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Identifying and supporting numeracy needs of first year undergraduate education students

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**Athens Institute for Education and Research
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INT2016-2202**

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Year Undergraduate Education Students**

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Identifying and Supporting Numeracy Needs of First Year Undergraduate Education Students

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Abstract

Currently Australian pre-service teachers' levels of personal numeracy are under a great deal of scrutiny. There are calls for universities to raise entry standards into teaching degrees and counter-calls that the output of universities should be gauged rather than inputs. In 2015, doubts about the ability of graduate teachers to convey the desired skills, knowledge and attitudes in mathematics led the Australian Government to mandate the introduction of the Literacy and Numeracy Test for Initial Teacher Education Students. From 2017, all pre-service teachers in Australia will be required to pass prior to graduation. The present research sought to identify specific areas of support that may be needed by first year primary education students in order to meet the anticipated numeracy requirements of the test.

Students' understandings were inferred from the analysis of the examination scripts of 471 first year primary education students. Common errors were identified and coded to reveal aspects of students' mathematical content knowledge requiring further attention. The results suggested that students would benefit from further support in areas such as operations with fractions, order of operations, line symmetry, converting fractions to decimals, and metric conversions. The results were used to inform the development of a series of online numeracy support videos. The perceived efficacy of these resources was examined in a series of focus group interviews conducted with students, leading to recommendations for the subsequent development and deployment of online numeracy support resources.

Keywords: Numeracy, First Year, Online, Support

Introduction

The Australian Professional Standards for Teachers (AITSL, 2011) require graduate teachers to demonstrate knowledge and understanding of the concepts, substance and structure of the content they teach. This is a daunting prospect for some primary education students who enter the course with little confidence in their mathematical ability and unhappy memories of their mathematics learning in school. Numeracy support is crucial if these students are to meet the professional standards and graduate into their chosen profession.

The first phase of the present study sought to identify priority areas of need for numeracy support amongst pre-service primary education students. In the second phase, a series of online numeracy support videos were developed using the SMART Notebook interactive whiteboard software (SMART Technologies, 2016). The online numeracy support videos were trialed with students during a number of focus group interviews and data were obtained as to their perceived effectiveness.

The primary aim of the research was to improve pre-service teachers' content knowledge in mathematics; although a secondary consideration was production of videos that modelled good pedagogical strategies. Analysis of the data obtained from the focus group interviews looked at the effect of the online numeracy support videos on students' mathematical content knowledge and their confidence in understanding the concepts, substance, and structure of the content they will have to teach. This research was seen as the first step in a longer process with the overall goal of producing a suite of research-informed numeracy support resources. The provision of high quality numeracy support has the potential to benefit the majority of students enrolled in primary mathematics education units on campus (currently more than 1,000 students) and, will be a practical means of providing support to online students in rural, remote, or overseas locations.

Literature Review

According to the Australian Mathematics Curriculum, "learning mathematics creates opportunities for and enriches the lives of all Australians... It develops the numeracy capabilities that all students need in their personal, work and civic life" (Australian Curriculum and Reporting Authority, 2016, p. 3). In contrast to the aspirational statements of the Australian Curriculum, there has been a growing perception that pre-service teachers are not being equipped with the skills to develop the required numeracy capabilities in their students. Media headlines such as "Teaching students failing numeracy, literacy exams" (Jean, 2015) and "Around 1 in 10 teaching students fail trial numeracy, literacy exam" (Doyle, 2015) have fuelled debate in Australia by placing the focus on the 10% who failed rather than the 90% who passed. However, disquiet has also been expressed by key stakeholders in education who raised significant

concerns about the level of content knowledge and pedagogical knowledge amongst mathematics teachers in Western Australia (Hackling, Murcia, West, & Anderson, 2014).

Hattie (2012) found that the influence of the teacher is one of the most significant factors in predicting student achievement and this was echoed in 2012 by Australia's Chief Scientist who suggested that "inspiring students to engage with mathematics and science can be best achieved by teachers who are passionate about the subject and have the knowledge and confidence to present the curriculum imaginatively" (Office of the Chief Scientist, 2012, p. 20). To this end, the Chief Scientist argued that the Professional Standards for Teachers should be applied *rigorously*. The Professional Standards for Teachers were devised by the Australian Institute for Teaching and School Leadership (AITSL) in 2011 and these standards include content knowledge and benchmarks for graduate teachers.

Australian tertiary institutions that prepare teachers will have their courses reviewed for their capacity to demonstrate that their graduates meet the AITSL standards. The Teacher Registration Board of Western Australia (TRBWA) sets the accreditation standards for initial teacher education programs in Western Australia. It is noted that

The Literacy and Numeracy Test for Initial Teacher Education Students (the test) is a single national instrument designed to demonstrate that graduates of Initial Teacher Education (ITE) programs have personal levels of literacy and numeracy within the top 30% of the population... It should be noted that the test is a *program accreditation* requirement, not a teacher *registration* requirement. (Teacher Registration Board of Western Australia, 2016)

Given that teacher education students in Australia often come from diverse educational backgrounds (Budgen, Main, Callcott, & Hamlett, 2014; Henderson & Noble, 2013; Larkin, Rowan, Garrick, & Beavis, 2016) it is imperative that strategies to support students to achieve the required standards are continuously developed. The push for higher teacher standards follows similar moves over the past decade in the UK and New Zealand. The requirement to demonstrate an appropriate level of subject knowledge has resulted in a number of publications specifically catering to pre-service teachers' need to secure their subject knowledge of mathematics. Haylock (2010) identified that mathematical misconceptions were prevalent amongst pre-service primary teachers in the UK and research in New Zealand (Linsell & Anakin, 2012) focused on defining the mathematical content knowledge pre-service teachers require. The ongoing challenge is to find ways to deliver the mathematical content knowledge required when the provision of numeracy support extends beyond what we can teach during class contact time.

The idea of providing mathematics support through online videos is not new. There is a profusion of these videos freely available on YouTube. Probably the most sophisticated use of this medium for mathematics instruction

is by the Khan Academy that has an extensive library of short mathematical content videos (Khan Academy, 2013). These resources are engaging but they are not necessarily appropriate for the pre-service teacher as they do not always model the content in a way that is pedagogically sound at primary school level. The significance of supporting pedagogical practice as well as mathematical content knowledge of pre-service teachers was highlighted in New South Wales where the chief of the Board of Studies for that State was reported as declaring that there was no margin for error in ensuring every primary teacher was confident about their mathematics content and confident about how to teach it (Loussikian, 2016).

The aim of the research reported in this paper was to produce short videos that would support students' content knowledge in mathematics whilst also modelling good pedagogical practice that could be transferred to the primary classroom. The pedagogical practice modelled in the videos involved the use of SMART Board technology which also assisted in preparing students for using the technology they will encounter in schools. Although this technology is widely available in schools, in many cases, teachers do not use it effectively (Glover, Miller, Averis, & Door, 2007). By using SMART Board technology to model good mathematical pedagogy, the intention was to also help to up-skill pre-service teachers in its effective use.

Methods

Initially permission was obtained from the Human Research Ethics Committee to examine the de-identified examination scripts of a one cohort of first-year Bachelor of Education (Primary) students. In total, data were gathered from the papers of 471 students. Specific mathematical content knowledge assessed in the examination included place value, fractions, decimals, percentages, factors and multiples, primes and composites, number sequences, measurement (including estimation, rounding and conversions) and geometry (including shape, location and transformations). Questions included multiple choice items and short answer questions. Students were not permitted to use calculators, notes or textbooks (including mathematical dictionaries) in the examination. A research assistant was employed to record and classify both the number and types of mathematical errors made by students. Correct responses, errors and apparent misconceptions were recorded using an Excel spreadsheet for both multiple choice and short answer items.

The data obtained were then used to inform the design and development of a number of online numeracy support videos entitled "Maths Minutes". Priority in the production of these videos was given to concepts that were found to be most challenging to the first-year students and were fundamental to the primary mathematics curriculum. The videos included three on the topic of mental computation strategies, three about fraction concepts, and individual videos focusing on concepts such as order of operations, factors, decimal place value, and multiplying and dividing by powers of ten. Each video was no more than three minutes in length, with the mean being around two minutes in duration.

In order to avoid confusion or information overload, care was taken to ensure that each video only addressed one concept.

Videos were created and recorded using SMART Notebook software (SMART Technologies, 2016), as a means of modelling the use of appropriate pedagogy while teaching mathematical content knowledge is being developed. SMART Notebook software was selected as SMART Board technology is widely available in schools and was available in selected venues at the authors' university. SMART Board technology also allows the user to create interactive and dynamic presentations that can be manipulated and recorded in real time.

A series of focus group interviews was conducted in a pilot study of the perceived effectiveness of the numeracy support videos. Four semi-structured interviews were conducted with approximately four students in each group. In order to elicit honest and valid feedback, the focus group interviews were moderated by an independent research assistant to ensure that students remained anonymous throughout the process. Initially students were asked to describe their own experiences of learning mathematics. Students were then shown two of the numeracy support videos and asked to respond to each. Students were asked to suggest ways in which the numeracy support resources could be further developed and/or refined.

Data Analysis

The initial phase of the project sought to identify the frequencies and types of mathematical errors made by first-year primary education students. Multiple choice item response data were recorded and analysed for all 471 students. Items received between 467 and 470 valid responses, with items that received multiple or no responses deemed invalid and excluded from subsequent analysis. Items were then ranked according to the proportion of the cohort that answered each item successfully. The short answer responses provided useful insight into students' thinking in relation to specific content areas, and revealed the need for additional numeracy support around fractions and mental calculation strategies in particular. Where possible, the predominant errors made by students were identified and classified by type, and illustrative examples provided for each category.

In the second phase of the project, student feedback was sought on the perceived efficacy of two sample online numeracy support videos through a series of focus group interviews. The focus group interviews were transcribed and the students' responses categorized using an interpretative approach (Gall, Gall, & Borg, 2006). In particular, students were asked to reflect on their experiences as a learner of mathematics, the perceived effectiveness of using video as a means of explaining mathematical concepts and providing numeracy support, and the potential application of numeracy support videos in the primary classroom.

Results

Phase One (Identification of Numeracy Support Needs)

Analysis of the item response data for the multiple choice questions provided information about specific aspects of students’ mathematical content knowledge. The percentage of correct responses for each of the items varied between 54% and 98%. Multiple choice items with the highest error rates are shown in Table 1. While students were not required to show how they had arrived at the answer to these questions, the distracter items often provided insights to students’ methods. For example, in the question, "What is $\frac{1}{6} + \frac{1}{6}$?", 21% of students gave the answer $\frac{2}{12}$, a response that suggests the student probably added both numerators and both denominators.

Table 1. Multiple Choice Items with the Highest Error Rates (n=471)

Item	Error rate %
Apply order of operations	46
Compare lengths measured in kilometres, metres, centimetres and millimetres	44
Identify the number of lines of symmetry of a rectangle	37
Identify the prime factors of a number	36
Calculate a percentage of an amount	33
Convert a ratio to a fraction	33
Continue a number pattern	32

Further insight into students’ understanding of fraction concepts was revealed in their responses to a short answer question which required a step-by-step explanation of the process of adding two fractions with unrelated denominators. The steps involved in the calculation were: (1) determining a common denominator, (2) finding equivalent fractions with a common denominator, (3) adding the numerators to obtain an improper fraction, and (4) converting the result to a mixed number. 43% of students were unable to provide a complete explanation of the process (including the correct answer in simplified form).

The predominant misconception, held by 14% of students, was that the sum of two fractions may be found by adding the two numerators and adding the two denominators. An example is shown in Figure 1.

Figure 1. Incorrectly Adding both Numerators and Denominators

Handwritten student work for the problem $\frac{2}{3} + \frac{5}{8}$. The student incorrectly adds numerators and denominators: $2+5=7$ and $3+8=11$, resulting in $\frac{7}{11}$. Annotations include "to find a common denominator" and "to add the numerators".

A similar proportion of students (21%) demonstrated the same misunderstanding in the multiple choice questions. Other errors that were observed included: making a fraction by adding the numerators to the opposite denominators (see Figure 2); dividing the numerator and the opposite denominator by a common factor (see Figure 3); and inverting one fraction and multiplying rather than adding (see Figure 4). In the latter case it is inferred that the student has incorrectly generalised the procedure for division of fractions to addition.

Figure 2. *Incorrectly Adding the Numerator and Opposite Denominator*

$$\frac{2}{3} + \frac{5}{8} = \frac{(3+5)}{8} + \frac{(2+8)}{3} = \frac{10}{15}$$

Figure 3. *Incorrectly Dividing Numerator and Opposite Denominator by a Common Factor*

$$= \frac{2}{3} + \frac{5}{8} \quad \text{start by cancelling out any common multiples.}$$

$$= \frac{1}{3} + \frac{5}{4}$$

Figure 4. *Incorrectly Inverting and Multiplying*

$$\frac{2}{3} + \frac{5}{8} = \frac{2}{3} \times \frac{8}{5} = \frac{16}{15}$$

$$= 1 \frac{1}{15}$$

Misconceptions about operations with fractions also extended to multiplication. Students were required to draw a diagram to illustrate the calculation $\frac{1}{3} \times \frac{1}{4}$ and provide the answer. Although 36% of students calculated the answer correctly, many of them provided diagrams that were unhelpful in explaining the concept of the question as shown in Figure 5. Of particular concern was that 77% of students were unable to answer the question correctly and produce a diagram that accurately illustrated the process.

Figure 5. Correct Answer with Unhelpful Diagram

$$\frac{1}{3} + \frac{1}{4} = \frac{1}{12}$$

$$\begin{array}{r} 1 \times 1 = 1 \\ 3 \times 4 = 12 \end{array}$$

This item also revealed a number of predominant alternative conceptions, the most common being to change the fractions to have common denominators, and then multiplying the numerators, keeping the denominators constant (see Figure 6).

Figure 6. Creating a Common Denominator, and Then Multiplying the Numerators

$$\frac{1}{3} \times \frac{1}{4} = \frac{4}{12} \times \frac{3}{12} = \frac{12}{12} = 1$$

Other students cross multiplied (see Figure 7); converted the fractions to have common denominators and then added the numerators (see Figure 8); added the numerators and added the denominators (see Figure 9); and some students appeared to realize that their strategy was incorrect but did not know how to proceed (see Figure 10).

Figure 7. Cross Multiplying

$$\frac{1}{3} \times \frac{1}{4} = \frac{3}{4}$$

Figure 8. Converting to Have Common Denominators Then Adding the Numerators

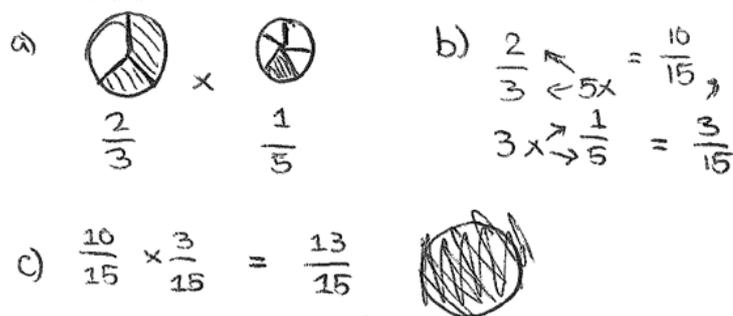


Figure 9. Adding the Numerators and Adding the Denominators

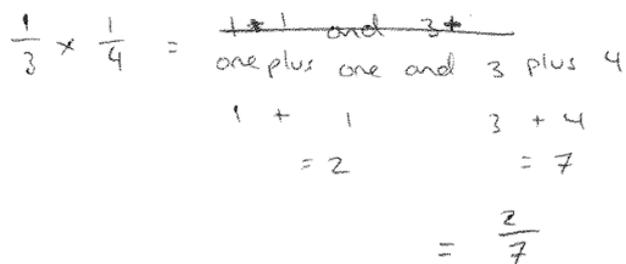
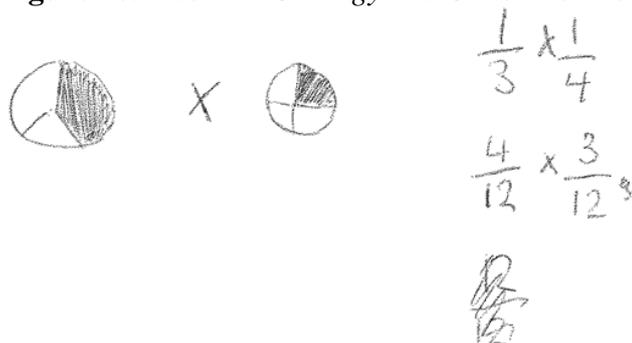


Figure 10. Incorrect Strategy and Unable to Proceed



Difficulties with fractions was not the only problem area for students, as revealed by the short answer questions. Items with the highest error rates are show in Table 2.

Table 2. Short Answer Items with the Highest Error Rates

Item	Error rate %
Describe three different mental computation strategies	71
Estimate a square root	69
Multiply two fractions	64
Continue a number pattern	47
Use of the distributive property	46
Add two fractions with unlike denominators	43
Compare rational numbers	43

The combined data from the multiple choice and short-answer questions revealed concepts that were not well-understood by first year students. The data provide insights into incomplete understandings and misconceptions that would limit the ability of some students to progress in their pre-service teacher training. The data also reveal that, for many students, the explanation of how to carry out the computation was the most challenging aspect of the task.

Phase Two (Pilot Study of Numeracy Support Videos)

A series of nine numeracy support videos entitled "Maths Minutes" was developed in response to the concepts that were identified as most challenging for first year students in the initial phase of this study. Given the significance of developing fraction concepts in the primary curriculum, it was decided to spotlight two of the fraction videos during the focus group interviews. Students were initially asked to reflect on their own experiences of learning mathematics then, after viewing the videos, to consider the perceived effectiveness of the videos as a means of explaining the concept, the value of the video as a means of student support, and potential for use in the primary classroom.

The results of the focus group interviews revealed considerable variation in students' own experiences of mathematics at school. Some students described their experience as varied and fun, as the following comment illustrates:

"[My year four teacher] made it fun. She always made it into games. Most of our maths stuff was made into games and we did a lot of hands-on stuff as well. She would use toys and that to - we would do a maths activity but we would do a lot of our sums using toys, and then we would have a small activity worksheet. So it wasn't all sitting at a desk and just writing what you're writing."

Other students agreed that hands-on learning can provide enjoyable and memorable kinaesthetic learning experiences:

"I remember the cardboard counters. I thought they were - whatever it was about them, they were a lot of fun, especially with multiplication, because I can still remember learning multiplication using the counters and then from there we went up to the times tables in year three, and we got drilled as well."

In contrast, many students' strongest recollections of mathematics lessons were of rote learning and a lack of teacher support. One student described their experience as particularly teacher-centred:

"...it [Mathematics] was bad. It was pretty teacher-centred when I grew up, so I don't get much to do – there's not really activities or anything going on. It was just about practice and practice".

This repetitive aspect resonated with a number of other students, as the following comment reveals:

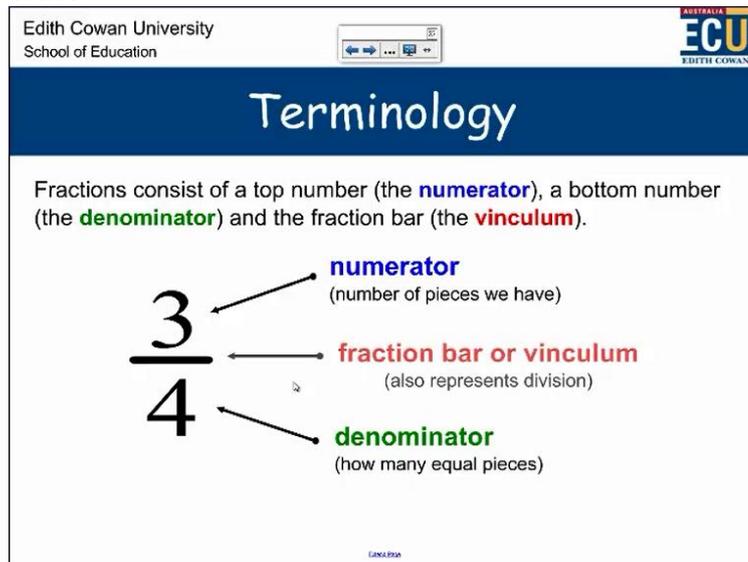
"A lot of repetitive drills ... Just lots and lots of practicing, going through algorithms, doing sums and sums and sums."

Another student described their teacher as reluctant to help, which compromised the effectiveness of the learning environment:

"If you didn't understand it the teacher wasn't really willing to help you, because she had too many kids in the class. It was more like figure it out in your own time. I ended up doing those Excel books at home."

Figure 11 shows a screenshot from the online numeracy support video that introduces the "Fraction Concept". This video is approximately 2.5 minutes in length. In the video, animation and highlighting has been used to draw students' attention to specific parts of the screen at various times. The video introduces the fraction symbol, mixed numbers and improper fractions, and equivalent fractions.

Figure 11. Screenshot from the Fraction Concept Online Numeracy Support Video



After watching the video, students were asked to comment on the usefulness of the resource. Students felt that the use of video allowed the concept to be illustrated in a very visual manner, as the following interaction suggests. Students also commented on the use of language.

Student 1: I've never seen the improper fraction shown as parts before.

Student 2: Yeah, it's just the number.

Facilitator: So did you think that those parts were helpful?

Student 1: Yes.

Student 2: It's a lot more helpful. It helps you visualize what the improper fraction actually is. I remember we were given one, it was a really big one, and I just didn't know how to split it because I couldn't visualise it.

Facilitator: Okay, cool. Do you think the language was okay?

Student 1: Yeah, simple.

Student 2: It was clear, concise.

Student 3: I reckon a Year 5 child would understand that.

Facilitator: That's going to be my next thing. Do you see that this would be a helpful resource for you during your study?

[Unanimous agreement]

In addition to their potential as a resource for their personal study, it appears that students would also consider online numeracy support resources as a teaching resource. Students from another focus group interview commented:

Student 1: It's concise, it's purposeful, it's got the vocabulary in it and the terminology that I don't necessarily have off the top of my head. Yeah, perfect.

Student 2: The same for me.

Facilitator: So would you use them to assist your teaching?

Student 2: Absolutely.

Student 1: Yeah.

Student 2: I would probably be modelling that very closely because I'm about to do fractions in my year two class... but absolutely. I will be going back to these.

Facilitator: Is it something that you could imagine even showing students yourselves?

Student 1: Yes.

Student 2: Definitely.

Students also commented that the length of the sample videos were "about right", although in some cases requested that the speed of the accompanying narration be reduced. Students unanimously agreed that each video should be restricted to a single topic. All of the students agreed that online video was an effective means of providing numeracy support, citing reasons such as continued availability, ease of access, the ability to watch the video several times and the combination of both audio and visual stimuli. Nevertheless, students felt strongly that video should not be the sole avenue of providing support.

Facilitator: Now that you've watched a couple of videos, what do you think about having online support with videos like this?

Student 1: I'd like it, but I wouldn't solely rely on it. I still do like the face-to-face, like asking a question and getting an answer... If you have a very

specific question that the video doesn't answer, I wouldn't rely just on the online help. I'd like to be able to go somewhere and talk to someone.

Student 2: Yeah, I like the videos but personally for me for example, I did my Diploma of Children's Services off campus, and I was given online resources and booklets to fill out. I still found that I needed the face-to-face contact because the video still wouldn't explain things that I didn't know.

Discussion

The present study sought to identify areas of need for numeracy support amongst first-year primary education students. The analysis of 471 examination scripts revealed a clear need for additional numeracy support in a number of specific areas including, but not limited to, mental computation strategies and fractions. This aligns with the results of recent research, that has raised concerns about the level of content and pedagogical knowledge amongst mathematics teachers in Western Australia (Hackling, Murcia, West, & Anderson, 2014).

The results of the analysis also reveal that, for many students, explaining mathematical procedures or drawing a diagram to illustrate how to carry out the computation were the most challenging aspects of the task. Since the teacher is among the most significant predictors of student learning (Hattie, 2012), it is vital that teachers have the ability to explain and illustrate mathematical concepts. In 2012, Australia's Chief Scientist argued that teachers should have the "knowledge and confidence to present the curriculum imaginatively" (Office of the Chief Scientist, 2012, p. 20).

Here it is argued that technology should be used as a supplement to effective teaching and not as its replacement. As Salman Khan argues, it is somewhat ironic that technology can be used as a means by which we can "humanise" the classroom (Khan Academy, 2013). The online numeracy support videos described here were created entirely by the members of the university's mathematics education team, who between them have considerable teaching experience at primary, secondary and tertiary levels. Other than a modest skill level developed in the course of their teaching, it should be acknowledged that none of the team members have received any formal training in the use of interactive whiteboards, instructional design, or video editing software. Furthermore, the online numeracy resources were developed without the aid of funding or specialist equipment (other than the SMART Board itself). Future research will look at ways in which the perceived and actual effectiveness of numeracy support resources can be improved by partnering with professionals with specialist expertise in these areas.

Developing resources that focus on well-documented areas of difficulty allows support to be targeted in ways that makes efficient use of limited instructional time and resources. Students who are absent from class, or those who are reluctant to ask questions in a face-to-face situation, can still access

support online. Making resources available online ensures that they can be accessed across a range of devices and in a range of locations (including regional and remote settings). In cases where bandwidth is insufficient for videos to be streamed "live" then they can be downloaded for use at a later time.

The focus group interviews revealed that students responded favorably to the online numeracy support videos. The majority of students commented that they would use these resources to develop their own mathematical content knowledge and skills. Students also stated that the videos could be used as a model on which to base their own teaching of specific mathematical concepts. A few students suggested that they could modify and adapt the resources as appropriate in different teaching contexts. We propose then that numeracy support videos can be used on at least three levels, as a means of: (1) teaching/learning particular mathematical concepts, (2) teaching/learning traditional mathematical pedagogies, and (3) contributing to the development of new mathematical pedagogies.

Conclusion

Over the course of this study it has become apparent that "emerging" technologies such as the iPad have the potential to complement and perhaps, ultimately, supersede interactive whiteboards in many educational settings. Initially the proliferation of mobile computers was met with concerns that these devices lacked the capability or flexibility to be used effectively in a classroom environment. Increasingly teachers and students have access to tools that allow them to create and not simply consume digital content that can greatly enhance the teaching and learning experience.

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