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Knowledge States in the Learning of "Time": Comparison of Primary Six Pupils' from Different Types of Schools in Penang

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Abstract: *The findings in this paper were a part of a bigger study which aimed to develop a cognitive diagnostic assessment [CDA] for primary mathematics learning of "Time". This paper aimed to discuss and compare the knowledge state of primary pupils from different types of schools in Penang. Knowledge state represented a pupil's mastery level on a defined set of attributes. These attributes were assessed by using a set of items and the responses were observed to find out a pupil's knowledge state. Two hundred and sixty-nine Primary Six pupils from 11 primary schools in Penang involved in the study. A set of CDA with 35 items consisting of four cognitive models were administered to the pupils. However, only three cognitive models were discussed in this paper. Students' responses were analysed by using Artificial Neural Network [ANN] to find the attribute probability of every pupil on each attribute. This probability was then classified and this set of classified attribute probability represented knowledge state of a pupil. Finding out the knowledge state of pupils helps teacher to investigate pupils' learning progress, identify pupils' misconception and thus make effective instructional decision. Results showed that Chinese Vernacular School pupils performed better than National School and Tamil Vernacular School pupils. Besides, the most common knowledge state in each cognitive model for each type of school was quite similar. The findings of this paper could be a preliminary step to demonstrate the usability and practicality of using CDA to obtain meaningful instructional inferences.*

Keywords: cognitive diagnostics assessment, time, primary six, knowledge state

Introduction

Assessment is an essential tool in teaching and learning. White (2007) stated that "Assessment is seen as a process of gathering evidence and making judgments about students' needs, strengths, abilities and achievements" (p.46). Hence, it's crucial to assess students effectively to obtain the feedback regarding their learning progress.

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Cognitive diagnostic assessment [CDA] is a relatively new assessment tool. As defined by Alves (2012), CDA is an assessment method which combined psychology of learning with statistical methods as well as models in order to make inferences regarding students' specific knowledge structures and processing skills. As CDA can provide fine-grained feedback, one of the results which can be obtained from CDA is knowledge state. Knowledge state reveals an individual's mastery level for a defined set of attributes. It is crucial to identify students' knowledge state as it informs educational stakeholders about students' current state of learning and discover incomplete or incorrect knowledge state. Thus, granting an appropriate and effective instructional decision.

This paper aimed to discuss knowledge state of primary pupils in three time-related cognitive model and compare the knowledge state of pupils from different types of primary schools. Topic of "Time" was focused in this study as "Time" is an important concept in daily life. However, Burny, Valcke & Desoete (2009) concluded that "Time" is a complex concept and it's not easy to teach to children. Perhaps, this might be caused by the abstract nature of "Time" (Harris, 2008). Although "Time" itself is a small, basic concept, however, there are many other concepts which are integrated from "Time" such as physics (mechanical time), history (chronology) and chemistry (reaction time). Thus, it's important to identify students' difficulties while learning "Time" since they are young and perhaps CDA could be used as a tool to achieve this purpose.

Furthermore, in this paper, knowledge states of pupils from different vernacular schools in Malaysia were compared. In Malaysia, there are three types of primary schools: (1) National School; (2) Chinese Vernacular School; and (3) Tamil Vernacular School. Each type of schools consisted of pupils from different ethnics. The primary mathematics curriculum implemented in these schools is the same and the only different is the instructional medium used. Boroditsky, Fuhrman & McCormick (2011) stated that pupils' time-related concepts could be different as different instructional medium was used. In Boroditsky's earlier study in 2001, he also found that an individual's perception of time was strongly related to their native language. Thus, it is interesting to find out if pupils from these different types of schools exhibited different types of knowledge state under the same curriculum but different medium of instruction used.

Moreover, Lim (2003) also found that different teaching approaches were employed in different vernacular schools. For instance, Chinese Vernacular Schools preferred more active learning in class, and more drills and practices as well as more competition and quizzes as compared to another two vernacular schools. Her studies also found that pupils from Chinese Vernacular School performed better in the given test. This indicates that pupils from different vernacular schools do perform differently. However, to what extent and how are these students perform differently? Also, what are their differences in terms of their mastery level of specific skills? It will be interesting to compare the mastery level of pupils from same education system but different instructional medium and teaching approaches in learning the topic of time.

Literature Review

Cognitive diagnostic assessment [CDA] is an assessment that aims to gather fine-grained feedback of learners' attribute mastery profile and their cognitive knowledge state at a learning point (Jang, 2009). This fine-grained result is meaningful as learners who obtain the same score in a test might have different attribute profile (or cognitive levels). The results from CDA helps the examinees to take essential actions to fulfill the gap between their current competency levels and their desired learning goals (Black & William, 1998). Besides, learners' cognitive strengths and weaknesses in a subject domain can be diagnosed by using CDA (Wu, Chen, Sung & Chang, 2012; Ye, 2005). Furthermore, CDA can also be used to measure learners' cognitive structures and processing skills (Leighton & Gierl, 2007).

Items in CDA are constructed based on cognitive model. In other words, cognitive model serves as the foundation of CDA. Leighton and Gierl (2007) defined cognitive model as "a simplified description of human problem-solving on standardized tasks at some convenient precisions or level of details in order to facilitate explanation and prediction of students' performances, including their strengths and weaknesses" (p. 6). The aim of constructing a cognitive model is to relate the interpretation of test score to the cognitive attributes (Roberts et al., 2012).

Pupils' responses towards the diagnostic tasks will exhibit their knowledge state in a particular cognitive model. Knowledge state which can be obtained from CDA is defined as "well-specified combinations of attributes that form the basis of students' conceptions of domain-specific knowledge and skills (Ketterlin-Giller & Yovanoff, 2009, p.7)." It exhibits students' mastery and non-mastery on a given set of attribute (knowledge, skills or processes) in a specific content area. In other words, it provides information to teacher whether a student has mastered certain attributes or not. However, it cannot be measured directly. Knowledge state can only be identified through observation and analysis of students' response pattern to items. Ideally, if student has mastered all the attributes that are required to solve an item, he/she will be able to solve the item correctly. Conversely, if a student has not mastered one or more attributes that were required to solve the item, he/she will not be able to give the correct response to the item. Thus, to identify examinee's knowledge states, a cognitive diagnostic assessment is administered to students.

CDA has been applied to various subjects such as mathematics (Alves, 2012; Broaddus, 2011; Ye, 2005) and English (Jang, 2009; Lee & Sawaki, 2009; Wang & Gierl, 2011). CDA has been applied in mathematics learning such as algebra (Roberts & Gierl, 2010; Tan, 2014), fraction (de la Torre & Douglas, 2008; Ketterlin-Geller, Jung, Giller & Yovanoff, 2008; Sun, Suzuki & Toyota, 2013;), 2-digits numeral subtraction (Alves, 2012), mixed number subtraction (Henson, Templin & Willse, 2009) to make diagnostic inferences based on learners' responses.

Among these studies, there were several past studies on knowledge state, for example, Birenbaum, Kelly and Tatsuoka (1993) which focused on the knowledge states in Algebra; Birenbaum, Tatsuoka and Yamada (2004) which compared the eighth graders' knowledge states in United States, Japan and Israel. In Birenbaum et al. (1993), the aims of the study were to classify examinees' responses into one of two pre-specified solutions for linear algebraic equations with one unknown and to diagnose their knowledge states. In their studies, knowledge states were predetermined and examinees were categorized into these knowledge states based on their responses. More than 50 knowledge states were found in their study. Consequently, examinees' mastery level of the assessed attributes was also reported in their study. The researchers suggested the teachers could use the results of this study to address the unmastered attributes and design remedial course based on individual's need.

Theoretical Framework

The theory underpinning this study is schema theory which first proposed by Bartlett (1932). Bartlett (1932) defined schema as "an active organisation of past reactions, or of past experiences, which must always be supposed to be operating in any well-adapted organic response. (p.3)". In other words, schema theory involved an individual's knowledge representation, organization, processing and utilization. According to Marshall (1993), a schema has content and structure. Thus, to assess the schema knowledge, the assessment tasks writer should consider two important aspects: (1) how knowledge is related to one another and (2) what is the knowledge stored in the schema. In this study, items were designed to make pupils' knowledge structure and processes observable. Each item required a set of specific schemata in order to solve it correctly. This set of schemata was generated based on experts' ways of solving these items. As stated by Chi, Feltovich and Glaser (1981), experts are assumed to have more mathematical knowledge in solving a mathematical task. Hence, in this study, experts' schemas were used as a foundation to identify the knowledge needed to solve each item and to investigate the connections between this knowledge. Then, based on analysis of pupils' responses, their knowledge states were identified.

Methodology

Participants

269 Primary Year Six consisting of 112 pupils from three Chinese Vernacular School [known as SJK(C) in this entire manuscript], 97 pupils from three National School [known as SK in this entire manuscript] and 60 pupils from four Tamil Vernacular School [known as SJK(T) in this entire manuscript] in Penang. Since this study aimed to diagnose pupil's strengths and weaknesses, the schools involved in this study were selected purposively. This was done based on two assumptions: (1) pupils from high-performing school (schools are classified as high, average and low-performing school by Ministry of Education Malaysia) would perform excellently, thus, they would be able to answer all the items correctly and (2) pupils from low-performing schools might not be able to complete the diagnostic tasks, thus, only limited inference could be made. Thus, only average performing schools were selected. The selection of schools also subjected to the availability and commitment of the schools. All of the Primary Year

Six pupils in the selected schools were involved in data collection process to ensure pupils from all range of academic achievement were included.

Instruments

A set of 35-items cognitive diagnostic assessment [CDA] was used. Four cognitive models were included in this CDA, however, only three cognitive models were discussed in this manuscript due to the relevancy between these cognitive models. These three cognitive models involved both 12-hour and 24-hour time system in order to find (1) the ending time of an event; (2) the duration of an event; and (3) the starting time of an event. The items in each cognitive model showed a Cronbach's Alpha coefficient of more than 0.7, which indicated that these items are reliable (George & Mallory, 2003; Nunnally, 1978). The validity of the assessment was evaluated based on its aspects of content and construct. The content and construct validity of the instrument was enhanced by (1) using Malaysian primary school mathematics curriculum specifications as the basis of the assessment; (2) involving seven experienced teachers in primary mathematics field to validate and revise the designed items; and (3) conducting think-aloud session in the form of interviews with pupils to investigate the required attributes to solve the selected tasks.

Analysis

Each cognitive model measured five attributes. these attributes were identified by the panel of experts which consisted of seven experienced primary school mathematics teachers from all three types of schools. These attributes were arranged hierarchically based on their complexity, i.e. from the most basic to the most complex attribute. Three items were designed to measure each attribute. This is to ensure the reliability of the analysis results. Pupils' responses towards the items were categorized into binary pattern "0" and "1" whereby "0" indicated either an inappropriate understanding which observed through the working step or an incorrect response; and “1” indicated either an appropriate understanding or a correct response. These responses were then analysed by using Artificial Neural Network [ANN] in MATLAB. This process was started by key in the expected outcome based on the arranged attributes. Then, students’ responses were key in. ANN analyses the results by comparing these two inputs, As a result, mastery probabilities of pupils for each attribute were generated. These probabilities were classified into three levels of mastery: (1) non-mastery (denoted as “0”) for probability lower than 0.5; (2) inconsistent mastery (denoted as “½”) for probability ranged more than or equal to 0.5 and less than 0.8; and (3) mastery (denoted as “1”) for probability more than or equal to 0.8. The set of probabilities for the attributes in each cognitive model formed the knowledge state of a pupil for that cognitive model at the moment of he/she is being assessed.

Findings and Discussions

Two-hundred-and-sixty-nine Primary Six pupils were involved in this study, yet only 246 responses were analysed as only completed scripts were used for analysis purpose. Pupils’ knowledge states for three cognitive models would be discussed in this section.

Cognitive Model 4 [CM4]: Finding the ending time of an event when both 12-hour and 24-hour time system were involved

Cognitive Model 4 [CM4] measured pupils’ ability to find the ending time of an event when both 12-hour and 24-hour time system are involved. There are five attributes in this cognitive model.

These attributes are: (1) knowing and converting 12-hour system and 24-hour system – limit to the items involve both system; (2) addition of time/duration involving 12-hour and 24-hour systems; (3) finding ending time as involving addition of starting time and duration (involving 12-hour and 24-hour systems); (4) transform words context into mathematical operation to find the ending time of an event; and (5) reasonability of the final answer as an ending time in 12-hour and 24-hour system for word problems.

For each KS, each digit of the string of number in the bracket indicated the mastery level of pupils for each attribute (see Table 1). For example, KS0 (00000) indicated that the pupils had not mastered any of the mentioned attributes. Meanwhile, KS5 (11110) indicated that pupils mastered the first four attributes, but not the fifth attributes which is these pupils were not able to provide reasonable answer of the given tasks. Since these attributes were arranged hierarchically from the most basic to the most complex, pupils were expected to master the prerequisite attributes before the more complex one. For instance, students should know the method to convert time between 12-hour and 24-time systems (the first attribute) before they can find the ending time of an event when it involves both time systems (third attribute). However, during data analysis, some unexpected patterns were found, which pupils did not follow the hierarchy as expected. Thus, these knowledge states are categorized as unexpected KS. For example, KS10 (11011) indicated that this pupil exhibited the ability to convert time between two time systems and perform addition (i.e. the first and second attributes), but he/she did not master the third attribute, then he/she showed the ability to solve tasks involved more complicated attributes (fourth attribute: transform word problems to find ending time and fifth attribute: provide answer reasonably).

Table 1

Examples of Knowledge State with Interpretation

Knowledge State	Interpretation
KS0 (00000)	Student did not master any attribute.

KS5 (11110)	Student is able to convert time from 12-hour time system to 24-hour time system and vice versa; perform addition of time/duration; finding ending time as involving addition of starting time and duration (involving 12-hour and 24-hour systems); and transform words context into mathematical operation to find the ending time of an event. Student is not able to present the final answer in terms of time.
KS10 (11011)	Student is able to convert time from 12-hour time system to 24-hour time system and vice versa; perform addition of time/duration; transform words context into mathematical operation to find the ending time of an event; and present the answer in correct form. Student is not able to find ending time as involving addition of starting time and duration.

Table 2

Knowledge States of Pupils for CM4 by Types of Schools

	SJK(C)	%	SK	%	SJK(T)	%
Expected Knowledge State						
KS0 (00000)	0	0.0	1	1.1	6	11.8
KS1 (10000)	3	2.8	3	3.4	2	3.9
KS2 (11000)	1	0.9	4	4.6	3	5.9
KS3 (11100)	3	2.8	8	9.1	4	7.8
KS4 (111½0)	0	0.0	1	1.1	0	0.00
KS5 (11110)	6	5.6	10	11.4	4	7.8
KS6 (1111½)	0	0.0	1	1.1	2	3.9
KS7 (11111)	91	85.0	58	65.9	27	52.9
Unexpected Knowledge State						
KS8 (10011)	1	0.9	0	0.00	0	0.00
KS9 (11010)	0	0.00	0	0.00	2	3.9
KS10 (11011)	1	0.9	1	1.1	0	0.00
KS11 (11½11)	1	0.9	1	1.1	1	2.0
Total	**107**	**99.8**	**88**	**99.9**	**51**	**99.9**

As shown in Table 2, 107 SJK(C) pupils, 88 SK pupils and 51 SJK(T) pupils' responses were analysed. 12 knowledge states were found based on the analysis of the responses. In addition, eight out of the 12 KS were expected KS which followed the attribute hierarchy and the other four were unexpected KS, i.e. KS8 (10011), KS9 (11010), KS10 (11011), KS11 (11½11). In fact, in the overall responses, only 3.3% of the pupils showed unexpected KS and pupils from all three types of schools did exhibit this kind of KS.

Besides, the high percentage of pupils (85%) exhibited mastery of all attributes measured in CM4 making KS7 (11111) the most common KS among SJK(C) pupils. Similarly, the most common KS for SK and SJK(T) pupils was also KS7. Among these three types of schools, SJK(C) pupils showed the highest percentage in mastering all the attributes. This result revealed that more SJK(C) pupils are familiar with this cognitive model and its attributes. Furthermore, pupils from SJK(C) had mastered at least one attribute (KS1; 10000) in CM4. Meanwhile, SJK(T) had the most pupils which showed mastery of none of the attributes measured in CM4. Based on this result, SJK(T) pupils seems weaker in this CM and SJK(C) pupils exhibited better understanding on this cognitive model as compared to the other two types of schools.

Moreover, it was also found that KS of SJK(C) pupils were very clear cut, i.e. there is no sign of ½ which indicated inconsistent mastery. This result shows that there is rarely misunderstanding or misconception for the concept to be measured. Pupils mastery level only fell into non-mastery or mastery.

Also noted that, the second most common KS for pupils from SJK(C) and SK was KS5 (11110), which pupils had master the first four attributes in CM4 but not the last attribute. However, the second most common KS for pupils from SJK(T) was KS0 (00000), which also indicated that pupils had not master any of the attributes. This again shows that, SJK(T) pupils might be comparatively weaker than the pupils from the other two types of schools in mastering this concept.

On the other hand, mastery level of the third attribute, i.e. finding ending time as involving addition of starting time and duration (involving 12-hour and 24-hour systems) was the cause of all the four unexpected KS. These pupils either did not master this attribute at all [KS8 (10011), KS9 (11010), KS10 (11011)] or mastered it partially [KS11 (11½11)], however, they were able to solve questions that involved more complex attributes. This attribute was assessed by item 8, 9 and 10. As shown in Table 3, item 9 had a much lower a p-value as compared to its parallel items (item 8 and 10). During data analysis, it was found that pupils understood the items; the low p-value was due to their confusion between the a.m. and p.m. used in the 12-hour time system.

Table 3

Difficulty Level (p-value) and Discrimination Index (DI) of Items in CM4

Item	p-value	DI
8	0.91	0.30
9	0.42	0.55
10	0.92	0.24

Figure 1 displays example of a pupil's response. This pupil added the starting time (9:15 p.m.) with the duration (5 hours 20 minutes). The answer obtained was 14 hours 35 minutes, and since the time was in 12-hour time system, the pupil subtracted 12 hours from the answer thus obtaining the answer of 2:35 p.m. However, the pupil had not considered that the starting time was in the afternoon (p.m.).

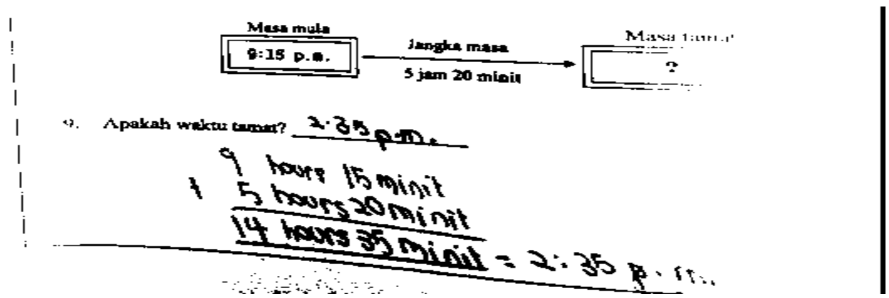

Figure 1. Example of a pupil's response for item 9.

This indicated this item is a good item to assess pupils' understanding and mastery level of this attribute. However, there is also possibility that this item involved another hidden attribute. Further investigation is needed to revise the item. In short, this is a common struggle among pupils from all the three types of schools as number of pupils who exhibited these unexpected knowledge states is similar.

Cognitive Model 5 [CM5]: Finding the duration of an event when involved both 12-hour and 24-hour time system

Table 4

Knowledge States of Pupils for CM5 by Types of Schools

	SJK(C)	%	SK	%	SJK(T)	%
Expected KS						
KS0 (00000)	1	0.9	1	1.1	7	13.7
KS1 (10000)	6	5.6	11	12.5	7	13.7
KS2 (1½000)	0	0.0	1	1.1	3	5.9
KS3 (11000)	2	1.9	2	2.3	4	7.8
KS4 (11100)	2	1.9	0	0.0	0	0.0
KS5 (11110)	2	1.9	3	3.4	2	3.9
KS6 (1111½)	0	0.0	2	2.3	1	2.0
KS7 (11111)	92	86.0	59	67.0	21	41.2
Unexpected KS						
KS8 (000½0)	0	0.0	3	3.4	0	0.0

KS9 (10010)	0	0.0	0	0.0	1	2.0
KS10 (10100)	1	0.9	3	3.4	1	2.0
KS11 (1½010)	0	0.0	0	0.0	1	2.0
KS12 (1½111)	0	0.0	0	0.0	1	2.0
KS13 (11010)	0	0.0	3	3.4	1	2.0
KS14 (11½10)	0	0.0	0	0.0	1	2.0
KS15 (1110½)	1	0.9	0	0.0	0	0.0
	107	**100.0**	**88**	**99.9**	**51**	**100.2**

Cognitive Model 5 assessed pupils' ability to find the duration of an event when both 12-hour and 24-hour time system were involved. Five attributes were included in this cognitive model. These attributes included (1) knowing and converting 12-hour and 24-hour systems (limit to the items involve both systems); (2) subtraction of time/duration involving 12-hour and 24-hour time system; (3) finding duration as involving subtraction of ending time and starting time; (4) transform words context into mathematical operation to find the duration of an event (involving both 12-hour and 24-hour time systems); and (5) reasonability of the duration as duration for word problems.

After analysed all the responses, the result shows that 16 KS consisting of eight expected KS and eight unexpected KS were found (as displayed in Table 4). 17 out of the 246 responses exhibited unexpected KS which two from SJK(C), nine from SK and six from SJK(T). One of examples for expected KS is KS5 (11110). Pupils who were categorized in this KS exhibited the consistent mastery of the first four mentioned attributes but they were unable to provide a reasonable final answer or state the answer in the correct format as a duration. For instance, they might write the duration of 3 hours and 40 minutes as 3.40 p.m. Meanwhile, KS8 (000½0) is an example of KS which was not expected by the experts. These students showed none mastery of the first (the most basic), second, third and fifth (the most complex) attributes, however, they somehow exhibited inconsistent mastery of the fourth attribute. This is a case which worth further study.

Among the expected KS, the most common KS for all three types of schools was KS7 (11111). Besides, there are SJK(C) pupils showed the highest percentage (86%) of mastering all the five attributes, then followed by SK pupils, then SJK(T) pupils. In addition, the KS with second highest frequency was KS1 (10000) for all types of schools in which pupils only mastered the first attribute in this cognitive model. Also note that, for SJK(T) pupils, the percentage of pupils who exhibited KS1 (10000) was the same the percentage of pupils who exhibited KS0 (00000).

For unexpected knowledge states, 13 out of 17 pupils showed they were unable to subtract time/duration involving 12-hour and 24-hour time system and/or finding duration as involving subtraction of ending time and starting time, yet, they were able to solve word problems to find the duration of a given event. Table 5 shows that items which measured the second attribute have lower p-value as compared to items which measured the third attribute. Besides, the items used to measure the third attribute have similar difficulty level to those used to measure the fourth attribute.

Table 5

Difficulty Level (p-value) and Discrimination Index (DI) of Items in CM5

Attribute	Item	p-value	DI
Second attribute:	5	0.69	0.75
subtraction of time/duration involving 12-	6	0.71	0.78
hour and 24-hour time system	7	0.70	0.82
Third attribute:	11	0.70	0.75
finding duration as involving subtraction of	12	0.85	0.45
ending time and starting time	13	0.85	0.42
Fourth attribute:	20	0.75	0.75

transform words context into mathematical operation to find the duration of an event (involving both 12-hour and 24-hour time systems)	21 22	0.83 0.76	0.54 0.75

This might because pupils were unable to interpret the diagram correctly. Figure 2 is an example of items which measured the second attribute. Pupils were expected to know that they should perform subtraction in order to find a time before a given time. Some pupils faced challenges in deciding which operation to use in order to obtain the answer.

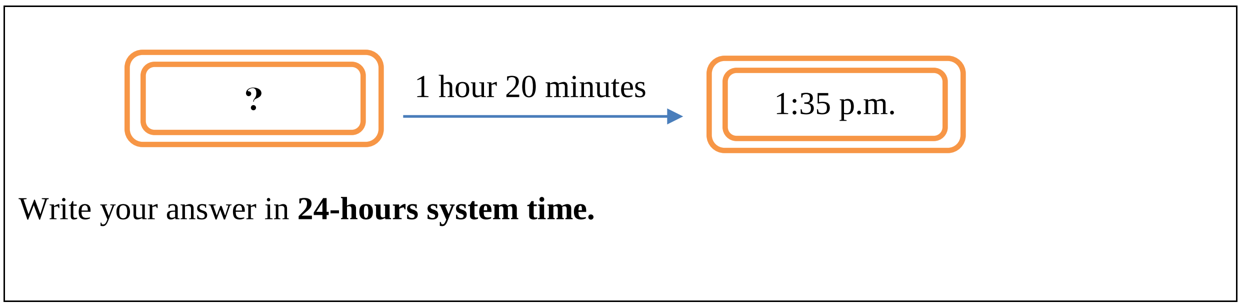

Figure 2. An example of items used to measure second attribute.

Figure 3 displays an example of item which used to measure third attribute. To solve this item, pupils need to have the prior knowledge of how to convert time between the 2 time system (12-hour and 24-hour time system) and how to subtract time when both time systems were involved. Then, with the knowledge of how to find duration between two give time, pupils could solve this item.

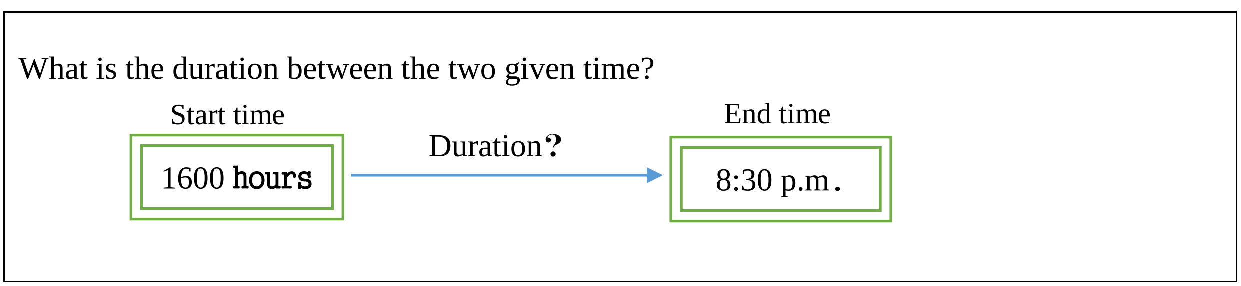

Figure 3. An example of items used to measure third attribute.

From pupils' perspective, diagram in Figure 2 might be more difficult to interpret as compared to the one in Figure 3, thus, explained the values obtained for difficulty level. Furthermore, pupils might not to see these types of items as often as the word problems, therefore, the understanding and solving word problem could be a little simpler than interpreting these items.

Cognitive model 6 [CM6]: Finding the starting time of an event when both 12-hour and 24-hour time system were involved

Table 6

Knowledge States of Pupils for CM6 by Types of Schools

	SJK(C)	%	SK	%	SJK(T)	%
Expected KS						
KS0 (00000)	1	0.9	1	1.1	7	13.7
KS1 (10000)	3	2.8	10	11.4	13	25.5
KS2 (1½000)	0	0.0	3	3.4	0	0.0
KS3 (11000)	10	9.3	9	10.2	7	13.7
KS4 (11½00)	0	0.0	3	3.4	2	3.9
KS5 (11½½0)	0	0.0	1	1.1	1	2.0
KS6 (11100)	9	8.4	13	14.8	6	11.8
KS7 (111½0)	1	0.9	0	0.0	0	0.0
KS8 (11110)	47	43.9	25	28.4	7	13.7
KS9 (1111½)	1	0.9	4	4.5	0	0.0
KS10 (11111)	35	32.7	19	21.6	8	15.7
Total	**107**	**99.7**	**88**	**99.9**	**51**	**100.0**

Cognitive Model 6 measured pupils' ability to find the starting of an event when both 12-hour and 24-hour system time were involved. Five attributes: (1) knowing and converting 12-hour and 24-hour systems (limit to the items involve both systems); (2) subtraction of time/duration involving 12-hour and 24-hour time system; (3) finding starting time as involving subtraction of end time and duration; (4) transform words context into mathematical operation to find the starting time of an event (involving 12-hour system and 24-hour system); and (5) reasonability of the final answer as start time in 12-hour system and 24-hour system for word problems were included in this cognitive model. These attributes were arranged hierarchically from the most basic to the most complex.

As shown in Table 6, 11 KS were found and all of them showed the expected pattern, i.e. pupils had mastered the more basic attributes before the more complex attributes. The most common KS for SJK(C) pupils was KS8, which 43.9% of the pupils had mastered the first four attributes but not the last attribute. Similar case occurred in the group of SK pupils. 28.4% of the pupils exhibited the KS of (11110). This revealed that these two groups of pupils were able to find the starting time of an event when involved both time systems, however, they were unable to represent the final answer in correct time format or as required by the items. For pupils from SJK(T), the most common KS was KS1 (percentage of 25.5), whereby pupils only mastered the first attribute in CM6.

Furthermore, in terms of number of pupils who had mastered this concept, SJK(C) pupils (32.7% of them) showed a better performance than SK pupils (21.6%) and SJKT pupils (15.7%). This result revealed that more SJK(C) pupils could mastered the attributes in this cognitive model better.

Discussion

In this study, each schema was represented by a cognitive model. The hierarchically arranged attributes in each model showed pupils' process of learning. According to Marshall (1988, 1993), a schema has both content and structure. Moreover, the content consists four types of knowledge: feature recognition, constraint, planning/goal setting as well as execution. A pupil will activate his/her existing schemata when solving a task. These schemata will help the pupil to decide the method to solve the task through the four types of knowledge. Based on the result, most of the students (96.75% for Model 4; 93.09% for Model 5 and 100% for Model 6) showed KS as expected by the experts. This indicated that the experts' schema matched with the pupils' schema. Besides, this also shows pupils' process of learning, i.e. pupils will learn one attribute first before the other attribute. By obtaining this feedback, teachers and mathematics curriculum developers can help pupils to learn about "Time" better. Discovering pupils' cognitive processes will help teachers to design their lesson plans more effectively as they are already clear about the hierarchical relationship between the attributes. Such planning will also encourage learners to learn with understanding (Broaddus, 2011).

Furthermore, as shown in these three tables regarding the KS for the three cognitive models, similar trends were found. First, there were always more SJK(C) pupils exhibited the KS which represented the mastery of all attribute in the cognitive model. Then, followed by SK pupils and SJK(T) pupils. This result was aligned with Lim (2003) and Barwell, Lim, Nkambule and Phakeng (2016) which suggested that pupils in Chinese Vernacular School [SJK(C)] outperformed in Mathematics. Second, SJKC pupils did not exhibit the KS which consisted inconsistent mastery (which was denoted as "½"). This revealed that SJK(C) pupils were either had mastered an attribute or had not. In other words, their responses did not show the case of misconception or systematic errors. Third, SJK(T) pupils had higher frequency of exhibiting the knowledge state of KS0, in which none of the attribute in the cognitive model was mastered. These trends revealed that SJK(C) pupils performed better in the cognitive models involved in this CDA. SJK(T) pupils might need more assistant in understanding the concepts assessed.

Conclusion – Implication, Limitation, Further Research

This paper aims to discuss Primary Six pupils' knowledge states in the learning of "Time", specifically in finding the ending time, duration and starting time of an event when both

12-hour and 24-hour time system were involved. Besides, the knowledge states of pupils from different types of schools in Malaysia were also compared. Due to the constraints of human resources and funding, this study was not able to involve all of the primary schools in Penang or Malaysia. However, these following findings are still valuable for future studies, It serves as a base data for future larger-scale research.

The findings show that for Chinese Vernacular and National School pupils, CM4 and CM5 had the similar difficulty while for Tamil Vernacular School pupils, CM4 was easier than CM5. CM6 was the most difficult cognitive model for pupils from all three types of schools as the most common knowledge state for CM6 was not full mastery of attribute, i.e. (11111).

Besides, the results also show that most of the pupils have mastered the basic attributes before the more complex ones. This indicated that the list of attributes was arranged in hierarchical order correctly. As suggested by Winterton, Delamre Le Deist and Stringfellow (2006), declarative knowledge (e.g.: knowing the relationship between two-time systems) must be acquired before procedural knowledge (e.g.: finding duration of an event when the given time involved both 12-bour and 24-hour time system). Perhaps this information will help teachers in designing their lessons.

The results also revealed that the performance of pupils from different types of schools varied. This is interesting as same curriculum was used by all three types of school but only differed in the medium of instruction. However, the performance of Tamil Vernacular School pupils was poorer as compared to Chinese Vernacular School and National School pupils. The reason behind is worth to be further explored. Besides, there were also some unexpected knowledge states found during the data analysis process. Since knowledge state is generated based on attribute probability which analysed based on students' responses, thus, the design of items might affect the knowledge state indirectly. The probabilities are, the items were not measuring the attributes that intended to be measured; or some pupils might have their different way in interpreting or solving the items or learning the attributes being assessed. Further investigation on this issue could help researcher to find out the underlying cognitive processes of these pupils.

The result of knowledge state informed educational stakeholders about pupils' mastery level of the specified attributes at one time. This help the educational stakeholders to understand the pupils' learning situation better and identify the misconception Subsequently, appropriate works can be carried out to remediate these misconceptions/deficits (Ketterlin-Giller & Yovanoff, 2009) and thus, help students to overcome their struggle in learning "time".

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