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Teachers' General Pedagogical Content Knowledge (PCK) and Content Knowledge of Algebra

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Abstract: The purpose of this study was to identify general PCK and content knowledge of lower secondary school teachers in Algebra based on years of service and teacher training background. About 34 lower secondary school teachers from a district in Melaka participated in the survey. And 2 teachers reported 1 year of teaching experience, 7 teachers reported 5-9 years and 25 teachers reported >10 years of teaching experience. In terms of teacher training background, 23 had acquired a certificate in Mathematics and 11 had various training backgrounds such as in Bahasa Melayu (Malay language teaching), Chinese language, Accounting, Economics and Engineering. A general PCK survey, using a 5-point Likert scale and a 21 item questionnaire on Algebra were adapted and utilized to gather data. Next, the level of teachers' general PCK was assessed using the mean score interpretation which classifies the mean score into three level: low (mean 1-2.33), moderate (mean 2.34-3.66) and high (mean 3.67-5.0). The results revealed that 97.1% of respondents had moderate (50%; Mathematics and educational Mathematics dimensions) and high levels (47.1%; strategy of teaching Mathematics dimension) of general PCK, even though they acquired different course specifications in their training and had various years of teaching experience. Therefore, the teachers in the present sample possessed good general PCK. However, the results also showed that teachers' content knowledge in Algebra was less than satisfactory. Specifically, scores on the Algebra questionnaire included the following 4 teachers received 2-4, 17 received 5-9, 11 received 10-14 and only 2 out of the 34 teachers obtained a score of 15 over 30. Additionally, 10 out of 13 teachers who earned a score of 10 or higher were those who took Mathematics education. These findings suggest that teachers collaborate to enhance knowledge and become more effective.

Key words: Pedagogical content knowledge, content knowledge, Algebra, Mathematics, teachers, Malaysia

INTRODUCTION

As the country's agents of paradigm shift and development teachers are directly responsible for implementing the new integrated curriculum for secondary schools which is in line with the National Education Policy. Hence, teachers must equip themselves with knowledge, skills and positive attitude. Shulman (1987) developed a theoretical framework, Pedagogical Content Knowledge (PCK), to conceptualize knowledge that is required for effective teaching and learning. The PCK defines how teachers transform content knowledge for student understanding. Shulman defined pedagogical content knowledge as that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding. Generally, the most important factor in determining the result of a learning process from its teaching strategy is how effective the applied strategy helped students toward meaningful learning.

Understanding teachers, PCK could provide the knowledge, methods, aims and determination to prepare teachers for the teaching profession (Abell, 2008). Pedagogical content knowledge is an essential and critical element to gauge teacher success in teaching and learning (Hill *et al*., 2005). However, research has demonstrated that teacher training institutes and colleges do not provide teachers with adequate PCK. Halim (1997) found that teacher trainings given by four teaching institutes, provided limited opportunities for teachers to develop their PCK. In addition, Ratnavadivel revealed that only 2 out of 18 courses for Mathematics majors at one local university placed emphasis on PCK. Meanwhile, trainings that are provided by institutes are a small fraction of the real teaching and learning process and development of teachers PCK is limited to only certain aspects. Another important aspect that teachers need is content knowledge, commonly defined as matters that must be learned by students (Ball and Bass, 2000) thus what teachers need to know is what they will teach students. Shulman (1986)

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defined content knowledge as the amount and organization of knowledge per se in the mind of the teacher. Therefore, what teachers need to know about content is more than what is being prepared in the school curriculum. Additionally, teachers are not only required to be capable of conveying information on subject content but they must also be able to explain and rationalize its necessity in relation to other subject content. According to Ball and Bass (2000), content knowledge includes the teacher's capability to rationalize questions, doubts and students' mistakes in learning. Teachers must also be able to relate or link Mathematical ideas within the content and correlate these with other topics in guiding student understanding.

Teachers play an active role in teaching and learning; however, results from the supervision records of Mathematics teachers in Malacca show a teacher-centered approach. Effective Mathematics teaching should focus on students' conceptual understanding rather than problem solving skills. Therefore, teachers must have a good conceptual and contextual understanding of the topic they teach before beginning to teach in a classroom. This is of particular importance because a teacher's ability to teach could affect student performance (Hill *et al*., 2005). For example, TIMSS reported that Malaysian students did not perform well in several topics including Algebra. Specifically, students were not competent in understanding the unknown concept and they face difficulty in solving linear equations. This is in line with a literature review that revealed students were having problems in Algebra at the lower and higher secondary levels. Wilkins (2008) found teachers backgrounds such as years of teaching, professional certificates and Mathematics courses taken indirectly affected teachers' practices. Hence, this research sought to identify teachers' PCK in general and their content knowledge in Algebra. Specifically, this research was conducted to achieve the following objectives:

- Identify the teachers general PCK and Algebra content knowledge based on years of teaching experience
- Identify the teachers general PCK and Algebra content knowledge based on course specification background

MATERIALS AND METHODS

This study was conducted in a district in Malacca, Malaysia. While, there are 15 schools in this district, the researchers administered the survey to 46 teachers within 11 schools; 34 teachers returned the completed questionnaires. Returned questionnaires included both the instruments; the general PCK questionnaire and the Algebra content knowledge test.

General Pedagogical Content Knowledge (PCK): The PCK consists of two dimensions. The first is on teachers' knowledge of Mathematics and Mathematics education and the second is on teachers' knowledge on the criteria for effective Mathematics teaching. Information on teachers' general PCK was gathered via responses on the general PCK instrument. This instrument was adapted from the Second International Mathematics and Science Study (SIMSS) and was translated and used in Tengku Zawawi's study. The questionnaire consists of 3 sections. Section A collects demographic information such as age, gender, race, teaching experience, level of education, teacher trainings, course specification and course attended. Section B consists of 24 items on knowledge and Mathematics education. For example, Mathematics is basically an abstract subject and Learning Mathematics mostly involves memorization. Respondents rated these statements on a 5-point Likert scale that ranges from 1 (strongly disagree) to 5 (strongly agree). Section C includes 37 statements that are related to the dimension of Mathematics teaching strategy. For example, I am able to change my teaching strategy whenever needed. Respondents rate these statements on a 5-point Likert scale that ranges from 1 (highly unimportant) to 5 (highly important). To determine teachers' PCK levels, the researchers used the mean score interpretation as shown in Table 1.

Teachers' content knowledge in Algebra: The instrument used to obtain information on teachers' content knowledge was adapted from Algebra questions used by Black (2007). Additionally, the data were derived from teachers' answers to the 21 questions given which yielded a maximum mark of 30. This instrument also included questions that required teachers to evaluate student work. The content of the questions was endorsed by an expert from the Curriculum Development Division, Ministry of Education, 2 Mathematics lecturers from a teacher training institute and local university, respectively and 2 expert teachers. Details on the item format are shown in Table 2. For multiple-choice questions, a mark of 1 was given for a correct answer and a mark of 0 was

Table 1: Interpretation of mean score level

Level	Mean score
Low	1.00-2.33
Moderate	2.34-3.66
High	3.67-5.00

Table 2: Item format in Algebra questions

Questions	Algebra content	Item format	Process
1	Simplifying Algebraic expressions	Multiple-choice	Symbols/representations involving multiple methods
2 (A-D)	General knowledge on Algebra	Always true, seldom true, unsure	Reasoning and related rationalization
3 (A-D)	Understanding number systems	Agree, disagree, unsure	Related reasoning and rationalization
4	Solving equations	Short answer with explanation	Symbols/representations involving multiple methods and technological application, communication, reasoning and rationalization
5	Simplifying Algebraic expressions	Teacher's explanation	Problem solving, symbols/representations, communication
6 (i-iii)	Using Algebra processes in geometric correlations	Multiple-choice with teacher's explanation	Real world application, symbolization involving multiple methods, reasoning, rationalization and communication
7 (i,ii)	Transformation/change rate	Multiple-choice with teacher's explanation	Application, symbols/representations, reasoning and verification, communication, symbols and correlations
8	Functions	Multiple-choice with teacher's explanation	Reasoning and verification, communication, symbols and correlations
9	Algebraic symbols in equations	Teacher's explanation	Symbols/representations, communication, correlations, reasoning and verification
10 (A-C)	Functions	Agree, disagree, unsure	Symbols using multiple methods, communication, reasoning, verification and correlations

given for an incorrect answer. For subjective questions that required an explanation, a mark of 2 was given for accurate answers and explanations, a mark of 1 for accurate answer but unclear explanation or no explanation and a mark of 0 for no answer or a wrong answer.

RESULTS

The results describe the respondent demographics and henceforth, answer the research questions formed.

Respondent demographics: Table 3 shows the respondents' demographic criteria. Participants included 34 teachers from 11 schools. A total of 21 participants were female and 13 were male. Only 2 teachers reported 1 year of teaching experience, 7 reported 5-9 years and 25 reported 10 or more years of teaching experience. In terms of professional training background, 23 earned a teacher training certificate in Mathematics and 11 had various teaching education apart from Mathematics; for example, Bahasa Melayu (Malay language), Chinese language, Accounting, Economics and Engineering. Therefore, teachers in this research were mostly experienced teachers with teaching background based in Mathematics. However, there was a small number of participants who taught Mathematics; however were not initially trained in Mathematics education.

Level of PCK and teachers' content knowledge based on years of teaching experience: The data with regard to the first research question concerning the level of general PCK and teachers' content knowledge in Algebra based on years of teaching experience is shown in Table 4. Overall, respondents' PCK levels were moderate and high. For the knowledge dimension on Mathematics and Mathematics education, 50% (17) had a moderate level whereas 47.1% (16) had a high level of PCK. Teachers'knowledge dimension on Mathematics teaching

Table 3: Demographic criteria of the respondents

Parameters	Values	Total
Schools	11	11
Gender		
Male	13	
Female	21	34
Training course specification		
Bachelor in Math	1	
Bachelor in non-Math	2	
KPLI/Dip in Math	10	
KPLI/Dip in non-Math	6	
Certificate in Math teaching	15	
Certificate in non-Math teaching	3	34
Teaching experience (Years)		
1-4	2	
5-9	7	
10-14	10	
15-19	4	
≥20	11	34

Dip: Diploma; KPLI: Post-graduate Education course

strategy revealed that 94.1% (32) had a high level of PCK. Data on teachers' content knowledge showed that 94.1% (32) teachers achieved marks below 15 out of 30 (total) for Algebra questions whereas 50% (17) obtained 5-9 marks. Based on years of teaching experience, 7 of 13 teachers who had taught for 20 years or more, achieved marks of 10 or higher. Only 2 teachers achieved marks of 15 (the highest); these teachers reported having taught for >20 years and between 10-14 years, respectively. These experienced teachers had good general PCK levels; however, they did not perform well in Algebra content knowledge.

PCK level and teachers' content knowledge based on specified training background: To answer the second research question, the data were analyzed to reveal PCK level and teachers' performance in Algebra questions based on their teacher training background. The results are shown in Table 5.

Table 4: PCK level and marks for teachers' content knowledge based on years of teaching experience

Teaching experience (years)	PCK level: Knowledge of Math and Math education			PCK level: Knowledge of Math teaching strategy			Algebra content knowledge (Total marks 30) Amount of marks/No. of teachers				
	Min.	Mod.	High	Min.	Mod.	High	0-4	5-9	10-14	≥15	No. of teachers
1-4			2			2		2			2
5-9		4	3			7		4	3		7
10-14	1	2	7	1		9	2	5	2	1	10
15-19		3	1		1	3	1	3			4
≥20		8	3			11	1	3	6	1	11
No. of teachers	1	17	16	1	1	32	4	17	11	2	34

Table 5: Level of general PCK and teachers' content knowledge based on teacher training background

Teaching experience (years)	No. of teachers	PCK Level: Knowledge of Math and Math education			PCK Level: Knowledge of Math teaching strategy			Algebra content knowledge (Total marks 30) Amount of marks/No. of teachers			
		Min.	Mod.	High	Min.	Mod.	High	0-4	5-9	10-14	≥15
Bachelor in Math	1		1				1			1	
Bachelor in non-Math	2			2			2		2		
KPLI/Dip. in Math	10		7	3		1	9		7	2	1
KPLI/Dip. in non-Math	6		3	3		1	5	1	2	3	
Certificate in Math teaching	12		5	7			12	1	5	5	1
Certificate in non-Math teaching	3	1	1	1	1		2	2	1		
No. of teacher	34	1	17	16	1	2	31	4	17	11	2

As shown in Table 5, 33 (97.1%) teachers had a moderate level of general PCK and a high level of Mathematics knowledge and education dimension; however, some (10) did not have a Mathematics education background. Next, almost all respondents (91.2%) had high PCK levels for knowledge dimension on Mathematics teaching strategy. Generally, respondents knew how to convey effectively content lesson to their students. Results on teachers' content knowledge revealed otherwise; specifically, 21 (61.8%) achieved marks <10. For those who achieved higher marks, 10 of 13 respondents had a Mathematics education background. Two teachers with Mathematics education background also achieved the highest marks of 15. Overall, it is clear that although teachers' general PCK was high, teachers' content knowledge provedotherwise. Furthermore, teachers with Mathematics education backgrounds yielded better performance in answering Algebra questions compared to those who did not have formal Mathematics education backgrounds.

DISCUSSION

The results show that teachers' general PCK was at moderate and high levels. These teachers at the very least had good knowledge on Mathematics elements and Mathematics education including effective teaching criteria. Therefore, they should be able to produce meaningful learning experiences for their students. However, this research did not perform observation methods to ensure that teaching process were on par with the teachers' level of knowledge. These researchers believe that PCK is not an easily acquired knowledge that can be passed on from an expert to a teacher; however, there is the component of an ever expanding knowledge that is obtained with experience. As mentioned by Halim (1997), new teachers are said to have little to no PCK. Thus, it is important for new teachers to collaborate with experienced teachers in performing professional discourse and development. The lesson study practice, for instance, could be one way for teachers to enhance their PCK. Stigler and Hiebert (1999) studied teaching practices in Japan, a country that acquired high TIMSS levels. They discovered that teachers provided more time for discussion among themselves as a means to determine and experiment with the best methods to convey lessons to their students.

The teachers' discouraging results on the Algebra items calls for attention. These results also parallel what Tengku Zawawi discovered on teachers' PCK in teaching the topic of fractions in primary school. Tengku Zawawi revealed that teachers' understanding of fractions was not on par with their vast teaching experiences. Tengku Zawawi also found experienced teachers who continued to teach by focusing merely on procedural understanding due to theirlack of conceptual understanding. Meanwhile, based on observations of teachers' teaching practices, Saad (2008) examined teachers' PCK in trigonometry classes and discovered that teachers lacked comprehension of the content's components which were

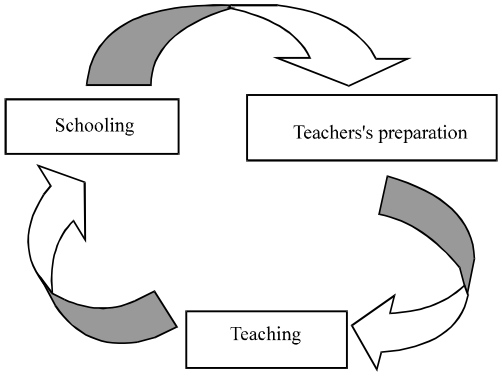

Fig. 1: Content knowledge cycle (Ma, 1999)

related to the aims and objectives of KBSM Mathematics. On the contrary, previous studies revealed that teachers who were more experienced in Mathematics gave clearer explanations, used better symbols or representations were more knowledgeable on questions asked by students and possessed an understanding of the structural basis of Mathematics and how they relate with one another (Borko *et al*., 1992; Ma, 1999).

However, teachers' content knowledge is non-static. Ma (1999) stated that teachers' PCK grows through the cycle of teaching and the learning process of the subject. Specifically, content knowledge develops through a cycle process shown in Fig. 1.

Generally, educational backgrounds determine teachers' content knowledge. In line with this result, teachers with educational backgrounds in Mathematics have better content knowledge than do others. Nevertheless, as seen Fig. 1 and developed by Ma (1999), teachers' content knowledge is also obtained through a cycle that teachers go through during teacher preparation and the lessons themselves. Therefore, teachers should reflect on their teaching processes. Subsequently, teachers can enhance their content knowledge via experience and further education.

CONCLUSION

The results show that teachers' high level of general PCK and lack of content knowledge may not describe a teacher's real capabilities in relaying lessons to students. However, this study at least provides additional value toward the perception of general PCK and teachers' content knowledge which is vital for teachers to provide an effective teaching and learning environment. Further, this researcher believes that when a person has chosen to teach Mathematics an interest in Mathematics is inherent. Thus, teachers should use this advantage and be more perceptive in their visions to explore a better understanding of Mathematical concepts. If teachers have strong conceptual and pedagogical knowledge, they will be able to see the relationship or link across subjects that are taught in school and the reality of life in relation to Mathematics. Teachers must be open-minded and ready to accept changes and they must be prepared to change and adapt their teaching methods to current situations.

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