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Mathematics Secondary School Teachers of Beliefs, Teaching Practices and Pedagogical Content Knowledge

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Abstract

This study was conducted to propose a model that consists of beliefs in mathematics, teaching practices and pedagogical content knowledge. Data was obtained from 254 mathematics teachers (203 females and 51 males) from selected secondary schools using stratified sampling. Teachers' variables, demographics, beliefs in mathematics, teaching practices (TP), and pedagogical content knowledge (PCK) were all employed as the variables of the study. Specifically, mathematical beliefs are about the nature of mathematics, teaching and learning. TP include both teacher-centered and student- centered instruction. PCK consists of their knowledge of the subject content, the knowledge of the students and their knowledge of pedagogy, particularly in algebra, which focuses on quadratic functions and quadratic equations. Descriptive and inferential statistics were applied in the data analysis. Frequency values and percentages have been applied to the respondents' profile information, while structural model is the inferential statistics in this study. Mathematics beliefs and teaching practices were confirmed to be significant by the structural equation modelling to be in this study. However, it was found that there was no link between mathematics beliefs and PCK, between pedagogical content knowledge and teaching practice. The enhancement of the teacher's professional development program to improve their teaching efficiency as well as their teaching quality should therefore be considered as early as the pre-service level.

Keyword: Mathematics, Beliefs, Teaching Practices, Pedagogical Content Knowledge, Teachers, Malaysia

Introduction

There are numerous studies on mathematics beliefs and discussions about their connections to teaching (Jung, Zhang & Chiang, 2019). Conceptualization of beliefs in mathematics could be seen in the teachers' perceptions (Campbell et al, 2014, Stipek et al, 2001; Staub & Stern, 2002) become then main interest among mathematics educators as reviewed by Voss et al

(2013). When beliefs and teaching practices are correlated, this has a strong impact on the level of their individual effectiveness and the teacher's efficacy as well. By shaping their mathematics beliefs during the teacher preparatory program then they are supposed to be skillful, highly driven and innovative. This is in keeping with the country's education strategy, which

puts a high priority on skilled teachers, mainly on the mathematics subject matter. Theories and experience give rise to appropriate teaching practices and beliefs. Beliefs and knowledge can be distinguished by the objectivity of their conceptualization. Knowledge can be beliefs which based on a consensus. Some researchers have categorized beliefs as either behaviorist (Niepel et al., 2018) or constructivist (Voss & Kunter, 2020).

Since limited empirical evidence exists on the link between mathematics beliefs, TP and PCK as demonstrated in past studies, except for Yang's work. (2020), this has become a motivation to conduct a study looking into this issue. On the contrary, the previous studies focused on the relationship between two of the variables such as knowledge of mathematics and PCK (Leong et al., 2015), pedagogical content knowledge and instructions (Karatas et al., 2017) and mathematics beliefs and teaching practices (Low, 2021). Some researchers aimed to identify the components of mathematics beliefs individually (Schoen et al, 2019), in addition to teaching practices (Hackenberg, Creager & Eker, 2020) and mathematics knowledge (Lowrie & Jorgensen, 2016). How are these variables related in mathematics teaching and the learning context? Do teachers really know the content of the topics that will be delivered to the students is? How do they perceive that their content that could impact their students' understanding? Do their experiences in teaching affect the teachers' beliefs and practices? (Shirrell, Hopkins & Spillane, 2019). This can be determined by the educational system and associated policies.

As for mathematics beliefs, they are related to the students' performance (Markovits & Forgasz, 2017) which implies an association with the teachers' teaching practices. Their mathematics beliefs direct them to teach the way that they believe in mathematics teaching. However, mathematics beliefs can be categorized as beliefs in mathematics teaching, beliefs in mathematics learning and beliefs in mathematics as nature (Viholainen, Ainen & Hirvonen, 2017). As such, Polly et al (2013) found that the teachers whose beliefs aligned with traditional teaching and learning had a higher frequency of teacher-centered practices such as controlling the learning process. This made the class passive. This triggers issues related to the type of mathematical knowledge that they should acquire to be effective teachers.

Up to now, most of the recent studies have been done on finalizing the category of mathematical knowledge which was initiated earlier by Shulman (1986). The extended work has been discussed using a systematic review by Charalambous et al (2019). Knowledge can be evidence of teaching as developed through age and experience (Slavit & deVincenzi, 2020). For instance, conceptual knowledge refers to the basic needs that should be acquired for effective classroom practice. Having a strong concern about the characteristics of the teaching practices allows the teachers to deal with various areas of knowledge including content knowledge, students' knowledge, general pedagogical knowledge, curriculum knowledge,

knowledge of the educational context and pedagogical content knowledge (Shulman, 1986). The teachers' challenges in terms of grasping mathematical knowledge or content knowledge are related to their conceptual and procedural knowledge. It seems that the teachers' knowledge designs what they want to be implemented in the classroom. Therefore, the teachers' role is vital when changing the teaching and learning process. At this stage, teachers are developing their belief in mathematics, which leads to them to

practice in the classroom. In the same way, their knowledge is also developed, which then develops a link between the aspects involved. As a result, the following are the research objectives:

- to determine the fit structural model of mathematics beliefs, TP and PCK
- to identify the relationship between mathematics beliefs, TP and PCK

Methodology

Using a random sampling, over 250 math teachers from 6 different regions in Malaysia were identified for this study. The justification for using the sampling technique is based on the coverage possible and having control of subgroups in the study Coppock, Leeper & Mullinix, (2018). For data collection purposes, official approval was obtained from the Ministry of Education and the educational state department was given the name of the selected schools. The researcher contacted each of the school representatives to manage the distribution of the questionnaire. To ensure respondents' willingness to participate in the study, the consent letter was attached to the questionnaire at the beginning. Prior to the data analysis procedure, 9 respondents were removed, leaving 254 for the next stage of cleaning and screening. Using Analysis of Moment Structure (AMOS) version 20.0, the data was analyzed accordingly to obtain the Structural Equation Modeling output. All the basic assumptions when performing the analysis of the structural equation modeling including normality, missing data, measurement and sampling errors and model fit indexes have been fulfilled.

The selected common fit indexed tests included Chi Square, Tucker Lewis Index (TLI), Comparative Fit Index (CFI), Goodness Fit of Index (GFI), RMR and Root Mean Square Error (RMSEA), chosen based on Hair et al (2010) recommendation. The cut-off point of each index test has criteria in terms of the fit indexes test as shown in Table 1. With a normed Chi Square value in the range of 1 to 5, all fitness indexes met the minimum requirement, and the TLI, CFI, and GFI values all more than 0.90. The value of RMSEA was less than 0.05 as suggested by Tennant and Pallant (2012).

Table 1: Fit index test limitation va

Fit index	CMIN/DF	TLI	CFI	RMR	GFI	RMSEA
Cut-off point	1< value< 5	> 0.9	> 0.9	< 0.08	> 0.9	< 0.08

Most of the respondents were female totaling 203 (79.9%) respondents where the majority of 81.9% were Malays. More than 50% of the respondents have a minimum 10 years teaching experience. While 70 (27.6%) of the teachers have less than 5 years teaching experience. Another important factor is academic background with 224 (88.2%) were degree holders.

Measures

The constructs from the respective variables are shown in Table 2 below. Mathematics beliefs can be defined by the nature, teaching, and learning of mathematics. While

teacher centered teaching and student-centered teaching are measured for mathematics teaching practices. Finally, pedagogical content knowledge (PCK) was obtained from Black (2007); Shuhua et al (2004). While teaching practices have 13 items which developed by Swan (2006) was categorized into teacher-centered teaching (9 items) and student-centered teaching (4 items). The next variable was pedagogical content knowledge (PCK) made up of 11 items with three sub-constructs: knowledge of content (4 items), knowledge of students (4 items) and knowledge of pedagogy (3 items).

Since most of the previous studies focused on quantitative studies, the chosen items were adjusted according to the local academic setting. Back-to-back translation was applied from English to Malay to help the respondents understand better when answering the research questionnaire. This method of translation has been proposed by most researchers to attain greater quality of translation and to avoid misinterpretation. In addition, all adapted instruments were approved for use by the instrument developer through their email notifications.

The Cronbach's alpha value of the instruments have passed the validation and reliability tests and are excellent." □ =0.81, teaching practices produced, □ =0.76 and PCK produced, □ =0.78.

Table 2: Definition of construct for the respective variables

Variable	Construct	Number of items
Mathematics Beliefs	Mathematics nature beliefs	11
	Mathematics beliefs in teaching	12
	Mathematics beliefs in learning	13
	Total	30
Teaching Practices (TP)	Teacher centered teaching	9
	Students centered teaching	4
	Total	13
Pedagogical Content Knowledge (PCK)	Knowledge of content	4
	Knowledge of students	4
	Knowledge of pedagogy	3
	Total	11

Results

The strength of the link between mathematics beliefs, teaching practices, and PCK was determined using structural equation modelling in this section. In developing a better fitting model, all the chosen fit indexes must fulfil the statistical requirement as shown in Figure 1. “MBeliefs” represents mathematics beliefs, “Teaching P” represents teaching practices and “PCK” represents pedagogical content knowledge. These variables are latent variables that can be measured by their respective observed variables represented in turn by the rectangle shape. As shown in Table 4, the null hypothesis failed to be rejected because all the fit indexes fulfilled the cut-off point value. The value of CMIN/DF approximately to 1 was TLI = 1.00 and

GFI=1 1.00, RMR=0.07 and RMSEA=0.000 which indicates model fit. The regression weights are

significant at the 0.01 significance level for mathematics belief ranging from 0.56 to 0.82 with the highest value referring to mathematics beliefs in learning. The teaching practices constructs had a regression weight of 0.82 for teacher-centered teaching and 0.87 for student-centered teaching. As for PCK, the regression weight ranged from 0.59 for content knowledge to 0.72 for the knowledge of the students and pedagogical knowledge. All regression weights for PCK are significant at 0.01.

Table 4 shows the structural model that represents the relationships of mathematical beliefs, teaching practices and pedagogical content knowledge. The path analysis of mathematics beliefs and PCK indicates that there is no relationship between the two variables (coefficient=0.06, t=6.53, $p > 0.05$) while mathematics beliefs and teaching practices show a significant relationship (coefficient=0.56, t=, $p < 0.01$). There is no link between PCK and teaching practices (coefficient=-0.06, t=, $p > 0.01$). Only hypothesis H_1 and H_3 are rejected while H_2 was failed to be rejected.

Table 4: Path Coefficients of the Structural Model

Path	Path Coefficients	T-statistics	P-value
Mathematics Belief →PCK	0.06	0.67	0.50
Mathematics Belief Teaching→ Practices	0.56	6.53	0.001**
PC→Teaching Practices	-0.06	-0.77	0.44

Note: **the loadings were substantial at the 99% confidence level if t-statistic > 2.58 ($p < 0.01$).

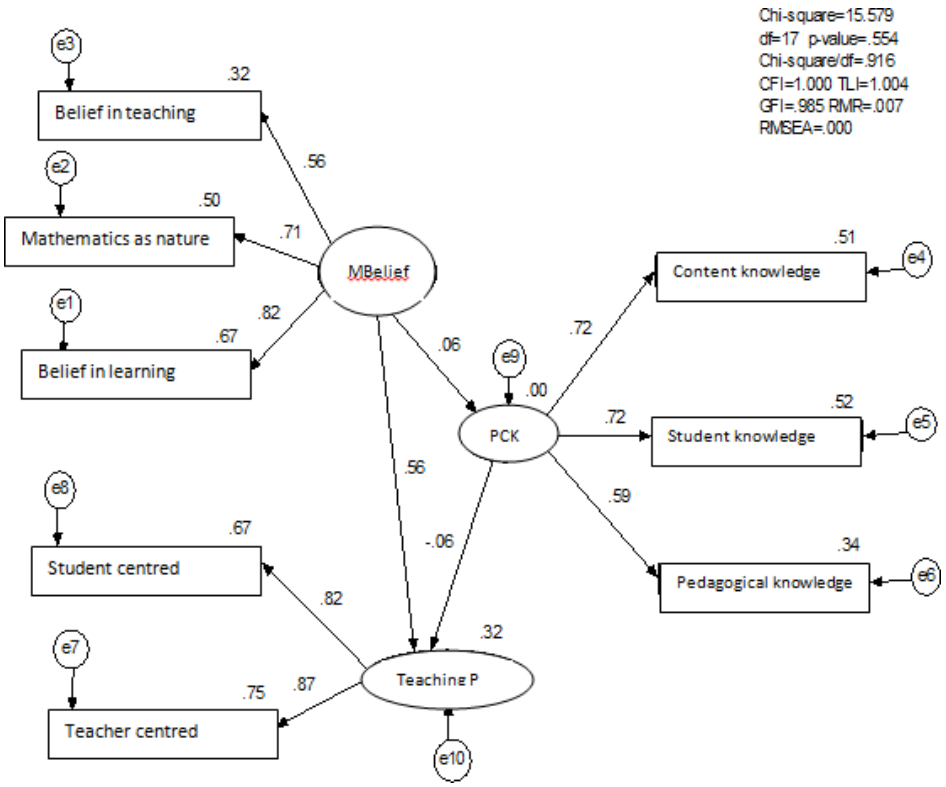

Figure 1: The Structural Model of Mathematics Beliefs, Teaching Practices and PCK.

Discussion

The structural model was designed to find out how content knowledge, pedagogy, and teaching practices are connected to mathematical beliefs in the teachers of mathematics secondary school. Based on the findings, a significant positive relationship between mathematical beliefs and teaching practices was discovered, while others found no such relationship between mathematical beliefs and PCK, nor between PCK and TP. This model agrees with the Wilkins study (2008) focused on 481 teachers. Wilkins (2008) used structural equation modelling to figure out how knowledge, attitude, beliefs, and teaching practices are related. Mathematics beliefs component is concerned with the way mathematics content is delivered in class. Fr instance, the effectiveness of teaching and learning mathematics depends on the frequency with which teachers use inquiry-based instruction. However, Wilkins (2008) has limited the analysis to two fit indices which were RMSEA and CFI to achieve the requirement of model fit.

Mathematical Beliefs and Teaching Practices

Wilkins' (2008) model confirmed that there is a positive and important relationship between mathematical beliefs and teaching practices. However, Wilkins' model deals with and is related to beliefs that positively impact on and play an important role in an inquiry-based practices. Meanwhile, Yates (2006) conducted a study on primary school teachers in South Australia which revealed that there was a significant relationship between the attitude towards mathematics and beliefs in mathematics held and their instructional practices. Yates obtained that teachers with high beliefs in a mathematical attitude tend to emphasize student-centered practices based on the low correlation value. According to other research, the consistency of belief and teaching

behavior has been demonstrated teaching method (Stipek et al, 2001; Speer, 2005). Teachers who believe in traditional mathematics tend to place little or no value on students' autonomy in the process of learning (Stipek et al, 2001). their lessons are grounded in mathematical assumptions that they have upheld for a long time (Speer, 2005) since the pre-service teacher level. This analysis verifies the previously held belief that there is a positive correlation between two variables, as stated by Yang et al (2020), Wilson and Cooney (2002) and Escandon (2020). Furthermore, the teachers have a moderate mathematical belief in their teaching practices. This finding is consistent with beliefs on teaching as argued by Stuart and Thurlow (2000). However, other research done by Thompson (1992) suggested differences in the respondents, the conditions, conditions, and demographics may produce variances in the findings.

There is a contradiction between the teachers' preconceived notions about what they taught before entering the training, and what they learned about teaching through their educational programs. There may be a problem with the way they measured their performance. Another factor that contributes to these conflicting results is that the academic environment, with beliefs and teaching habits, (Potari & Georgiadou- Kabouridis, 2009). There are courses available at universities that focus on the development of teachers, particularly their academic knowledge. Teaching in a school, on the other hand, is about application of knowledge gained. The teachers who participated in the survey have strong mathematical beliefs in every way, but they do not fully apply them in their classrooms. This could be due to factors that have become stumbling blocks, including the exam-driven educational system and the classroom environment (Barkastas-Tasos & Malone, 2005; Beswick, 2005). Teachers must complete the syllabus within the given time frame. As a result, teachers' teaching methods are more teacher centered.

Other contributing factors to the link between mathematical beliefs and teaching strategies are the classroom environment, as well as the teacher's stress levels. (Handal, 2003). Teachers must, by necessity, have less opportunity to do their mathematical practices suggested in the class curricula because of the large number of unexpected incidents. A new method of instruction will be difficult to implement because the teacher will find it difficult to change their established beliefs. Teachers would feel more at home with the standard approach because of familiarity. These reforms may seem contrary to what they believe. In this case, the importance of the beliefs that have to do with math is usually lost, but this one has shown them to be part of teaching.

Mathematical Beliefs and Pedagogical Content Knowledge

According to the findings, the coefficients for the belief in and teaching knowledge pathways are zero. This indicates that there is no relationship between the two variables. Muhtarom, Juniat, and Siswono (2019) have found an extremely low correlation between beliefs and knowledge of mathematics. Contrary to the findings of this research, this is likely to be due to some reasons. Focusing on learning outcomes, the existing educational model pays less attention to students' understanding than abilities and knowledge. This happens because less preparations from teachers to begin their required tasks after undergoing teacher training even though they have

good mathematical beliefs. The mathematical beliefs of pre-service teachers were influenced by what they have been taught (Yang et al., 2020).

As such, to produce excellent mathematics teachers, promoting the ability to engage in mathematics at the pre-service level should be incentivized. To meet the objectives, teachers are also required to take several fundamental mathematic courses in preparing them to be competent in class. Courses such as teaching psychology, teaching philosophy, teaching sociology, and teaching technology are important for teacher trainees to obtain the necessary skills and knowledge. The teachers must have a richer understanding of the trainees' knowledge acquired as they are exposed to more challenging subjects and experiences. Furthermore, the required 8-hour teaching credit may contribute little to their teaching abilities while still enhancing the trainee teacher knowledge component.

Next, the mathematics education programs are conceptualized in two ways, namely from the view of the educator (specifically) and the perspective of the mathematician. pedagogy and subject matter are equally important to the mathematical educator According to mathematical pedagogical principles, on the other hand, mathematicians emphasize mathematical content and fundamental knowledge as requirements for being a teacher. Teachers with adequate mathematical knowledge and pedagogy produce solid beliefs. Teaching allows them to feel more confident in their pedagogical abilities.

Pedagogical content knowledge is commonly known related to teachers' knowledge that also associated with what they perceive in mathematics. Thompson (1992) stated that teachers' knowledge is being determined by their beliefs in mathematics. Swars and their colleagues (2006) stated that beliefs are linked positively with the teachers who gained formal educational program. Thus, the degree of knowledge and knowledge must be congruent with the teachers' area of expertise (Palmer et al, 2005). However, the gap in the middle of their area of specialty at degree and learning is not consistent (Ansah, Quansah & Nugba, 2020). Likewise, the teachers' academic background does relate to their content knowledge as claimed by the previous researchers (Mills, Bourke & Siostrom, 2020). It is important to note that the personal beliefs of teachers before and during their training may not impact their current knowledge.

As a result, pedagogical content has no impact on beliefs in mathematics. The assumptions which they are working with should have an impact on the approach taken in the classroom.

Pedagogical Content Knowledge and Teaching Practices

Like the results demonstrate that there is no significant relationship between pedagogical content knowledge and teaching in this study. If the results of this experiment were consistent with the null hypothesis, then we would expect this to be found. Teachers know pedagogical content, but not pedagogical practices. it also illustrates that pedagogic knowledge one brings to the classroom does not affect student performance, but it depends on the teaching method and how that is used and how it can help students.

This study differs from the earlier studies, such as Simon's, which show otherwise et al (2000) and Raymond (1997). This leads to Shaw's (1989) this clearly demonstrates that teacher beliefs have not been followed in the classroom. These findings may be due to the accuracy of the

measurement of the variables (Rowan et al., 2002) which due to the collected data is not an accurate depiction of the classroom situation (Palardy & Rumberger, 2008). Knowledge and beliefs are factors that influence their instructional practices and attitude. (Simon et al, 2000). It was shown in a study conducted by Lubinski (1994) that their teaching approach was strongly guided by their beliefs and understanding of pedagogy.

Nonetheless, the results of this research supported the notion that teachers' pedagogical knowledge has no correlation with any other investigated variable. Teachers should be conscious of their knowledge to the appropriateness in the context of their students and classroom and various methods to translate it into instructional strategies. Conversely, the Malaysian education scenario shows that teacher-centered instruction explains why students are less proactive in the classroom. Furthermore, teachers' pedagogical knowledge can be limited if teachers depend on curriculum only and not being creative.The teacher's knowledge and what students are being taught may also be inaccurate. Teachers tend to instruct students to do revisions during the exam through memorization and exercises. The teaching has neglected important concepts because the focus has shifted to covering the syllabus. the teachers' achievements are related to how successful their students will be in life.

To improve the current study, future proposed work should consider a longitudinal study to determine the changes in the teacher's development, particularly their knowledge (Metsäpelto et al, 2020). Having said that, an advanced analysis of multi- level modeling such as hierarchical linear modeling can be considered to test the concept of teacher-school nested data (Bash, Howell & Trantham, 2020). This is to have an in-depth understanding of how the three variables are related. A case study is recommended to be applied in future work.

Conclusion

This study has identified the structural model of mathematics beliefs, teaching practices and PCK as well as the relationship between the variables. The most obvious result of this study is the link between beliefs and practices in mathematics, implying that the issues in teaching are not to do with beliefs. It is required that teachers be up to date on current mathematics teaching methods. Teaching should help teachers develop their PCK and help them improve their teaching practices. Similarly, their beliefs can be shaped through their experience and teaching. Reflecting on the students' practices in the classroom could benefit the students Teachers must also be able to be professional when delivering content knowledge, teaching methods, and use the established beliefs. To strengthen the PCK at the earliest pre-service level, also, related parties should examine the findings. By putting into practice of the philosophy of mathematics, it will help to foster teachers' mathematical knowledge.

As of contribution to the theoretical and contextual aspects of this paper, the finding confirms the hypothesized model that consists of three major variables of mathematics beliefs, teaching practices and PCK. These variables are linked to indicate the importance of having profound mathematics beliefs that can be translated through teachers' teaching practices that work effectively with their knowledge. The cognitive aspect of beliefs play role in shaping teachers' action in class which can be improved throughout their experience in delivering a significant types of knowledge to their students.

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