

Using Transactional Distance Theory to Redesign an Online Mathematics Education Course for Pre-Service Primary Teachers

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This paper examines the impact of a series of design changes to an online mathematics education course in terms of transactional distance between learner and teachers, pre-service education students' attitudes towards mathematics, and their development of mathematical pedagogical knowledge. Transactional distance theory (TDT) was utilised to investigate and describe the interactions among course structure, course dialogue and student autonomy in an online course over a two-year period. Findings indicate that Web 2.0 technologies, when used thoughtfully by teachers, can afford high levels of structure and dialogue. Feedback from pre-service teachers indicated an improved attitude towards mathematics and an increase in their mathematical pedagogical content knowledge. These findings have implications for universities moving towards the delivery of teacher education courses entirely online.

Keywords: mathematics education · transactional distance theory · attitudes · pedagogical content knowledge · online education

Introduction

The current state of mathematics and mathematics education in Australia has been characterised as precarious (Rubinstein, 2009). The Australian Association of Mathematics Teachers (AAMT, 2006) has repeatedly expressed concerns about Australia's capacity to develop a critical mass of young people with an appropriate mathematical background to pursue careers requiring mathematics. According to data from the *National Numeracy Review* (Commonwealth of Australia, 2008), many students fail to enjoy or recognise the personal relevance of mathematics and few voluntarily continue to study it. Although it could be argued that attitudes fluctuate during the school years, negative attitudes towards mathematics persist and are difficult to change (Attard, 2011). These negative attitudes are also found amongst many pre-service teachers studying mathematics education, many of whom have narrow, formal, and rigid beliefs regarding mathematics that are well established and resistant to change (Grootenboer, 2008). Unsurprisingly, these negative attitudes are thus present in many current primary and secondary mathematics teachers (Brown, 2009; Hoogland, Jarvis, & Gadanidis, 2003).

Such concerns are highly relevant to the online primary mathematics education methods course central to this paper as many of the students are completing the course only because it is mandatory, rather than as a choice to learn more about mathematics education. A key assumption of the course is the view that mathematical learning is enhanced when it occurs in supportive learning environments characterised by participation, communication with peers, manipulation



of learning resources and opportunities for collaboration.

Although universities have invested heavily in the use of online learning management systems (LMS), there has not been an accompanying emphasis on the development of an appropriate pedagogy to support student learning online (Larkin & Jamieson-Proctor, 2012). We argue that in the current higher educational context, many factors must converge in the preparation of future primary teachers to enable them to teach mathematics for understanding underpinned by a constructivist paradigm. These include the development of conceptual knowledge, as opposed to procedural and declarative ways of knowing and doing mathematics (Charnitski, & Croop, 2000); the significant decline, over the past decade, in positive attitudes of Australian students toward mathematics (Brown, 2009); and the changing landscape of higher education including the delivery of mathematics courses completely online (Polly, 2011). It is therefore critical to investigate appropriate pedagogies for the teaching of mathematics that foster positive attitudes towards the learning and teaching of mathematics.

Previous research by the authors examined the usefulness of various digital technologies in delivering a mathematics education methods course. This article explores how digital technologies were used to minimise transactional distance, and to foster positive student attitudes towards mathematics and towards studying mathematics online, so that pre-service teachers were able to develop relevant mathematical pedagogical content knowledge (MPCK).

As part of their teaching, academics attempt to improve the quality of their courses, but changes often take the form of trial and error and are based mainly on their own informal reflections and tacit knowledge. Whilst not minimising the importance of reflection, this article reports on a methodologically rigorous approach to course redesign, based on transactional distance theory (TDT), a theoretical framework that has been used extensively in research investigating distance education. Our contribution to knowledge in this paper is the use of the TDT framework to redesign an online mathematics course, given that online education mirrors some of the elements of distance education, albeit with the possibility of a far more synchronous approach. This article presents and discusses how explicit design changes, based on TDT, were made to improve student learning outcomes. This is a specific account of one learning context and thus is not generalisable to all contexts; but other higher education mathematics teacher educators will likely be able to use elements of our design changes to improve their own course offerings, particularly if they are moving courses totally online.

There is a clear expectation from professional mathematics bodies that Education graduates are knowledgeable about best practice in relation to mathematics education; including knowledge of students, knowledge of mathematics, and knowledge of students' learning of mathematics (Frid, Goos, & Sparrow, 2008/2009, p. 2). The Australian Institute for Teaching and School Leadership (AITSL) has clear expectations that graduating teachers will possess high levels of personal and professional numeracy. Given these expectations, a priority for universities is ensuring that graduates are competent and confident teachers of mathematics.

A large body of research exists concerning quality graduates and the necessity for such students to demonstrate what Mishra and Koehler (2006) have described as technological pedagogical content knowledge (TPACK). We have discussed the importance of TPACK in pre-service mathematics education in a previous article (Larkin, Jamieson-Proctor & Finger (2012). This article concerns the design of a course that encourages the development of both mathematics content knowledge (MCK) and mathematics pedagogical content knowledge (MPCK), both recognised as critical ingredients in quality mathematics teaching (Ball, Hill, & Bass, 2005; Livy & Vale, 2011; Ma, 1999). In this article, based on our evaluation of student assessment that focussed on mathematics pedagogy, and also based on formal and informal student feedback, we will suggest that the design changes to the course increased student opportunity to develop as graduates with a sound knowledge of MPCK. Although a direct measure of MCK was not

permitted in this course (due to university policy), we suggest that a flow on effect of these design changes indeed demonstrated an improvement of student MCK.

Our investigation of the literature suggests that a key inhibitor to an overall successful experience of pre-service mathematics education is the high level of mathematics anxiety evident in many students (Grootenboer, 2008) resulting in negative attitudes towards mathematics. It is our contention that addressing the issue of student anxiety is essential, as self-confidence and self-efficacy are essential elements in the development of MPCK (Rayner, Pitsolantis, & Osana, 2009) and the formation of positive attitudes towards the learning and teaching of mathematics.

Anxiety Defined

Anxiety concerning teaching mathematics is common among mathematics education students and may reflect perceived and real deficits in personal levels of mathematics, deficits in pedagogical skills, and/or past occurrences of mathematics failure (Peker, 2009). Mathematics anxiety, which goes beyond a dislike of mathematics, has been defined in the literature in numerous ways. Newstead (1998) defines mathematics anxiety as “feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations” (p. 54). Mathematics anxiety manifests in terms of discomfort towards the teaching of mathematical concepts, theories, or formulas or during problem-solving tasks (Peker, 2009). Gresham (2007) believes mathematics anxiety to be a “state of discomfort that arises when mathematical tasks are perceived of as threatening to self-esteem” to such an extent that it can foster negative attitudes towards mathematics which in turn can “interfere with Mathematics performance and inhibit subsequent learning” (p. 182).

Whilst mathematics anxiety exists in many educational contexts, it appears to be much more prevalent in primary pre-service mathematics education students (Peker, 2009). Brown, Mcnamara, Hanley, and Jones (1999) confirmed widespread anxieties among the students in their study regarding their own learning of mathematics and concerns with the prospect of teaching the subject to primary school students. Pre-service primary school teachers had the highest level of mathematics teaching anxiety (Peker, 2009) and were also more likely to hold negative views towards mathematics; may recognise only traditional methods for doing mathematics; and may be highly resistant to developing alternate ways of teaching mathematics (Brady & Bowd, 2005; Grootenboer, 2008). Research by Rayner, et al., (2009) indicates that lowering mathematics anxiety amongst students increases their performance in mathematics and mathematics-related courses. These various research findings have pedagogical implications for how mathematics education courses are designed and delivered, and especially in the current higher education context, delivered online. We did not specifically measure anxiety with an instrument such as the *Mathematical Anxiety Rating Scale* (MARS) (Richardson & Suinn, 1972); but given the general discussion in the literature, it is prudent to presume in designing an online mathematics education course for pre-service primary teachers that many students in the course would be experiencing anxiety in relation to either studying mathematics or in relation to studying online, or both. Although not discussed here, as the focus is on mathematics education, our experience suggests that many of the students were also anxious regarding the high level of ICT expertise required to successfully complete an online course (Larkin, et al., 2012). We therefore were very conscious of offering a course that would encourage a positive experience of studying mathematics online, with the likely flow-on effect of minimising student anxiety.

In summary, we developed the understanding that the major design challenges in moving our mathematics methods course online were the development of a structure to support student mathematical learning and the provision of opportunities for student dialogue with each other and with us as their teachers. It was hypothesised that in such a collegial environment, positive attitudes to mathematics would be fostered and consequently student anxiety towards



mathematics would likely be minimised. As online education is a sub-set of distance education, we examined the research literature in this domain for a suitable framework to direct our course re-design. TDT appeared to meet our design needs.

Theoretical Framework Underpinning the Course Design

Moore (1993) suggests that transactional distance is the “psychological and communications space” (p. 22) that occurs between learners and is shaped by the learning environment and by the patterns of activity of individuals within the environment. TDT encompasses the range of educational approaches currently in use in higher education namely: face-to-face, blended, or completely online. Transactional distance is influenced by three interrelated factors: the structure of the program; the dialogue that exists between the teacher and the learner (and increasingly between learners); and the level of autonomy of the individual learner. Deliberate teaching strategies, for example modifications to LMS or the creation of forums for discussion, are located within the variables of structure and dialogue, with learner autonomy the independent variable (Moore, 2007) (Figure 1). Autonomy, Anxiety and MPCK are clustered together (see Figure 1), as they specifically relate to the disposition of each individual learner.

Dialogue refers to the interplay of words and actions between teacher and learner when one gives instruction and the other responds. Although interactions are necessary for the creation of dialogue, interactions are not synonymous with dialogue, defined as a positive interaction “which is purposeful, constructive and valued by each party” (Moore, 1993, p. 24). Furthermore, Moore (1993) indicates that the medium of communication is a key component in determining the types of dialogue that can occur and, by manipulating the communications media, it is possible to increase dialogue between learners and their teachers, thus reducing the transactional distance.

Structure refers to the extent to which an educational course or entire program can be responsive to the learning needs of individual students. According to Moore (1993, p. 26) structure “expresses the rigidity or flexibility of the programme’s educational objectives, teaching strategies, and evaluation methods”. The quality of the structure is determined by how carefully these elements are constructed.

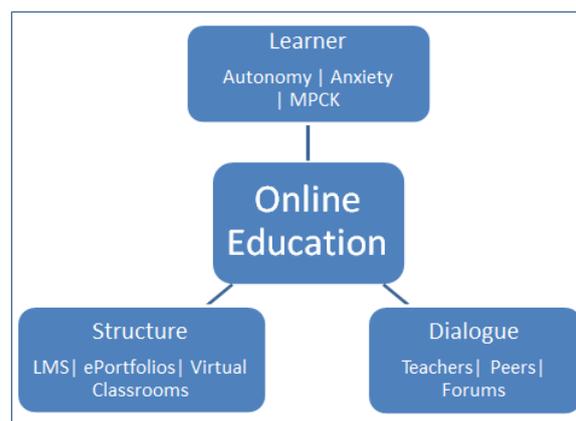


Figure 1. A graphical representation of TDT and key online course design elements.

The identification and manipulation of structure and dialogue are key elements in minimising transactional distance; however, care needs to be taken not to overstress these elements at the expense of the agency of the learners. This agency is described by the third variable of

transactional distance: learner autonomy.

Learner autonomy recognises that it is ultimately “the learner rather than the teacher who determines the goals, the learning experiences and the evaluation decisions of the learning programme” (Moore, 1993, p. 31). The key theoretical understanding underpinning Moore’s initial conceptualisation of TDT is the relationship between dialogue, structure and learner autonomy: “the greater the structure and the lower the dialogue in a programme, the more autonomy the learner has to exercise” (Moore, 1993, p. 27).

In addition, in this initial conception, an inverse relationship usually exists between structure and dialogue in that a more highly structured program presents a reduced space for dialogue, interaction, and the negotiation of meaning in the teaching/learning process (Gokool-Ramdoe, 2008). Furthermore, manipulations of these elements increase or decrease transactional distance, which in turn demands more or less autonomy from students in managing their learning (Gokool-Ramdoe, 2008). Research by Benson and Samarawickrema (2009) suggests that online learners in the early years of a degree program demonstrate low levels of autonomy and thus require, at a minimum, high levels of structure in order to limit transactional distance. Consequently, educators “need to design for high levels of dialogue and structure ... in order to support students”, particularly in the early years of their program (Benson & Samarawickrema, 2009, p. 17).

It needs to be acknowledged here that we, as the course designers and teachers of a large online course, could not determine precisely the level of appropriate learner autonomy for each student in the cohort. However, based on our extensive experience with the teaching of first year students, and based on student feedback in the face-to-face course on which the online course is based, we took the view that learner autonomy was likely to be low. Therefore, in our design changes we focussed on a blend of structure and dialogue that would support low levels of learner autonomy.

Recognising the impact of current Web 2.0 technologies, Park (2011) proposes a new understanding of TDT, adapted to fit the affordances of digital technologies instead of the primary print based medium of Distance Education. This version incorporates both individual and collective activities facilitated by emergent social technologies such as Facebook, Flickr, Instagram, and Twitter. New communication tools offer opportunities for courses to be developed that are high in both structure and dialogue, without the high transactional distance that might be implied when considering initial conceptions of TDT (Benson & Samarawickrema, 2009). This is an important reconceptualisation of Moore’s (1993) initial suggestion concerning the inverse relationship between structure and dialogue. If Benson and Samarawickrema (2009) are correct, the implication of their position is that, via the use of Web 2.0 technologies, it is possible to have high structure without the associated detrimental effect of lowering opportunities for dialogue. In other words, it is a ‘win-win’ scenario with structure and dialogue both contributing to lower levels of transactional distance. Our findings support this claim.

Whilst TDT has been generally well received in the academic literature, there have been concerns regarding its usefulness. Particularly critical of the theory are Gorsky and Caspi (2005) who suggest whilst the theory is important conceptually, its usefulness is limited as research has yet to show a correlation between student outcomes and variations of course design minimising transactional distance. Murphy and Rodriguez-Manzanares (2008) suggest a weakness of TDT in that it narrowly focuses on an analysis of interactions between teacher and learner rather than investigating the more important element of the development of a community of learners as opposed to learners interacting in isolation with materials and with the teacher.

Despite these concerns, in our view, TDT is a useful and appropriate framework for analysing and describing our learning and teaching environment (i.e., first-year pre-service primary students, likely to enter with high levels of anxiety concerning mathematics, less than optimal

mathematical backgrounds, and studying totally online) as well as for maintaining high levels of dialogue and structure to cater for the anticipated low levels of learner autonomy. As indicated earlier, we are very aware that this claim is a 'broad brush' as within any cohort individual students will demonstrate higher or lower levels of autonomy than their peers. However, our claim is based on the use of TDT in a number of studies investigating distance education (Albion, 2008; Benson & Samarawickrema, 2009) and its use by the lead author in research investigating student learning in blended and online environments (Kawka, Larkin, & Danaher, 2011; 2012).

In arguing for the role of technology we are not diminishing the role of the teacher. However, as the two teachers involved in the online offering were also the teachers in the face to face offerings, we have largely excluded our impact as teachers to focus on the design changes made to the course to facilitate success online.

Methodology

Our two research questions were:

1. Can a successful face-to-face mathematics education course be redesigned to effectively cater for the educational needs of first year pre-service primary teachers studying completely online?
2. Is TDT a valuable explanatory framework to guide course redesign?

When moving to an online environment, major modifications were required to the existing face-to-face course to reduce transactional distance via the manipulation of dialogue, structure, and learner autonomy. A design-based experiment approach was used to direct ongoing modifications to the course in order to facilitate high levels of both structure and dialogue and also to enhance student MPCK, improve student attitudes towards mathematics, and reduce anxiety regarding the learning and teaching of mathematics. In brief, a design-based experiment is concerned with the study of learning in specific contexts and then extending knowledge by generating models of successful innovation (Design-Based Research Collective, 2003). As indicated previously, this does not imply generaliseability to all contexts but does suggest approaches that may be useful in similar contexts.

The design-based experiment cycle of data collection and reflection, course re-design, and implementation of design changes was followed across three consecutive semesters (2010-2011) and is an authentic research approach as individuals involved in a teaching context are best placed to identify, at the local level, changes that need to be made to improve learning and teaching (Cohen, Manion, & Morrison, 2002).

Although we used a process of individual and joint teacher reflection in guiding our course redesign, and made design changes at the conclusion of each semester to enhance student learning, for conciseness of discussion and ease of reading, the successes and shortcomings of the three semesters are condensed into one overall account of our experience.

Data Collection and Analysis

Data were collected from students at the conclusion of each of the three semesters via the formal Student Evaluation of Course (SEC) process conducted by the university. These students had just completed an initial mathematics education course focussing on Numeracy, Number, and Algebraic Thinking. Although it is a core course for a range of undergraduate programs, a significant majority of the students were first year, primary pre-service teachers. The main aim of

the course was to develop MCK and MPCK in the *Number and Algebra* strand of the *Australian Curriculum: Mathematics* and also to develop an overall appreciation of the importance of numeracy in our society. Assessment included an ePortfolio of teaching resources, lesson plans, and theories of mathematical learning as well as an end-of-semester exam focussing on MPCK.



Students responded to 14 statements concerning their experience of the course using a 5-point Likert scale (Strongly Agree to Strongly Disagree). Students had the opportunity to provide a written comment on each statement and/or about the course in general.

Although the generic statements incorporated facets of structure, dialogue and learner autonomy, it was not possible to separate these based on the wording of many of the statements. Therefore, the Likert scale responses by students may reflect structural modifications, patterns of dialogue, changes to student levels of autonomy, or course feedback outside the scope of any of the transactional distance variables. For example, Item 2 in the course evaluation survey is "Course content was presented in ways which greatly assisted my learning" and this implies on one level a structural element (course content); but how the course was *presented* implies decisions regarding course activity, for example dialogue. Likewise, Item 13: "My understanding of the subject has improved as a result of feedback" emphasises the quality of dialogue between teacher and student; but as feedback was delayed in one of the course offerings, student ratings likely reflected a judgement on a structural dimension.

Therefore, due to difficulties in interpreting the quantitative data precisely, our analysis focussed on the qualitative student responses. This qualitative coding was based on the work of Benson and Samarawickrema (2009) who used this methodology to investigate eLearning in six blended and online courses at Monash and Deakin universities. Each student comment was examined and coded as reflecting an element of structure (S) or dialogue (D). In some cases, comments were coded as both S and D, as they included aspects of both elements. Further, the coding categorised the comments as indicating a positive structural element (+S), a negative structural element (-S), a positive dialogue element (+D), or a negative dialogue element (-D), with (+S and +D) indicating the elements decreased transactional distance, and conversely (-S and -D) indicating the elements increased transactional distance. Prior to the full coding process, the authors reviewed a range of student comments to develop a consistent benchmark for (a) what would be considered as positive or negative student comments concerning structure and dialogue; and (b) which type of student comments would be excluded. For example, general comments about satisfaction with the course were excluded (unless they indicated also that the satisfaction was due to structural or dialogic elements). The student comments over the three semesters were then coded according to the schema.

Presented below are two examples of the process in action. The student comment - "*The Wimba tutorials were fabulous! Web students then get the same amount of support as on-campus students*" (Student, 2010) was coded as +D as the Wimba tutorials provided an opportunity for online students to communicate synchronously with their lecturer, tutor, or peers. The student comment - "*The website was laid out in an easy to understand manner. I had no trouble navigating to find the information I needed. I like that the tutorials were recorded so that I could view them later*" (Student, 2011) was coded as +S as it reflects an appreciation that the structure of the course aided knowledge gathering. Some student comments, such as "*The course is great*" or "*nothing could be improved*" were ignored because they were not identifiable with either structure or dialogue.

The remainder of this article outlines the changes made to the primary mathematics education course during 2010-2011 and then, based on student feedback and our reflection on the course delivery, explores how TDT was used to direct future modifications to support student dialogue, develop MPCK, and engender positive attitudes towards mathematics.

Moving to an Online Environment – Triumphs and Tribulations!

Although the course had previously been offered in blended mode (a combination of face-to-face lecture and tutorial delivery and online content), Semester 3, 2010 was the first occasion on which it was offered solely online.

The key changes made in relation to structure and dialogue over the three semesters under



investigation are presented in Table 1 and are identified as either changes to structure or dialogue. The group Wiki assessment task (replaced by an ePortfolio in 2011) was designed to incorporate both structure (Content Knowledge and Assessment) and dialogue (Group Work, Peer Support). As both the 2011 semesters utilised a very similar course design to that on offer in the first semester in 2010, all three semesters will be discussed together to highlight the global story of course development.

Table 1
Key TDT Design Changes 2010–2011

2010 Element Changed	TDT component	Brief description of design change
Online lectures	S	Lecture podcasts were recorded in mp3 or mp4 format
Video demonstrations	S	A series of short videos were made demonstrating use of mathematics manipulatives; e.g., MAB blocks for addition
Group Wiki	S & D	A wiki was used as a group assessment task
Virtual classrooms (Wimba)	D	Virtual classrooms were used on a weekly basis for synchronous student collaboration
Discussion forums	D	Forums were established for each topic; e.g. addition & pre-number
LMS (Moodle)	S	All resources needed for online learning were available via the Moodle LMS
2011 Element Changed	TDT component	Brief description of design change
Video lectures	S	Weekly lectures were recorded using both audio (mp4) and full video (QuickTime, WMV)
ePortfolio	S	Students created an individual ePortfolio rather than a group wiki
Assessment rubric	D	Assessment rubric was modified to provide clearer feedback

Key *structural* modifications to the course design in 2010 encompassed changes to the LMS incorporating the use of podcast lectures and short video demonstrations. Key modifications to *dialogue* were the use of a virtual classroom (Wimba), forums and the Wiki (also a structural change). The university LMS was the vehicle for making content accessible and for encouraging online student engagement with both the course materials and with their peers.

The course was delivered via 11 topics organised into four modules—operations, whole numbers, fractions and problem solving, and higher order thinking. Within each module the content was further sub-divided into specific topic headings (e.g., whole number was composed of pre-number, early number, numeration, and mental computation).

The creation of the four modules allowed the content to be made “visible”; that is, opened for students to access in a systematic and meaningful way throughout the semester and this structure allowed us to significantly scaffold student learning. Feedback from students suggests to us that this structural change enhanced student understanding.

I liked the release of materials in chunks. (Student, 2010)

I've studied over thirty university subjects and this has to be the most useful, and well-presented



subject. (Student, 2010)

The learning resources for each topic were consistently presented in folders (e.g., lecture resources in one folder, tutorial resources in a second folder, supplementary resources in a third folder, etc.).

The recorded lectures and video demonstrations were critical components in relation to students' development of MPCK. Short videos were created and uploaded to the appropriate modules of the LMS: including use of manipulatives such as counters; using picture books; and demonstrations of correct language, materials, and symbols for each concept.

The final structural change was the Wiki, which was intended to be both a mechanism for students to submit their major assessment piece and also as an opportunity for students to work collaboratively in developing their mathematical understanding.

Two key changes to support student dialogue were (a) a virtual classroom (Wimba) for weekly online tutorials; and (b) 'topic based' discussion forums. Wimba is a synchronous, Java-based program that "recreates" a physical classroom environment virtually. Within this space, students and teacher can interact in real time via text, audio, and video, and also can share files and websites.

Supporting the synchronous Wimba tutorials were weekly discussion forums that mirrored the delivery structure of the 11 topics and provided further opportunities for student and teacher dialogue.

Transactional distance theory

The design changes noted above were based on our understanding of TDT, with the explicit aim of providing high levels of structure and dialogue such that a learning environment would exist where students would feel supported in learning mathematics content and pedagogy and where opportunities for meaningful collaboration were an integral component of the course structure.

Student feedback suggests we achieved these aims in varying degrees and is provided when relevant to the discussion. Table 2 provides a numerical summary of student data according to the major themes that emerged in their feedback regarding their experience of the course. In Table 2, 'n' indicates the number of students who supplied additional written feedback in their course evaluation survey; but students may have commented more than once regarding these elements hence the total numbers of responses is greater than the total number of students providing feedback.

The discussion below Table 2 examines elements of the course design, most often commented on by students over the three semesters, using the four dimensions of positive structure (+S), negative structure (-S), positive dialogue (+D), and negative dialogue (-D). An N/A indicates that the relevant theme was not relevant to the students in that particular year (e.g., changes to the online lectures in 2011 resulted in this being noted as a highly positive structural element when it had been identified in 2010 as a significant negative structural element).

Table 2
2010-2011: Dominant Themes and Frequency of Student Responses

Dominant Themes	2010 n=120 response rate 55%	2011 n = 188 response rate 49%
<i>Course elements decreasing transactional distance: (+ Structure)</i>		
Video demonstrations and digital manipulatives	45 (36%)	71 (38%)
LMS and content organisation	31 (26%)	55 (29%)
Online Lectures	N/A	119 (63%)
<i>Course elements increasing transactional distance: (- Structure)</i>		
Online lectures	27 (23%)	N/A
The Wiki / EPortfolio and ICT issues	18 (15%)	46 (24%)
<i>Course elements decreasing transactional distance: (+ Dialogue)</i>		
Supportive teaching staff (Email/phone communication forums)	87 (73%)	79 (42%)
Virtual Classroom (Wimba)	63 (53%)	134 (71%)
<i>Course elements increasing transactional distance: (- Dialogue)</i>		
Assignment Feedback	8 (7%)	39 (21%)

Structural Course Elements Decreasing Transactional Distance: (+ Structure)

Offering the course in fully online mode required a pedagogical shift in relation to the use of concrete manipulatives, a key component of the face-to-face offering, in an online environment. The key solutions to this problem were major changes to the layout of the course in an online environment and the digitisation (videoing) of our pedagogical modelling of the use of concrete manipulatives in mathematical concept development.

In relation to the course layout redesign, the university utilised Moodle as the LMS and the content space was referred to as the Study Desk. The decision to sub-divide the course learning into 11 topics and then cluster these topics into four modules was very successful and supported the developing mathematical understanding of the students throughout the semester.

The layout of the study desk was the best I have seen! Content was logically and sequentially arranged. (Student, 2010)

Course content was released to students in a carefully planned manner. The course is demanding in terms of workload and previous experience had indicated to us that students were initially anxious as to how they would complete all that was expected of them.

Student feedback to us suggests that releasing just the operations module, and then a few weeks into the course the whole number module assisted students in locating teaching videos and digital manipulatives for *just in time* rather than *just in case* learning, resulting in an increased understanding of MPCK.

I could always find what I was supposed to do, and see where resources were, and where I was supposed to be up to. (Student, 2011)

... as an online student, watching Kevin demonstrate with resources allowed me to get a visual understanding of how to use particular resources. (Student, 2011)

Digital images of the concrete resources used in the lectures and tutorials were made available to the students online. The key focus in the lectures and tutorials was the use of manipulatives to develop an appropriate constructivist pedagogy for mathematics education. Once we moved online we were acutely aware of the need to demonstrate this pedagogy to online students and so a comprehensive suite of short video demonstrations was created. These videos were well received by students -

The video demonstrations and short videos by Romina showing how to teach certain concepts were very helpful. (Student, 2010)

The extra videos made available explaining certain components in more detail and the additional resources folder with suggested websites, templates, class activities etc. were helpful. (Student, 2010)

Structural Course Elements Increasing Transactional Distance: (- Structure)

The design elements noted above are suggestive of a lowering of transactional distance, as student feedback (Table 2) indicated. Many students felt “highly supported” in their mathematics learning via the use of videos, digital manipulatives, and the highly organised structure of the course site.

However, not all design elements were positively regarded, as student feedback indicated structural problems with the online lectures and with the Moodle Wiki. The 2010 lectures were made available to students as audio only mp3 and mp4 files with accompanying PowerPoint slides. A structural problem with the lectures was that they were recorded as one large file so there were issues with (a) downloading the files; and (b) maintaining focus for long periods of time when listening to the two-hour lectures.

Just one minor thing—in the recorded lectures, I found it hard listening to the lectures in one go and I had to stop them all the time. Maybe they could be made much shorter. (Student, 2010)

A more significant issue in terms of developing MPCK was that students could not see what was being discussed with the resources during the lecture as they only received audio files. Although this was mitigated by the creation of separate video demonstrations, it was confusing for students listening to the lectures, and this detracted from their learning. This feedback resulted in a major change to lecture delivery in 2011, as students were very clear in indicating that the lecture experience would be enhanced if they could see what was occurring in the lectures.

Being a web student and only having the audio of the lectures and not being able to see what was being demonstrated at times was a little frustrating. (Student, 2010)

I was unable to view lectures and some presentations that were discussed during the lectures. I wish I could download the lectures like I could the Wimba tutorials. (Student, 2010)

In 2011, in response to the feedback we received regarding the delivery of the online lectures, the lectures delivered to the face-to-face students were made available to online students in full video format, either in streaming mode or in a format that could be downloaded and played back later on a desktop or mobile device. This format is not merely the capturing of the PowerPoint slides with audio; but involved a real-time videoing of all activity in the lectures—questions from students, demonstration of manipulatives, and so forth. Student feedback indicates that this was

highly successful, although it would be worthwhile, although impossible due to anonymous nature of the student feedback, to discuss further what the second student quoted below meant by the use of the term “active” – perhaps this is a comparison with relative inactivity in other online courses this student had participated in.

I really liked watching Romina’s lectures (Student, 2011)

It was great to see the lectures that Romina had recorded in the class setting ... made me, as an online student, feel like I was an active student (Student, 2011)

The lecture recordings were split into shorter segments so that online students could more easily download them. The shortened segments were also more likely to maintain student attention. These structural changes made to the online lectures changed this element of the course from being a strong negative impact on transactional distance in 2010 to being one of the most positive aspects of the course for students in 2011.

Student feedback indicated that the video lectures complemented the highly interactive nature of the Wimba tutorials to offer online learning experiences that facilitated student learning and their development of MPCK.

The video and tutorial lectures were most helpful and made it really feel like I was in the classroom and I am sure all this contributed to my thorough understanding in this course. (Student, 2011)

The second structural element that increased transactional distance was the use of the Moodle wiki for the assessment task. One of the structural realities of an online course is that, due to distance and time constraints, a mechanism for digital submission of student work is required. As the assessment tasks required student demonstration of resource use, it was not possible for them to submit a paper copy, so it was decided to use the university-provided wiki as the assessment submission platform. This was fraught with problems due to the unstable and complicated nature of the Moodle wiki environment; and a clear finding from the thematic examination of the data was that there were significant student concerns with the use of the wiki, related substantially to technical issues, but also to a lesser degree to the use of ICT in a mathematics education course. The wiki was not user friendly in terms of its interface and students who were unfamiliar with web-based technology required a significant amount of technical support.

I would like to question the need for the assignment to be submitted via the wiki. It created immense frustration because the program did not work properly and was extremely time consuming, one thing most of us don't have. (Student, 2010)

Too much time spent formatting the wiki due to its temperamental nature. (Student, 2010)

It is widely recognised in the literature that ICT plays an important role in the learning and teaching of mathematics (Larkin, et al., 2012). However, the technical issues evident with the use of the wiki translated into a negative experience of ICT use in mathematics education for many students. This resulted in less time for content development and in turn perhaps prompted many students to challenge the role of ICT in mathematics as evidenced by comments such as:

A lot of time was wasted formatting the WIKI instead of learning the material- it was a great time waster. Wiki software has lots of problems! Lots of time wasted on technical issues which could have been better spent on content. (Student, 2010)

Get rid of the wiki. Honestly, it was the most malfunctioning, frustrating, time consuming program there is. This is a math course, not an ICT course. (Student, 2010)

In 2011, we attempted to resolve the ICT issues associated with the university wiki by changing the platform to the university Mahara ePortfolio system in order to minimise many of the technical problems evident in the use of the wiki in 2010. Unfortunately, this design change was



unsuccessful as the system was not able to cope with the large cohort of students and crashed on the day that the assignments were due to be submitted. This caused additional angst amongst the student cohort.

Having to use a web interface to create our assignments – good in theory but not when there are more than 600 people using the system at the same time. (Student, 2011)

The e-portfolio was a nightmare for me. I felt disadvantaged due to my lack of computer knowledge and I struggled to remedy this. (Student, 2011).

Whilst not directly related to mathematics, technical issues must be resolved if students are to experience the positive advantages of online learning. Apart from the technical issues, many students across the two years of the course redesign and development expressed pedagogical concerns regarding the use of ICT in a mathematics course.

I think there was too much time wasted on creating an interactive portfolio rather than the content and mathematical knowledge. (Student, 2011)

The Mahara part of the assessment was not valid for assessing numeracy pedagogy. (Student, 2011)

The challenge of educating students in the appropriate use of ICT in education in general, and mathematics education in particular, is a real one. Many students hold views of mathematics teaching that exclude the use of ICT and these attitudes need to be challenged as increasing numbers of schools now utilise online environments to enhance student learning of mathematics. Therefore, there is a clear need to prepare pre-service teacher educators to understand how ICT and mathematics intersect (see Larkin, et al., 2012; Niess, 2009) and pre-service mathematics methods courses have a role to play in modelling effective ICT pedagogies for mathematics education.

However, what is clear from the student feedback is that ICT remains a challenge for many students both in relation to the technical issues associated with technology and also with the pedagogical issues of incorporating ICT into mathematical experiences. Unfortunately, the structural ICT issues experienced in this course over the two-year period increased the transactional distance experienced by the students in the course.

Dialogue Course Elements Decreasing Transactional Distance: (+ Dialogue)

Although technical limitations in relation to the recording of the lectures and the use of the wiki were structural elements that increased transactional distance, other ICT tools were very successful in supporting the development of positive attitudes towards mathematics and also the development of MPCK. Data presented earlier in Table 2 indicate that the course design was highly successful in supporting student dialogue. The two key dialogue elements were the use of the 'Wimba' virtual classroom and the use of forums to support student learning.

An online Wimba classroom, reproducing many elements of a face-to-face classroom, was used to provide weekly online tutorials. The virtual classroom offers a shared blackboard space upon which both students and tutors can write. Students are able to ask questions verbally or via a chat interface. There are "breakout rooms" available where students can complete group tasks before returning to the main classroom to share their findings, a similar pedagogy to having students in a face-to-face tutorial work on tasks in small groups and then report back to the whole class. The tutorials are recorded and archived and therefore available for retrieval by students who were unable to attend synchronously or for those who wished to revise content presented in the tutorial.

The Wimba tutorials were fabulous and were great to be able to listen to if you didn't attend one! Being able to listen and follow the recording was immensely valuable. These are a MUST if you, as



a university, are going to support your online students. (Student, 2010)

The effective use of Wimba moves the learning environment beyond one which merely delivers static content via an LMS, to a collaborative learning space where the joint development of mathematical understanding with the tutor and peers is a key outcome (see Van der Linden & Renshaw, 2004). The Wimba classrooms were therefore instrumental in fostering a positive experience of mathematics and in developing students' MPCK.

Wimba classes were great—live opportunity to ask questions and gain from other class members. (Student, 2010)

The Wimba tutorial was essential for online students. It was an opportunity to ask questions and practice knowledge and skills, and learn in a supportive environment. (Student, 2011)

Wimba was complemented by email and forums to further foster dialogue.

A key consideration for many students is the promptness of replies to emails or forum posts as unanswered questions can leave students feeling isolated. Many comments were made by the students, highlighting the importance of the staff in supporting their learning.

This is the most remarkable of any university subject I have ever undertaken in terms of student support from the teaching team, which prompted students to communicate with each other more. (Student, 2010)

A further positive outcome in relation to increased levels of dialogue was the impact the discussions had on the anticipated level of mathematics anxiety exhibited by many first year students studying mathematics. An overarching aim of the course was to increase student confidence, thereby reducing the anticipated high levels of anxiety, and assisting all students to begin to establish an appropriate pedagogy for mathematics education. Feedback from the students across both 2010 and 2011 suggested that the course was successful in these aims. In terms of student confidence to teach mathematics, the following student feedback is indicative of where many students felt they were in their learning journey at the start of the course and how the course may have eased some of their significant concerns regarding their ability to teach mathematics.

Doing this course improved my own understanding of numeracy and gave me an increased confidence to perform and teach numeracy in general. I'll be doing my utmost to ensure the cycle of abuse is not perpetuated. (Student, 2011)

Loved this course, learnt a lot and have changed my attitude towards mathematics—am more positive and confident now. (Student, 2011)

The anticipated effect of improving student dialogue was an accompanying improvement of student attitudes towards mathematics with the outcome being a reduction in their levels of anxiety, thus maximising the potential for student learning (Gresham, 2007).

Dialogue Course Elements Increasing Transactional Distance: (- Dialogue)

Assignment feedback was the one key element of dialogue which left room for improvement both in terms of the timing and amount of feedback and also in relation to student understanding of the assessment rubric used. The issue of timing in the 2010 iteration largely related to matters outside of the control of the teachers (major flooding in SE Qld); but the related issue of the amount of feedback suggests that students preferred more feedback than was provided on the rubric.

How do you figure that [the rubric] out? When a few words are highlighted in the 2/5 section, a



few are highlighted in the 5/5 section. Where do you come up with the results? (Student, 2010)

The lack of feedback for the assignments was very disappointing. It's hard to improve on something when you don't have any idea what you did wrong. (Student, 2011)

Although the level of feedback is also an issue in many face-to-face courses, it is exacerbated in large online courses involving numerous casual markers, as students may feel that they do not have the same level of opportunity to discuss their feedback with course teachers. The assessment rubrics used to evaluate student performance were very detailed; but many students still felt they did not receive enough feedback on their work.

Despite our best efforts to improve feedback in 2011, some students still reported lack of substantive feedback and slow turn-around time as a concern, and this was the major reported element increasing transactional distance. We acknowledge that speed and amount of feedback remained an issue; but with very large cohorts (600+ students enrolled overall with 120 and 188 enrolled fully online across the two semesters examined in this article), quick turnaround and consistency of feedback across up to 10 markers is a major challenge; especially given that results and feedback cannot be released to students until all the marking has been completed and moderated.

Additionally, and quite deliberately as a design decision, the assignments focussed on pedagogies for teaching mathematics and included concept and skill development, critiques of resources, and an intervention plan for assisting future student learning. Consequently they were more time-consuming to mark, but we felt that this type of assignment was more authentic in developing and assessing students' MPCK.

Conclusion

Over the two year period, the process of data analysis and self-reflection, facilitated the delivery of a mathematics course which, guided by TDT, was designed to provide strong structural support for students without compromising opportunities for high levels of dialogue.

Structural elements (LMS, video lectures) allowed us to model good practice by replicating many of the aspects of the course experienced by on-campus students.

This was a fantastic online learning experience. I never felt at a disadvantage to on campus students. (Student, 2011)

Dialogue was fostered via the use of the virtual classroom (Wimba), which became the focal point for online students to develop MPCK, in collaboration with their peers, as well as positive attitudes to teaching mathematics. The dialogue encouraged in Wimba was supported by regular email and forum exchanges with course teachers.

In this course, students were provided with multiple opportunities to "articulate their own emerging theories and generalisations, to formalise their ideas and to test them in the public domain" (Tanner & Jones, 2002, p. 79). The structure and dialogue elements present in this course enabled students to reflect upon their learning and to start to develop an understanding of an approach to teaching mathematics that focusses on the use of manipulatives to enhance student understanding.

A consequence of the high structure and high dialogue we provided was the development in these students of what we identify to be a necessary pedagogy for mathematics education that may slow the decline in current school students' attitudes towards mathematics evident in much of the research. The course challenged the methods of learning mathematics many of the students had experienced in their own school experience and fostered the use of manipulatives and accurate mathematical language in developing MPCK. Student comments suggest a high degree



of success in this endeavour.

This course has taught me how to do mathematics in a new light. I had to retrain my thinking. I have benefited by having a current and up to date understanding of mathematics in education. Great for confidence in the classroom. (Student, 2010)

Mathematics is something I have wanted to conquer for a while after such negative teaching of it during my own schooling; this has helped me see that Mathematics can indeed be exciting, adventurous and imaginative! (Student, 2011)

The students in the course were embedded (via high structure and high dialogue) in a mathematics community of practice that supported their learning. The design of the course was critical for many of these students as they strove to develop a more positive attitude towards mathematics. They were also provided with strong pedagogical frameworks for the teaching of mathematics, which they can build upon in subsequent mathematics courses in their primary teaching degree.

As a direct consequence of our research into the redesign of a mathematics education course, we are of the view that TDT is a very useful exploratory framework for educators considering the delivery of mathematics education courses online.

Positive, formal student evaluations over the three semesters discussed (2010–2011) clearly indicated that, via structural and dialogic modifications to the initial face-to-face course, the students experienced a positive mathematical environment such that they likely developed a more positive attitude to mathematics and began to develop an appropriate pedagogy for their future teaching of mathematics to primary school students.

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References

- Attard, C. (2011). "My favourite subject is mathematics. For some reason no-one really agrees with me": Student perspectives of mathematics teaching and learning in the upper primary classroom. *Mathematics Education Research Journal*, 23(3), 363–377. doi: 10.1007/s13394-011-0020-5
- Australian Association of Mathematics Teachers (AAMT) (2006). *Standards of excellence in teaching mathematics in Australian schools*. Retrieved from <http://www.aamt.edu.au/Activities-and-projects/Standards/Standards-document>
- Albion, P. (2008). *Virtual worlds: exploring potential for educational interaction*. Paper presented at the EDMEDIA 2008: World Conference on Educational Multimedia, Hypermedia and Telecommunications, Vienna, Austria. <http://eprints.usq.edu.au/4279/>
- Ball, D., Hill, H., & Bass, H. (2005). Knowing mathematics for teaching: Who knows mathematics well enough to teach third grade, and how can we decide? *American Educator*, 29(3), p. 14–17, 20–22, 43–46.
- Benson, R., & Samarawickrema, G. (2009). Addressing the context of e-learning: Using transactional distance theory to inform design. *Distance Education*, 30(1), 5–21. doi: <http://dx.doi.org/10.1080/01587910902845972>
- Brady, P., & Bowd, A. (2005). Mathematics anxiety, prior experience and confidence to teach mathematics among pre-service education students. *Teachers and Teaching: Theory and Practice*, 11(1), 37–46. doi: <http://dx.doi.org/10.1080/1354060042000337084>
- Brown, G. (2009). Review of education in mathematics, data science and quantitative disciplines. Report to



- the Group of Eight Universities. Retrieved from http://www.go8.edu.au/_documents/go8-policy-analysis/2010/go8Mathematicsreview.pdf
- Brown, T., Mcnamara, O., Hanley, U., & Jones, L. (1999). Primary student teachers' understanding of mathematics and its teaching. *British Educational Research Journal*, 25(3), 299322. doi: <http://dx.doi.org/10.1080/0141192990250303>
- Charnitski, C. W., & Croop, F. (2000, March). *Examining the feasibility of using computer supported collaborative work-space in pre-service mathematics methods: A Vygotskian perspective*. Paper presented at the Society for Information Technology & Teacher Education International Conference 2000, Chesapeake, VA.
- Cohen, L., Manion, L., & Morrison, K. (2002). *Research methods in education* (5th ed.). London, UK: RoutledgeFalmer.
- Commonwealth of Australia, (2008). National Numeracy Review Report. Retrieved from https://www.coag.gov.au/sites/default/files/national_numeracy_review.pdf
- Design Based Research Collective (The). (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher*, 32(1), 5-8.
- Frid, S., Goos, M., & Sparrow, L. (2008/2009). What knowledge is needed for effective teaching of mathematics? *Mathematics Teacher Education and Development*, 10, 1-3.
- Gokool-Ramdoo, S. (2008). Beyond the theoretical impasse: Extending the applications of transactional distance theory. *International Review of Research in Open and Distance Learning*, 9(3), 1-17.
- Gorsky, P., & Caspi, A. (2005). A critical analysis of transactional distance theory. *Quarterly Review of Distance Education*, 6(1), 1-11.
- Gresham, G. (2007). A study of mathematics anxiety in pre-service teachers. *Early Childhood Education Journal*, 35(2) p. 181-188. doi: 10.1007/s10643-007-0174-7
- Grootenboer, P. (2008). Mathematical belief change in prospective primary teachers. *Journal of Math Teacher Education* 11, 479-497. doi: 10.1007/s10857-008-9084-x
- Hoogland, C., Jarvis, D., & Gadanidis, G. (2003, March). 'Mathematical romance' and the online education of elementary pre-service teachers. Paper presented at the *Society for Information Technology & Teacher Education International Conference 2003*, Chesapeake, VA.
- Kawka, M., Larkin, K., & Danaher, P. (2011). Emergent Learning and Interactive Media Artworks: Parameters of Interaction for Novice Groups. *The International Review of Research in Open and Distance Learning*, 12(7), 40-55.
- Kawka, M., Larkin, K. M., & Danaher, P. (2012). Creating Flickr photo-narratives with first-year teacher education students: The possibilities and pitfalls of designing emergent learning tasks. *Australian Journal of Teacher Education*, 37(11), 1-17.
- Larkin, K., Jamieson-Proctor, R., & Finger, G. (2012). TPACK and pre-service teacher mathematics education: Defining a signature pedagogy for mathematics education using ICT and based on the metaphor "mathematics is a language". *Computers in the Schools*, 29(1-2), 207.
- Livy, S., & Vale, C. (2011). First year pre-service teachers' mathematical content knowledge: Methods of solution for a ratio question. *Mathematics Teacher Education and Development*, 13(2), 22-43.
- Ma, L. (1999). *Knowing and teaching elementary mathematics: Teachers' understanding of fundamental mathematics in China and the United States*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6), 1017-1054.
- Moore, M. (1993). Theory of transactional distance. In D. Keegan (Ed.), *Theoretical principles of distance education* (pp. 22-38). London: Routledge.
- Moore, M. G. (2007). The theory of transactional distance. In M. G. Moore (Ed.), *Handbook of distance education* (pp. 89-105). Mahwah, NJ: Lawrence Erlbaum Associates.
- Murphy, E., & Rodríguez-Manzanares, M. Á. (2008). Revisiting transactional distance theory in a context of web-based high-school distance education. *Journal of Distance Education (Online)*, 22(2), 1-13.
- Newstead, K. (1998). Aspects of children's mathematics anxiety. *Educational Studies in Mathematics*, 36(1), 53-71.
- Niess, M. (2009). Mathematics teacher TPACK standards and revising teacher preparation. Retrieved from http://math.unipa.it/~grim/21_project/Niess445-449.pdf
- Park, Y. (2011). A pedagogical framework for mobile learning: Categorizing educational applications of mobile technologies into four types. *International Review of Research in Open and Distance Learning*, 12(2), 78-102.



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- Peker, M. (2009). Pre-service teachers' teaching anxiety about mathematics and their learning styles. *Eurasia Journal of Mathematics, Science & Technology Education*, 5(4), 335-345.
- Polly, D. (2011). Examining how the enactment of TPACK varies across grade levels in mathematics. *Journal of Computers in Mathematics and Science Teaching*, 30(1), 37-59.
- Rayner, V., Pitsolantis, N., & Osana, H. (2009). Mathematics anxiety in preservice teachers: Its relationship to their conceptual and procedural knowledge of fractions. *Mathematics Education Research Journal*, 21(3), 60-85.
- Richardson, F. C., & Suinn, R. M. (1972). The mathematics anxiety rating scale: Psychometric data. *Journal of Counseling Psychology*, 19, 551-554.
- Rubinstein, H. (2009). A national strategy for mathematical sciences in Australia. University of Melbourne, Melbourne. Retrieved from <http://www.science.org.au/natcoms/nc-Mathematics/documents/National%20Strategy%20for%20Math%20Sciences%20in%20Australia.pdf>
- Tanner, H., & Jones, S. (2002). Using information and communications technology to support interactive teaching and learning on a secondary mathematics initial teacher training course. *Technology, Pedagogy and Education*, 11(1), 77-91. doi: 10.1080/14759390200200124
- Van der Linden, J., & Renshaw, P. (2004). *Dialogic learning: Shifting perspectives to learning, instruction, and teaching*. Netherlands: Kluwer.
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