Transactional Distance Theory (TDT): An Approach to Enhancing Knowledge and Reducing Anxiety of Pre-Service Teachers Studying a Mathematics Education Course Online

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This paper describes the use of transactional distance theory (TDT) as a c onceptual framework to underpin the design and delivery of a fully online first-year mathematics education methods course to pre-service teachers. It identifies key issues evident in the mathematical literature concerning mathematics education in general and pre-service teacher mathematics education in particular. It describes the use of a course design process based on data collection and reflection, course redesign, and implementation of design changes in a cyclical process to achieve course objectives.

The current state of mathematics education in Australia has been characterised as precarious (Rubinstein, 2009). The Australian Association of Mathematics Teachers (AAMT) 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. This situation does not look like improving as the number of students enrolling in higher-level mathematics courses at universities is declining (AAMT, May 2008, p. 1) . This decline is of significant concern to organisations such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Bureau of Statistics (ABS) who are experiencing difficulty in recruiting appropriately qualified graduates (Brown, 2009). The significant issues expressed concerning the need for the development of quality pre-service mathematics teacher education programs (Gresham, 2007) are potentially exacerbated by the substantial expansion, in recent years, in the number of universities offering mathematics education courses totally online or in a blended mode, where substantial communication with students and delivery of content occurs asynchronously.

Such concerns are particularly relevant to the authors in relation to the mathematics education methods course, central to this paper, which is delivered fully online. A key understanding 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 learning management systems (LMS), there has not been any accompanying emphasis on t he development of an appropriate pedagogy to support student learning online (Larkin, Jamieson-Proctor, & Finger, 2012). Given the range of issues presented in the literature, including the preparation of future primary teachers who are able to teach mathematics in a way that develops conceptual knowledge as well as procedural and declarative ways of knowing and doing mathematics; the changing landscape of higher education in terms of the delivery of mathematics courses; and the significant decline, over the past decade, of Australian students' attitudes toward mathematics; it is timely that appropriate mathematical pedagogies be designed and implemented to enhance pre-service teacher learning in mathematics methods courses (Brown, 2009).

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This article outlines a conceptual framework we used to support students studying online in order to minimise student anxiety and develop mathematics content knowledge (MCK) and mathematics pedagogical content knowledge (MPCK). This paper is a scholarly enquiry in progress and reports on the design changes we have made to date, based on our research, to reduce transactional distance and as such comprehensive data analysis and discussion will be presented in future publications.

Literature Review

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), responsible for teacher registration, has clear expectations that graduating students 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.

There exists a large body of research concerning the development of quality graduates and, whilst it is a contested topic, much of the research in relation to pre-service mathematics education has focused on the importance of developing pedagogical content knowledge (PCK) (see Chick, Baker, Pham, & Cheng, 2006; Larkin, Jamieson-Proctor, & Finger, 2012), and PCK is recognised as a critical ingredient in quality mathematics teaching (Ball, Hill, & Bass, 2005; Ma, 1999). In addition, recent research by Livy and Vale (2011) suggests that a further sub-division of PCK may be helpful in exploring the types of knowledge teachers require to be effective mathematics teachers. Building upon the work of Ball et al. (2005) and Chick et al. (2006) they suggest that mathematics teachers require deep mathematical content knowledge and also pedagogical knowledge specific to mathematics content. To be consistent with the naming convention in the literature, we refer to the deep knowledge of mathematics content as MCK and the appropriate pedagogy for teaching mathematics as MPCK.

Developing student MCK and MPCK is a key aim of the methods course discussed here and is critical in the development of graduates with a profound understanding of fundamental mathematics (PUFM) (Ma, 1999). Our investigation of the literature suggests that a key inhibitor to an overall successful experience of pre-service mathematics education and the development of MCK and MPCK is the high level of mathematics anxiety evident in many pre-service educators (Grootenboer, 2008). It is our contention that addressing the issue of anxiety in pre-service educators is essential as self-confidence and self-efficacy are fundamental for the development of MCK and MPCK (Rayner, Pitsolantis, & Osana, 2009).

Anxiety Defined

Anxiety concerning teaching mathematics is common among pre-service educators and may reflect perceived and real deficits in personal levels of numeracy; deficits in pedagogical skills; and also 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).

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 interfere with Mathematics performance and inhibit subsequent learning" (p. 182). Mathematics anxiety also manifests in terms of discomfort towards the teaching of mathematical concepts, theories, or formulas or during problem-solving tasks (Peker, 2009).

Whilst mathematics anxiety exists in the general student population, it appears to be much more prevalent in pre-service education students (Peker, 2009). Brown, Mcnamara, Hanley, and Jones (1999) confirmed widespread anxieties among the pre-service education students in their study concerning their own learning of mathematics during their schooling and also concerns with the prospect of teaching the subject. Pre-service primary school teachers had the highest level of mathematics teaching anxiety (Peker, 2009). In somewhat of a "double whammy", mathematics anxious pre-service educators are also 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, Pitsolantis, and Osana (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 to pre-service educators in both face-to-face and online modes.

Impacts of anxiety on student learning in mathematics.

Whilst mathematics anxiety may cause difficulty for pre-service educators it is also a cause for greater concern in relation to its negative impact on a teacher's effectiveness in the classroom (Gresham, 2007; McCulluch Vinson, 2001), as anxiety transfers from teacher to students, and, second, mathematics-anxious teachers are likely to use fewer and less effective instructional techniques (Brady & Bowd, 2005). McCulluch Vinson (2001) reports that a failure to provide positive mathematical experiences to students resulted in the learning of math-anxious behaviours. Furthermore, mathematics-anxious university students avoided courses requiring either moderate or high mathematics pre-requisites, suggesting that mathematics anxiety is a significant factor in career choice (Rayner, Pitsolantis, & Osana, 2009).

In summary, the literature suggests a crisis in mathematics education in terms of the development of conceptual, procedural, and declarative knowledge of pre-service educators (PUFM). Accompanying the concerns regarding mathematical knowledge are concerns related to the development of positive attitudes to mathematics, and beliefs about how mathematics should be taught (Pedro Da Ponte, Oliveira, & Varandas, 2002). Teaching and learning are collegial activities and thus pre-service educators develop positive attitudes towards mathematics both individually and in collaboration with other learners. A major design challenge in our online mathematics methods course was not only the development of MCK and MPCK but also the provision of opportunities for dialogue with peers as well as teachers. It was hypothesised that, in such a collegial environment, student anxiety would 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. Transactional distance theory (TDT) appeared to meet our design needs.

Transactional Distance Theory

In defining a theory for distance education, Moore (1993) suggested that transactional distance is not defined in terms of geographical distance, but rather it is a pedagogical concept encompassing the separation of learners and teachers by time and space. Transactional distance is the “psychological and communications space” (Moore, 1993, p. 22) that occurs between learners and teachers and is shaped by the environment and by the patterns of activity of individuals within the environment. TDT encompasses all the types of educational approaches currently in use in higher education, namely face-to-face, blended, or fully 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 between learners; and the level of autonomy of the individual learner. Deliberative teaching strategies are located within the variables of structure and dialogue, with learner autonomy the independent variable (Moore, 2007).

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 that is defined as a positive interaction “which is purposeful, constructive and valued by each party” (Moore, 1993, p. 24). It is recognised 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 program, or course within a 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.

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). Moore further suggested that there is a “relationship between dialogue, structure and learner autonomy, for 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, an inverse relationship 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-Ramdoo, 2008).

Manipulations of these elements increase or decrease transactional distance, which in turn demands more or less autonomy from students in managing their learning (Gokool-Ramdoo, 2008). Research by Benson and Samarawickrema (2009) suggests that online learners in the early years of a program demonstrate low levels of autonomy and thus require, at a minimum, high levels of structure in order to limit transactional distance. This was not the case with more mature learners who were more able to manage their own learning and the social construction of knowledge through peer-to-peer and learner-to-teacher networks. As a result, 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). Recognising the impact of new Web 2.0 technologies, Park (2011) suggests a new understanding of TDT that incorporates both individual and collective activities facilitated by emergent social technologies such as Flickr, Twitter, and Facebook. These 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).

Whilst generally well received in the academic literature, there have been concerns expressed in some recent articles regarding the usefulness of TDT. 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 is 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 the concerns of both Gorsky and Capsi (2005) and Murphy and Rodriguez-Manzanares (2008), in our view, TDT is a useful and appropriate framework for analysing our learning and teaching environment (first-year students, high levels of anxiety concerning mathematics, potentially weak mathematical backgrounds, studying online) and then determining the correct balance of dialogue and structure which match the projected level of learner autonomy. This claim is based on the use of TDT in a number of studies investigating distance education (Albion, 2008) and its use by the lead author in research investigating pre-service education in blended and online environments (Kawka, Larkin & Danaher, 2011; 2012). As further data are collected and analysed we will be able to more fully evaluate the efficacy of TDT for mathematics education in blended and online environments.

Methodology

Our guiding research question was: *How can an online mathematics methods course be designed to minimise transactional distance between teacher and learner and learner and learner, in order for pre-service teachers to develop appropriate attitudes and competencies for teaching mathematics?* Our primary goal was to ensure students developed MCK and MPCK when they studied the mathematics methods course online. Major modifications were required to the existing face-to-face, on-campus course to reduce TD and attain an effective balance among dialogue, structure, and learner autonomy. An action research approach was used to direct modifications to the course to facilitate high levels of structure and dialogue in order to develop MCK and MPCK and reduce students' anxiety about the learning and teaching of mathematics. The action research cycle of data collection and reflection, course re-design, and implementation of design changes was followed across three semesters to make on-going course modifications with the overall aim of enhancing student learning outcomes. This is an authentic research approach in mathematics education (Sakshaug & Wohlhuter, 2010) as individuals involved in a teaching context are best placed to identify, at the local level, changes which need to be made to improve learning and teaching (Cohen, Manion, & Morrison, 2002). By way of example, Table 1 indicates initial changes to the course design that resulted from our understanding of how the TDT elements of structure and dialogue could be modified to reduce student anxiety and improve MCK and MPCK.

Table 1
Initial TDT Design Modifications

Element Modified	TDT component	Brief description of modification
Online lectures	S	Lectures podcasts were created for later download by students in mp3 and mp4 format
Video demonstrations	S	A series of videos were made demonstrating use of Mathematics materials for teaching e.g., using MAB blocks, story books
ePortfolio	S & D	Students created an individual ePortfolio (using Mahara software) outlining their mathematical learning.
Virtual Classrooms (Wimba)	S & D	Virtual classrooms were used on a weekly basis for online tutorials and as meeting spaces for student collaboration.
Forums	D	Forums were established for each concept e.g. Addition, Subtraction, Algebra, or Decimal Fractions
LMS (Moodle)	S	All resources needed for online learning were available via the LMS e.g., videos / podcasts noted above

Data were collected from students at the conclusion of each of three semesters via the formal Student Evaluation of Course (SEC) process conducted by the university. Each student statement 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). Following this, key themes in the data were extracted. Presented below are two examples of the process in action. *"The Wimba tutorials were fabulous! Web students then get the same amount of support as on-campus students"* (Student 2010) was coded as +D and themed as virtual classroom (Wimba). *"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 and +D and themed as LMS and course organisation and virtual classroom (Wimba). At this juncture these initial examples serve only as an indication of how future data will be coded and as this is a report of an on-going research project, final data analysis has not been conducted. Thus, interpretation of data is ongoing at this time.

Future Directions

The focus of this paper's methodology section is to explain how we collected the data and analysed it to make initial modifications to the course. The research is on-going. In future articles we will present comprehensive details of our data analysis collected across the three semesters of design, implementation, and reflection, as well as the research findings. Early indications suggest however, the course modifications have been successful in attaining two of our significant goals of the course: reducing student anxiety regarding learning and teaching mathematics; and the establishment of an appropriate level of MCK and MPCK for first-year teacher education students. As further data is collected and analysed we will be able to further determine the usefulness or otherwise of TDT as a conceptual framework.

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