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# STRUCTURAL MODEL OF BELIEFS, CONCEPTUAL KNOWLEDGE AND EXPERIENCE AMONG TRAINEE MATHEMATICS TEACHERS

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**ABSTRACT:** Beliefs, conceptual knowledge and experience play important roles in enhancing the quality and effectiveness of the teaching and learning of mathematics. As such, this study is conducted with the aim of profiling three main constructs, namely beliefs, conceptual knowledge and experience among trainee mathematics teachers. The study is also intended to produce a measurement model of these constructs and subsequently a structural model that incorporates all the hidden and observed variables. 317 trainee teachers from six Higher Education Institutions (HEIs) (public universities) were randomly selected to participate in this study. Beliefs, conceptual knowledge and experience are measured using mathematical beliefs questionnaire (MBQ), mathematical experience questionnaire (MEQ) and a test of conceptual knowledge (TCK), focusing on the topic of fractions. The structural model shows that there is a weak correlation between mathematical beliefs and mathematical experience; a very weak correlation between conceptual knowledge and mathematical beliefs; and a very weak correlation between conceptual knowledge and mathematical experience. In addition, SEM analysis shows that there is a significant contribution of the four variables on the mathematics beliefs of the trainee teachers. Furthermore, regression coefficient of mathematics content knowledge experience of the respondents is the highest among regression coefficients of the predictor variables.

**Key words**: Beliefs, conceptual knowledge, experience, trainee mathematics teachers

## INTRODUCTION

Mathematical beliefs refer to what is true about mathematics, and generally, it is based on an individual's experience as a student of mathematics (Liljedahl, 2005). According to Beijaard et al. (2004), beliefs, on the other hand, are the main component of a teacher's identity. Thus, understanding pre-service teachers' beliefs is pivotal in mathematics education. This understanding would ensure effective teachers' education programmes are developed and executed (Barlow & Reddish, 2006).

Other than mathematical beliefs, pre-service teachers' conceptual knowledge of mathematics is also an important element to be studied. Conceptual knowledge refers to a teacher's ability to connect one mathematical idea to another and to the network of other mathematical ideas, and provide examples. Therefore, a teacher's conceptual knowledge needs to be established and improved upon, so that it would correspond with the aims and objectives of the school curriculum. One of the objectives of the curriculum is to enable students to explain mathematical problems using accurate mathematical terms (Curriculum Development Centre, 2004). To achieve this objective, emphasis on both understanding of concepts and development of skills must be balanced (Noraini, 2005).

Mathematical experience refers to what has been experienced by individuals during their course of studying mathematics, both at school and tertiary levels. Generally, when they have become teachers, they would apply the knowledge and experiences which they have acquired into their teaching and learning processes in the classroom. In this sense, all the approaches and techniques are the same as the ones practiced by their own former teachers. Thus, duplicating of experience takes place, and if this continues, creativity and innovation is hampered in the education system, and specifically, in mathematics education.


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# STRUCTURAL EQUATION MODELING (SEM)

Structural Equation Modeling (SEM) is specifically designed to model the relationship between multiple dependent and independent constructs simultaneously (Zulkifley & Kamarulzaman, 2009). Thus, SEM is selected for the study to connect existing theoretical relationships between the variables simultaneously. SEM is preferred to path analysis because it produces measurements with better validity and reliability (Chua, 2009). Besides that, it can also be used to test the hypothesis of a study (Zainudin, 2010).

To analyze the measurement model, confirmatory factor analysis (CFA) is utilized in this study. CFA is used to determine whether or not a hypothesis fits certain set of data (Byrne, 2010; Hair *et al.*, 2010). Several values are obtained, which are factor loadings, variance and modification indices (MI) in order to get the best model fit. In determining the model fit, a few values are used. Kline (2005) suggested at least four tests be used: Chi-square ($\chi^2$), Goodness of Fit Index (GFI), Normed Fit Index (NFI) or Comparative Fit Index (CFI), Non-Normed Fit Index (NNFI) and Root Mean Square Residual (RMSR). In this study, six fit indices are employed, which are GFI, Absolute Fit Measure (AGFI), NFI, Tucker Lewis Index (TLI), Incremental Fit Index (IFI) and CFI (Byrne, 2010; Hair *et al*., 2006; Hair *et al*., 2010). The values of these indices range between 0 and 1.00, with values 0.90 and above considered as a good model fit (Byrne 2010; Hair *et al*. 2006; Hair *et al*. 2010). However, for Parsimonious Fit Measure (CMIN/df), some researchers allow up to value 5.00 as a good model fit. There are also some researchers who use values 2.00 or less. Nonetheless, the value of CMIN/df used in this study is less than 3 (< 3), corresponding with Kline (2005).

# METHODOLOGY

The respondents selected in this study are pre-service teachers in their third and forth years from education faculties of six HEIs which offer mathematics education programmes. During the 2007/2008 academic session, the total number of pre-service teachers in their third and forth years who are enrolled in mathematics education programmes is 494. Out of the 494 pre-service teachers, 371 (60 males and 257 females) are selected as respondents of the study.

The respondents are selected using two levels of stratified random sampling. The first level is clustered random sampling, which involves selecting six out of eight public higher education institutions that offer mathematics education programmes, which are UM (24), USM (26), UPSI (185), UKM (33), UPM (29) and UTM (20). The second level is purposive random sampling which is based on the years of study (third and forth years).

# RESEARCH FINDINGS

**Structural Model of Study**

In this study, the structural model consists of two dimensions of mathematical beliefs, three dimensions of mathematical experience and one dimension of conceptual knowledge. The mean values of mathematical beliefs, mathematical experience and conceptual knowledge constructs are used to represent each construct. The first structural model of the study is constructed to include all three variables, which are mathematical beliefs, mathematical experience and conceptual knowledge of the pre-service teachers. Analysis of SEM indicates that there is a significant relationship between those variables in this study.

The results of the SEM analysis show that each of the variables has a significant relationship with another; between conceptual knowledge (CK) and mathematical experience (ME) ($\beta$ =0.13, $p < 0.05$), between mathematical beliefs (MB) and mathematical experience (ME) ($\beta = 0.39$, $p < 0.05$), and between mathematical beliefs (MB) and conceptual knowledge (CK) ($\beta = 0.11$, $p < 0.05$). The study finds that there is a weak correlation between mathematical beliefs and mathematical experience ($\beta = 0.39$). Even weaker correlations are found between conceptual knowledge and mathematical beliefs ($\beta = 0.11$), and between conceptual knowledge and mathematical experience ($\beta = 0.13$). However, based on the fit index values, the model is found to be ill-fitting and not the best model fit of the study. Out of six fit index values used in determining the best model fit of the study, only GFI meets the requirement, with value > 0.90. The value of RMSEA = 0.105, greater than the fixed value of 0.08; and the value of CMIN/DF = 4.481 (>3) is quite high. Therefore, the first structural model of the study needs to be modified to obtain the best model fit which fits the data of the study.

The modifications are based on a suggestion by the modification index (MI), which suggested inserting a connection between error e2 and error e4. Further analysis shows that all fit indices meet the requirement of the study. The analysis of SEM shows that there is a significant relationship between the variables; between mathematical beliefs (MB) and mathematical experience (ME) ($\beta = 0.38$, $p < 0.05$), and between mathematical beliefs (MB) and conceptual knowledge (CK) ($\beta = 0.11$, $p < 0.05$). The relationship between conceptual knowledge (CK) and mathematical experience (ME) is also significant (β = 0.13, $p < 0.05$). However, weak correlations still exist between mathematical beliefs (MB) and mathematical experience (ME) (β = 0.38), between conceptual knowledge (CK) and mathematical beliefs (MB) (β = 0.11), and between conceptual knowledge (CK) and mathematical experience (ME) (β = 0.13).

The analysis of SEM indicates that there is a significant relationship between beliefs and experience of the pre-service mathematics teachers. While there are weak correlations between the predictor variables in the study, the structural model is accepted as the structural model of the study. No improvement can be made on the model since it has met all requirements as model fit. Besides, improvements would result in the correlation values between predictor variables and criterion variables to become weaker.

**The Contribution of Beliefs on Conceptual Knowledge and Experience of Pre-service Mathematics Teachers**

A regression test is conducted on the variables of the study to see whether or not the independent variables have any significant contribution on the dependent variables. Since mathematical experience, which includes respondents' experience of the mathematics content knowledge, the pedagogical experience of their mathematics teachers as perceived by them, their experience as students of mathematics and their conceptual knowledge has a significant contribution on the pre-service teacher's beliefs, further analysis determines how those predictor variables could explain the variance of mathematical beliefs. This is conducted based on the values of multiple correlation squared or $R^2$.

The value of $R^2$ for mathematical beliefs is 0.56, which means that 56.0% of variance of mathematical beliefs could be determined by regression equation for mathematical experience, which are respondents' experience of the mathematics content knowledge, the pedagogical experience of their mathematics teachers as perceived by them, their experience as students of mathematics and their conceptual knowledge, as the predictor variables. From the perspective of effect size as suggested by Cohen (1983), the value of the contribution is medium.

The analysis also shows that the regression coefficient of mathematical experience, which is respondents' experience of mathematics content knowledge is β=0.70; the regression coefficient of pedagogical experience of the respondents' mathematics teachers as perceived by them is β=0.21; the regression coefficient of the respondents' experience as students of mathematics is β=0.14; and the regression coefficient of conceptual knowledge is β=-0.01. Clearly, the regression coefficient of mathematics content knowledge experience is the highest at β=0.70, compared with the regression coefficient of other predictor variables. This implies that the respondents' experience of the mathematics content knowledge contributes the most to their mathematical beliefs.

## DISCUSSION and CONCLUSION

**Structural Model of Study**

The findings of the study agree with the study by Quillen (2004) who also found that there is a significant relationship between mathematical beliefs, knowledge of contents and mathematical experience. His study showed that respondents who have good knowledge of contents have positive emotions towards mathematics compared with those who do not. They are also more inclined towards the use of teaching aids if their former teachers had also used them. Additionally, another study by White *et al*. (2006) found that there is a significant relationship between attitudes, beliefs and mathematics achievements in the teacher-trainees of a primary school at University of Western Sydney.

The findings also are consistent with the findings by Anne and Michael (2006) who stated that mathematical beliefs of the pre-service teachers are mostly gained from their experience and interpretation of their former mathematics teachers. A study by Marchionda (2006) also found that there is a positive relationship between mathematical beliefs and conceptual knowledge, whereby if one's conceptual knowledge is high, his mathematical beliefs are also affected. In addition, Ernest (1989) stated that beliefs are the main safeguard in professional behavior of teachers in the mathematics classroom. His findings demonstrated that beliefs influence and guide teachers in making decisions, carrying out teaching strategies (Van Zoest et al., 1998) and practicing what is learnt in the mathematics classroom (Wilson & Cooney, 2002). A study by Teo (1997, in Golafshani 2004) yielded similar findings as well. Hongying (2009) also found that pre-service teachers' beliefs are influenced by their learning experience. Such experience can have either a positive or negative effect on their beliefs. However, the findings of this study disagree with the findings by Willcox-Herzog (2002) and Villena-Diaz (2005) who stated that there is no significant relationship between beliefs and teaching practice in the mathematics classroom. Siti Mistima (2011) also found that mathematical beliefs do not have a significant relationship with pedagogical knowledge of contents.

This study and previous studies have shown that there are discrepancies in the findings when it comes to mathematical beliefs. Some studies indicate a significant relationship (Anne & Michael, 2006; Marchionda, 2006; Quillen, 2004) between variables of mathematical beliefs and other variables, while other studies indicate no significant relationship (Siti Mistima & Effandi, 2010; Villena-Diaz, 2004) between those variables. Such discrepancies could be the result of several factors, such as the selected respondents, scope of study and demography, such as genders or learning experiences. Thus, there are conflicting findings in the studies about the relationship between mathematical beliefs and other variables. In addition, these conflicting findings could exist because the pre-service teachers' core beliefs do not correspond with the information on the beliefs that they relay. Besides, the environment of the universities where they receive their education also influences their mathematical beliefs (Aida Suraya et al., 2008). Moreover, the relationship between the pre-service teachers' learning experience and the knowledge they acquired is not optimized. This is supported by Lilia (2009) who claimed that pre-service teachers' acquired knowledge still needs to be improved upon, especially acquired knowledge based on experience.

### The Contribution of Beliefs on Conceptual Knowledge and Experience of Pre-service Mathematics Teachers

The analysis of multiple correlations squared or $R^2$ shows that value $R^2$ of beliefs is 0.56. This means that 56% of variance of beliefs could be explained by the regression equation for experience, which is respondents' experience of the contents of mathematics, the pedagogical experience of their mathematics teachers as perceived by them, their experience as students of mathematics and their conceptual knowledge, as the predictor variables. The results of analysis also show that the regression coefficient of respondents' experience of the contents of mathematics is higher compared with the regression coefficient of the pedagogical experience of the respondents' mathematics teachers as perceived by them, the regression coefficient of their experience as students of mathematics, and the regression coefficient of their conceptual knowledge. This indicates that the respondents' experience of the contents of mathematics plays a very important role in shaping their beliefs. Experience related to the contents of mathematics influences the evaluation and selection of teaching strategies by the teachers (Lloyd, 2002). Besides that, the teachers' knowledge of the contents of mathematics is relevant to what their students would be learning (Hill et al., 2005).

Teachers who lack adequate knowledge of the contents of mathematics would not be able to associate the students' existing knowledge to the new knowledge that they are acquiring. In addition, such teachers also have a tendency to focus only on algorithm (process of calculation), and not the underlying mathematical concepts (Cai, 2005; Llinares, 2000). On the other hand, teachers who are knowledgeable would prefer students' mathematical questions, and to solve them together with the students, as opposed to merely providing answers to their questions.

The findings of the study are different from a study by Siti Mistima (2011) who found that mathematical beliefs, teaching practice, teaching experience and education level contribute very little or in a small percentage to the variance of pedagogical knowledge of contents. Clearly, there are discrepancies in the findings of this study and previous studies on mathematical beliefs. This is could be due to the different variables or respondents in the studies. Moreover, it could also be caused by external factors, such as the respondents' age and genders.

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