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Adapting an online learning system for school mathematics to mathematics teacher education

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ABSTRACT: Recent Australian Institute of Teaching and School Leadership (AITSL) standards for primary mathematics teacher education highlight the significance of mathematical content knowledge for graduating teachers. Online learning systems have become popular for school mathematics in recent years. As the development and maintenance of such systems requires more resources than a teacher education faculty is likely to have available, this study identifies ways of adapting a commercial resource intended for schools to one that is appropriate for teacher education. The study reported is based on the experiences of the authors in building Cambridge *HOTmaths* into the design of two early undergraduate units for pre-service primary mathematics teachers at Murdoch University over 2011 and 2012. Students are provided with a licence for personal use of the online learning system, and a small mark was allocated to reflect individual student's engagement with the online materials, partly to recognise the significant learning of mathematics involved, but also to provide an inducement to use it. The software is used periodically in plenary lectures and in workshops, according to individual teacher preferences and practices; specific advice for *HOTmaths* use is provided in weekly learning guides accessed online by all students. Differences between school use and teacher education use are described in the paper. Data on the extent to which students have made use of *HOTmaths* are presented, together with student feedback regarding the value of the online experience. Different approaches taken by teaching staff to the use of *HOTmaths* are also reported. Together, the evidence suggests that there is considerable merit in adapting this resource for use in primary mathematics teacher education.

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Introduction

This paper describes an innovative use within teacher education of a commercial online learning system, *HOTmaths* (Cambridge University Press, 2011), which is principally designed for use in Australian schools and provides some preliminary data on the effects of the innovation.

Mathematics teacher educators generally recognise the importance of mathematical content knowledge in pre-service teachers. For example, summarising research in the field, Forrester and Chinnappan (2011) noted, "Teacher's mathematics content knowledge affects the quality and nature of their teaching … and has been found to positively predict student achievement … There is little disagreement that teachers need to acquire and understand mathematics in order to teach it effectively". (p. 261)

Despite consensus on its importance, mathematical content knowledge is regularly regarded as problematic, however. Both empirical research and informal discussion amongst mathematics teacher educators frequently suggest that pre-service primary students are under-prepared in mathematical understanding, beliefs and confidence to become teachers. Consequently, anxiety, fear and even loathing of mathematics are not uncommon phenomena amongst entrants to primary teacher education. Such negative views are not unique to Australia, as a UK researcher working in the USA observed: "People don't like maths because of the way it is mis-represented in school. The maths that millions of school children experience is an impoverished version of the subject that bears little resemblance to the mathematics of life or work, or even the mathematics in which mathematicians engage". (Boaler, 2009, 16-17).

While such deep problems can hardly be expected to be resolved with a single initiative in a single unit, a number of features of *HOTmaths* suggested that there might be benefits associated with its use in teacher education. These included the likelihood of providing students with an experience different from their previous experiences with mathematics, the possibility of students exercising more personal choices then typically possible to suit their particular needs and interests, the capacity for catering for a very wide spread of students' backgrounds and dispositions, the focus in the software on understanding mathematical concepts rather than simply procedural knowledge and the potential for 'anytime, anywhere' learning associated with online learning systems in a technological age. In this paper, we describe how this initiative was undertaken, and provide some initial appraisal, mostly positive, of its effects to date.

Review of the Literature

As Callingham et al (2011) noted, concern for primary pre-service teachers' knowledge of mathematics has a long history (and has been well documented) (Tobias & Itter, 2007; Senate

Standing Committee on Workplace Relations and Education, 2007). Primary teacher education programs in Australia typically devote attention to the development of mathematical knowledge, rather than assuming that aspiring teachers have already developed adequate expertise on entry to a course; the CEMENT project has accordingly focused attention on various forms of teacher knowledge, and in particular, Mathematical Content Knowledge (Callingham et al, 2011). The significance of content knowledge has been underlined further by the recent Australian Institute of Teaching and School Leadership standards for accreditation of teacher education courses (AITSL, 2011b), which follow directly from the AITSL *National Professional Standards for Teachers* (2011a), both of which explicitly acknowledge the importance of teachers understanding the content they will be teach. In addition, and although it is not the main focus of this paper, it is important to note that the AITSL teacher standards also refer to the use of ICT for teaching and learning, so that pre-service teacher use of *HOTmaths* might be expected to provide some support for the achievement of this standard.

While Shulman's seminal work (1987) has had a major impact on teacher education through introducing the concept of Pedagogical Content Knowledge (PCK), it is important to recognise that he also recognised the critical role of other forms of knowledge for teachers, upon which PCK might build; in particular, he highlighted the key role of the knowledge of subject-matter. Hill, Ball and Schilling (2008) have built on Shulman's work to further refine the dimensions of teacher knowledge to teach mathematics. Those dimensions include mathematical knowledge required across a range of occupations (Common Content Knowledge) but also particular mathematics knowledge that would enable teachers to represent, explain and understand unusual problem solving strategies (Specialised Content Knowledge), in addition to various aspects of pedagogical content knowledge.

While some have suggested that problems with teacher background knowledge can be addressed by tightening entry standards, the evidence suggests otherwise. For example, Tobias and Itter (2007) concluded that it was unwise to presume that pre-service teachers who have completed Year 12 studies in mathematics will know mathematics sufficiently well to enable them to teach primary school mathematics meaningfully. Similarly, Cooney (1999, p.165) suggested, "often pre-service teachers have a poor understanding of school mathematics [because they] last studied it as teenagers with all the immaturity that implies". The preparation strategies for final external examinations often involve a focus on procedural knowledge rather than on the deep connected conceptual knowledge that is required of teachers, suggesting caution in placing too much reliance on pre-service teachers having met entry qualifications. In this regard, Tobias and Itter (2007) suggested, "[p]erhaps, these students have a performance view instilled in their prior learning experiences, where a 'learn and forget' attitude prevailed due to a lack of emphasis on understanding during the middle years of schooling" (p. 14). For many pre-service teachers, procedural knowledge continues to be valued over conceptual knowledge and dominates their mathematical thinking. (Lange & Meaney, 2011; Forrester & Chinnappan, 2011).

Mathematics teacher educators have recently explored the use of the Internet and ICT as part of a repertoire of resources to develop mathematical content knowledge. Published studies investigating the use of the Internet for this purpose are scarce at present. Two recent examples are of interest. Lin (2010) demonstrated the effectiveness of Internet-based resources in helping pre-service teachers to understand fractions in a supported laboratory environment. In contrast, Lange and Meaney (2011) found that many students saw Internet resources as having limited value for their own mathematics learning and so did not make much use of the rich collection that was provided for them on a CD-ROM. There appear to be few, if any, empirical studies involving the use of an online learning system such as *HOTmaths* for pre-service teacher education, however. Cavanagh and Mitchelmore (2011) reported an Australian study on ways in which some secondary teachers made use of *HOTmaths* in a school environment, focussing on the role of the teacher, but the present study shifts the responsibility to use the software effectively from teachers to students, and focuses on learning outside the classroom.

HOTmaths for schools

Cambridge *HOTmaths* (Cambridge University Press, 2011) is a commercial online mathematics. learning system used in many primary and secondary schools in Australia. Schools purchase an annual subscription for their students. Teachers generally manage the subscription, direct student use of the software and can access extensive records of individual student and class progress. *HOTmaths* comprises online student materials grouped into various courses (such as those for Middle Secondary students, those for a particular Year of the Australian Curriculum: Mathematics or those for a particular textbook). Courses are further divided into Topics, which in turn comprise individual Lessons. Each Lesson includes a variety of materials including illustrated notes and a suitable combination of Resources, Walkthroughs, Questions, Scorcher and Games, as described briefly in the following paragraphs.

Resources include *Widgets*, which are interactive digital objects often used by a teacher for demonstration of a particular concept or skill, and *HOTsheets*, which provide targeted exercises and activities for students that can be printed and for which answers are also available. *Walkthroughs* consist of a set of questions that 'walk students through' a particular mathematical procedure (such as finding one number as a percentage of another); students are intended to use these to rehearse procedures and obtain immediate feedback.

Questions are at several levels, ranging from Level 1 (which mostly repeat the information provided in the notes) to Challenge Level (which requires students to engage in problem solving related to the material). (Cambridge University Press, 2011). Students are also able to take a *Quiz*, which includes a selection of questions from each of the Lessons in a Topic. *Scorchers* provide students with an opportunity to respond to mathematical questions quickly, and to compare their scores and performances with their previous scores or with others. Students (or their teachers) can turn off the timer for Scorchers and focus only on the mastery of particular mathematical skills.

There is also a substantial online *dictionary* of mathematical terms with mechanisms for searching for material related to a particular aspect of mathematics within *HOTmaths*. Finally, *Games* are interactive experiences with game-like elements, intended to be used by a single person and which focus on particular mathematical concepts or skills.

Students using *HOTmaths* are assigned to a particular class, under a particular teacher, who is able to obtain information on which aspects of the system students have used, and with what levels of success. Teachers can also set and manage tasks for individual students or classes, and generate suitable tests of student progress, as well as communicating directly with students regarding their work in the system.

HOTmaths adapted for teacher education use

Prior to 2011, students in a large first year mathematics unit within the School of Education at Murdoch University were encouraged to use *HOTmaths* for their personal study, and were provided with an opportunity to do so. However, few students took the opportunity provided, presumably since it was regarded as an optional activity, rather than being incorporated into the design of the unit. To explore further the potential of the software for student teacher use, the authors chose to include the use of the software as an integral component of two first year units, beginning in 2011.

For the two units concerned, *EDN110 Mathematics for Teaching*, and *EDN114 Thinking Mathematically*, *HOTmaths* was included in the unit design in similar ways. The first of these units, EDN110, was an elective unit designed for students who felt that their backgrounds in school mathematics were weak, with many students advised (although not required) to undertake the unit following an optional diagnostic test available at enrolment. The second unit, EDN114, is a mandatory unit for all students undertaking teacher education courses leading to a Murdoch University qualification as a primary teacher (including a joint qualification as a primary and early childhood teacher). Each unit has a principal aim of strengthening students' Mathematical Content Knowledge, prior to later studies in a student more directly focused on teaching mathematics in the primary school (and thus with a more overt focus on Pedagogical Content Knowledge). In each unit, the Australian Curriculum: Mathematics (Australian Curriculum, Assessment and Reporting Authority, 2012) is used as the principal lens to decide which Mathematical Content Knowledge is of prime importance, which of course leads to a good match with *HOTmaths*, which is increasingly based on a similar principle.

In each unit, all enrolled students were provided with a personal licence to use the software freely over the course of the semester, and were given regular advice on which aspects of mathematics might benefit from such use. On a weekly basis, particular *HOTmaths* topics related to the week's agenda were recommended for students to use in whatever way they found to be helpful. In addition, space was allocated specifically to *HOTmaths* in the online discussion list, so that students and staff could discuss issues related to the use of the software in the unit.

By its nature, most university learning is more independently conducted than learning in schools. In the case of these two units, although there was a weekly agenda for learning, not all material is covered in classes, partly because there are fewer classes than is typically the case in a school. In addition, with a wide range of students, it is inevitable that some student teachers will already have attained adequate standards for particular mathematical topics, while others will need more attention to them. (This is particularly so for the mandatory unit, EDN114, as some students entering the university with substantial school mathematics backgrounds are nonetheless obliged to complete the unit.) In contrast, in schools, the teacher generally controls more directly the agenda of the learning for each student each week.

In the light of the previous experience, for which the resulting use of *HOTmaths* was patchy when it was regarded as optional, engagement with *HOTmaths* was formally expected of students in each of these two units in 2011 and in 2012. The mechanism for doing so was to allocate a mark for the unit that reflected engagement with *HOTmaths* over the course of the semester. In each case, 10% of the unit assessment for each student resulted from a tutor's rating of their engagement with the software. Although this was described as 'engagement', in fact, students needed to engage successfully to some extent in order to be recognised as engaged, since a major criterion involved successful completion of some of the lesson questions at various levels.

Tutors allocated a mark to each student individually, after briefly examining their recorded achievements (in the form of levels of questions completed) and the amount of time they spent using the software, which was routinely available online. Further information about engagement included the extent to which they had accessed *Walkthroughs* and *Topic Quizzes*, although it was slightly more difficult to obtain information about these. Data about use of *Widgets* and *HOTsheets* was not readily accessible, but was assumed to be captured by the data showing time on task. In general, tutors gave students a higher mark for more extensive engagement, for more time spent on the site and for a spread of engagement with different lessons, topics and courses.

Having embarked on adapting *HOTmaths* which is primarily designed for school mathematics to mathematics teacher education, three aspects of the adaptation warranted some research: first, the staff approaches to using *HOTmaths* (if any) in their contact with students; second, the extent to which students made use of *HOTmaths*; and third, students' opinions regarding the use of *HOTmaths* as part of the unit of study.

Sources of data and methods of analysis

The data for the first aspect about staff approaches to using *HOTmaths* were collected through tutors' report of their use, if any, of *HOTmaths* and the manner in which it was incorporated into their contact with students. Given that the data set was small and that the reports were anecdotal in nature, the analytical approach taken was to identify noteworthy features of the staff approaches.

For the second aspect about the extent of students' access, the authors requested and obtained an extraction of the data from the commercial vendor. The raw data were then filtered through to get a cohort of EDN110 students from Semester One (S1) of 2012. Of the 159 who were enrolled for that semester, reliable data for use was available only for 137 students. Based on the observation that roughly similar distributions were noted for the other two semesters, a quantitative analysis of the amount of time each student from this one semester spent at the website was undertaken and assumed to be illustrative. In addition, limited and indirect evidence of student engagement with *HOTmaths* was available from a discussion list in the online Learning Management System for the unit.

For the third aspect regarding students' comments on the use of *HOTmaths*, data were extracted from student surveys conducted online by the University's Research and Evaluation Services over three semesters. Each of the surveys had 18 Likert items pertaining to various aspects of the unit and four written response items. In due consideration of an assortment of standard survey items and time constraints, and the fact that student participation was voluntary, the authors included only one written response item directly related to *HOTmaths*. The surveys were conducted in consecutive semesters starting in S1 of 2011, then S2, and ending in S1 of 2012.

The main set of data was extracted from students' written responses to the above items. They were taken as descriptive data where students were describing their personal views or experiences with using *HOTmaths*. The analysis of descriptive data involved data reduction in the form of coding by way of classification and use of key words (Keeves & Sowden, 1997). The responses were classified as clearly positive, somewhat positive, somewhat negative or clearly negative. Noteworthy key words identified were understand/understanding, learn/learning and assessment-related words.

Results

1. Staff approaches to using *HOTmaths*

Teaching staff used *HOTmaths* in a variety of ways. Lecturers used it occasionally, drawing on the *widgets* to demonstrate some mathematical concepts. The *widgets* and *walkthroughs* were used intermittently by tutors in their workshops. Another common feature tutors drew on was the *HOTsheets* to provide some practice or exploration to complement workshop activities. Some tutors made a provision for students to ask *HOTmaths*-related questions. They reported that the few questions students asked were related to procedures or clarification of the procedures provided by *HOTmaths*.

The staff found the assessment aspect of students' use of *HOTmaths* problematic. It was technically complicated and time-consuming to extract all the relevant information about students' time online, the various parts of the site accessed and the range of topics they visited, as well as the level of questions and challenges they completed. Based on practical considerations, the marks were assigned on the basis of students' time online and a quick glance at the records of the questions and quizzes they did.

2. The extent to which students make use of *HOTmaths*

Of the 137 students in the Semester 1 cohort of 2012, 12 students did not access *HOTmaths* at all in the semester despite it carrying 10% of the overall grade. For the 125 who did access it, the time spent ranged from 5 minutes to 62 hours, with a mean of nearly 8.5 hours. Figure 1 shows each of the 125 students represented by a circle icon illustrating the distribution of the total times spent over the whole semester. A box-and-whisker plot is superimposed to indicate the first quartile, the median and the third quartile at 1.8, 5.8 and 11.3 hours respectively. The plot also shows the outliers of students spending 26 hours or more.

Figure 1 about here

The first quartile of students spent between 5 minutes and nearly two hours. In particular, nearly half of this quartile group spent 30 minutes or less for the whole semester. We believe that for this group, particularly those in the lower half, *HOTmaths* did not make any significant impact.

Half the total number of students spent between 2 and 11 hours; with the second quartile between 2 and nearly 6 hours and the third quartile between 6 and 11 hours. The fourth quartile has the broadest range from 11.3 hours to 62 hours. The high usage suggests that these students must have found *HOTmaths* helpful. This seems especially likely for the outlier cases of 9 students who spent 26 hours or more, averaging at least 2 hours per week for the semester.

In summary, for the cohort of 137 students, about 9% did not access *HOTmaths* at all. Of the 125 who did access the site, about 10% did so only very briefly, for 30 minutes or less, while the next 15% spent between half an hour and 2 hours. The middle 50% of the students spent between 2 and 11 hours, with the median of about 6 hours. The next 18% spent between 11 and 22 hours and the most frequent users make up the remaining 7%, spending between 26 and 62 hours.

As noted earlier, separate areas related to *HOTmaths* were set up on the discussion list used by students on the general Learning Management System for each unit. These also provide an indication of the extent to which students have been involved with *HOTMaths*. Detailed analysis of these has not been undertaken, but a sense of scale is available from counting the numbers of items involved. Thus, for example, in the mandatory EDN114 unit in Semester 2 of 2011, 96 of the 1299 items on the online list were concerned with *HOTmaths*; the corresponding figures for the elective unit EDN110 in Semester 1, 2012 were 73 *HOTmaths* discussion postings out of a total of 505. While some of the postings were procedural, concerned with the mechanics of accessing the site, and others with questions regarding what was necessary or appropriate to do, many of the postings engaged students in public discussions about mathematical concepts that had arisen as a result of their use of *HOTmaths*.

3. Students' views about the use of *HOTmaths* as part of their Unit of study

Table 1 provides information about student enrolment for each of the three semesters, the numbers who responded to the overall survey as well as the numbers who responded to the particular *HOTmaths* item.

Table 1 about here

For the first survey, out of 156 enrolled students, 51 or nearly a third of them responded to the *HOTmaths* item. It was noted that while the item was about the lecturer's use of *HOTmaths*, many of the responses were more about the use of *HOTmaths* in general. In any case, the main focus was on students' feedback related to the experience of *HOTmaths* use. Responses were classified accordingly: out of the 51 responses, 45 were classified as clearly positive with statements like "Yes the exercises on *HOTmaths* he showed us were great visual aids and helped with particular topics", "Yes, I found Barry's use of the website *HOTmaths* assisted me in my understanding and learning at hand" and "*HOTmaths* was brilliant...thoroughly enjoyed any work we did with *HOTmaths*." Five of the responses with adverbs like "sometimes", "at times" or "a little bit" were classified as somewhat positive. The single negative response was from a student who wrote "I had a lot of trouble with *HOTmaths*. I found that if I needed help I would go to the textbook."

The second survey related to a mandatory unit, required of all primary pre-service teachers. Of the 277 students, 92 or nearly a third of them responded to the item asking for a description of the extent to which *HOTmaths* had contributed to their learning. There were 78 clearly positive, 9 somewhat positive, 1 somewhat negative, and 4 clearly negative responses. Many of the clearly positive responses cited *HOTmaths* as a useful resource: "This has been a valuable tool for me. Being able to go at my own pace and reiterate my understanding of a topic. The widgets and walk throughs are a great way of understanding a subject"; "*HOTmaths* has been really good, it's helped me practice maths that I have learned and assisted me in understanding things that I did not totally grasp in lectures/tutes." The negative responses either said it was 'annoying', 'repetitive' or 'not useful'. One student wrote about her preference for another software: "I did not engage much with this site since I did not find it as engaging as another site I like to use, *Maths Online*."

For the third survey, 53 students responded to the *HOTmaths* item, again about a third of the total enrolment. The item was similar to that in the second survey, asking students the extent (if any) to which they found *HOTmaths* to be helpful. Responses were coded in the same way as previously. There were 43 clearly positive, 1 somewhat positive, 2 somewhat negative and 7 clearly negative responses. The negative responses had words like 'not relevant' and 'confusing'; one student wrote "It was really quite a useless program. I did not find *HOTmaths* useful or easy to understand. If anything it confused me further and I was upset by the fact that not using it affected my grade in the unit." This contrasts sharply with many of the positive responses. For instance, one student wrote "*HOTmaths* was extremely helpful, a great site that is easy to use. I will definitely be using it close to exam time to revise everything we have learnt and do some practice questions.", while another wrote "It was fun. I enjoyed answering the questions and revisiting mathematical concepts I learnt in high school and still use now. Visually stimulating experience while learning at the same time".

Overall for the three surveys, the response rate to the *HOTmaths* survey item was about 33%. Table 2 summarises the number of responses coded into each of the four categories, showing a large majority of clearly positive opinions about the use of *HOTmaths*.

Table 2 about here

Besides coding the responses in terms of the four categories, the use of keywords was also employed as an additional way to get another sense of what the students wrote. The 196 students wrote a total of about 5100 words, averaging about 26 words per student. The length varied from a single word to 108 words. Keywords are gleaned from a list of frequently used words, not including common articles like 'the' and prepositions like 'of'. To give an overall impression, Figure 2 shows a word cloud generated in *Wordle* (Feinberg, 2011) from all the words the students wrote, with the relative sizes reflecting the frequencies of occurrence.

Figure 2 about here

Of particular interest are the frequencies of occurrence of some major keywords in student comments, which are summarised in Table 3. The table also includes a column for the number of students who used the corresponding keyword and an example of how that keyword was used.

Table 3 about here

The high frequencies of these keywords suggest that many students thought of *HOTmaths* in terms of whether or not it was useful or helpful. In nearly all occurrences, these words were used in a positive sense. A similar tone was also noted in the use of the other keywords, further suggesting that many students found *HOTmaths* to be useful in their learning and that it helped them significantly in their understanding of mathematics content.

One of the concerns the authors had was the allocation of 10% of the overall marks as an inducement for students to use the software. Responses that were related to the keywords 'assessment', 'grade' or 'marks' were singled out; there were 16 such responses. For many of them the allocation of marks was regarded positively. For example, one student wrote: "It was amazing! I hated the fact that we had to do it and complained endlessly, but in my attempt to get good marks for it, I learnt a great deal and covered most of the areas I was lacking in. It should be used as it forces you to learn and makes it easier to gain an understanding of a wide range of topics." A few others felt that more marks should be allocated because of the amount of time they spent on it, but one suggested that assigning a mark was 'silly' and should not be done. Based on such student feedback, there is some support for the allocation of marks as an inducement for them to use the software.

In summary, the staff incorporated some use of *HOTmaths* into their lectures and workshops. They found it difficult to assign marks to students' use, because of technical and time constraints. For students, the availability of *HOTmaths* did not make any significant difference to about a quarter of the cohort of students surveyed. On the other hand, for the remaining three quarters, their time spent was sufficient to imply *HOTmaths* was useful in some ways. In particular, about a quarter spent enough time to suggest they tapped into it as a learning resource regularly. In terms of student feedback about the value of their *HOTmaths* use, more than 90% had positive things to say about their experience, with keywords like ‘helpful’ and ‘useful’ occurring frequently.

Discussion

It seems that the initiative described in this paper to encourage pre-service students to make use of *HOTmaths* in these two pre-service units shows some promise. It seems plausible that the incentive of attaching some marks to recognise the extent of student engagement has had a positive effect, as some students noted explicitly in their responses. The data related to usage of the website suggest, however, that use of *HOTmaths* is not uniform, with a substantial proportion of students – as many as a quarter of those enrolled - making fairly limited use of the software. At the other extreme, it is also clear that there are students who have spent considerable time using the software, far more time than might be expected if they were driven entirely by the inducement of a 10% allocation of marks. These students presumably formed the opinion that time spent on *HOTmaths* is personally valuable, while many student responses suggest that they hold strongly positive views about the value of using *HOTmaths* for personal learning of mathematics content. Discussion list postings also suggest that *HOTmaths* has been a significant part of the work of students in the units, along with the many other kinds of activities in which they have been engaged.

Direct student data reported in this paper regarding the merits of *HOTmaths* use need to be interpreted with some caution, noting that responses to the student surveys are entirely voluntary. While responses to the unit and teaching surveys were attracted from substantial proportions of students (in each case around one third of enrolled students), it is not possible to determine the extent to which these students constitute representative samples of those enrolled in the units, as survey respondents are kept strictly private as a matter of University principle; for similar reasons, data are not available regarding the relationship between student engagement with *HOTmaths* and their eventual success with the units concerned. With those caveats in mind, however, the data suggest that many students are very positive about their use of *HOTmaths*, with a considerable majority of respondents clearly regarding the use of the software to be personally valuable.

While they are provided by a distinct minority of students, there are also student data suggesting that *HOTmaths* was less beneficial for some students than for others. Reasons for this can only be inferred in this study, but it is clear that some students do not regard *HOTmaths* as a necessary learning tool, perhaps because they feel that they already have a firm grasp on unit material; this may be especially the case for those students in the mandatory unit, *EDN114*, if they have completed high level mathematics courses in their recent school work. There is also a potential problem for the substantial number of students who take the sequence of units, EDN110 and EDN114, in successive semesters; a small number of these students have expressed irritation at the repetition of *HOTmaths* in each unit, and the deletion of their records between units to allow the marking of *HOTmaths* engagement in each semester to be validly undertaken. In addition to these possible effects, it is important to realise that the students enrolled in the two units involved in this study are all first-year students, with a corresponding diversity of backgrounds, maturity, interests and practices as they navigate their way between school and university. It would be unreasonable to expect a completely uniform response to any initiative from such a diverse group of university students.

While there has been some use of *HOTmaths* in both lectures and workshops, the great majority of students' use of the website has occurred on their own initiative and in their own space and time, so that responses to survey items have necessarily provided limited information about the ways in which the website has been used by students. While some anecdotal responses from students about *HOTmaths* have also been very positive, it is clear that it would be helpful to obtain more substantial information to understand better the effects involved. Ideally, a follow-up study to the present one would include interviews with a sample of students to obtain information directly on which features of *HOTmaths* were of particular benefit, how the students use them in practice, and which aspects were regarded as less beneficial or even neglected altogether.

The major emphasis of this study of first year students has been the development of mathematics content knowledge, but is also important to recognise the potential effects of *HOTmaths* use on the development of pre-service students' pedagogical content knowledge. While not directly measured in this study, student engagement with the online learning system seems likely to have given students an initial understanding of the role of such systems for school and teacher use. It is anticipated that students will find the experience of interacting with *HOTmaths* as a learner to provide an important foundation for their later consideration of the use of *HOTmaths* or similar systems as a teacher. As noted earlier, the development of expertise with the use of ICT for learning is recognised as important in AITSL's *National professional standards for teachers*. (2011, p. 11), and so early exposure to this sort of experience seems likely to contribute to this expertise more generally.

From the perspective of staff, the initiative has provided some opportunities for new approaches to teaching, both in lectures and in workshops, although these have come to an extent at the cost of having to find an efficient way to allocate a suitable *HOTmaths* engagement mark for each student. The software intended for schools has not been designed with this sort of process in mind, so that a median course between excessive surveillance of student activity and inadequate quick impressions of students' productive use of *HOTmaths* has had to be charted. It is anticipated that this problem will diminish with staff experience with the software, but will not entirely disappear.

Conclusion

Although the designers of *HOTmaths* have targeted the software at the environment of primary and secondary schools, there seems to be some merit in adapting it for use in pre-service mathematics teacher education, as described in this paper. While further research is needed, to understand in more depth precisely how students make good use of *HOTmaths* when left mostly to their own devices, and to explore the relationships between *HOTmaths* use and student achievement, the data available to this study are encouraging that the initiative has been worthwhile in supporting the development of Mathematical Content Knowledge, and that it merits further detailed attention.

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Figures and Tables to be inserted

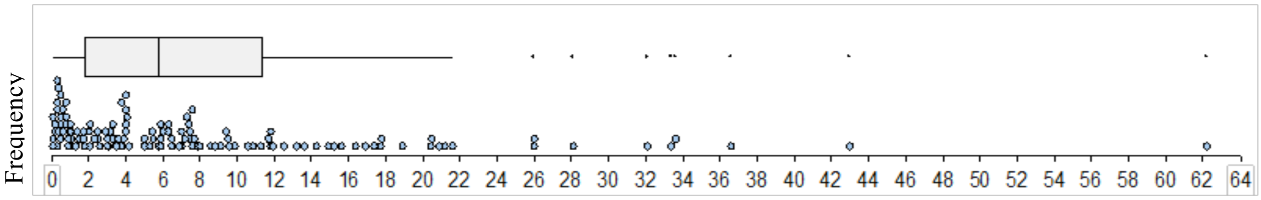

Figure 1: Amount of time a cohort of students from S1 of 2012 spent at the *HOTmaths* website in hours

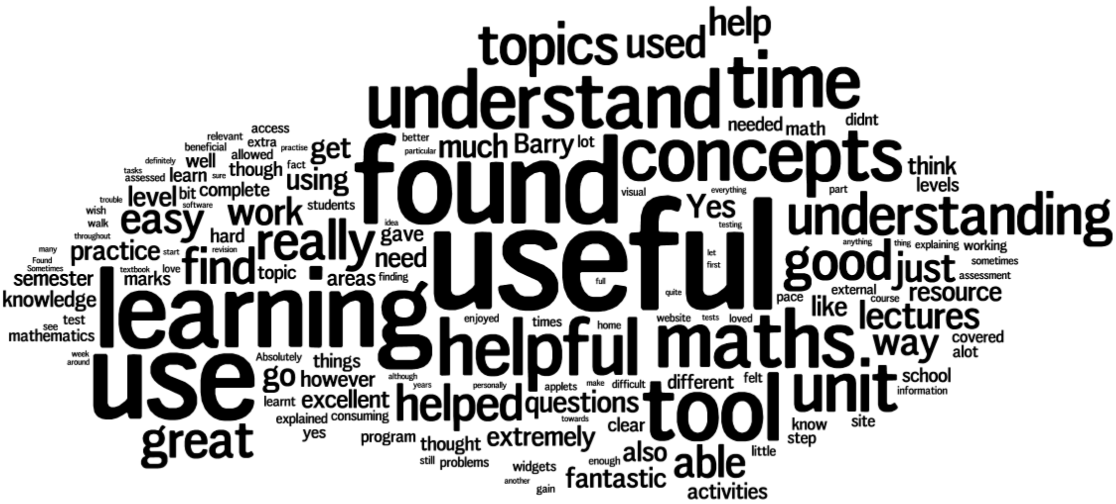

Figure 2: Word cloud showing the frequencies of words used in student comments by the relative sizes

Table 1: Student enrolment, number of responses and the *HOTmaths* survey items

Period	Enrolled	Overall Survey response	Responses to *HOTmaths* item	*HOTmaths* Item
S1 of 2011 EDN110 (Elective)	156	69	51	Lecturer's use of *HOTmaths* in lectures has been helpful for my learning.
S2 of 2011 EDN114 (Mandatory)	277	100	92	Please describe the extent to which you have found *HOTmaths* to be a useful contribution to your learning in this unit.
S1 of 2012 EDN110 (Elective)	159	76	53	To what extent, if any, and in what ways did you find *HOTmaths* to be helpful for your learning in this unit?
Total	592	245	196	

Table 2: Summary of coding of student survey comments

HOTmaths Item	Clearly positive	Somewhat positive	Somewhat negative	Clearly negative	Total
S1 of 2011	45	5	0	1	51
S2 of 2011	78	9	1	4	92
S1 of 2012	43	1	2	7	53
	166 (84.7%)	15 (7.7%)	3 (1.5%)	12 (6.1%)	196 (100%)

Table 3: Frequency of occurrence of major keywords in student comments

Keyword	Frequency of occurrence	Number of students using the keyword	Example
help or helpful	66	57	"Very helpful, able to complete tasks i wanted for extra help and at my own pace."
useful	53	50	"*HOTmaths* was useful in testing my prior knowledge and to show what I needed to work further on."
learn or learning	45	43	"*HOTmaths* was really helpful in explaining concepts as well as providing working examples, that further helped in learning."
understand or understanding	49	42	"*Hotmaths* has been very helpful to me throughout the unit! Helped me understand topics from every level!"