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TELPS: A method for analysing mathematics pre-service teachers' Pedagogical Content Knowledge

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HIGHLIGHTS

- A survey to analyse pre-service mathematics teachers' PCK is introduced.
- Pre-service teachers analysis of lesson plans is used to determine PCK.
- The survey indicates changes in elements of PCK can be determined over time.

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ABSTRACT

A pre-service teacher's Pedagogical Content Knowledge (PCK) and their personal constructs of teaching develop throughout their teacher education program. PCK integrates generic pedagogical knowledge, mathematical teaching methodology and knowledge of the discipline of mathematics and this paper reports on a survey that can be used to assess a pre-service teacher's PCK. TELPS (Teacher Education Lesson Plan Survey) was developed to determine the PCK of pre-service teachers during their teacher education program. TELPS is shown to analyse pre-service teachers' PCK with some indication that the pre-service teacher's development of PCK can be observed.

1. Introduction

Pre-service mathematics teachers begin their teacher education program with beliefs and ideas about teaching mathematics that are well established by their own experience in school (Barkatsas & Malone, 2005). During their teacher education program the pre-service teachers are exposed to many new ideas, expanding both their knowledge about teaching mathematics and content knowledge. They generally excelled in the classroom environments of their own education and so, at the beginning of their program, often believe that a good teacher will teach as they were taught (Wilson, Cooney, & Stinson, 2005). University teacher education programs seek to broaden and deepen their assumed model of good teaching. To explore this process we developed the Teacher Education Lesson Plan Survey (TELPS). This survey uses the pre-service teachers' analysis of mathematics lesson plans for insight into their Pedagogical Content Knowledge (Shulman, 1986). While other research projects analyse teachers' Pedagogical Content Knowledge (PCK) with classical test items (e. g. Krauss, Neubrand, Blum, & Baumert, 2008), TELPS uses an adapted Repertory-Grid Method (Kelly, 1955) which is a psychoanalytical method that establishes peoples' constructs by comparing objects in a standardised way. The advantage of using Repertory-Grid is the ability to analyse the data in a nomothetic as well as in an ideographical way (Scheer, 1996). Thus, TELPS can explore the development of mathematics teachers' PCK during their teacher education program to find individual phenomena in their development of PCK or phenomena in connection with their teacher education program. We use TELPS to measure the personal constructs (Kelly, 1955) of Australian and German pre-service teachers about mathematics lesson plans during their teacher education program. Hence, TELPS will help us to answer the following research question:

Can TELPS measure pre-service teachers' PCK through their analysis of lesson plans?

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To answer this question TELPS should be able to show a variety of PCK elements that fit into other definitions of PCK (e.g. Ball, Hill, & Bass, 2005; Shulman, 1986).

This article focuses on presenting TELPS as a new way of analysing mathematics teacher's PCK. We will explain the theoretical framework of the TELPS, present first results as an example of data analysis, and discuss the quality criteria of this survey by using the early results of TELPS at two universities in different countries with different teacher education programs.

1.1. Pedagogical Content Knowledge

Content knowledge is a necessary but not sufficient condition for good teaching. Mathematics teaching needs more than knowledge of content (e.g. Ball et al., 2005; Goulding & Suggate, 2001; Mewborn, 2001; Shulman, 1986), because teachers need to recognise that an answer is incorrect (or correct), analyse the source of any errors and then work with the student to improve the mathematics. It involves choosing appropriate examples and exercises and sequencing these so that students are guided in their learning. Developing alternative representations of the mathematics is a major part of teaching. Consequently, planning a mathematics lesson includes these requirements of teaching. Shulman (1986) defined the knowledge needed to cope with the challenge of teaching into three categories of teachers' content knowledge: Subject Matter Content Knowledge, Pedagogical Knowledge and Pedagogical Content Knowledge (PCK). The knowledge of designing 'good' mathematic lessons is a part of Pedagogical Content Knowledge (PCK), because Shulman (1986) defined it as

> "the distinctive bodies of knowledge for teaching. It represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented and adapted to the diverse interests and abilities of learners, and presented for instruction" (p. 8).

PCK is an integration of generic pedagogical knowledge, mathematical teaching methodology and knowledge of the discipline of mathematics (Lim-Teo, Chua, Cheang, & Yeo, 2007; Shulman, 1986; Stacey et al., 2001).

Shulman's theory of teacher knowledge is the foundation of many research projects on mathematics teacher education. For example, the COACTIV project in Germany (Baumert et al., 2010), the 'Michigan Group' in USA (Hill, Ball, & Schilling, 2008), Lim-Teo's group in Singapore (Cheang et al., 2007; Lim-Teo et al., 2007), and the international comparative study, TEDS-M, which examined how different countries prepare their teachers to teach mathematics in primary and lower-secondary mathematics (Schmidt, Blömeke, & Tatto, 2011), each consider different aspects of PCK.

The relationship between Subject Matter Knowledge (SMK) and the PCK required for teaching is still not fully understood. Pre-service teachers who had several representations for mathematical ideas and whose knowledge was already richly linked were able to draw upon them both in planning and in spontaneous teaching interactions (Huckstep, Rowland, & Thwaites, 2002). However, the boundaries between SMK and PCK may well be blurred and a deep understanding of both is important. Consequently, Kahan, Cooper, and Bethea (2003) believe that mathematicians, whose content knowledge is without question, may not necessarily possess PCK because so many additional attributes are needed. The results of Wong and Lai (2006) further support these findings, because they show no statistical relationship between PCK and SMK. Blömeke, Houng, and Suhl (2011) were also able to differentiate PCK from SMK.

Hill et al. (2008) broaden the Shulman definitions by proposing a model of mathematical knowledge for teaching by further dividing Subject Matter Knowledge and Pedagogical Content Knowledge (Fig. 1). In mathematics, Subject Matter Knowledge includes the Common Content Knowledge (CCK) and the Specialised Content Knowledge (SPK) that one would expect a teacher to know, but also includes Knowledge at the Mathematics Horizon which Ball and Bass (2009) define as "a kind of mathematical 'peripheral vision', a view of the larger mathematical landscape, … in which the present experience and instruction is situated" (p. 6).

Hill et al. (2008) also further divide Shulman's PCK (Fig. 1). In order to prepare and teach a lesson, a teacher must be capable of putting in place all the partitions of PCK: namely the Knowledge of Content and Students (KCS), the Knowledge of Content and Teaching (KCT), and the Knowledge of the Curriculum.

There are problems in detecting the PCK of the mathematics teachers. A teacher's ability to know that students often make errors at certain points in a topic is linked with the teacher's reasoning about what students are thinking or doing. PCK is complicated and Hill et al. (2008) suggest the importance of explicit criteria to measure conceptualisation and development of PCK. A number of researchers analyse mathematics teachers' PCK using different instruments; for example, COACTIV (Baumert et al., 2010), TEDS-M (Schmidt et al., 2011), and the studies of Hill et al. (2008), with multiple-choice and open questions to learn about teacher's knowledge.

Rowan, Schilling, Ball, and Miller (2001) surveyed teachers' PCK using a bank of items in reading/language arts and mathematics. They used classroom scenarios in a multiple-choice survey to differentiate between content knowledge, knowledge of students' thinking and knowledge of pedagogical strategies. Their results were mixed because of difficulties in developing scenarios and writing the items, and their use of a small sample (this study reported a pilot), but they do indicate the possibility of measuring particular facets of teachers' PCK.

Wong and Lai (2006) used direct observation of pre-service primary teachers in schools and the lesson plans they used in the teaching. They found that the pre-service teachers who were further through their course had better results in PCK than those in the early years, suggesting PCK improves as the pre-service teacher progresses through the course.

1.2. Developing a survey to measure PCK

PCK is a very complex construct with different levels. Thus, we used lesson planning via TELPS to cover the general ideas of designing a mathematics lesson. These general ideas of

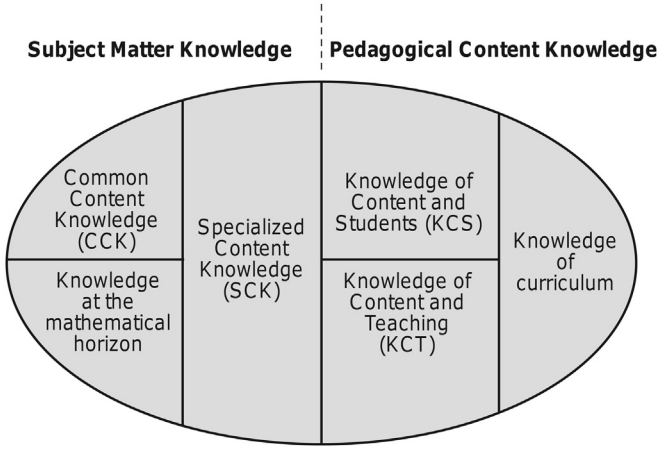

Fig. 1. Domain map for mathematical knowledge for teaching (Hill et al., 2008, p. 377).