Measurement Model of Reasoning Skills among Science Students Based on Socio Scientific Issues (SSI)

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Abstract

The lack of reasoning skills has been recognized as one of the contributing factors to the declined achievement in the Trends in Mathematics and Science Studies (TIMSS) and Programme for International Student Assessment (PISA) assessments in Malaysia. The use of socio-scientific issues (SSI) as a learning strategy offers the potential of improving the level of students' reasoning skills and consequently improves students' achievement in science subjects. This study examined the development of a measurement model of reasoning skills among science students based on SSI using the analysis of moment structure (AMOS) approach before going to second level to full structured equation modelling (SEM). A total of 450 respondents were selected using a stratified random sampling. Results showed a modified measurement model of reasoning skills consisting of the View Knowledge (VK) was as a main construct. The items that measure the level of pre-reflection of students fulfilled the elements of unidimensionality, validity, and reliability. Although the level of student reasoning skills was still low but this development of measurement model could be identified and proposed teaching methods that could be adopted to improve students' reasoning skills.

Keywords

Reasoning skills, socio-scientific issues, independent knowledge, instrument development, measurement model

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Introduction

A country with good results and achievements in TIMSS and PISA can be considered a country with the best educational system in the world (Liou & Hung, 2015; Luschei, 2017). Conversely, if TIMMS and PISA results indicate a decrease, then a negative reflection is reflected on its education system. This is because the world Knowledge-Economy (K-Economy) competition requires the mastery of science, mathematics, and technology (Breiner, Johnson, Harkness, & Koehler, 2012). The decline in the number of students taking science and mathematics is not only happening in Asian countries, but also in other developed countries such as in United Stated, Canada, South Korea, and China. PISA 2009 and TIMMS 2012 results show that the number of American students taking science and mathematics subjects experienced a significant drop in K-economy competition, where this competition gave a great blow as there were four countries that led such as Finland, Canada, Korea, and China. Despite this problem, the same thing has happened in Malaysia (Tienken, 2013). Ironically, the education system in Malaysia is the same as the education system in another country - a system that emphasizes the development of strong knowledge content through subjects like science, mathematics and language. However, there is a growing global awareness that 3M's control (reading, writing, and counting) alone is not enough for students who leave the world of schooling. On the other hand, the focus given to the students is not only for the sake of acquiring knowledge, but also towards the higher level of thinking skills (KBAT) to produce the first-class students (Primary Education Report of Malaysia 2013-2025).

Based on TIMSS and PISA results for science subjects tested in 2006, 2012, and 2015, Malaysia is experiencing a decline compared to other developing countries. Even in 2015, the results of TIMSS and PISA experienced a slight increase, yet still did not reach the 500 points level in international achievement. Therefore, the emphasis on the need for reasoning skills should be given attention to students in Malaysia (Ministry of Education, 2013). Referring to the TIMSS and PISA questions tested, most questions require the mastery of the science concept associated with the student's daily life. Social scientific issues are used to focus on understanding the concept of science through observation, reading, and discussion that require high level thinking skills through analysis and synthesis skills. In teaching and learning, these thinking skills and analyses are known as reasoning skills (Bao et al., 2009). This skill enables students to make observations, inferences, and conclusions and can relate to the concepts taught through the existing curriculum (Dunbar & Klahr, 2012).

In this regard, the Ministry of Education has transformed education from pre-school level by introducing reasoning skills. According to the National Education Policy 2012, since 2011, the reasoning skills have been applied to pre-school students in order to provide the first-year students with creative and critical thinking skills. Therefore, the objective of this study was to develop a measurement model of reasoning skills that could explain the characteristics of students in Malaysia based on scientific socio-issues. The implications of this study can provide guidance on educational practices to improve the science curriculum, especially biological subjects. Hence, this study would answer the research question: Which is the model of reasoning skills that can explain the true characteristics of students in Malaysia based on socio-science issues?

Literature Review

Reasoning skills

Reasoning skill is a process that allows students to engage in problem solving skills and build a logical conclusion (Daempfle, 2012). During this process, pattern and level of reasoning can be measured by referring to the answers given. The answers can determine the level of the student's reasoning either at low, medium, or high levels. Accordingly, the choice of reasoning skills as an endogenous variable is able to identify the processes, stages, and patterns of our students making decisions. During the process of reasoning, cognitive constructivist theory was cited as the theory that was able to form students' cognitive constructivism (Piaget, 1976).

Other models involving the reasoning process are also given a priority during the discussion as it helps the researcher to identify and differentiate the student's reasoning. Among the models to be considered are reflective judgment (King, 1981; King, Patricia, & Kitchener, 1994) and relativist model (Perry, 1979). Siegler (2016) stated the stages of reasoning were divided into three levels, which are low (concrete), moderate (transitional), and high (formal). At a low level, the phase of concrete involves students to feel or observe the real situation for them to better understand the learning and concepts taught. While for the moderate level is the transitional process in which the student needs a command to do something after a student wants to feel or try first. At this stage, the students do not have intuition to conclude or implement hypotheses (Hogan, Dwyer, Harney, Noone, & Conway, 2015). At the highest point of action, the phase involved is formal. At this point, students are able to build and generate knowledge and want to test for clarification when they are faced with an ambiguity on given problems. Table 1 shows each available reasoning model and its comparison.

Table 1. *Comparison table of RS level*(Daempfle, 2012)

RS Level	Piaget	Perry	King & Kitchner
Low	Concrete	Dualism	Pre-reflective
Medium	Transitional	Multiplicity	Quasi-reflective
High	Formal	Relativisms	Reflective

Socio-scientific issues (SSI)

Science literacy can be linked to the skills of understanding, embedding, and applying. This is because science literacy involves the skills of scientific knowledge (Nuangchale, 2009). When focused on the subject of science, literacy becomes a necessary knowledge of understanding and clarification of the idea that is derived from the relevance of natural phenomena. Thus, in explaining the relevance of environmental phenomena and science, socio scientific issues play an important role in generating ideas for solving problems. Furthermore, the development of science and current issues are complementary (Oecd, 2011).

At present, the development of science is in line with technological developments. For that reason, the general understanding of the principles of science is very important in their daily lives. Communities need to be aware of issues affecting such as health issues and pollution issues as a result of human activities (Sadler, 2009). Hence, the problems associated with the phenomenon of science and with students' life can have an impact if the students are able to argue and give their opinions. In line with the questions from TIMSS and PISA, each student needs to know the scientific issues related to the subject matter, and can explain the scientific phenomenon that occurs and is capable of submitting scientific evidence. The study of Siegel and Ranney (2003) indicates that students agree that the concept of science taught can be linked to the phenomenon of the often-occurring scientific phenomena in their daily lives.

Indirectly, students can add the concept of science by doing activities that do not conflict with the issues discussed or observed the phenomenon occurring in their environment for certainty. According to Guzzetti, Synder, Glass, and Gama (1993), student's conception of scientific phenomena is based on observation and daily experience. After experiencing such a situation, this method can give students new ideas or concepts to think. This can prevent students from misunderstanding the concepts learned. This is because when a concept of science has been mixed in the students, it is difficult for them to change it even if a proper concept has been taught by the teacher (Hmelo-silver et al., 2007). The concept is usually developed on what has been seen and experienced.

A measurement model

The first step, in order to produce and obtain a matching model of measurement is through the construction of research hypotheses. Then, the value of uni-dimensionality, validity, and reliability is measured and analysed to determine the models fixed. According to Gallagher and Brown (2013), the measurement of model fixed to the data collection procedures that can develop the reliability of the full structured equation model (SEM). If the development of measurement model does not have matching data, then the steps to produce a fully structured equation model (SEM) are not worth for the study data (Byrne, 2013; Kline, 2011; Piaw, 2014; Zainudin, 2015).

The construction stage of the measurement model is also known as a validation factor analysis or confirmatory factor analysis (CFA). CFA is used to measure the consistency of items or significant indicator variables in the selected latent variable (Gallagher & Brown, 2013). Researcher also analysed the fitness indexes to ensure that the data constructed for the development of a structured equation model were matched. Zainudin (2015) states that what needs to be identified and measured in the validation factor analysis at this stage is uni-dimensional, convergent, construct, and discriminant validity and consistency of internal, construct, and average variance extracted (AVE). To measure uni-dimensionality, the correlation value on the factor loading of a low item will be removed. The load factor acceptance value is greater than 0.5 and above (> 0.5). Item removal can only be done on an item only and then the researcher needs re-specification to achieve the uni-dimensionality of the item. In addition, to measure the validity of the instrument that is what should be measured in each construct; there are three types of legality that must be fulfilled.

The first validity is the convergent validity to ensuring that all items are statistically significant with reference to the average variance extracted or AVE with a value greater than or equal to 0.5. The second validity is the construct validity which is looking at the value of validity when fitness indexes meet the Goodness of Fit Index (GFI) value of equal or greater than 0.90 ($\geq$ 0.90), Then, the Comparative Fit Index (CFI) with the value equal to or greater than 0.90 ($\geq$ 0.90). Next, the Root Mean Square Error Approximation (RMSEA) with the value equal to or smaller than 0.08 ($\leq$ 0.08) and finally Chi square test (Chisq / df) with a value greater than 5.0. The third validity is the discriminant validity which refers to the state of legality independent of the items overlapping in the same contract or other contract.

Methodology

The data collection technique in this study was a survey. 450 respondents were selected in this study by using a two-stage stratified random sampling (Cragin & Shankar, 2006). The first stage was to use a simple random sampling of a state based on five zones (north, central, east, and south), the researcher determined the state of each zone using a simple random one state, and the states finally selected were Kedah, Perak, Terengganu, and Johor. As for the second stage was a simple random in order to determine the number of students in each state (Saunders, Lewis, & Thornhill, 2012). Table 2 shows the method to determine the number of respondents in this study.

Table 2. *Method to determine the number of respondents in this study*

Number of respondents	Number of students selected
North Zone (Kedah) 5,057	97
Central Zone (Perak) 7,168	138
East Zone(Terengganu) 2,462	47
South Zone (Johor) 8,761	168
Total: (Four Zones) 23,448	450

The instrument set used in this study was in the form of a written test to measure the level and pattern of scientific reasoning of science students based on socio scientific issues (Bell & Lederman, 2002). According to Bell and Laderman (2002), this instrument has a high degree of validity since it has passed the validity process of six experts -four science teachers and two scientists. The scenario questioned in this instrument is based on socio-scientific issues that can be used for biology subjects. The reasoning skill instrument has three different scenarios that discuss the issues of SSI adapted from Bell and Laderman (2002). The scenario is common queried and can be answered by the students stating the reason for their decision, in addition to saving time. This instrument refers to the dimension of reasoning which consists of three scenarios, the scenario I (climate change) and II (nutrition), there are five sub-questions and for scenario III (smoking and cancer), there are 3 sub-questions. Each question requires students set decided whether to agree or not and why? Because the answer that gets a high score rubric is the answer that needs justification, mechanisms, and examples. Table 3 shows an example of scenario III through the issue of smoking and cancer were administered to students.

To analyse the questions to the students scientific reasoning skill, argumentation reasoning rubric complex analysis has been carried out (Tal & Hochberg, 2003; Zohar & Nemet, 2002). The section devoted to supporting each student's response to their arguments by stating the justification and by explaining the mechanisms that was showed in Table 4. Rubric given score will refer to the score level of RS. The same reasoning score level with a study conducted by Perry (1999) and King and Kitchner (1994) involving the RS scheme scoring in determining the level of reasoning is as shown in Table 5 (Lawson, 2004).

Table 3. *An example of scientific reasoning questions for Scenario III*

Scenario III	Many researchers believe that smoking accounts for a large proportion of all cancers and as much as 30% of all cancer deaths. Cigarette smoking has specifically been implicated as the cause of cancer of the lung, oral cavity, larynx, oesophagus, bladder, kidney, and pancreas. Additionally, the risk of developing cancer is greater for people who smoke more and who start smoking at a younger age. Furthermore, researchers believe that smoking may be the cause of 25–30% of all heart disease. Exposure to passive tobacco smoke is very likely a significant cause of cancer in non-smokers. Some scientists believe that the increased risk could be as high as 50%. It has been estimated that thousands of people die each year due to exposure to passive cigarette smoke. Recently, nicotine in cigarette tobacco has been identified as a drug whose addictiveness exceeds that of opium and heroin. In addition to this, documents have come to light that indicate that some tobacco companies have used a variety of methods to increase the amount and potency of nicotine in cigarette tobacco. Finally, it has been shown that many people begin smoking as teenagers, and once started, have a very difficult time quitting. In contrast to these claims, tobacco companies have consistently asserted that while tobacco may be associated with increased risk for various cancers and heart disease, it has never been proven to cause these diseases. Furthermore, to smoke or not is a free choice that should be up to the consumer, not government agencies.
Sub-questions	3a. Given the reported dangers of cigarette smoke and its addictiveness, should legislation be passed that would make cigarette smoking illegal? Why or why not? 3b. Would you support legislation that makes it more difficult for minors to obtain cigarettes and/or penalizes tobacco companies who target minors in their advertising? Why or why not? 3c. Do the alleged dangers of passive cigarette smoke justify banning smoking in public places such as restaurants and bars? Why or why not?

Table 4. *The schematic showing the score and answers to students' reasoning*

Scenario	Score	Reasoning score
I, II, & III	0	No answer or No justification in context of question
	1	One justification of decision: mechanism unelaborated
	2	Two or more justifications of decision: mechanisms unelaborated
	3	One justification of decision: mechanism explained with examples
	4	Two or more justifications of decision: one mechanism explained
	5	Two or more justifications of decision: multiple mechanisms explained

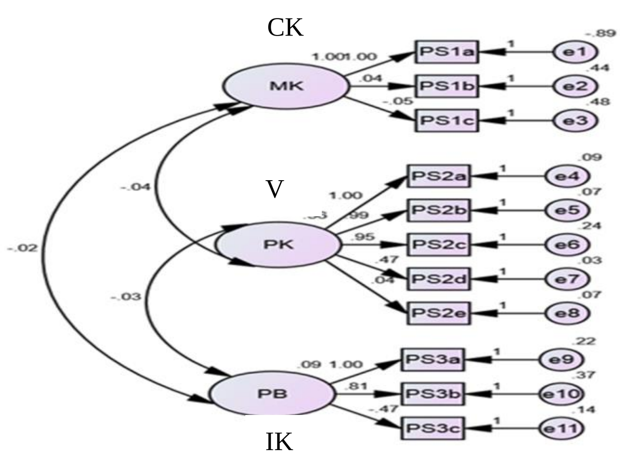
Table 5. *The score scheme and the level of reasoning skill*

Score	Level of RS
0-1	Level 1 (low – pre reflective)
2-3	Level 2 (medium – quasi reflective)
4-5	Level 3 (High – reflective)

Results

The research hypothesis tested for the measurement model of reasoning skills is: H1-the measurement model of reasoning skills has validity and has fixed with the study data. In this model there are three sub-constructs that measure RS as a result of the built EFA: view knowledge (VK), context knowing (CK), and independent knowing (IK). Figure 1 shows the measurement model of RS which is being constructed. This model was developed based on data from written test instruments. This measurement model of RS did not match with the study data. This model was not significant and the research hypothesis was rejected. There are six items that do not meet the criteria for subtracting, namely CK (PS1a, PS1b, and PS1c) and IK (PS3a, PS3b, & PS3c).

Figure 1. *The first measurement model of reasoning skills*



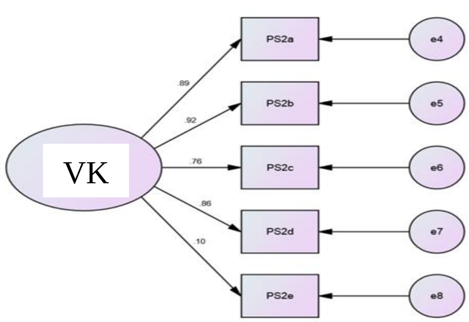
In table 6, sub-constructs that do not meet the requirements of uni-dimensionality, validity, and reliability through load factor assessment (PS1a, PS1b, PS1c, PS3a, PS3b, and PS3c). Whereas, the value of C.R in the sub-construct of CK is 3.165 and AVE = 3.221. While for IK, the value of C.R is 0.190 and AVE = 0.119.

Table 6. *The value of each substructure and item*

Variables	Sub constructs	Items	*Outer Loading* (>0.5)	Removed Items	C.R (≥0.6)	AVE (≥0.5)	AVE SQUARED
Reasoning Skills (RS)	Context Knowing (CK)	PS1a	3.08	removed	3.165	3.221	1.779
		PS1b	0.059	removed			
		PS1c	-0.07	removed			
	View Knowledge (VK)	PS2a	0.898		0.593	0.858	0.770
		PS2b	0.917				
		PS2c	0.758				
		PS2d	0.856				
		PS2e	0.096				
	Independent Knowing (IK)	PS3a	0.549	removed	0.190	0.119	0.435
		PS3b	0.377	removed			
		PS3c	-0.354	removed			

To ensure the measurement model of RS, six non-fixed items were removed. After six items from the CK and IK sub-constructs were removed, the modified measurement model of RS developed on the second was significant and fixed to the study data. Hence the hypothesis was accepted. Table 7 and Figure 2 show the acceptance measurement model of RS and the only remaining VK sub-contract with five items (PS2a, PS2b, PS2c, PS2d, & PS2e).

Figure 2. *The measurement model fixed to the study data*



The measurement model of RS fixed the study data is shown in the analysis through Table 7. The value of the five remaining items in the VK sub-constructs has been uni-dimensional requirements of more than 0.5. While for the value of C.R is 0.593 mean that ≥ 0.6 and AVE is 0.858 which is ≥ 0.5.

Table 7. *Findings of the modified measurement model of RS was fixed to the study data*

Variable	Sub-construct	Items	*Outer Loading* (>0.5)	C.R (≥0.6)	AVE (≥0.5)	AVE SQUARED
RS	View Knowledge (VK)	PS2a	0.898	0.593	0.858	0.770
		PS2b	0.917			
		PS2c	0.758			
		PS2d	0.856			
		PS2e	0.096			

Discussion

In this study, reasoning skill is a process of generating grounds through generating ideas to solve problems (Voss, Perkins, & Segal, 2009). This RS represents the ability of students to engage in various empirical-inductive patterns of thinking to hypothetical-deductive thinking (Gerber, Cavallo, & Marek, 2001). This instrument was taken from the socio scientific issue of Bell and Lederman (2002), which had three major scenarios related to and 11 questioned items. It is the environmental issues such as nutrition, effects of cigarettes and cancer, and genetic engineering. The measurement model of RS which was developed on the second was valid and fixed the study data. The findings of the measurement model of RS illustrate to the researcher that students in Malaysia were not able to explain the process of claiming to more concrete by getting a simple reason and giving a less complete explanation. This model is parallel to the reflection model between Piaget (1976), Perry (1999), and King and Kitchner (1994) involving the level and pattern of reasoning. For Piaget (1976), the low level is known as concrete while Perry (1999) is known as dualism and King and Kitchner (1994) known as pre-reflection. This finding is different from Bhat (2016), the knowledge and context of teaching in science should have a significant relationship with what the student learns.

When measuring students' level of reasoning in this study, descriptive results shows 78% of students answer at a low level by giving a short answer without a detailed explanation (Ikhwan, Sadiah, & Eshah, 2017). The findings of Darus' (2012) study, based on the results of TIMSS and PISA indicate that students in Malaysia still have an inadequate attitude when answering questions, especially questions requiring longer reading or essay questions. In addition, students have become accustomed to short, structured, and multi-choice question formats on previous tests.

Conclusion

In conclusion, the development of measurement model of reasoning based on socio scientific issues is able to conform and identify the levels and constructs that need to exist during the process of clarifying for science students especially in biological subjects. The study of Tal, Kali, Magid, and Madhok (2011), a solution to solving socio-scientific issues can expose students to the ability to understand and make students more active in class than passive through traditional methods. Compared to students in Malaysia, they are still unable to formalize and reflect on any questions raised. This implication actually allows students learn to be centralized. Students are free to give reasons for each question as long as they are able to argue in the classroom. There is no wrong answer from the student, can indirectly foster the process of reasoning. Students' learning strategies need to be diversified to make students more independent and share in getting information to build their own reasoning.

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