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Exploring Quality Teaching in the Online Environment Using an Evidence-Based Approach

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Abstract: Online learning is increasingly ubiquitous in higher education. However, research regarding online teaching often focuses on the affordances of the online environment rather than on the quality of pedagogy. In this paper we consider how online learning could be enhanced using rich pedagogical models that are consistent with a wealth of existing knowledge on pedagogy for face-to-face settings. To do so, we apply an established framework, the Quality Teaching model, to explore pedagogy in the online environment and illustrate its potential benefits using a case study of 60 students in a tertiary mathematics teacher education program. We conclude that the use of an evidence-based pedagogical model can help guide online instructors in the development of high quality online courses.

Introduction

There is ample evidence that teaching quality is a key determinant of student learning outcomes during schooling (Darling-Hammond, 1999; Fullan, 2007; Kyriakides, Christoforou & Charalambous, 2013). However, in the higher education setting, particularly in the context of online learning, the evidence supporting a similar link is less robust. Moreover, given that technology acts as a mediator of the teaching and learning experience within online learning scenarios, methods commonly employed to determine the quality of teaching in face-to-face settings, particularly as it impacts on the learning experience of students, are often seen as unsuitable in this environment (Ginns & Ellis, 2007).

Defining and evaluating the quality of teaching in online learning environments, which many have characterised as substantially different from traditional classrooms, is a central focus of recent educational research in online teaching (Garrison, 2011). Several examples of instructional principles for courses were developed early for the online medium with clear guidelines for staff-student interactions, encouraging cooperation and active learning, giving prompt feedback, and setting clear deadlines (Graham, Cagiltay, Lim, Craner, & Duffy, 2001). Whilst many of these earlier guidelines acknowledge pedagogy as important, they have tended to focus on the affordances of the specific online environment such as accessibility, communication, reliability of the interface, and bandwidth demand (Herrington, Herrington, Oliver, Stoney & Willis, 2001). More recent work centres on general pedagogical principles that would be applicable across any online delivery system (Kidney, Cummings, & Boehm, 2014; Margaryan, Bianco & Littlejohn, 2015). Some authors argue for more work in the online context in order to “inform learner outcomes, learner characteristics, course environment, and institutional factors related to delivery system variables in order to test learning theories and teaching models inherent in course design”

(Tallent-Runnels et al., 2006, p.93). Indeed, some argue specifically that the development of such models could benefit from drawing on the existing wealth of well-established research on classroom-based pedagogies (Haythornthwaite & Andrews, 2011).

A major issue identified in early research on online learning when utilising comparisons with face-to-face teaching is that in non-classroom based environments the notion of a 'lesson' is substantially different (De Wever, Schellens, Valcke, & Van Keer, 2006). Lessons in online and blended environments can be understood as 'units of work' delivered via a range of media including discussion forums, blogs and individual email communication with the teaching academic. Hence, it is primarily the interactions occurring through these media that can be studied and analysed. Typically, interactions are student–student, student–teacher, or student–content, and it has been found that there is an association between the frequency of interactions and increased student achievement (Bernard et al., 2009; Tamin et al., 2011). Many different instruments and measures are available to analyse the content of online interactions, although concerns about the validity and reliability of some of them have been raised (De Wever et al., 2006).

The purpose of the study reported in this paper is to explore the applicability of an evidence-based approach to evaluating pedagogy in classrooms for the review and refinement of teaching in online and blended environments for pre-service teachers. In so doing, we explore the potential of pedagogical frameworks for informing the improvement of teaching in the online environment.

We undertake this exploration using the Quality Teaching (QT) model (NSW Department of Education and Training, 2003b), a conceptually and empirically robust model guiding developed to guide the quality of teaching in primary and secondary schools. Very minor adjustments to the wording of the coding instrument (NSW Department of Education and Training, 2003a) were made in order to apply the model to the specific features of 'lessons' and 'interactions' in the online environment. We use a case study of two online courses to illustrate how a pedagogical model, in our case the QT model, can be used to analyse teaching in the online environment. The elements that constitute the model, described in the following section, provide a strong and accessible conceptual basis and set of principles for guiding course development and interactions online. These principles have been shown in face-to-face environments to be linked with improved teaching, improved outcomes for students and narrowing of equity gaps for students from traditionally under-represented groups and equity target groups (Amosa, Ladwig, Griffiths & Gore, 2007).

The Quality Teaching Model

Quality teaching and how we define and recognise it has been the object of research for many decades. In the most populated state in Australia, New South Wales (NSW), the Department of Education and Training commissioned the development of a model for teaching quality, comprehensive in scope, and applicable across all subject areas and grade levels, as a framework for teachers' professional self-reflection and for school improvement practices. This Quality Teaching model (NSW Department of Education and Training, 2003b) is now well established in NSW and Australian Capital Territory public schools and there is growing evidence of its efficacy for improving teaching and student learning outcomes (Gore, 2007; Gore, 2014; Gore & Bowe, 2015; Ladwig, Smith, Gore, Amosa, & Griffiths, 2007).

The QT model is a refinement of the Productive Pedagogies model (Hayes, Lingard, & Mills, 2000) which in turn was an extension of Authentic Pedagogy (Newmann, 1996). It features teaching practices that have been linked to improved student outcomes and can be characterised as representing three dimensions of pedagogy: pedagogy that promotes high levels of intellectual quality, pedagogy that promotes a quality learning environment, and pedagogy that develops and makes explicit to students the significance of their work (NSW Department of Education and Training, 2003b). Each of these three dimensions is elaborated through six elements as detailed in Figure 1. For brief explanations of each element please see Appendix 1.

Dimensions

Elements	Intellectual Quality	Quality Learning Environment	Significance
	Deep knowledge	Explicit quality criteria	Background Knowledge
	Deep understanding	Engagement	Cultural knowledge
	Problematic knowledge	High expectations	Knowledge integration
	Higher order thinking	Social support	Inclusivity
	Metalanguage	Students' self-regulation	Connectedness
	Substantive communication	Student direction	Narrative

Figure 1. Elements and dimensions of the Quality Teaching model (NSW Department of Education and Training, 2003a, p.10)

Studies using the QT model are often designed around the observation of teachers and their interaction with students in the classroom (NSW Department of Education and Training, 2003a; Gore et al., 2015). However, as we argued in the introduction, the 'observation' of virtual classroom practices requires a different approach, involving the observation of student-student, student-teacher, and student-content interactions through the systematic analysis of discussion forums and other forms of online communication. In this paper we use the QT model for analysing interactions in a virtual environment in higher education. This investigation extends previous research which found the model to be an effective tool with which to analyse the quality of assessment practice in the social sciences in the tertiary setting (Gore, Ladwig, Elsworth, Ellis, Parkes & Griffiths, 2009).

Case Study: Mathematics Online

Teaching mathematics online is a relatively new practice in which educators need to be aware not only of the affordances of the online medium, but also of issues inherent to mathematical concepts such as notation or the highly structured way in which concepts need to be scaffolded. These issues all play a major role in how courses are designed and delivered (Threlfall, Pool, & Homer, 2013). In pedagogical terms, Engelbrecht and Harding (2005) point out that while "little has been done in developing a pedagogy for online mathematics courses, there are some clear guidelines. Care should be taken to have a sound balance between teacher- and learner-centred activities and that interaction should be carefully planned; interaction between learner and content, between learner and instructor and between learner and learner" (p. 254). This is not specific to mathematics; in fact identical considerations are used for all learning areas with the proviso that evidence-based approaches for improving online learning are used (Abrami, Bernard Bures, Borokhovski, & Tamim, 2011).

Our case study focused on the teaching of mathematics in the online environment to explore how a pedagogical model, the QT model, can be used for interpreting and evaluating teaching practices. Case studies are generally undertaken to ‘describe, explain or evaluate particular social phenomena’ (Gall, Gall & Borg, 2005, p.306) and in doing so, they aid in understanding complex social situations. In this study we use the lens of the QT model to systematically analyse the pedagogical features evident in two online courses. The two courses form part of a Master’s level program, intended for practising teachers and other educators who wish to gain postgraduate teaching qualifications in mathematics education. The student cohort we focused on for this study was comprised of 60 practising teachers who were re-training to be high school mathematics teachers. There were 34 female participants in the study (56.7%). The backgrounds of the students who enter this program are diverse, but most are secondary school teachers who have previously specialised in areas other than mathematics and believe that re-training in mathematics will provide better career prospects at a time when there is a shortage of mathematics teachers.

We selected two concurrent semester-long courses in the Master’s program for the case study that had recently been updated with new technologies. Previously, these courses had been taught online asynchronously, whereby students were sent textbooks and other text-based course materials and asked to submit two written assignments and sit a final exam. In this earlier version, students were able to communicate via email with teaching academics to seek help with mathematical concepts or request feedback. They also participated in discussion board tasks in response to instructor prompts. In the revised offering of the courses we aimed to provide a wider range of online learning experiences for students. To do so, we utilised a range of digital resources available for online teaching and assessment to enable interactions of students to occur with each other and with the instructor in synchronous and/or asynchronous fashion (Holmes, 2005).

The two courses were focused on mathematical concepts. The first (Course 1) focused on Calculus concepts including limits and continuity, derivatives and basic integration. The second (Course 2), contained elements of Number Theory, Combinatorics and a thorough introduction to Complex Numbers including their geometrical applications. Course 1 was undertaken by 41 students (46% female) and Course 2 by 50 students (62% female). There were 31 students who studied both courses (51% female).

In general, the teaching of mathematics in online environments centres heavily on the mathematical concepts to be delivered. Using the constructs of the QT model (see Appendix 1), the emphasis is customarily on the Intellectual Quality dimension of the teaching. In particular, the elements of Deep Knowledge, Deep Understanding, and Higher Order Thinking are often favoured. When we set out to improve the online delivery of the two courses in our case study, guided by the pedagogical principles underpinning the QT model, our primary focus was to also achieve a Quality Learning Environment, where Explicit Quality Criteria, Engagement, High Expectations, Social Support, Students’ Self-regulation and Student Direction would be more deliberate in our teaching. We also aimed to increase the Significance of the concepts we taught by including Narrative and Cultural Knowledge in our course design.

To progress towards an improved Quality Learning Environment and increased Significance, we produced two types of resources during the intervention. On the one hand, and to facilitate Students’ Self-regulation, Engagement and Social Support, a series of resources were either specifically created for the course or externally sourced from the Internet. Externally sourced materials comprised two open-source text-based mathematics books and many short videos and interactive demonstrations covering most of the topics in the course. Our internally produced materials included:

- A course blog, which integrated many of the externally sourced short videos and interactive demonstrations. Our pedagogical aim with the course blog was to promote Engagement using a Narrative created by the lecturer and to include elements of the world history of mathematics thus promoting Cultural Knowledge.
- Pencasts, i.e. interactive documents containing both written text and voice, were provided to students on request, thus promoting Student Direction, and frequently involved further explanations of mathematical problems raised in units of work, thus promoting Deep Understanding.
- Discussion forums, aimed at promoting Social Support, were designed to enhance Intellectual Quality through discussion of the concepts in each of the units of work. The pencasts referred to above were included in these forums.

In addition, to ensure Explicit Quality Criteria and High Expectations, we created a series of assessment tasks to be submitted fortnightly by made available to students from the beginning of the course. In previous iterations of these courses we had allowed students to submit handwritten mathematical work covering all topics at the end of the semester. This time we opted for two different forms of assessment to make better use of the online environment: a timed multiple-choice test to check for basic understanding of the topics presented in the preceding two weeks, and a more challenging long-response question to ensure Higher Order Thinking and Deep Understanding of the topics. The second task differed from previous years as it was to be typed, and plotted if necessary, with mathematical software provided to all students prior to the commencement of the course. This type of formative assessment was designed to help these teachers develop skills needed in modern-day technology-rich mathematics classrooms. The software used was suggested by practicing mathematics teachers who expressed how beneficial it would have been to learn to use it during their pre-service years.

Methodology

All data collection occurred in the first semester of 2013. Our case study comprises two separate courses, with different instructors, each involving six ‘units of work’. Each ‘unit of work’ was delivered fortnightly to students. Our university learning management system allows the running of analytics concerning use of the different resources included in the course, and we used these as the starting point for our analysis. In a previous paper (Prieto & Holmes, 2014) we presented a comprehensive analysis of the student activity and how it correlated with student achievement in the course, finding a positive relationship between the time spent within the learning management system and achievement in the course. In this previous paper, we used Engelbrecht and Harding’s (2005) framework to classify the interactions between students and academics in online mathematics courses. Their framework is comprised of seven factors ranging from instructor facilitation to internet resources, focusing mainly on the affordances of the online environment rather than on the pedagogical approach to teaching online.

In this paper we analyse only the content of the forums where students discussed the units of work. By content we mean all written interactions occurring within the learning management system in the fortnightly period when that unit was delivered. As discussed in the introduction, content analysis of online interactions is often carried out by creating instruments specific to the online environment. However, in their review of content analysis schemes for discussion groups in online teaching, De Wever et al. (2006) expressed concern about the instruments used. In particular they referred to the empirical validity of instruments and the reliability of coding. Our methodology addresses those concerns. By utilising the QT model, which has been systematically tested in classrooms, we use a coding instrument tested and validated in pedagogical research (Gore, 2007). The coding scales, used in relation with the focus question for each element as well as descriptions of each element/construct, are detailed in Appendix 2.

To address issues of reliability in our study, the coding of content in the 273 posts contained in the discussion forums was undertaken by an experienced coder using the QT model. A random sample of 44 posts were independently doubled coded by another experienced coder, achieving an initial agreement of 85%. Subsequently, the two coders discussed the disparities and came to an agreed ‘best’ code for all posts.

The forums were downloaded from our University’s learning management system by using its “Collect” functionality and then imported as text files into QSR NVivo 10 for coding and analysing purposes (NVivo qualitative data analysis Software; QSR International Pty Ltd. Version 10, 2012). For each unit of work the coding was conducted by highlighting portions of text in the discussion board corresponding to that unit, and coding it in relation to relevant elements of the QT model. The codes were pre-determined by creating “’Nodes’ within the NVivo environment. Double (or in some cases triple) coding was allowed since several elements could be present in the same portion of text. Examples of these extracts are given in the Results section. This approach enabled us to produce an accurate analysis not only of the degree to which the different elements in the QT model were evident in students’ interactions, but also the amount of text devoted to each of the elements as a percentage of the total amount of text students wrote in the forums. NVivo’s analytical tools enabled us to determine the amount of text that each of the different QT elements represented by using the Node summaries. It also enabled us to see the proportion of text coded to each element relative to the whole text for each forum examined.

We only report here the interactions occurring in the forums that were not part of formal assessment for the courses. In other words, the focus of our study was on those online interactions that mimic the informal, but nevertheless crucial, connections between students and teachers which occur as part of typical face-to-face instruction. The discussion forums were organised with three different foci: assessment questions, mathematical questions, and miscellanea. The first forum was designed for students to communicate with their lecturer about all matters relating to assessment of the course, including mathematical questions which were part of their assignments. The second two forums were also monitored by the lecturer, but were used mainly by students to communicate amongst themselves, sharing resources and ideas or extending their learning beyond the course syllabus. All three forums have been analysed for this study. All individuals were de-identified for the purpose of this research. Human Research Ethics Committee approval at our institution was obtained (Approval No. H- 2013-0023), with active consent from students for us to anonymously report on their answers.

Results

In this section we provide results organised according to three different perspectives. First, we focus on the overall coding of each element in the QT model for each of the six units in both courses to get an overall picture of the pedagogical quality of the courses. Next, we analyse the proportion of text in the forums coded for each of the QT elements, and argue the limitations of this type text analysis for online forums. Lastly, we focus on in-depth content analysis of the text in the forums for each element of the QT model.

Overall QT Coding

The agreed QT coding of the content in discussion forums for the six units in each of the two courses is presented in Figure 2. It is apparent that the scores given for each QT element were consistent across units demonstrating that certain features of the Quality Teaching model are more evident in these online courses than others. In particular, the elements of Deep Knowledge, Substantive Communication, Explicit Quality Criteria, Student Support, Student Self-Regulation and Inclusivity, scored highly in all units in both courses. In contrast, there was very little evidence found of Higher-order Thinking, Metalanguage, Cultural Knowledge and Narrative. In terms of the QT dimensions, Quality Learning Environment and Intellectual Quality consistently scored higher than Significance across all units of work.

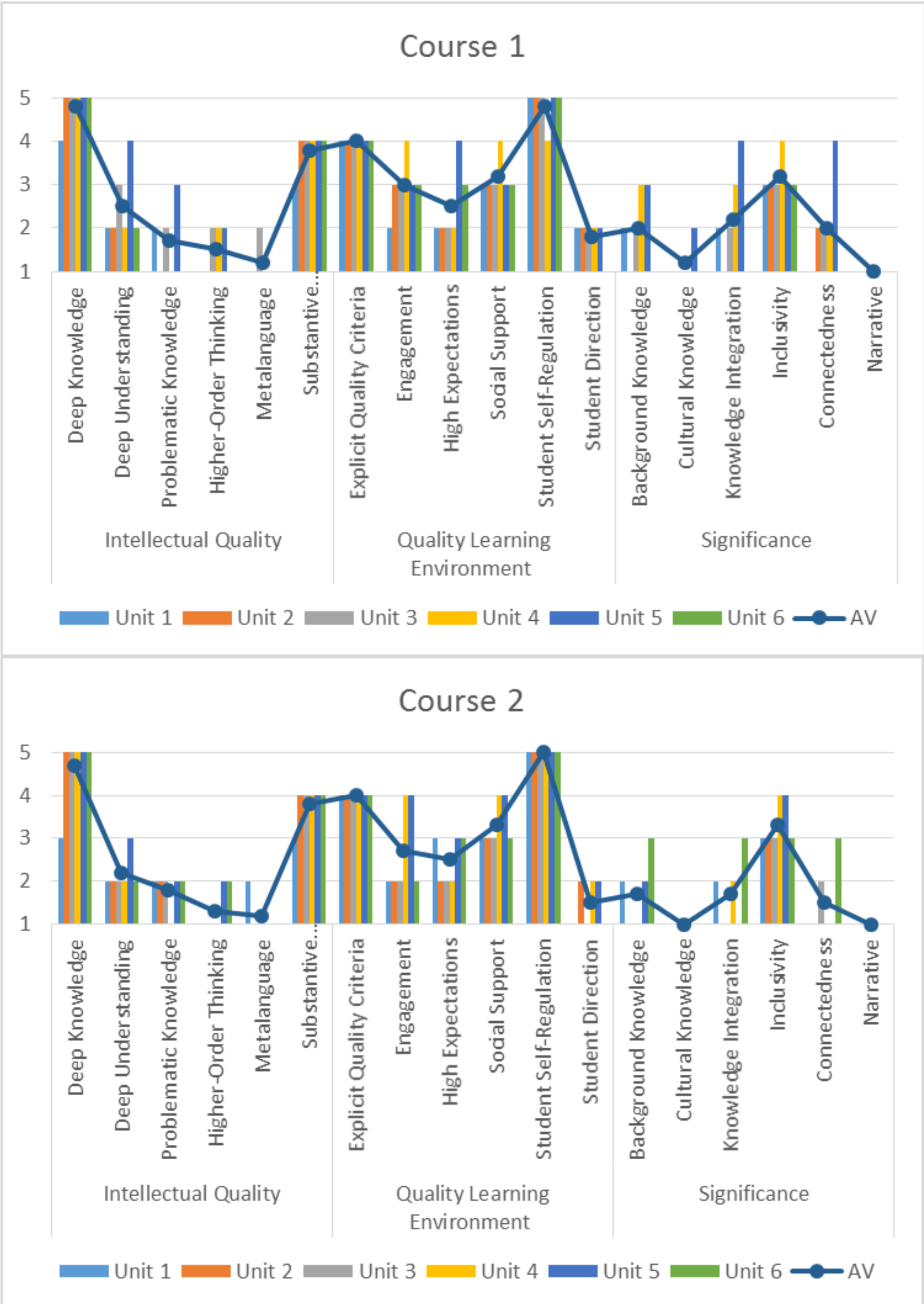

Figure 2. Coding of all units of work in Course 1 and Course 2

The mean scores for each element in each module of each course are displayed in Figure 3. It is clear that although the courses were conducted independently by two different instructors, the overall pattern of scores is highly consistent across all 18 elements (r=0.96, n=18, p=.000).

Proportion of Text

Another measure of the prevalence of the QT elements across units is the percentage of text explicitly devoted to each element in the discussion boards. This measure could be considered equivalent to measuring the proportion of class time 'devoted' to each of the QT elements.

The analysis was undertaken using text analysis software by highlighting portions of text and coding them against one or more QT elements as explained in the Methodology section. The software takes into consideration the total amount of text in each unit of work and consequently allocates a percentage to the text highlighted. Figure 2 presents the average coding over the 6 units of work for each of the elements in the course and the percentage of text devoted to each of the elements.

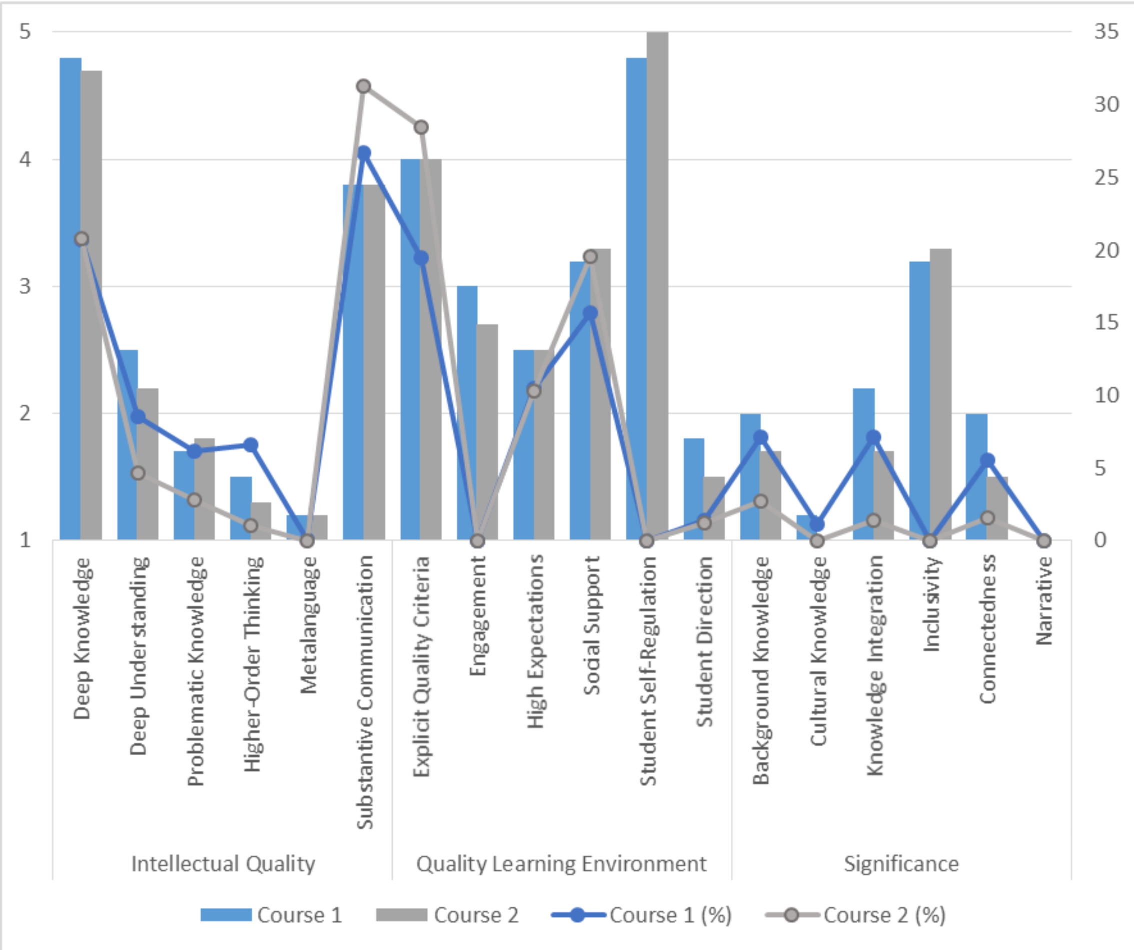

Figure 3. Mean scores and proportion of text for each element

The elements of Deep Knowledge, Substantive Communication, Explicit Quality Criteria, and Social Support are prevalent in both courses when analysed using the proportion of text as a measure of their presence in the forums. This aligns with the overall coding presented in the previous section. Also similar to the overall coding, Deep Understanding, High Expectations and Knowledge Integration show medium levels of presence in the courses, and Metalanguage, Student Direction, Cultural Knowledge and Narrative are virtually non-existent in the discussion forums.

One interesting point arising when comparing the two approaches to analysis of the courses, by overall coding and by proportion of text, is that some elements (i.e., Engagement, Student Self-regulation and Inclusivity), are coded higher in Table 1 than the percentage of text devoted to it in the coded discourse would seem to indicate at a first glance (see Figure 3). For these elements, we considered that unsolicited student participation in the discussion board acted as a proxy measure of their presence. As an example of this, the element Engagement does not appear explicitly in any percentage of text in either of the forums, but we have coded it as high as 4 depending on the level and quality of unprompted engagement that students showed with the mathematical concepts taught that fortnight. If we were to continue the analogy with face-to-face settings, 'proportion of text' would be equivalent to 'time spent in class' in a setting where students are highly engaged. Essentially, participation in the discussion forums implies engagement with the course, and so, all students who post comments are engaged to some degree. Therefore even though there is nothing in the text of student posts that indicates engagement, the existence of the text at all indicates the presence of this element. Taking this into consideration, we interpreted the presence of the comments as a proxy to engagement, and coded accordingly for the previous section.

In the case of Student Self-Regulation, the fact that there is no text in the forums devoted to it is equivalent to having no time in a classroom when the teacher has to discipline students or redirect their attention to the task at hand. In this sense the absence of such text denotes high levels of self-regulation by students. Similarly, Inclusivity was not mentioned by the students but was considered evident in posts from diverse students including males and females.

Analysis of Content

Analysis of the content of interactions in relation to each of the QT elements will now be presented in turn, using examples where available to illustrate in detail how the characteristics of Quality Teaching can be observed in the online environment.

Dimension: Intellectual Quality

Deep Knowledge

In both courses, across all units, the element of Deep Knowledge was coded highly indicating that within each unit the discussions focussed on a small number of key concepts and the relationships between those concepts. In many cases the discussion began with a student question:

> *looking at the nature of points of inflection. a horizontal point of inflection occurs when both first and second derivitives [sic]= 0 and there is a change in concavity. An oblique point of inflection occurs when the first derivitive does not = 0 but there is a change in concavity and second derivative =0. Is this correct?*
>
> *Student post, Course 1, Unit 2*

The question was typically followed by an instructor response:

Points of inflection must all have their second derivative =0 (this is a necessary condition). However, the first derivative may or may not be 0. If the first derivative is NOT zero, they are sometimes referred to as "oblique". The function y=x^3+x is an example of this. If the first derivative IS zero, then they are sometime referred to as "horizontal". The function y=x^3 is an example of this. Please note that there must always be a change in concavity for it to be an inflection point. So answering your question: yes, you are correct :)

Instructor post, Course 1, Unit 2

In some cases, other students also offered responses to student queries, enlarging the discussion and thus demonstrating substantive communication as defined in the QT model. The units within each course were often accompanied by an instructor-written blog post (not included in the analysis conducted for this paper), introducing the concepts for the unit and thereby providing the necessary focus for the discussion that followed. These examples point to the necessity of planning cohesive, carefully focussed units within courses in order to promote discussions that go beyond superficial treatment of key concepts.

Deep Understanding

In comparison with the element of Deep Knowledge, the coding for Deep Understanding across both courses indicates that most students were demonstrating only superficial knowledge of the key concepts under discussion. This is to be expected because the forums were designed as spaces for the students to seek help. Instructors would be more likely to see this element demonstrated through the formal assessment tasks associated with each course, rather than in student posts. At times, however, the students did demonstrate Deep Understanding, particularly when helping each other:

I think I can help with your question one query.
If you included 1 as a value (by shading the circle) the equation would be undefined. This is because when you substitute x=1 back into the equation you would get 1-1=0 for the denominator. The denominator cannot be zero because anything divided by zero is undefined.
I hope this makes sense. :)

Student post, Course 1, Unit 6

Problematic Knowledge

Mathematics as a school subject is rarely presented as being socially constructed and/or open to question. It is not surprising that the transcripts analysed here show little evidence of the Problematic Knowledge element. There are several examples, however, where the instructors encourage students to embrace the fact that there are many different ways to complete most mathematics problems:

Sometimes the graphs are long and skinny, you just have to tell me where the important features are. Sometimes you label them a,b,c etc or you could just state it under the graph. Sometimes we need a 1-1scale, we don't want graphs to be stretched (we don't want a circle looking like an elipse). The question will be looking at your setting out, how do you communicate all the data to me in a neat and easy to read fashion. There may be different ways to do this, it is up to you how you set everything out and format your answer.

Instructor post, Course 1, Unit 3

Higher-order Thinking

There was little evidence of the Higher-order Thinking element in either course, however, this could be absent for similar reasons outlined above for Deep Understanding. The nature of online discussion boards to answer mathematical questions in the course encouraged brief, rather than extended interactions between participants, usually focussing on specific difficulties. Therefore, responses indicative of higher-order thinking about the course content, involving analysis, synthesis and evaluation, was not expected to be prevalent in these forums but expected in responses to formal assessment tasks which were not included in this analysis.

Metalanguage

While there was ample evidence of discussion *using* mathematical language, there was little evidence of discussion *about* mathematical language. One of the few examples of the Metalanguage element comes from an instructor post:

> *Now into turning points: They're known as "turning points" as this is where the curve 'turns' from 'going up' to 'going down' (or vice versa). Mathematically we can see this happening because the gradient changes from being positive to negative (or vice versa).*
>
> *Instructor post, Course 1, Unit 3*

Substantive Communication

The Substantive Communication element is one of the most prevalent across all units in both courses. This is not surprising as any communication via an online discussion board, by necessity, has to be elaborated sufficiently for other participants to make sense of the post.

Dimension: Quality Learning Environment

Explicit Quality Criteria

The Explicit Quality Criteria element refers to the extent to which the characteristics of high quality student work are made clear and are reinforced throughout the unit, ensuring that students are able to assess their own progress against these criteria. We found a consistently high level of evidence for this element across all units in both courses, typically in the form of students asking for detailed clarification of assessment task requirements or seeking feedback on their progress towards a high quality product. Also, students posted work-in-progress for feedback which was given by the instructor and in some cases by other students.

Engagement

The level of engagement of students in each course varied significantly across units, with some units having most students actively engaged in discussion and others with only a few engaged on a regular basis. In the online environment, engagement is on the one hand very easy to identify, as any posting indicates a conscious choice by the student to engage in conversation. However, student engagement could be occurring 'behind the scenes' with students accessing and reading posts but choosing not to engage by posting themselves. It is difficult to determine the factors related to these different levels of engagement; this may be a fruitful area for future research.

High Expectations

This element refers to the degree to which students are engaged in challenging work and are encouraged to take risks. In general we found that only some students explicitly showed that they were engaging in challenging work, and indeed, it could be said that these students were taking a risk by posting their work publicly online as demonstrated by the following post:

> *There is no solution for this question so I don't know if I got it correct. If anyone else has completed this question can you compare your answer to mine below, please. If you get something different can you put it up. If you get the same can you let me know too please.*
>
> *(u^2-3v)^4 = u^8-12u^6v+54u^4v^2-108u^2v^3+81v^4 Thanks*
>
> *(Student post, Course 2, Unit 5)*

Social Support

The Social Support element is related to the degree to which the (online) learning environment is free from negative put downs and is an environment where contributions are valued and encouraged. Across all courses, no negativity was found; however, we generally observed a relatively neutral environment, with some positive and encouraging feedback such as the following comment from a student to the instructor:

> *Thank you for providing this information and yes, I agree that a whiteboard would have been very handy. I have made notes from the video and I understand it better now. I really appreciate the time you take to answer our questions.*
>
> *Student post, Course 1, Unit 6*

And this from one student to another:

> *Thank you for your brilliant explanations. I get it !! Yeah!! Thank you again and congratulations for working out 10d. I will need to read over it a couple more times before I get it but thanks for sharing.*
>
> *Student post, Course 2, Unit 5*

Students' Self-Regulation

The element of Students' Self-Regulation focusses on the extent to which students act autonomously when interacting in the online environment rather than only participating when prompted by others. Given the nature of the online learning environment, the element is coded highly across all units in both courses. Inherently, the online learning environment, particularly for adult learners, requires students to be self-regulating as they juggle their daily responsibilities with their learning trajectory, even when tight timelines are set for online activity.

Student Direction

In the two courses under analysis there was very little opportunity for Student Direction, with students demonstrating only minimal amounts of control over the direction of their learning. These choices were mostly the pace at which they went over mathematical concepts and the assessment tasks, or alternative sources (videos, websites, etc.) they used for their learning. This has prompted the academic staff teaching the courses to re-design the structure of the discussion boards so that more input from students could be present. In particular the "Miscellanea" forum in both courses has been altered to include more Student Direction. We include an outline of those changes in the "Implications for course design" section below.

Dimension: Significance

Background Knowledge

The presence of the element of Background Knowledge is measured through observation of references to students' prior knowledge obtained within or outside formal educational experiences. Across all units in both courses there is little evidence of this element; however, occasionally students do share pertinent personal details:

> *Thank you for sharing this article, I have an interest in this area. I am Food Tech trained and have always incorporated a lot of maths into my lessons. I plan to do the reverse as a maths teacher.*
>
> *Student post, Course 1, Unit 4*

Cultural Knowledge

The element of Cultural Knowledge is one of the lowest scoring elements across all units of work. In general, there was no acknowledgement made that alternative cultural approaches to mathematics are possible. This finding possibly reflects on the nature of mathematics as a discipline rather than on the online learning environment under analysis here.

Knowledge Integration

Knowledge Integration was found to be one of the most variable elements in the Significance dimension across all units. In one unit, several meaningful connections were evident between topic areas; however, in most of the units of work only trivial connections were made. For example, the following instructor post is illustrative of the Knowledge Integration element:

> *Last week we dealt with some very important concepts when graphing functions: tangents and normals. This week we will build on those concepts, mash them up with what we know about continuity, intercepts and voila, we will be ready to graph any polynomial function that is thrown in front of us. Isn't it great?*
>
> *Instructor post, Course 1, Unit 3*

Inclusivity

The element of Inclusivity is evident in the online environment through observation of the participation levels across units of work. In our analysis, most students contributed to the online discussion, although there was some level of variation in both courses. We did not find that the variation was gender-related, and other social differences were difficult to appreciate in an online environment.

Connectedness

Connectedness refers to the degree to which learning is related to ‘real world’ settings and/or students are given the opportunity to engage with an audience outside of the confines of the learning environment. In the case of online learning, the latter could possibly be achieved through engagement with the internet beyond the boundaries imposed by the learning management system, however, we found no evidence of this in either course.

Narrative

Across all units we found no evidence of the Narrative element.

Implications for Course Design

Implications for course design were drawn from applying the QT model to our case study of mathematics courses. First, the analysis of the 12 units of work from two online courses, with different instructors, produced remarkably consistent coding across the 18 elements of the QT model which also aligns with what has been found previously in the face-to-face classroom-based environment (Gore, 2014).

In terms of the Intellectual Quality dimension, we found that the elements of Deep Knowledge and Substantive Communication were most apparent in the online interactions across all units of work. While the other elements in this dimension were detectable, they were not as prevalent, possibly due to the concise nature of online discussions or alternatively due to the nature of mathematics as a subject. However, each of the lower coded elements, Deep Understanding, Problematic Knowledge, Higher-order Thinking and Metalanguage, could be enhanced in the forums through careful planning. Using the forums to pose higher-order tasks undertaken, as opposed to simply using these forums as a springboard for asking lecturers direct mathematical questions, could increase the quality of the courses.

Considering the Quality Learning Environment dimension, the most highly coded element was Students’ Self-Regulation, however, in the online learning environment this element must be assumed to be present as adult students in higher education are, by definition, self-regulating. Secondly, the element of Explicit Quality Criteria was coded reasonably highly across all units, indicating students’ focus on explicit assessment requirements as a key component of learning. Three elements, Engagement, High Expectations and Social Support are all present in both courses, but do show some variation in coding across the units of work. The element of Student Direction is the lowest coded element in this dimension indicating a general lack of planned opportunities for students to influence the direction of their learning, with the exception of pacing. Opportunities to incorporate Student Direction needed to be provided in the courses, and subsequently new learning activities to achieve this goal have been incorporated in the Masters program. An example of these activities has been adding a ‘question time’ to the weekly course blog and prompting students to ask about issues they would like their lecturer to expand on in the following blog post. This has effectively replaced the existing ‘Miscellanea” forum and added an extra component for Student Direction to it. Students who have taken the course since this change occurred have positively embraced this new feature and chosen topics relating not only to mathematical concepts but also current issues in mathematics education.

Lastly we considered the dimension of Significance, which was consistently coded at a lower level than the other two dimensions. The highest coded element was Inclusivity which is observable in levels of participation among students from different social backgrounds. It should be noted that in our study, gender was the only obvious marker of social difference and we found no pattern in participation by gender. We found varying levels of the elements Student Background, Knowledge Integration and Connectedness, indicating that it is possible to observe these elements in the online learning environment. In contrast there was little or no evidence of the elements of Cultural Knowledge and Narrative in any of the units of work.

The lack of certain Significance elements in the discussion forums may have had an impact on the students’ annual evaluation of courses undertaken by our institution. Using this official avenue, students provided feedback at the end of the course suggesting that they would have preferred the discussion forums and course blog to be blended into one interface. We interpret this feedback as an indication that Significance and the other two dimensions (Intellectual Quality and Quality Learning Environment) should have been integrated to provide a more cohesive learning experience for students, instead of being delivered using different media: the forums and the blog. It is important to remember here that both courses included a weekly blog delivered to students independently of the student forums. The weekly course blogs were purposely created to incorporate Narrative and Cultural Knowledge into the courses but since they didn’t include student interactions, they are not part of the analysis reported in this paper.

Our exploration of the courses’ pedagogy using the QT model, through a coding process that gives specificity and structure to key points of consideration, reveals some consistent areas of strength in the methods employed in the online teaching of mathematics, specifically a clear focus on Deep Knowledge and Explicit Quality Criteria. Also, the nature of the virtual environment, where students are only observable based on their online postings and interactions, ensures that Substantive Communication, Students’ Self-regulation, Inclusivity and Social Support, are consistently displayed. In contrast, evidence to support the presence of the remaining elements was variable across units of work and clearly exposed areas ripe for pedagogical improvement. Interestingly, some of these areas of improvement were independently confirmed by student feedback upon completion of the courses. The main such area identified was a need for a thorough integration of the course blog and the student forums.

Conclusions

With this paper we demonstrate the applicability of evidence-based methods for appraising quality teaching in face-to-face classrooms to quality teaching in online environments. In particular, we illustrate how the Quality Teaching model can be used to analyse, review and improve teaching in the online environment using a case study of a series of mathematics courses for practising teachers who wish to gain postgraduate qualifications. While we acknowledge that our case study is small in scope and results are not generalizable, we contend that the Quality Teaching model can be a useful analytical tool for improving online learning environments.

We utilised a range of digital resources available for online teaching focusing on creating a Quality Learning Environment, where the work of students is Significant and of high Intellectual Quality. This type of environment is explained in detail in the Quality Teaching model (NSW Department of Education and Training, 2003a). Our research indicates that an evidence-based pedagogical model is a feasible model for analysing, understanding and improving online teaching. The model clearly identified some strengths within our current practices but also revealed some important areas for improvement, in particular in the dimension of Significance.

Online instruction is often guided by the affordances of technological tools; however it is clear that such a limited focus can omit vital components of quality teaching. Our study supports the view expressed by Margaryan, Bianco and Littlejohn (2015), that general pedagogical principles should be explored and applied to any online learning environment regardless of size and scope. We contend that a classroom-based pedagogical framework, the Quality Teaching model, can be a comprehensive tool for directing pedagogical improvement in online learning. This kind of analysis can assist online learning instructors to supplement their instructional strategies with consideration of key characteristics of quality face-to-face teaching which can be overlooked in the virtual environment.

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