Significant gains from pre- to post-test scores were observed for all five categories of knowledge assessed with an effect size considered to be moderate or large. In addition, correlations between time spent using video podcasts and changes in all five areas of pre-calculus knowledge were positive and significant. Finally, as stated earlier, students strongly believed that the problem-based video podcasts had a significant impact on their learning. Significant gains in understanding and knowledge are consistent with previous research and the impact of video podcasts (e.g., Alpay & Gulati, 2010; Crippen & Earl, 2004; So et al., 2009; Traphagan et al., 2010).

It should be noted that students may have used other aids such as pdf files, practice quizzes, and review of secondary textbooks to augment their pre-calculus knowledge, so increases in self-assessed knowledge can not be solely attributed to the using video podcasts. In addition, it is important to recognize that any conclusions are limited because the data collected was based on self-assessment. A more rigorous evaluation would involve strict monitoring of use and completion of actual pre- and post-tests.

5.5. Caveats and future research

This study is a first attempt at using problem-based video podcasts to address gaps in pre-calculus knowledge. Efforts were made to ensure the quality of the analysis by providing a detailed description of the video podcasts used, collecting data from a large sample, and employing multiple data collection tools. Nonetheless, several caveats are worth addressing for future research. First, actual student behaviours while using problem-based video podcasts were not examined. Collecting data using think-aloud protocols, interviews, or focus groups with a small sub-sample of students would help gather more information on which patterns of video podcast use are associated with negative and positive outcomes. In addition, data could be gathered on the specific design features of video podcasts that inhibit and enhance learning. Second, a formal pre- and post-test on pre-calculus concepts would provide more convincing data regarding the impact of video podcasts on learning performance. Third, since this study was a formative analysis, the reliability and validity of the survey instruments were not provided. Data collection tools on the attitudes of students towards video podcasts could be further refined and developed. Finally, the time period in which students used video podcasts was relatively short – only 21 days. Use of video podcasts over an entire course targeting tests that count for grades is necessary to assess the longer term impact of video podcasts in more realistically meaningful situations for students.

5.6. Summary

Over the past four decades, various reports have noted that many higher education students have a limited understanding of the kinds of mathematical concepts required to be successful in university Calculus. A set of 59 problem-based video podcasts was designed to help students improve their pre-calculus knowledge. Two-thirds of the students viewed over 4500 video podcasts during a 21 day period. Students used video podcasts because step-by-step, visually based explanations helped them learn when and how they wanted. Students rated problem-based video podcasts as useful, easy to follow, and effective in helping them understand new material. Students also reported significant pre-calculus knowledge gains as a result of using video podcasts. Overall, the evidence indicates that problem-based video podcasts are readily accepted by first year university students and help improve understanding of pre-calculus knowledge concepts.

Appendix A. Description of attitudes towards video podcasts survey.

Background information
1. Gender
2. Program of study
3. Calculus grade in high school
Use of video podcasts
1. Online tracking of website use
2. When did you visit the pre-calculus video podcast (1 week before classes, first week of classes, just before the test, after the test)
3. How many times did you visit the video podcast website?
Video podcasts
1. Did you use the video podcasts? Why or why not?
2. Which topics were reviewed?
3. How much time (in minutes) was spent using the video podcasts?
4. How useful were the mini clips (not at all, somewhat, useful, very useful)
5. Using a 5 point Likert scale (strongly disagree to strong agree)
a. The clips were easy to follow
b. The math problems were well explained
c. I liked doing the "student problem"
d. The writing in the clips was easy to read
e. Good tips were provided
f. The clips were helpful because I could do them on my own time
g. The clips helped me understand math concepts better
h. I liked using the clips better that a textbook
Performance
1. Using a 5 point Likert scale (very weak to very strong), five areas of pre- and post pre-calculus knowledge were self-evaluated
a. Functions
b. Solving equations
c. Linear functions
d. Exponential and logarithmic functions
e. Trigonometric functions

Appendix B. Coding scheme for reasons to use or not to use video podcasts.

	Description
Reasons to use video podcasts	
Learn	• Student talked about learning including remembering better, reviewing old material, helping to solve or understand problems better, or dynamic visualization of problems
Good explanations	• Student refers to some aspect of the video podcast explanation including quality, ability to follow, step-by-step presentation
General comments	• Student notes that video podcasts were generally helpful or useful
Design	• Student talks about design features like ease of use, choice of examples used, repetition, pace
Interactive	• Student refers specifically to the student problem component of the video podcast
Better than written	• Student believes that video podcasts are better than written materials
Curious	• Student is simply curious about what video podcasts look like
Control	• Student talks about increased control over pace and level of learning
Reasons not to use video podcasts	
Did not need help	• Student understands concepts and did not need extra help
Did not know	• Student was not aware that video podcasts were available
No time	• Student noted that they did not have time to use video podcasts
Technology problem	• Student cited a technology problem that prevented them from using video podcasts
Used other method	• Student noted that they preferred another method of learning

References

Alpay, E., & Gulati, S. (2010). Student-led podcasting for engineering education. *European Journal of Engineering Education, 35*(4), 415–427. doi:10.1080/03043797.2010.487557.

Atkinson, R. K., Derry, S. J., Renkl, A., & Wortham, D. (2000). Learning from examples: instructional principles from the worked examples research. *Review of Educational Research, 70*(2), 181–214. doi:10.3102/00346543070002181.

Bennett, P., & Glover, P. (2008). Video streaming: implementation and evaluation in an undergraduate nursing program. *Nurse Education Today, 28*(2), 253–258. doi:10.1016/j.nedt.2007.04.005.

Bransford, J. D., Brown, A. L., & Cocking, R. C. (2000). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.

Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and Instruction, 8*(4), 293–332. doi:10.1207/s1532690xci0804_2.

Chester, A., Buntine, A., Hammond, K., & Atkinson, L. (2011). Podcasting in education: student attitudes, behaviour and self-efficacy. *Educational Technology & Society, 14*(2), 236–247.

Clark, R. C., & Mayer, R. E. (2008). *E-learning and the science of instruction*. San Francisco: Pfeiffer.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences* (2nd ed.). New York: Academic Press.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*(1), 155–159. doi:10.1037/0033-2909.112.1.155.

Copley, J. (2007). Audio and video podcasts of lectures for campus-based students: production and evaluation of student use. *Innovations in Education and Teaching International, 44*(4), 387–399. doi:10.1080/14703290701602805.

Crippen, K. J., & Earl, B. L. (2004). Considering the effectiveness of web-based worked example in introductory chemistry. *Journal of Computers in Mathematics and Science Teaching, 23*(2), 151–167.
Dupagne, M., Millette, D. M., & Grinfeder, K. (2009). Effectiveness of video podcast use as a revision tool. *Journalism & Mass Communication Educator, 64*(1), 54–70.
Fernandez, V., Simo, P., & Sallan, J. M. (2009). Podcasting: a new technological tool to facilitate good practice in higher education. *Computers & Education, 53*(2), 385–392. doi:10.1016/j.compedu.2009.02.014.
Fill, K., & Ottewill, R. (2006). Sink or swim: taking advantage of developments in video streaming. *Innovations in Education and Teaching International, 43*(4), 397–408. doi:10.1080/14703290600974008.
Foertsch, J., Moses, G. A., Strikwerda, J. C., & Litzkow, M. J. (2002). Reversing the lecture/homework paradigm using eTeach® web-based streaming video software. *Journal of Engineering Education, 91*(3), 267–274.
Green, S., Voegeli, D., Harrison, M., Phillips, J., Knowles, J., Weaver, M., et al. (2003). Evaluating the use of streaming video to support student learning in a first-year life sciences course for student nurses. *Nurse Education Today Journal, 23*(4), 255–261.
Griffin, D. K., Mitchell, D., & Thompson, S. J. (2009). Podcasting by synchronising PowerPoint and voice: what are the pedagogical benefits? *Computers & Education, 53*(2), 532–539. doi:10.1016/j.compedu.2009.03.011.
Heilesen, S. B. (2010). What is the academic efficacy of podcasting? *Computers & Education, 55*(3), 1063–1068. doi:10.1016/j.compedu.2010.05.002.
Henry, A. (2011). *YouTube hits 3 billion views per day, 48 hours of video uploaded per minute*. [Web log post]. Retrieved from. http://www.geek.com/articles/news/youtube-hits-3-billion-views-per-day-48-hours-of-video-uploaded-per-minute-20110526/.
Hill, J. L., & Nelson, A. (2011). New technology, new pedagogy? Employing video podcasts in learning and teaching about exotic ecosystems. *Environmental Education Research, 17*(3), 393–408. doi:10.1080/13504622.2010.545873.
Holbrook, J., & Dupont, C. (2010). Making the decision to provide enhanced podcasts to post-secondary science students. *Journal of Science Education and Technology, 20*(1), 233–245. doi:10.1007/s10956-010-9248-1.
Jarvis, C., & Dickie, J. (2009). Acknowledging the 'forgotten' and the 'unknown': the role of video podcasts for supporting field-based learning. *Planet, 22*, 61–63, Retrieved from. http://www.gees.ac.uk/planet/p22/cjjd.pdf.
Jarvis, C., & Dickie, J. (2010). Podcasts in support of experiential field learning. *Journal of Geography in Higher Education, 34*(2), 173–186. doi:10.1080/03098260903093653.
Jourdan, N., Cretchley, P., & Passmore, T. (2007). Secondary-tertiary transition: what mathematics skills can and should we expect this decade?. InWatson, J., & Beswick, K. (Eds.). (2007). *Mathematics: Essential research, essential practice, Vol. 2* (pp. 463–472) Adelaide, Australia: Mathematics Education Research Group of Australasia Inc.
Kay, R. H. (2011). *Pre-calculus course website containing video podcasts*. Retrieved from. http://faculty.uoit.ca/kay/precalc/math1010/.
Kay, R. H. (2012). Exploring the use of video podcasts in education: a comprehensive review of the literature. *Computers in Human Behavior, 28*(3), 820–831. doi:10.1016/j.chb.2012.01.011.
Kester, L., Lehnen, C., Van Gerven, P. W. M., & Kirschner, P. A. (2006). Just-in-time schematic supportive information presentation during cognitive skill acquisition. *Computers in Human Behavior, 22*(1), 93–116. doi:10.1016/j.chb.2005.01.008.
Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*(2), 75–86. doi:10.1207/s15326985ep4102_1.
Lawson, D. A. (2003). Changes in student entry competencies 1991–2001. *Teaching Mathematics and Its Applications, 22*(4), 171–175.
Leijen, A., Lam, I., Wildschut, L., Simons, P. R. J., & Admiraal, W. (2009). Streaming video to enhance students' reflection in dance education. *Computers & Education, 52*(1), 169–176. doi:10.1016/j.compedu.2008.07.010.
London Mathematical Society. (1995). *Tackling the mathematics problem*. London: LMS.
Lonn, S., & Teasley, S. D. (2009). Podcasting in higher education: what are the implications for teaching and learning? *Internet and Higher Education, 12*(3), 88–92. doi:10.1016/j.iheduc.2009.06.002.
Loomes, M., Shafarenko, A., & Loomes, M. (2002). Teaching mathematical explanation through audiographic technology. *Computers & Education, 38*(1–3), 137–149.
McCombs, S., & Liu, Y. (2007). The efficacy of podcasting technology in instructional delivery. *International Journal of Technology in Teaching and Learning, 3*(2), 123–134.
McGarr, O. (2009). A review of podcasting in higher education: its influence on the traditional lecture. *Australasian Journal of Educational Technology, 25*(3), 309–321.
Medina, J. (2008). *Brain rules*. Seattle, WA: Pear Press.
Moss, N. D., O'Connor, E. L., & White, K. M. (2010). Psychosocial predictors of the use of enhanced podcasting in student learning. *Computers in Human Behavior, 26*(3), 302–309. doi:10.1016/j.chb.2009.10.012.
O'Bryan, A., & Hegelheimer, V. (2007). Integrating CALL into the classroom: the role of podcasting in an ESL listening strategies course. *ReCALL, 19*(2), 162–180. doi:10.1017/S0958344007000523.
Ontario Ministry of Education. (2006). *Report of the minister's task force on senior high school mathematics*. Retrieved from. http://www.edu.gov.on.ca/eng/document/reports/seniormath/.
Pilarski, P. P., Johnstone, D. A., Pettepher, C. C., & Osheroff, N. (2008). From music to macromolecules: using rich media/podcast lecture recordings to enhance the preclinical educational experience. *Medical Teacher, 30*(6), 630–632. doi:10.1080/01421590802144302.
Renkl, A. (2005). The worked-out examples principle in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning*. New York: Cambridge University Press.
Shantikumar, S. (2010). From lecture theatre to portable media: students' perceptions of an enhanced podcast for revision. *Medical Teacher, 31*(6), 535–538. doi:10.1080/01421590802365584.
So, W. W., Pow, J. W., & Hung, V. H. (2009). The interactive use of a video database in teacher education: creating a knowledge base for teaching through a learning community. *Computers & Education, 53*(3), 775–786. doi:10.1016/j.compedu.2009.04.018.
Sweller, J. (1988). Cognitive load during problem solving: effects on learning. *Cognitive Science, 12*, 257–285.
Sweller, J., van Merriënboer, J. J. G., & Paas, F. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10*, 251–296.
Tapscott, D. (2009). *Grown up digital*. Toronto, Ontario: McGraw Hill.
Traphagan, T., Kusera, J. V., & Kishi, K. (2010). Impact of class lecture webcasting on attendance and learning. *Educational Technology Research and Development, 58*(1), 19–37. doi:10.1007/s11423-009-9128-7.
Vajoczki, S., Watt, S., Marquis, N., & Holshausen, K. (2010). Podcasts: are they an effective tool to enhance student learning? A case study from McMaster University, Hamilton Canada. *Journal of Educational Multimedia and Hypermedia, 19*(3), 349–362.
Wieling, M., & Hofman, W. (2010). The impact of online video lecture recordings and automated feedback on student performance. *Computers & Education, 54*(4), 992–998. doi:10.1016/j.compedu.2009.10.002.
Willingham, D. T. (2009). *Why don't students like school?* San Francisco: Jossey-Bass.
Winterbottom, S. (2007). Virtual lecturing: delivering lectures using screencasting and podcasting technology. *Planet, 18*, 6–8, Retrieved from. http://www.gees.ac.uk/planet/p18/sw.pdf.
Zhang, D., Zhou, L., Briggs, R. O., & Nunamaker, J. F., Jr. (2006). Instructional video in e-learning: assessing the impact of interactive video on learning effectiveness. *Information and Management, 43*(1), 15–27. doi:10.1016/j.im.2005.01.004.
Zhu, X., & Simon, H. A. (1987). Learning mathematics from examples and by doing. *Cognition and Instruction, 4*(3), 137–166. doi:10.1207/s1532690xci0403_1.