A Confirmatory Factor Analysis of Mathematics Teachers' Professional Competences (MTPC) in a Mongolian Context

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ABSTRACT

This study aimed to determine and validate a version of the MTPC with 4 belief, 4 knowledge, 4 practice, and 3 attitude items. The sample size of the study was 218 participants. Structural equation modeling (SEM) was used to analyze research data. The results of the study revealed that after deleting 3 items of attitude, a 3-factor model was validated and well fit the research data. Therefore, the model best fits the Mongolian context in comparison to other models.

Keywords: Mathematics Teachers' Professional Competences (MTPC), Mongolia, 3-factor correlated model for MTPC

INTRODUCTION

There has been a great deal of interest that in model to cognitive and affective domain in the education of teachers over many years. Perhaps a critical moment in the attention and study of affect was associated with the investigation of issues related to professional knowledge of teachers starting in the middle 1980's (e.g. Leinhart and Smith, 1985; Shulman, 1986). Shulman (1986) defined the professional knowledge of teachers as four facets: content knowledge, pedagogical content knowledge, curricular knowledge and generic pedagogical knowledge.

The broader and more comprehensive term as "teachers' professional competence" is now more commonly used. There are many different kinds of competences in the research (Gupta, 1999; Weinert, 2001; Deakin, 2008). A competence is described as "a complex combination of knowledge, skills, understanding, values, attitudes and desire which lead to effective, embodied human action in the world, in a particular domain" (Deakin, 2008). Teacher's competences imply systemic view of teacher professionalism, on multiple levels – the individual, the school, the local community and professional networks. … Components of teacher's competencies define - knowledge and understanding, skills and dispositions (OECD, 2013). Teacher's competence is defined as a combination of professional knowledge, skill, experience and attitude for teaching. It is divided into three components as follows individual, professional and social. The general framework related to teacher's professional competencies is explained based on three fields such as learning and teaching, communication, and research competencies (Munkhjargal, 2013).

In this study the factors that MTPC were determined and explored. This study sought to answer the following research question: What are the suitable model those factors of MTPC?

A LITERATURE REVIEW

At the beginning of this century, "Mathematics Teacher Tetrahedron" model was developed based on the Theory of Learning (Luvsandorj et al., 2003). The model consists of side competences, which are disposition, introduction to mathematics, introduction to mathematics didactics, and teacher professional knowledge. They believed that the content of potential was comprised of only knowledge, and the content of knowledge was comprised of only skills and abilities.

Döhrmann et al. (2012) considered mathematics teachers' professional competencies in terms of cognitive and affective-motivational facets. They divided cognitive abilities (professional knowledge) into three sections as *content knowledge, general pedagogical knowledge* and *pedagogical content knowledge* (PCK), and affective-motivational characteristics into two sections as teachers' professional beliefs and, motivation and self-regulation. Given

Contribution of this paper to the literature

- This study aims to investigate the suitable model of mathematics teacher in the Mongolian context.
- In this study framework MTPC were determined and explored.
- Results of analysis looked that 3-factor correlated model for MTPC is best fit with the Mongolian context: teacher knowledge, teacher belief and teacher practice.

framework became theoretical basis of the international study called "Teacher Education and Development Study in Mathematics (TEDS-M)".

Moreover, there are many research papers about knowledge, skill, attitudes and practices related to mathematics teacher's professional competencies (Ernest, 1989; Grossman, 1990; Fennema and Franke, 1992; Koehlor and Grouws, 1992; An et al., 2004; Attoprs, 2006; Sandt, 2007; Ball, 2009; Leong, 2013; etc.).

Koehlor and Grouws (1992) proposed framework on mathematics teacher behavior. Based on their works, Sandt (2007) revised and developed the framework. They note that teacher's behavior is influenced by the three factors: teacher knowledge, teacher attitudes and beliefs about teaching and mathematics. Each factor consists of many components. Four components distinguished in teachers' knowledge consist of teacher's knowledge of student learning, subject content knowledge, pedagogical knowledge and curriculum knowledge. Teachers' belief is the second factor and consists of four components: learning of mathematics, teaching of mathematics, nature mathematics and students as learners. Teachers' attitude is the third factor and consists of a teacher's attitude towards mathematics, teaching of mathematics and teacher's attitude towards students.

Leong (2013) divided different kinds of knowledge are needed by teachers to be effective such as: 1) content knowledge (Shulman, 1986); 2) pedagogical content knowledge (PCK) (Shulman, 1986); 3) theory of knowledge (Schoenfeld, 1998); 4) teacher knowledge and its impact (Fennema and Franke, 1992); and 5) mathematics knowledge for teaching (Ball & Bass, 2004) and for elementary school teachers and their content knowledge (Ball, 2004, 2007; Brown and Borko, 1992; Ma, 1999).

Ball and Sleep (2007) developed the notion of mathematical knowledge for teaching (MKT) a practice-based framework focused on both what teachers do as they teach mathematics, and what knowledge and skills teachers need in order to be able to teach mathematics effectively. MKT defined as "mathematical knowledge needed to carry out the work of teaching mathematics" (Ball, 2009) to bridge the gap in good teaching. The researchers divided MKT into two broad categories – subject matter knowledge (SMK) and pedagogical content knowledge (PCK). SMK has been divided into common content knowledge, specialized content knowledge, and horizon content knowledge. And PCK comprised of divisions knowledge of content and students, knowledge of content and teaching and knowledge of content and curriculum. Each division refers to a hypothesized type of mathematical knowledge that is needed by teachers.

AAMT (2006) described the knowledge, skills and attributes required for good teaching of mathematics and developed Standards for Excellence in Teaching Mathematics in Australian School. The standards are organized into three domains: professional knowledge, attributes and practice.

MATHEMATICS TEACHERS' PROFESSIONAL COMPETENCES (MTPC)

The MTPC, based on Döhrmann's et al., (2012) theories, are presented from four factors: teacher knowledge, teacher beliefs, teacher attitude and teacher practice. First three factors, which are teacher knowledge, teacher beliefs and teacher attitude, were proposed by Sandt (2007) and other one, teacher practice, was proposed by AAMT (2006).

Teacher Knowledge

The author agreed with Sandt (2007) that teacher knowledge is a large, integrated, functioning system and is an important indicator of overall teacher effectiveness. The knowledge divides into four components: mathematics content knowledge, pedagogical content knowledge, curricular knowledge and teachers' knowledge of student learning.

The first component, *mathematics content knowledge,* is knowledge of the subject and its organizing structures (Shulman, 1987). Leong (2013) believes (according to the National Council of Teachers of Mathematics, 1991), mathematics content knowledge is described as: "The content and discourse of mathematics, including mathematical concepts and procedures and the connections among them; multiple representations of mathematical concepts and procedures; ways to reason mathematically, solve problems, and communicate mathematics effectively at different levels of formality".

Table 1. Categories of teacher beliefs (Beswick, 2005)

Beliefs about the nature of mathematics (Ernest, 1989)	Beliefs about mathematics teaching (Van Zoest et al. 1994)	Beliefs about mathematics learning (Ernest, 1989)
Instrumentalist	Content focused with an emphasis on performance	Skill mastery, passive reception of knowledge
Platonist	Content focused with an emphasis on understanding	Active construction of understanding
Problem solving	Learner focused	Autonomous exploration of own interests

The second component, *pedagogical content knowledge,* the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations — in a word, the most useful ways of representing and formulating the subject that make it comprehensible to others... Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons (Shulman, 1986).

The third component, *curricular knowledge*, is knowledge of texts and scheme used to teach mathematics, their contents and ways to use them; school produced curriculum materials; other teaching resources and teaching apparatus; examinations; tests and syllabi (Turner-Bisset, 2001). Curriculum knowledge is explicitly added to the model as knowledge of the subject content (concepts, procedures) and knowledge of different ways of presenting the content (pedagogical knowledge) does not guarantee knowledge of different and effective teaching and assessment resources such as computer software (Sandt, 2007).

The fourth component, *knowledge of students* (teachers' knowledge of student learning), is conceptions, learning difficulties, styles, misconceptions and errors (Ball & Bass, 2000).

Teacher Beliefs

Beliefs defined as one's personal views, conceptions and theories (Thompson, 1992). Teacher beliefs are crucial for the perception of classroom situations and for decisions on how to act (Schoenfeld, 2010). Teacher beliefs consist of nature of mathematics, mathematics teaching, mathematics learning and students as learners (Sandt, 2007).

Ernest (1989) defined teachers' beliefs about the *nature of mathematics* are conscious or subconscious beliefs, concepts, meanings, rules, mental images, and preferences concerning the nature of mathematics. He described three categories of teacher beliefs about the nature of mathematics. In Instrumentalist view, mathematics is seen as "an accumulation of facts, skills and rules to be used in the pursuance of some external end". The Platonist view sees mathematics as a static body of unified, pre-existing knowledge awaiting discovery. In the problem solving view in which mathematics is regarded as a dynamic and creative human invention. Beswick (2005) summarized connections among Ernest's (1989) categories of beliefs about the nature of mathematics, an adaptation of the corresponding categories that he proposed for beliefs about mathematics learning, and Van Zoest, Jones and Thornton's (1994) categories relating to mathematics teaching – as presented in **Table 1**.

Sandt (2007) describes a component of students as learners. The component includes beliefs about differences in individuals or groups of learners regarding the learners' talent for mathematics and learners' intellectual abilities to successfully learn mathematics.

Teacher Attitude

Attitudes are defined as internal beliefs that influence personal actions. The attitude is learned indirectly through one's experience and exposures (Schunk, 1996). Teachers' attitude consists of a teachers' attitude to mathematics, the teaching of mathematics and towards students (Sandt, 2007). Teachers' attitudes to *mathematics* may influence their enthusiasm and confidence to teaching the subject. This in turn may affect the classroom ethos and consequently affect their students' perceptions of mathematics (Ernest, 1989). Teachers' attitude to the *teaching of mathematics* include liking, enjoyment and enthusiasm for the teaching of mathematics, and confidence in the teacher's own mathematics teaching abilities (Ernest, 1989). Attitude *towards students* is attitudes teachers towards individual learners, groups or classes of learners (Sandt, 2007).

Teacher Practice

In factor of teacher practice, AAMT (2006) defined that excellent teachers of mathematics are purposeful in making a positive difference to the learning outcomes, both cognitive and affective of the students they teach. They are sensitive and responsive to all aspects of the context in which they teach. This is reflected in the learning environments they establish, the lessons they plan, their uses of technologies and other resources, their teaching practices, and the ways in which they assess and report on student learning. The teacher practice includes four components: the learning environment, planning for learning, teaching in action and student assessment.

Table 2. Demographical Data

Variable	Description	Number	Percentage
Sex	Male	69	31.9%
	Female	147	68.1%
Education degree	Doctor	10	4.6%
	Master	65	30.1%
	Bachelor	141	65.3%
Teacher experience (year)	Above 26	24	11.1%
	Between 21 – 25	24	11.1%
	Between 16 – 20	20	9.3%
	Between 11 – 15	42	19.4%
	Between 6 – 10	49	22.7%
	Between 2 – 5	43	19.9%
	Between 0 – 1	14	6.5%
Geographics of teacher work	Capital (Ulaanbaatar)	96	44.4%
	City (Center of Province)	68	31.5%
	Sum (village)	52	24.1%

METHODOLOGY

Population and Sample

The secondary mathematics teachers, specialists of mathematics in provinces, specialists Mongolian Institute for Educational Research, Teachers Development Center and lecturers of mathematics education of universities with mathematics teachers' preparation programs in Mongolia constitute the population. Present time in Mongolia are working 2449 secondary mathematics teachers (in 22 provinces), 22 specialists of mathematics in provinces and 69 mathematics lectures of university with mathematics teachers' preparation programs in Mongolia constitute the population (MECS, 2016). The sample of the study includes 198 secondary mathematics teachers of 21 provinces, 11 specialist and 7 lecturers. To promote the generalizability of results from the sample to secondary mathematics teachers in population in each province in Mongolia were chosen for study. The background of participants summarized in **Table 2**.

Instrument

The survey tool was two sections, section A covers demographic data and section B comprises 15 items. The section A asked participants to identify their sex, education degree and teacher experience, geographic of teacher work. The section B of the questionnaire was composed of the 15 items that measured four factors: teacher knowledge, teacher beliefs, teacher practice and teacher attitude. **Table 3** lists the dependent variables and the items measuring these variables. Responses to these items were measured using a 7-point Likert scale anchored between (1) strongly disagree to (7) strongly agree.

Table 3. Descriptive statistics of MTPC items

Number Items	Note Items	Variable	M	SD	SKEW	KURT
	Teacher knowledge					
1.	K1	Mathematics content knowledge	6.58	0.53	-0.695	-0.746
2.	K2	Pedagogical content knowledge	6.62	0.54	-1.027	0.014
3.	K3	Curricular knowledge	6.41	0.64	-0.736	0.042
4.	K4	Knowledge of student learning	6.40	0.62	-0.550	-0.608
	Teacher beliefs					
5.	B1	Nature of mathematics	6.53	0.62	-1.089	0.682
6.	B2	Learning of mathematics	6.46	0.62	-0.803	0.275
7.	B3	Teaching of mathematics	6.47	0.65	-0.839	-0.379
8.	B4	Students as learners	6.32	0.74	-0.739	-0.313
	Teacher practice					
9.	P1	Learning environment	6.32	0.68	-0.663	0.107
10.	P2	Planning for learning	6.58	0.59	-1.087	0.190
11.	P3	Teaching in action	6.62	0.57	-1.352	1.641
12.	P4	Student assessment	6.44	0.68	-0.987	0.449
	Teacher attitude					
13.	A1	Attitude towards mathematics	6.65	0.57	-1.527	2.190
14.	A2	Attitude to the teaching mathematics	6.64	0.54	-1.180	0.410
15.	A3	Attitude towards students	6.57	0.56	-0.917	-0.161

Data Collection Procedures

Data were collected in June and August 2016. The study was carried out in different phases. First, sample of the study were selected. Then, in June data collected from specialists and lecturers of mathematics education and in August from secondary mathematics teachers. Each participant in survey was to filled instrument and conducted in paper version. Next, the instrument filled out by each participant was coded. One numerical code was assigned to each participant. Later, the data entered into SPSS and in line with research questions, appropriate statistical procedures were applied.

Data Analyses

The study used descriptive statistics and confirmatory factor analysis to validate the underlying hypothesized factor structure of MTPC. The items of the MTPC were represented by measured or observed variables.

RESULTS

Descriptive Statistics of MTPC Items

A descriptive statistics was performed using SPSS 21.0. The MTPC items were treated as observed variables. First, the data were subjected to tests of multivariate normality. The skewness and the kurtosis of the distribution ranged from – 1.527 to – 0.550 and from – 0.726 to 2.190 respectively. These satisfy the working guideline that the absolute values of skewness and kurtosis are less than 3 and 8 respectively (Kline, 2010). Missing responses were less than 3%, and to avoid considerable loss in sample size in this multivariate setting and to maintain the consistence of the sample base, missing responses were replaced by the mean values of the corresponding items. We consider, that if mean value is equal or greater than 5.8, which means 80%, as a good mean.

There were four items in the teacher knowledge factor, relate to subject content knowledge, pedagogical content knowledge, curricular knowledge and teachers' knowledge of student learning. The means, are good indicators, suggest that the participants were clearly aware and convinced of the knowledge.

The four items in the teacher beliefs included to beliefs about the nature of mathematics, the learning of mathematics, the teaching of mathematics and their students as learners. The participants showed an inclination to respond to this category with means, were good indicators, with the exception of item B4. B4 had the lowest mean, and participants generally beliefs about their students as learners did low influence in teacher beliefs.

There were four items in the teacher practice, and they referred to learning environment, planning for learning, teaching in action and student assessment. The means of items of teacher attitude ranged from 6.32 to 6.62 and there were had high index. Participants were given a high priority to these items.

Table 4. Fit Indices for Eight Models

	χ^2	df	χ^2/df	RMSEA	GFI	CFI	AGFI	TLI
Single factor	219.0	90	2.2	0.076	0.885	0.863	0.847	0.841
Single factor (deleted 3 items of attitude)	114.8	54	2.1	0.072	0.912	0.903	0.874	0.881
3 factor correlated (deleted 3 items of attitude)	73.5	51	1.4	0.045	0.943	0.964	0.913	0.953
3 factor uncorrelated (deleted 3 items of attitude)	247.0	54	4.6	0.129	0.837	0.691	0.764	0.623
3 factor correlated (a factor with belief and attitude)	159.7	87	1.8	0.062	0.907	0.911	0.871	0.893
3 factor uncorrelated (a factor with belief and attitude)	365.6	90	4.1	0.119	0.814	0.664	0.752	0.608
4 factor correlated	133.1	84	1.6	0.052	0.921	0.940	0.887	0.925
4 factor uncorrelated	385.2	90	4.3	0.124	0.783	0.640	0.711	0.580

The teacher attitude factor with means in the ranged from 6.57 to 6.65. In general, these participants showed high attitude to continue studying it.

Reliability

To assess internal consistency, Cronbach's alpha coefficients for the subscales were estimated using SPSS 21.0. These values were larger than the cut-off point of 0.70 for reliability (Hair et al, 2010). Cronbach's alpha values were obtained for the overall scale (0.857) and all the subscales: Knowledge (0.747), Belief (0.719), Practice (0.717) and Attitude (0.629).

Confirmatory Factor Analysis

Confirmatory factor analysis (CFA) is often employed to test whether a hypothesized factor structure is supported by the data. The simplest structure is the one-factor model, when the observed variables load onto a single factor, but alternative structures are also tested to find a good model to fit the data (Abdul et al., 2013).

In this study, the three subscales of MTPC were an acceptable value of internal consistency. Hence, a 3-factor correlated (deleted items of attitude) model was tested. This model was compared to 2 single-factor models, a 3-factor uncorrelated model, and 2 four-factor correlated and uncorrelated models (**Table 4**).

Seven indices are commonly used to examine model fit, and these are shown in **Table 4**: χ^2 (chi-square), χ^2/df (chi-square with degrees of freedom), RMSEA (root mean square error of approximation), GFI (goodness-of-fit index), CFI (comparative fit index), AGFI (adjusted goodness-of-fit index) and TLI (Tucker-Lewis index). There is disagreement in the literature about the criteria used to establish goodness of fit (Hooper, Coughlan and Mullen, 2008). Among these criteria are the following.

The Chi-Square value is assesses the magnitude of discrepancy between the sample and fitted covariance matrices (Hu and Bentler, 1999). χ^2/df ratio recommendations range from as high as 5.0 (Wheaton et al, 1977) to as low as 2.0 (Tabachnick and Fidell, 2007). Siti et al. (2011) suggested the relative chi-square (χ^2/df) must be between 1 and 5. Steiger (2007) suggested RMSEA of 0.07 or lower, while Hu and Bentler (1999) required an RMSEA of 0.06. Then Schumacker and Lomax (2010) considered RMSEA value must be lower than 0.08. The GFI, CFI, AGFI and TLI values should be in range of 0 to 1. Bentler and Bonett (1980) suggested GFI and CFI of 0.90 and AGFI of 0.80, while Hu and Bentler (1999) noted the value of 0.95 for CFI and GFI. Arbuckle (2009) suggested that GFI, TLI and CFI should be equal or close to 0.90. Likewise, the respective TLI, CFI and CFI value must exceed 0.90 in order to obtain an acceptable fit with the data (Schumacker and Lomax, 2010). The article of Hooper, Coughlan and Mullen (2008) summarized fit indices and their acceptable thresholds: RMSEA values less than 0.07, the respective GFI, AGFI, TLI and CFI values must greater than 0.95, 0.90, 0.95 and 0.95 in order.

The indices shown in **Table 4** suggest that the 3-factor correlated model (deleted 3 items of attitude) is the best fit with the data, which conducted in Mongolian context when compared to the alternative models. As seen in **Figure 1**, the 3-factor correlated model for MTPC specifies the relations between observed variables and latent variables.
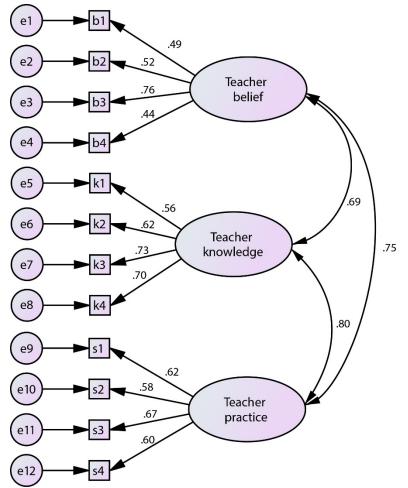
Figure 1. 3-factor correleted model for MTPC

The observed variables and the latent variables are represented by the boxes and the ellipses respectively. The value of .40 is a common cut-off value which is typically used in any factor analyses and the double-headed row represents the covariance, which also can be interpreted as correlation (Hair et al., 2010). Factor loadings provide evidence for the extent to which an item relates to the underlying latent factor. The factor loadings shown in **Figure 1** were quite high, ranging from 0.44 to 0.76.

CONCLUSION

The aim of the paper was to assess the reliability and validity of a version of the MTPC with 4 belief, 4 knowledge, 4 practice, and 3 attitude items. Results of the CFA support a 3-correlated factor model. In addition, the items showed good internal consistencies and displayed Cronbach's alphas similar to those obtained for the 3-correlated factor model. The model (deleted 3 items of attitude) is most suitable when compared to the alternative models. Thus, this study has validated a version of MTPC for the Mongolian context.

DISCUSSION

The author believes that teacher knowledge, teacher beliefs and teacher practice are emphasized almost equally. However, when author divided those factors into its more detailed components it was that fields of teacher development are stressed differently.

For example, excellent teachers of mathematics establish an environment that maximizes students' learning opportunities. The psychological, emotional and physical needs of students are addressed and the teacher is aware of, and responds to, the diversity of students' individual needs and talents (AAMT, 2006). In other word, the learning environment of teacher practice is highly dependent on the teacher's experience.

Koponen et al. (2017) divides teacher knowledge into six components, three of which are mathematical (subject matter). Based on their results, Common content knowledge is clearly the most strongly emphasized component of

Subject matter knowledge in the studied teacher education program. According to the perceptions of both groups, the graduated teachers had learned pure mathematical issues better however, there were some exceptions, such as statistics, which does not belong to the present teacher education program.

Therefore, further research is study on the correlation between teacher development and components of MTPC.

A paper by Beswick (2012) suggests that beliefs about mathematics can usefully be considered in terms of a matrix that accommodates the possibility of differing views of school mathematics and the discipline.

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