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Relationship between mathematics beliefs, conceptual knowledge and mathematical experience among pre-service teachers

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Abstract

Mathematical beliefs, conceptual knowledge and mathematical experience play an important role in enhancing the quality and effectiveness of the teaching and learning of mathematics. As such, this study is conducted with the aim of profiling these three main constructs, namely mathematical beliefs, conceptual knowledge and mathematical experience among pre-service 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 pre-service teachers from six institutions of higher learning (public universities) were randomly selected to participate in this study. Mathematical beliefs, conceptual knowledge and mathematical experience are measured using mathematical beliefs questionnaire (MBQ), a test of conceptual knowledge (TCK) and mathematical experience questionnaire (MEQ) respectively, focusing on the topic of fractions. The findings indicate that the overall teachers’ mathematical beliefs are high, mean score of the teachers’ conceptual knowledge is good, while mathematical experience is moderate. Further analysis reveals that there exists a significant correlation between these three variables. Implications and suggestions are provided for better understanding of mathematical beliefs, conceptual knowledge and mathematical experience, particularly within the context of teaching and learning of mathematics.

Keywords: Mathematics beliefs, conceptual knowledge, mathematical experience, pre-service teachers;

1. Introduction

Mathematics beliefs refer to what is true about mathematics (truth value) and generally, it is based on an individual’s experience as a student of mathematics (Liljedahl, 2005). For example, there are students who believe that mathematics is a “difficult” subject, “useless”, “it’s all about one answer” or “it’s all about memorization of formulae”. Beliefs, according to Beijaard et al. (2004), are the main component of a teacher’s identity. Thus, understanding future teachers’ beliefs is pivotal in mathematics education. This understanding would ensure effective teachers’ education programmes are developed and implemented (Barlow & Reddish, 2006).

Other than mathematics 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 relate one mathematical idea to another,
connect them to the network of mathematical ideas, and provide examples. The mental network of mathematical ideas is the foundation of conceptual knowledge. Therefore, a teacher’s conceptual knowledge needs to be established and improved upon, so that it would be consistent 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, 2000). To achieve this objective, emphasis on both understanding of concepts and development of skills must be balanced (Idris, 2005).

Mathematical experience, on the other hand, 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 similar to 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.

2. Methodology

317 pre-service mathematics teachers from six public universities are chosen as respondents of the study using stratified random sampling. They are pre-service teachers in their third and fourth years. These respondents are made up of students from six public universities which offer mathematics education programmes; specifically 24 students (7.6%) from UM, 33 (10.3 %) from UPM, 26 (8.2 %) from USM, 20 (6.3 %) from UTM, 29 (9.1 %) from UKM and 185 (58.4 %) from UPSI. From here, 60 (18.9%) are male and 257 (81.1%) are female. The majority of the respondents, which is 261 (82.3 %) are Malays, while 43 (13.6%) are Chinese, 6 (1.9%) are Indians, and 7 (2.2 %) are bumiputras of Sabah/Sarawak.

3. Results and Discussion

Tests are conducted on the measurement model to determine the scale of mathematical beliefs, conceptual knowledge and mathematical experience of the pre-service teachers. Analysis of respondents’ score shows that all assumptions are within normality, and conforms to extreme values and outliers. Analysis of confirmatory factor analysis (CFA) is carried out on the data of the study, and values which are taken into consideration are CMIN/DF, RMSEA and the six fit index models: GFI, CFI, AGFI, IFI, NFI and TLI. Modification of the model is made by removing variables which do not contribute significantly in explaining hidden variables with low factor loading values. However, these variables are not removed simultaneously to prevent inadequate information in the analysis which can hinder achieving the objective of the measurement in the study (Saghaei & Ghasemi, 2009).

3.1 Mathematics Beliefs

The measurement model of mathematics beliefs consists of constructivism beliefs (15 items) and traditional beliefs (7 items). Based on confirmatory factor analysis (CFA), CMIN/DF = 1.430. The fit index model is found to be diverse. RMSEA is 0.037, lower than 0.08 as the best-fitting model of the study. The values of GFI, AGFI, IFI, TLI and CFI are greater than the value fixed by the study, while the value of NFI is lower than 0.90. This shows that the fit model is ill-fitting and weak as the study data. To revise the measurement model of mathematical beliefs (MB), a modification has been made to the model. Variables with very weak correlation values are omitted from the model. Although there is no regression correlation value, the value of the fit model is still not sufficient. While the values of CMIN/DF and the fit indices GFI, CFI, AGFI, IFI and TLI are sufficient, the value of NFI is still lower than 0.90, and RMSEA is 0.037, much lower than 0.08 as the best-fitting model of the study.

To revise the measurement model of mathematical beliefs to fit the data of the study, researchers take into account modification model (MI) by AMOS. Connections that are given priority are the ones with high MI values, which connect errors e1 to e15 in the construct of constructivism beliefs. Analysis of the modification produces CMIN/DF = 1.243, fit indices GFI, AGFI, CFI and TLI greater than 0.90 and RMSEA = 0.028. Therefore, the final
measurement model of mathematical beliefs consists of twelve (12) items, which are constructivism beliefs (8 items) and traditional beliefs (4 items).

The results of the analysis which show that hidden variables of mathematical beliefs consists of two factors support the model of mathematical beliefs presented by Jeongyeon (2009) and Villena-Diaz (2005). However, this finding contradicts with the model of mathematical beliefs presented by Ernest (1991) and Yu (2008) who put forward three main factors in mathematical beliefs. Van der Sandt (2007), on the other hand, states that mathematical beliefs consists of four main factors that measure the beliefs, which are the nature of mathematics, the learning of mathematics, the teaching of mathematics and students as learners of mathematics.

3.2 Conceptual knowledge

The measurement model of conceptual knowledge consists of 24 items. Based on confirmatory factor analysis (CFA), CMIN/DF = 2.811. The fit index models are found to be diverse. RMSEA is 0.076, lower than 0.08 for the best-fitting model of the study. The values of GFI, AGFI, NFI, IFI, TLI and CFI are lower than the value fixed by the study. This shows that the fit model is ill-fitting and weak as the study data. To revise the measurement model of conceptual knowledge (CK), a modification has been made to the model. Variables with very weak correlation values ($r < 0.5$) are omitted from the model. The correlation values of items d1, d2, d3, d4, d5, d6, d7, d8 and d9 are found to be lower than the fixed value. Thus, all nine items are removed from the measurement model of conceptual knowledge. However, the fit index values are found to be not sufficient. Despite the values of CMIN/DF and four indices GFI, AGFI, NFI and TLI being greater than the fixed value, the values of IFI, TLI and CFI are still lower than 0.90, and RMSEA is greater than 0.08. Modification to the measurement model of conceptual knowledge needs to be carried out to achieve the best-fitting model of the study.

To revise the measurement model of conceptual knowledge (CK) to fit the data of the study, researchers take into account modification model (MI) by AMOS. Connections that are given priority are the ones with high MI values, which connect errors e10 to e12, e13 and e14; e12 to e14 and e15; e21 to e22 and e24; e14 to e15; e15 to e20; e19 to e22; and e20 to e23. Analysis of the modification produces CMIN/DF = 2.020, fit indices GFI, AGFI, CFI, NFI, IFI and TLI greater than 0.90, and RMSEA = 0.057, lower than 0.08. Therefore, the final measurement model of conceptual knowledge consists of fifteen (15) items, which are items d10, d11, d12, d13, d14, d15, d16, d17, d18, d19, d20, d21, d22, d23 and d24.

The measurement model of conceptual knowledge consists of only one structure: conceptual knowledge. This indicates that conceptual knowledge in this study comprises of one hidden variable which measures it. The correlation values are moderate, and the observed variables which are omitted have very low correlation values. The results of the analysis which indicate that hidden variables of conceptual knowledge consists of this one factor support the conceptual knowledge model put forward by Cramer et al. (2002) and Newton (2008).

3.3 Mathematical Experience

The structure of measurement model of mathematical experience consists of the respondents’ experience with the contents of mathematics (7 items), respondents’ perception of their teachers’ pedagogical experience (5 items), and respondents’ experience as students of mathematics (4 items). Based on confirmatory factor analysis (CFA), CMIN/DF = 2.203. The values of four fit indices GFI, AGFI, IFI and CFI are greater than 0.90, while NFI and TLI are lower than 0.90. RMSEA is 0.062, lower than 0.08. This shows that the fit model is ill-fitting and weak as the study data.

To revise the structure of measurement model of mathematical experience, a modification is made on the model. Variables with very weak correlation values have been omitted from the model. However, based on the generated regression correlation values, it has been found that there is no low regression coefficient value. Hence, to revise the measurement model of mathematical experience to fit the data of the study, researchers take into account modification model (MI) by AMOS. AMOS suggests connecting several errors other than the errors with hidden variables. Connections that are given priority are the ones with high MI values, which connect errors e4 to e13, e7.
and e10, and e7 to e12. Analysis of the modification produces $CMIN/DF = 1.570$, fit indices GFI, AGFI, NFI, IFI, CFI and TLI greater than 0.90, and RMSEA = 0.042. Thus, the final measurement model of mathematical experience consists of eleven (11) items.

The measurement model of mathematical experience consists of three sub-scales: the respondents’ experience with the contents of mathematics, respondents’ perception of their teachers’ pedagogical experience, and respondents’ experience as students of mathematics. In other words, mathematical experience in this study is measured by three hidden variables. The results of the analysis which show the hidden variables of mathematical experience consists of these three factors support mathematical experience model presented by David (2001) and Quillen (2004).

3.4 Relationships between Mathematical Beliefs, Conceptual Knowledge and Mathematical Experience among Pre-service Teachers

Analysis of SEM shows that there is a significant relationship between all the variables in this study. However, based on the values of fit indices, the model is found to be not the best-fitting model for the study. Of all the six fit index values used to determine the best-fitting model of the study, only GFI meets the requirement with a value of $> 0.90$. The value of RMSEA = 0.105, far greater than the fixed value at 0.08, and $CMIN/DF = 4.481$ is very high. Therefore, modification needs to be made to the structural model of the study to produce the best-fitting model which fits the data of the study.

The modification is based on the proposition of the modification model (MI), which is to include connecting e2 and e4. Further analysis shows that all the fit indices meet the requirement of the study. Thus, Figure 1 is accepted as the structural model of the study. As a result of the modification, it is observed that there is a significant relationship between all the fixed variables (Table 1). Based on Table 1, the variables are found to indicate that there is a significant relationship between mathematical beliefs (MB) and mathematical experience (ME) ($\beta = 0.38$, $p < 0.05$), and between mathematical beliefs (MB) and conceptual knowledge (CK) ($\beta = 0.11$, $p < 0.05$). Also significant is the relationship between conceptual knowledge (CK) and mathematical experience (ME) ($\beta = 0.13$, $p < 0.05$). Nonetheless, there is still a weak correlation relationship between mathematical beliefs (MB) and mathematical experience (ME) ($\beta = 0.38$); between conceptual knowledge (CK) and mathematical beliefs (MB) ($\beta = 0.11$); and between conceptual knowledge (CK) and mathematical experience (ME) ($\beta = 0.13$).

Table 1: Significance between variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Value $\beta$</th>
<th>Value p</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK and ME</td>
<td>0.13</td>
<td>0.047*</td>
<td>Significant</td>
</tr>
<tr>
<td>MB and ME</td>
<td>0.38</td>
<td>0.003*</td>
<td>Significant</td>
</tr>
<tr>
<td>MB and CK</td>
<td>0.11</td>
<td>0.019*</td>
<td>Significant</td>
</tr>
</tbody>
</table>

*Significant at $p < 0.05$
The results of the study indicate that there is a significant relationship between mathematical beliefs and conceptual knowledge, mathematical beliefs and mathematical experience, and conceptual knowledge and mathematical experience. These results correspond with the study conducted by Quillen (2004) who also finds that there is a significant relationship between mathematics beliefs and mathematical experience, and between mathematics beliefs and mathematics content knowledge. However, these findings are different from the findings of studies conducted by Willcox-Herzog (2002) who finds that there is no significant relationship between beliefs and teaching practices in a mathematics classroom.

4. Conclusion

Overall, the study shows that mathematical beliefs of pre-service teachers are positive, and lean towards constructivism beliefs. The level of conceptual knowledge is good and mathematical experience is inclined towards the experience with the contents of mathematics. The SEM model, on the other hand, indicates that there is a weak correlation relationship between mathematical beliefs and mathematical experience, an extremely weak relationship between conceptual knowledge and mathematical beliefs, and an extremely weak relationship between conceptual knowledge and mathematical experience. It is suggested that more studies should be conducted to investigate mathematical beliefs, conceptual knowledge and mathematical experience, particularly using quantitative approach. In addition, some considerations in validating the measurement as well as testing the question in a different context of study are highly recommended for future studies. This may lead to the betterment and advancement of the teaching of mathematics.

References


