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An Exploratory Factor Analysis in Developing Pedagogical Content Knowledge Scale for Teaching Science

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Abstract: This study aims to validate a Pedagogical Content Knowledge (PCK) scale that consists of 56 items. The instrument was distributed to 301 (16 years old) secondary science students. These students were required to respond to a 5 point Likert scale instrument. Using factorial analysis, 16 items were established which was divided into three components of PCK namely i) Knowledge of science pedagogy, ii) knowledge of students and iii) knowledge of concept representational. The final model of PCK was significant (p = 0.000) (RMSEA = 0.075; CFI = 0.910; and TLI = 0.892). This validated survey instrument serves as an evaluation tool for analyzing science teachers PCK that is less laborious and time-consuming.

Keywords: Confirmatory factorial analysis, effective science learning, pedagogical content knowledge, secondary students

INTRODUCTION

Teacher knowledge is a valuable investigation subject in the field of education as it gives insight to improvement of science teaching (Rohaan *et al*., 2009). Research on Pedagogical Content Knowledge (PCK) had become a trend among science educators as the literature review revealed that PCK as a special amalgam of teachers pedagogy and understanding of content (Abell, 2007), that is the key point to quality teaching and promoting meaningful learning. According to Shulman (1987), PCK is a specific teacher knowledge that combines content and pedagogical knowledge to form an understanding of how the topic, problems or issues are organized, delivered and used in teaching to suit various students' interests and abilities. Without a strong PCK, science teachers are said to have little knowledge of potential students problems and specific preconceptions and have difficulties selecting appropriate representations of subject matter (Van Driel *et al*., 1998).

The early conception of PCK by Shulman (1987) has since being refined by other researchers. Among of the PCK concepts described are: pedagogical content knowledge means the ability of teachers to translate the content by modifying the subject based on students prior knowledge, interests and abilities in order to facilitate students learning (Halim *et al*., 2001; Magnusson *et al*., 2002; Loughran *et al*., 2003); pedagogical content knowledge is knowledge about skills required to prepare teaching and learning based on content-specific reasoning by means of taking into account the learning needs that exist in the content-specific learning (Bucat, 2004). The general understanding of PCK is that Lederman and Gess-Newsome (1992), Gess-Newsome (1999), Koppelman (2008), Nilsson (2008) Othman and Majid (2009) and Jimoyiannis (2010) PCK derives from the overlapping between content knowledge, pedagogical knowledge and context knowledge. While Carlsen (1999) addressed PCK as four components of required teachers knowledge that were knowledge of general students misconception, knowledge of specific curriculum, knowledge of specific teaching strategies and knowledge of teaching and learning objective. Based on these conceptions, it can be derived that PCK for science teaching would consist of content knowledge, knowledge of specific teaching strategies, knowledge of students understanding, knowledge of context and knowledge of concept representational. Another component that is knowledge of assessment which is less investigated (De Jong, 2009) deserves similar attention.

While PCK is shown to be composed of various components of knowledge, most of the studies developed those components based on the practice of experience and beginning and pre service teachers. Lack of studies explained it from the students perspective and the components of science teachers PCK that facilitate their learning. Tuan *et al*. (2000), Jang (2010) had used instrument development method to identify the components that build up PCK concepts from secondary school students and college students perspective. Their

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research was based on the argument that students perceptions will enable researchers and teachers to appreciate the perceived instructional and environmental influences on students learning processes. As a result, the components derived from their study were instructional repertoire, representational repertoire, subject matter knowledge and knowledge of students understanding. Although students perceptions might not be consistent with the reality generated by outside observers, Knight and Waxman (1991) argued that they can present the range of reality for individual students and their peers in the classroom.

Thus, this study aims to develop a Science PCK model required by the science teachers to promote learning as perceived by the students. This study also aims to validate the model using Exploratory Factorial Analysis (EFA) method.

METHODOLOGY

A total of 301 Form Four (16 years old) science students from two states in Malaysia participated in the survey. The survey was administered in August 2010. The students were asked to rate the importance of teachers knowledge stated in the form of 56 items of five point Likert scale questionnaire (1 = very unimportant, 2 = unimportant, 3 = less important, 4 = important and 5 = very important). Students were briefed and reminded to reflect on their science learning experience and to indicate the teachers knowledge that promotes their learning based on the five point Likert scale. As Adediwura and Tayo (2007) argue that when students perception of teachers knowledge was taken into account in a study, the assumption is absolutely will depends on the fact that they have been taught by the teachers and have minds already pre-occupied with memories and reaction that inventory for data collection will measure.

The questionnaire was developed based on six component of Science PCK which are knowledge of subject matter, knowledge of instructional strategies, knowledge of concept representational, knowledge of teaching objectives and context, knowledge of students understanding and knowledge of evaluation, which were derived from the literature review. Knowledge of evaluation as a PCK component was suggested by De Jong (2009) while another five of the components were adapted from Tuan *et al*. (2000).

In order to develop a Science PCK model, the data was first analyzed using Principal Component Analysis (PCA) to determine the number of factors or components for classification of items (Miller *et al*., 2002; Norusĭs, 2005; Pallant, 2005). Eigenvalue rule and scree plot test were used to determine the appropriate number of components of PCK. Direct Oblimin rotation procedure was executed with the assumption that each of the components was related to each other in order to measure the importance of particular teachers knowledge. As a result, some items were reduced due to low factor loading. Based on the consideration of the sample size, the cut off value of factor loading used was 0.30.

Table 1: Exploratory factor analysis result

KMO test	Bartlett test of sphericity (Sig.)	Eigenvalue: Number of factor	Eigenvalue: Cumulative percentage (%)
0.869	0.000	16	66.84

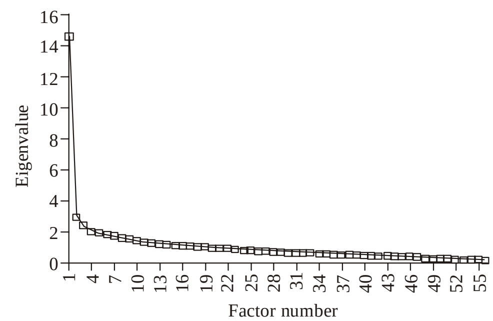

Fig. 1: Scree plot

To develop a good fit science PCK model, the data was analyzed using multivariate analysis method. Goodness-of-Fit (GOF) statistical information indicates how well the parameters of the factor model are able to reproduce the sample correlations (Brown, 2006). The components yield from the model then was renamed to indicate the components of Science PCK developed from the study. Construct reliability for each component was also analyzed in order to identify component reliability of the new instrument. The complete new instrument is in Appendix (Table 6, 7 and 8).

RESULTS

Findings: Table 1 displays the results of KMO and Barllett Test of Sphericity in order to determine whether PCA can be implemented in this study. KMO value was 0.869 and Barllett Test of Sphericity reached statistical significance standard (p = 0.000). These values is considered good as the KMO value exceeding the recommended value of 0.6 and the Barllett Test of Sphericity results supporting the factorability of the correlation matrix (Pallant, 2005). In addition, inspection of the correlation matrix revealed the presences of many 0.30 coefficients value and above, which indicate strong intercorrelation between items. By mapping these results, point out it can be concluded that the Science PCK questionnaire is appropriate for the implementation of PCA.

In order to identify the number of underlying factor that best represent the interrelationships among the set of variables, only total initial eigenvalues of above 1.00 from the result of total variation explained was considered. For

Table 2: Seperation of 3 rotated component factor using direct oblimin

Component	1	2	3
B5	0.742		
B6	0.739		
D2	0.694		
G5	0.672		
G3	0.671		
G1	0.659		
G6	0.649		
D3	0.643		
F4	0.639		
B7	0.617		
D4	0.589		
G2	0.563		
D1	0.524		
F9	0.520		
B13	0.516		
B12	0.511		
D7	0.510		
C3	0.496		
C1	0.494		
F5	0.484		
C5	0.463	0.348	
B10	0.459		
G4	0.450		-0.380
F3	0.419		
B11	0.416		
C4	0.396		
D6	0.366	0.345	
A4		0.790	
A6		0.686	
B2		0.630	
A10		0.598	
A7		0.560	
B4		0.540	
A9		0.518	
C2		0.499	
A8		0.473	
C10		0.471	-0.447
C7		0.443	
B9		0.436	
B1		0.403	
B3		0.394	
F6		0.386	
F2		0.371	
B8	0.336	0.350	
F1	0.332	0.349	
C9			-0.656
C11			-0.570
C8			-0.524
C6		0.448	-0.482
A1	0.328		0.398
A3	0.320		0.379
D5		0.304	-0.360
F7			-0.335

the Science PCK questionnaire used in this study, 16 components with eigenvalues exceeding 1.00 were present, explaining 66.835% cumulative percentage. However, the inspection of the screeplot in Fig. 1 revealed a clear break after the third component. In the basis of this finding, it was decided to precede the study by retaining the three components.

A number of 56 items was rotated by using Direct Oblimin rotation procedure. As shown in Table 2, the items which show loading factor equals to 0.30 and above only were retained into the components. This turn into result that 53 items were considered to be kept in the

Table 3: Value of fit statistic

χ^2	Df	(χ^2/df)	p	RMSEA	CFI	TLI
1686.178	692	2.44	0.000	0.069	0. 803	0.789

instrument while the other three items that are below the level set were omitted. This result explained the change into 34.639% cumulative percentage of variance with Component 1 contributing 25.433%, Component 2 contributing 5.202% and Component 3 contributing 4.004% respectively.

The rotated solution also revealed the presence of some cross loading items between factors. According to Din *et al*. (2011), it can be concluded that preferences questionnaire still contained multicollinear items. Thus, it was decided to place those items into the component based on the greater value of loading factor. Expert revisions of the items by the science education specialists suggest some adjustment to the instrument namely; another five items were omitted and a few items relocated into another component.

Based on the findings of the PCA and specialist suggestion, the instruments was further analyzed using Confirmatory Factor Analysis method (CFA) by means of Structural Equation Modeling (SEM). CFA performed has been assigned with three numbers of factors. As described by Din *et al*. (2011), based on the prescription in the CFA stages procedure (Hair *et al*., 2006), ll components are allowed to correlate with all other components and all measured items are allowed to load on only one component each but the error terms are not allowed to relate to any other measured variable Then, maximum likelihood estimation was adopted to generate estimates in the full-fledged measurement model. This has resulted into findings of relative chi-square (χ^2/df) and GOF as shown in Table 3.

The findings found that the p value had reached significant level, that is p = 0.000; relative chi-square meet the suggested ratio of approximate ($\chi^2/df \leq 5.00$); and the root-mean square error of 0.069 approximation below threshold of 0.080, the standard value to represents how well a model fits the population. However, both fit indicators, CFI and TLI reflect a possible fit problem as both of the values are less than 0.90 (Green and Pearson, 2004; Maat and Zakaria, 2009; Hair *et al*., 2006). A closer examination of the results revealed two possible reasons for the model lack of fit in term of CFI and TLI. The presences of cross-loading between items and low factor loading suggested model modification through convergent validity test. Consequently, a number of items were removed to bring up the CFI and TLI to approach the required threshold. Items removed were based on the modification indices and cut-off values (0.60) set for factor loading.

The model resulting from the modification is shown in Fig. 2. The numbers of items of each component have been reduced, 18 items were omitted from component 1, 15 items were omitted from components 2 and 4 items

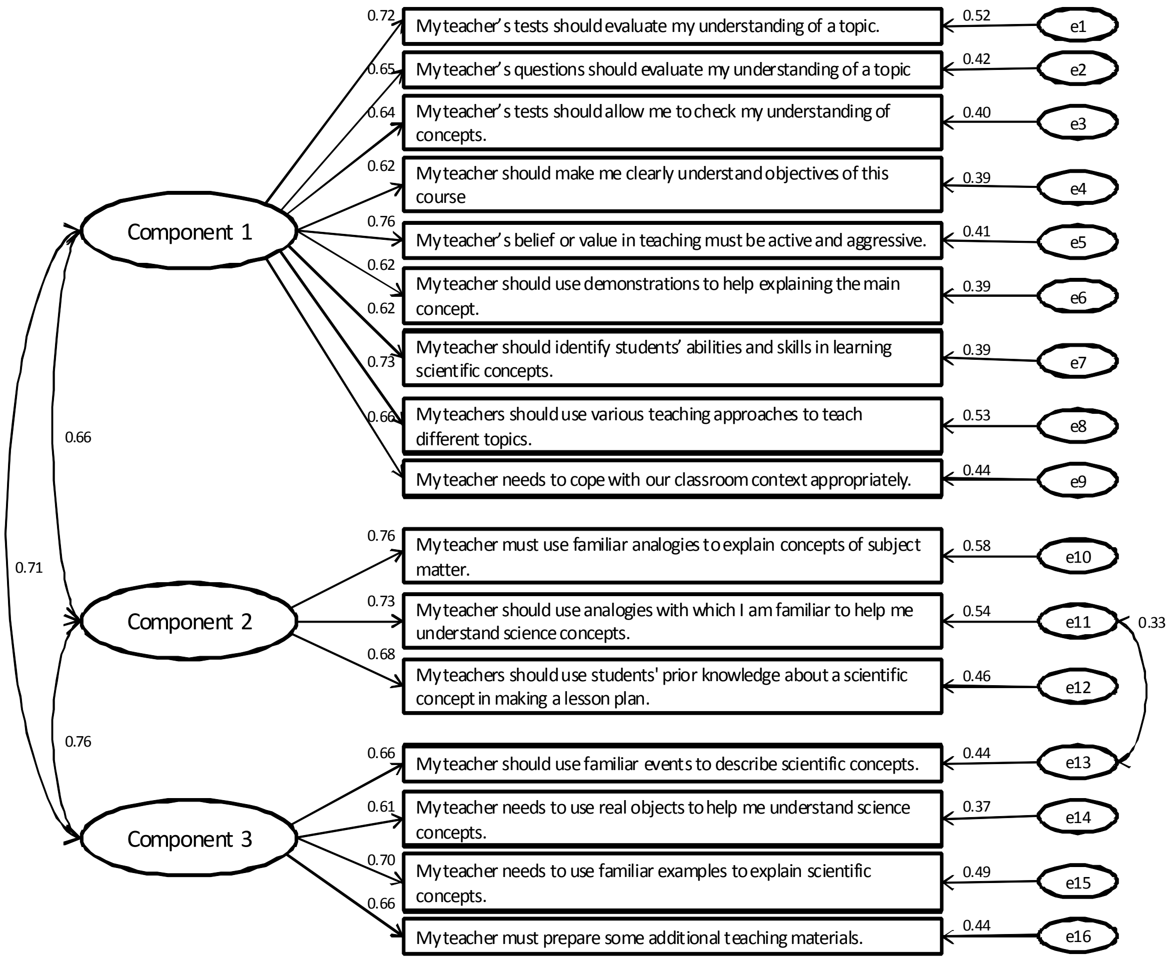

Fig. 2: The final CFA model of science PCK

were omitted from the third component, leaving the number of items in each respective component is nine, three and four. These remaining items are free from offending estimates, ranging from 0.61 to 0.76. The items in the instrument developed indicate at least 37% of the variance of the item and 63% of the error variance. In addition, cross-loading between e11 and e13 indicates there exist discriminant validity problem between the two items namely "My teachers have to use common analogies to help me understand the concepts of science" and "My teachers should use the common event/incident to explain the concepts of science". Although these items were grouped in different components, but both item were found related to the representation method required to explain a specific concept of science. However, the first item (e11) was seen to describe the representation method more specific compared to the item e13; that is the representational method selected by the teachers should be reasonable in the context of their students. Based on this consideration, both of the two items were maintained although the cross-loading between the items exceeding 0.30 as recommended by Hair *et al*. (2006).

Table 4: Value of fit statistic of final science PCK model

Chi-square (χ^2)	df	(χ^2/df)	P	RMSEA	CFI	TLI
267.562	100	2.676	0.000	0.075	0.910	0.892

The final model also shows the correlational relationship of 0.66 between component 1 and component 3, 0.76 between components 2 and 3 and 0.71 between components 1 and 3. This indicates that the shared variance for each pair of these components were respectively 44 percent, 58 and 50%. Based on these values, the effect size between these components is found to be at high levels (Pallant, 2005). However, even the effect size is high, but the components seems does not dependent upon another as the correlational relationship are less than 0.80 (Hair *et al*., 2006).

Table 5: Value of alpha cronbach for construct reliability test

Component	No of items	Alpha cronbach correlation coefficient
Knowledge of science pedagogy	9	0.87
Knowledge of students	3	0.76
Knowledge of concept representational	4	0.75

Finally, the values of GOF were rechecked to ensure that the new instrument developed comply with the suitability concept of the model. GOF values for the final model of science PCK is shown in Table 4.

The new model of Science PCK developed had achieved significant value, $p = 0.000$. In addition, the value of $\chi 2$, df, χ^2/df, RMSEA and CFI also met the concept of a fit model. Fit indicator of TLI is slightly less than the threshold of 0.90. However, since five out of six GOF indicate the fit model, then this model has been accepted as the final model. Furthermore, if further changes are made to get the fit model, we expect that the items in component 2 and 3 will be reduced. Whereas, according to Chua (2009), each constructs in a research instrument should have at least three items. In addition, continuous modification to this model might produce a web-like cross-loading between items. Hair *et al*. (2006) pointed out that a tiered model that has too much capacity of the cross-loading factor between items is not a good model.

As the model was finalized, the three components of science PCK identified from the study were named as knowledge of science pedagogy, knowledge of students and knowledge of concept representational. In order to ensure the internal consistency estimates satisfy the standard deemed necessary in scale construction, construct reliability for each component of science PCK has been calculated through alpha Cronbach score measurement. As shown in Table 5, all three components of science PCK have strong construct reliability as the correlation coefficient value for each of them is above 0.70, indicates strong correlation between items within the construct (Jackson, 2003; Norusĭs, 2005).

DISCUSSION

Based on the instruments developed in this study through EFA and CFA analysis, it was found that the science students perceive and seek for three components of PCK that promotes their learning. The components of PCK are knowledge of science pedagogy, knowledge of learners and knowledge of concept representation. The names of the components were decided after the items within each component were reviewed. The three components found in this study are in consistent with the early conceptualization of PCK by Shulman (1987), in particular relating to knowledge of science pedagogy and knowledge of learners.

The content knowledge component that is often described as one of the major components of PCK was found to exist across each of the three components. This findings support Van Driel *et al*. (1998) review of PCK in that subject matter knowledge or content knowledge is the foundation knowledge or component of PCK. Thus, an effective science teaching will occur when the subject is taught by teachers with the appropriate specialization.

Items found under the knowledge of science pedagogy relate to three distinct pedagogical knowledge; namely knowledge of assessment, knowledge of pedagogy and knowledge of classroom context. It is interesting to note that knowledge of assessment is given emphasis by the students. Students needs for better evaluation on the part of teachers indicate that teachers less focus on evaluating students understanding when teaching in classroom. Experience shows that teachers in Malaysia rely heavily on science curriculum specification in planning their teaching and learning.Existing Malaysian science curriculum specifications tend to emphasize on learning objective and teaching strategies. Less stress is given in the curriculum document about the assessment related to the learning objectives and teaching strategies.

Students in the survey also suggest teachers with knowledge of students understanding and knowledge of concept representation will encourage learning. These components of teacher knowledge and its items are relevant for science teaching and which science concept and principles are seeing as abstract to students understanding.

CONCLUSION

This study took into account of students perception of teachers PCK required to enhance their science learning. The model of PCK identified through exploratory factor analysis confirms the basic components of PCK identified by previous researchers. The model could be further improved through the use of Structural Equation Model analysis. This analysis method perhaps will provide an insight into the wider concept of PCK model including the other factors that may influence the formation of the concept and subsequently formation of the model. This validated instrument could be an alternative to identifying teachers PCK from the common method namely observation of teachers practice in the classroom. Further study of developing this instrument should also involve asking the students perspective in what the teachers actually do in the classroom.

Appendix: Give your opinion about the importance of the following action of your teachers in order to promote effective science learning (Table 6, 7 and 8).

Table 6: Knowledge of science pedagogy

Scale item	1 Very unimportant	2Unimportant	3Less important	4 Important	5 Very important
My teacher's tests should evaluate my understanding of a topic.					
My teacher's questions should evaluate my understanding of a topic.					
My teacher's tests should allow me to check my understanding of concepts.					
My teacher should make me clearly understand objectives of this course.					
My teacher's belief or value in teaching must be active and aggressive.					
My teacher should use demonstrations to help explaining the main concept.					
My teacher should identify students' abilities and skills in learning scientific concepts.					
My teachers should use various teaching approaches to teach different topics.					
My teacher needs to cope with our classroom context appropriately.					

Table 7: Knowledge of learners

Scale Item	1Very unimportant	2Unimportant	3Less important	4Important	5Very important
My teacher must use familiar analogies to explain concepts of subject matter.					
My teacher should use analogies with which I am familiar to help me understand science concepts.					
My teachers should use students' prior knowledge about a scientific concept in making a lesson plan.					

Table 8: Knowledge of concept representation

Scale item	1Very unimportant	2Unimportant	3Less important	4Important	5Very important
My teacher should use familiar events to describe scientific concepts.					
My teacher needs to use real objects to help me understand science concepts.					
My teacher needs to use familiar examples to explain scientific concepts.					
My teacher must prepare some additional teaching materials.					

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