KNOWLEDGE STATES OF PRIMARY PUPILS ON THE TOPIC OF TIME INVOLVING DATES

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KNOWLEDGE STATES OF PRIMARY PUPILS ON THE TOPIC OF TIME INVOLVING DATES

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ABSTRAK

Status pengetahuan adalah tahap pengetahuan, menyatakan secara spesifik tahap masteri murid dan memaklumkan kekuatan dan kelemahan mereka dalam domain yang diuji. Terdapat tiga objektif dalam kajian ini: (1) untuk mengenal pasti status pengetahuan murid sekolah rendah dalam topik "Masa" yang melibatkan tarikh; (2) untuk membandingkan status pengetahuan murid sekolah rendah antara tiga jenis sekolah rendah; dan (3) untuk mengenal pasti jenis-jenis kesilapan yang dibuat oleh murid-murid didiagnosis dengan status pengetahuan paling umum dalam setiap model kognitif. Kaedah tinjauan digunakan dalam kajian ini untuk mengukur status pengetahuan murid-murid. Instrumen yang digunakan dalam kajian ini adalah Penilaian Diagnostik Kognitif (*Cognitive Diagnostic Assessment [CDA]*) yang mengukur empat konsep: (1) konsep 'selepas'; (2) konsep 'sebelum'; (3) tempoh termasuk dua tarikh; dan (4) tahun lompat. CDA ini telah direka bentuk oleh enam orang guru yang berpengalaman. Seterusnya, CDA ini diuji atas 544 orang murid Tahun Enam dari tiga jenis sekolah rendah, iaitu Sekolah Kebangsaan (SK), Sekolah Jenis Kebangsaan Cina (SJKC) dan Sekolah Jenis Kebangsaan Tamil (SJKT). Hasil kajian menunjukkan terdapat 18 status pengetahuan didiagnosis bagi konsep 'selepas'; 14 status pengetahuan bagi konsep 'sebelum'; 12 status pengetahuan bagi konsep tempoh termasuk dua tarikh dan lima status pengetahuan bagi konsep tahun lompat. Konsep tempoh termasuk dua tarikh adalah konsep yang paling sukar bagi murid-murid kerana majoriti murid-murid menunjukkan ketidak-penguasaan untuk

atribut-atribut yang diuji dalam model kognitif tersebut. Perbandingan antara jenis sekolah menunjukkan bahawa murid-murid SJKC adalah lebih baik daripada dua jenis sekolah yang lain sedangkan murid-murid SJKT secara perbandingannya lebih lemah dalam kesemua konsep yang diukur. Jenis-jenis kesilapan yang lazim adalah: (a) keliru sama ada memasukkan atau mengecualikan tarikh yang diberikan sebagai satu hari dalam pengiraan tempoh di dalam keadaan yang berbeza; dan (b) pengumpulan semula bilangan hari dalam sebulan kepada bilangan hari yang salah dan sebaliknya. Analisis status pengetahuan murid dan kesilapan lazim mereka bukan sahaja menunjukkan secara eksplisit tahap penguasaan mereka dalam domain yang diuji, tetapi juga menyediakan keputusan diagnostik terperinci bagi para guru. Maklumat tersebut boleh digunakan oleh guru-guru dalam persediaan untuk pengajaran berpelbagaian dan aktiviti pemulihan yang lain bagi membantu murid-murid mereka.

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ABSTRACT

Knowledge state is a state of knowledge, specifying pupils' level of mastery and informing their strengths and weaknesses in the tested domain. This study has three objectives: (1) to identify knowledge states of primary pupils in the topic of "Time" involving dates; (2) to compare the knowledge states of primary pupils across the three types of primary schools; and (3) to identify the types of errors made by pupils diagnosed with the most common knowledge state of each cognitive model. Survey research design was used in this study to gauge the knowledge states of the pupils. The instrument used in this study was a Cognitive Diagnostic Assessment (CDA) which measured four concepts: (1) concept of 'after'; (2) concept of 'before'; (3) duration of two inclusive dates; and (4) leap year. The CDA was designed by a group of six experienced teachers and was administered to 544 Grade Six pupils from three types of primary schools, i.e. National School (SK), Chinese Vernacular School (SJKC) and Tamil Vernacular School (SJKT). The result showed that pupils possessed different types of knowledge states indicating the mastery level of the pupils for the attributes measured in each cognitive model. There were 18 knowledge states diagnosed in concept of 'after'; 14 knowledge states were diagnosed in concept of 'before'; 12 knowledge states were diagnosed in concept of duration of two inclusive dates and five knowledge states were diagnosed in concept of leap year. Concept of duration of two

inclusive dates was the most difficult concept for the pupils as majority of the pupils showed non-mastery for the attributes tested in this cognitive model. Comparison among types of schools showed that SJKC pupils outperformed the other two types of schools while SJKT pupils were comparatively weaker in all the four concepts measured. The types of errors found were: (a) confused whether to include or exclude the given date as one day in the calculation of duration under different conditions; and (b) regrouping a month into the incorrect number of days and vice versa. Analysis of the pupils' knowledge states and their common errors not only made explicit their mastery level of the tested domain, but also provided teachers with detailed diagnostic information. This information can be used by the teachers to prepare differentiated instruction and other remedial activities to help their pupils.

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CHAPTER 1

INTRODUCTION

1.0 Introduction

Knowledge state is a state of knowledge, specifying the level of mastery for the tested domain. Knowledge state also refers to a pattern of attribute mastery formed by a defined set of attributes in a specific topic, such as duration of time (Lee, Park, & Taylan, 2011). Knowledge state is corresponding to a unique combination of attributes. An attribute of a task is a description of "procedural and declarative knowledge" (Gierl, Wang, & Zhou, 2008, p. 3), skill and process needed to successfully solving the task. For a task testing three attributes, the knowledge states can range from 'knowing-nothing-state' (000) to the 'knowing-all-state' (111). A knowledge state of (100) indicates that the pupil has mastered the first attribute, but not the second and third attributes. Similarly, a knowledge state of (110) indicates that the pupil has mastered the first and second attributes but not the third attribute.

An individual pupil's knowledge state diagnosed by the domain specified cognitive model is explicitly described as an "attribute mastery profile" (Katz, Martinez, Sheehan, & Tatsuoka, 1993, p. 11) which is also known as cognitive profile. The tested attributes in a cognitive model are fine-grained to enable specific diagnostics inferences to be made based on the test performance of a pupil and reported collectively as a cognitive profile.

In order to measure knowledge state of an individual pupil, we can use Cognitive Diagnostic Assessment (CDA). CDA is an assessment which aims to

diagnose pupils' specific knowledge structures and processing skills for a particular topic (Leighton & Gierl, 2007a). Each item in CDA is attributed with knowledge, skills and process needed to solve it. Through estimating attribute mastery probabilities, CDA enables the knowledge state, which is latent in an individual, to be distinctive as a score (Birenbaum, Tatsuoka, & Yamada, 2004).

The score of attribute mastery probability estimated for each attribute, ranging from 0 to 1, is used to denote the mastery level of the pupil in the attribute tested. A higher value represents the higher possibility that the examinee possesses or masters the attribute. The attribute mastery probability will then be represented by values of '0', '½' and '1' in knowledge state which corresponds to 'non-mastery', inconsistent-mastery' and 'mastery' in cognitive profile to pinpoint the strength and weaknesses of the pupil.

To give a clearer picture, the attribute mastery probability score above 0.8 is represented by value of '1' in the knowledge state and reported as 'mastery' for that attribute in the cognitive profile; attribute mastery probability score 0.5-0.8 is represented by value of "½" in knowledge state and reported as 'inconsistent-mastery' and attribute mastery probability score below 0.5 is represented by value '0' in knowledge state and reported as 'non-mastery' of the attribute. These cut offs scores for attribute probabilities are current reporting standard for the Acceptable Standard and the Standard of Excellent used by Alberta Education (Alves, 2011) and it is adopted in this study.

The items designed in this CDA focuses on the topic of "Time", involving dates in particular because time is vital in today's society as it is a basic concept that is used in everyday life. "Time" is an important concept as it is "interconnected with almost everything" (Gough, 1999, p. 191, as cited in Harris, 2008, p. 28) in our life.

Yet, time is an abstract and intangible concept. Hence, it is important for educational stakeholders, parents and pupils themselves to know their knowledge state, which inform on the strength and weaknesses of pupils' learning in "Time" involving dates to provide reference in designing remedial work tailored for individual pupils.

1.1 Background of study

1.1.1 Primary School Standard Curriculum

In order to improve pupils' learning, in the year 2011, Primary School Standard Curriculum (*Kurikulum Standard Sekolah Rendah* [KSSR]) was introduced as an effort to restructure and to improve the existing curriculum. This effort is also to ensure that pupils are provided with the relevant knowledge, skills and values to meet the current needs and challenges of the 21st century (Ministry of Education Malaysia [MOE], 2011a). The Malaysian MOE has implemented KSSR in stages starting from Primary One pupils for the year 2011. It was fully implemented by the year 2016. The main aim of KSSR is to enable every primary pupil to master the basic literacy skills at the end of six years of formal primary schooling (MOE, 2011a).

As stated in the Curriculum Standard and Assessment Document of KSSR, pupils from Primary One till the end of Primary Six are expected to equip themselves with knowledge and skills of "Time" which includes: (1) determine the appropriate unit of time of measurement for different events; (2) convert between units of time; (3) estimate interval of time for certain events; (4) use of calendar and timetable in solving word problem; (5) calculate duration between two given time in any units by using the four operations; (6) read both analogue and digital clock and write time in 12 hour system and 24 hour system; (7) know the relationship and convert time in 12 hour system to 24 hour system and vice-versa; (8) solve daily problems involving

time, including time zone (MOE, 2002; 2011a; 2011b; 2012; 2013b, 2014a; 2014b). The detailed Standard of Contents and Standard of Learning for the topic of "Time" in mathematics are attached in Appendix C.

1.1.2 School-based assessment [SBA]

Under KSSR, the teacher employed school-based assessment [SBA] or *Pentaksiran Berasaskan Sekolah* [PBS] as a new method to evaluate the Year One pupils' learning progression since year 2011. Two years after introducing KSSR, in year 2013, the Ministry of Education launched the Malaysia Education Blueprint (2013- 2025) which was a major transformation in the Malaysian education system. This education reform initiative led to official implementation of SBA in lower secondary Form One pupils. Under this new method of assessment which is aligned with the National Educational Philosophy (MOE, 2013a), a pupil is assessed in four components: school assessment, psychometric assessment, physical activity assessment as well as sports and co-curriculum assessment. This is an initiative to shift the focus of education in Malaysia from exam-oriented to holistic evaluation by focusing on pupils' overall performance and participation in classroom instruction.

For lower secondary school, Form Three Assessment (*Pentaksiran Tingkatan 3* [PT3]) is a huge change in the national level assessment under the Malaysia Education Blueprint. PT3 has replaced Lower Secondary Assessment or *Penilaian Menengah Rendah* (PMR) which has been abolished at the end of year 2013. PMR was used to be a centralized national examination for all Form Three students whereas PT3 is a school-based examination which is executed nationwide in a given time frame. Mathematics would be assessed via written test in which questions, given by the Malaysian Examination Syndicate in a form of questions bank, were selected by respective school and would contain questions of low, medium and difficult level

in each set (Kang, 2014, March 23). The questions labeled within the same difficulty level were claimed to be similar and hence school administrator would randomly choose questions from the questions bank and to be inserted as items in the PT3.

For primary school, UPSR has been improved with the focus of assessment for learning and assessment of learning (Examination Syndicate, MOE, 2011). The total score of this assessment considering weightage of 60% on the centralized written examination and 40% on the school- based assessment. This improved UPSR will impact Year One pupils in year 2011, who will be sitting for UPSR in year 2016.

In current practice for Mathematics lesson, teacher is encouraged to do SBA in a form of formative assessment after every subtopic to monitor on the pupils' progress to make sure that pupils mastered the intended learning outcome of the subject. SBA can be in oral or written form. There are certain criteria outlined in the Standard Curriculum and Assessment Document, which must be fulfilled by pupils in order to attain band one to band six. Each pupil will be awarded with the grade (band 1 to 6) based on their work and performance. Band 1, Know; Band 2, Know and understand; Band 3, Know, understand and able to do; Band 4, Know, understand and able to do systematically; Band 5, Know, understand and able to do systematically and is praiseworthy. Band 6, Know, understand and able to do systematically and exemplarily (MOE, 2012, November 27).

The score reporting under SBA only reported the mastery level of pupils according to band and without specifically pointing out the knowledge, skills and process possessed by the pupils. These bands thus do not give fine-grained and specific information about pupil's strength and weaknesses of a particular tested skill; instead, the assessment judge and grade pupils' achievement based on criteria and standards specified in the syllabus of the subject.

1.1.3 Learning of Time

According to Dowden (2009), "Time is a series of instants". Time is defined as a component of a measuring system used to arrange the order of events, to calculate the duration of events and the amount of time taken for an activity (Burny, Valcke, & Desoete, 2011). The ability to tell time is an important life skill that allows us to plan our daily activities, to get organized and to function in a society that is driven by time (Bock, Irwin, Davidson, & Levelt, 2003). Clock and Calendar are tools used to measure time. According to Droit-Volet (2013), even "infant can time temporal intervals at early age … as they possess a 'primitive sense' of time" (p. 221). In the Malaysian school mathematics syllabus, the learning of "Time" begins as early as preschool till Lower Secondary One. After Lower Secondary One, pupil will not be taught further on the topic of "Time". Hence, it is rather crucial to help pupils strengthening their knowledge in the topic of "Time" involving dates at the primary educational level.

1.2 Problem Statement

The concept of "Time" is important in our daily life. However, time is a complex concept and difficult for children to learn (Burny, 2012). In Trends in International Mathematics and Science Studies (TIMSS) 2011, a word problem on addition of time was solved correctly by only 52% of Grade 4 pupils internationally, on average (Mullis, Martin, Foy, & Arora, 2012). In a few studies (McGuire, 2007; Pérez-Sedano, 2015), school pupils were found to have problems in learning the topic of "Time" in measurement. They were confused especially when it involved duration (measuring the time elapsed) and conversion involving years, months and days (Harris, 2008). Pérez-Sedano's (2015) study confirmed that almost all Primary One to

Four pupils in his study could read and interpret calendar but these pupils had problem in the construction task in which they were asked to arrange two types of cards which was labelled with (1) "morning", "afternoon" and "evening" each and (2) cards with drawing of activities. They had problem indicating the reasons for their choices.

In spite of that, as pointed by the Queensland Studies Authority (2005, p. 185, as cited in McGuire, 2007, p. 30) that the learning of "Time" was different from the learning of other topics of measurement because of its abstract nature that the unit used to measure time cannot be physically compared to the length of time being measured. This makes the concept of "Time" abstract for children. For example, pupil can see and compare the unit of meter to the distance measured but this concrete observation cannot be done in learning the topic of "Time". Hence, most pupils struggle with the learning of "Time" that adults may often take for granted (McGuire, 2007).

Several studies (Burny, 2012; Burny et al., 2009; 2011; Hoodless, 2002) have shown that the learning of time-related competencies in pupils were very much depending on teachers' instruction. According to Hoodles (2002), teachers played an important role in helping the primary school children in understanding and using accurate terms relevant to time. Likewise, Burny et al. (2009; 2011) claimed that teachers took years to teach the sub skills of reading and writing of clock time because "clock reading is a complex cognitive skill that makes great demands upon children and teachers" (Burny et al., 2011, p. 18). Hence, it is important for teachers to identify the learning problems that still persist among pupils so as to ensure that pupils grasp full conceptual understanding on the topic of "Time".

However, an informal interview with a few primary school teachers revealed that pupils often confused and were struggling when solving problems that involve calculating the number of days, whether or not to include the starting date given. For example, in the following two word problems:

1) Today is 27th of December and Tommy will celebrate his birthday after a week. When is Tommy's birthday?
2) Linda joined a camp on 27th of February 2013. This camp ended on 3rd of March 2013. How many days was the camp?

To solve the above two problems, the pupils need to consider if the starting date given should be included as one day when performing calculation of the number of days. For problem 1, pupils should not include the starting date given as one day because the information given was 7 days after the given date. However, many pupils may not be able to solve this problem as they might not know 1 week = 7 days. To find the date of birth of Tommy, pupils also need to know that December has only 31 days and hence the answer is 3rd of January. As for problem 2, pupils should count the starting date, 27th February as one day as it is the first day of the camp. The pupils would also need to know that February has 28 days for year 2013 as it is not a leap year. Hence the camp duration is 5 days in total.

Many pupils failed to solve these two problems. When pupils were asked to give feedback on why they could not solve the problem, pupils could not tell exactly what they don't know and what they already knew. A pupil's inability to answer question 1 could be due to not knowing December has 31 days or not knowing 1 week = 7 days, same for pupils who failed to answer question 2, they may not know that the starting date should be counted as one day, some may not know if February in year 2013 has 28 or 29 days. Teachers do not have an idea whether a pupil has

mastered the relevant basic concept prior to solving problem involving higher order thinking skills. In an effort to help these pupils and clarify which part that they were weak at, a diagnostic assessment would play its role to diagnose the knowledge of pupils and problems faced by each individual.

Moreover, from an informal teachers' interview, pupils were found to make mistakes when they were solving problems involving dates. The errors made by pupil could, to certain extent, reflect the misunderstanding in the pupils' conceptual thinking (Ketterlin-Geller & Yovanoff, 2009; Li, 2006). These errors if not remedied may worsen the misunderstanding leading to serious misconception. Consequently, pupils may lose interest and develop phobia in learning the topic of "Time" involving dates. As for teachers, particularly novice teachers, they may not have an idea about the errors that pupils make while solving problems involving dates. Hence, during the instructional planning, these novice teachers may not be able to plan well in giving proper emphasis and clarification on the errors that pupils make.

Hence, teachers need a tool to help them to diagnose the pupils' mastery level on the attributes which the teachers intend to measure. Teachers also need to have a picture of the types of errors made by the pupils while solving the problems in topic of "Time" involving dates in order to design remedial work to help the pupils in need. In fact, as emphasized in KSSR, teachers need to assess the ability of each pupil and determine their level of ability based on a list of standard performance which has been prepared in accordance with the topics of learning. The teachers need a tool which is able to provide them with an insight into the ability of their pupils.

Even though with the implementation of SBA in primary school, the scoring report only shows the mastery level in terms of bands from Band one (able to

understand basic knowledge of mathematics) to Band six (able to master and apply knowledge and skills in solving complex mathematics problems in a creative and innovative way). The feedback from SBA about mastery of each pupil on the topic of "Time" was still too brief and general for teachers to plan any remedial work to cater to the needs of every pupil in a class. In addition, under SBA, teachers are given bigger roles to be able to plan and design tasks as well as to adjust instructional decisions to help pupils. Teachers need to know why the pupils could not solve time-related tasks, what is the current knowledge on the learning of "Time" that the pupils have formed in their minds (knowledge state of pupil) and what are the common errors made by the pupils when solving the time-related problems. In order to help the teachers, an instrument such as CDA, is needed to help them to diagnose the pupils' strengths and weaknesses in the learning of "Time" involving dates.

Apart from that, pupils who faced problems solving questions involving "Time" may come from different learning environment such as national and vernacular schools. Anecdotal evidences from other researchers (e.g. Boroditsky, 2001; Boroditsky, Fuhrman, & McCormick, 2011) showed that pupils who learnt "Time" in different language results in difference in terms of their time-related concepts. Boroditsky (2001) concluded that native language has strong influence on how a person thinks about time. This is supported by Boroditsky, Fuhrman, & McCormick (2011) that English and Mandarin speakers think about time differently. Hence, to focus in the context in Malaysia, does different medium of instruction used in learning mathematics in different types of schools has any impact on the knowledge states of "Time" among the pupils from three types of vernacular schools? To the best knowledge of the researcher, there has yet to be any research done in this area.

In addition, there are still very few research studies on the topic of "Time" involving dates, both internationally and locally, as well as on the use of CDA. Hence, the knowledge states of primary pupils on the topic of "Time" involving dates remains to be explored. With this in mind, this study aims to apply CDA which has been developed to diagnose the learning problem of pupils for the topic of "Time" involving dates.

1.3 Research Objectives

This study is carried out to identify the knowledge states of pupils in learning the topic of "Time", particularly involving dates for the three types of vernacular schools in Malaysia. More specifically, the study aims

1) To identify primary pupils' knowledge states in learning "Time" involving dates.
2) To compare the knowledge states of pupils from the three types of primary schools.
3) To identify the types of errors made by pupils who were diagnosed with the most common knowledge state in each cognitive model.

1.4 Research Questions

This study aims to address the following research questions:

1) What are the primary pupils' knowledge states on learning of "Time" involving dates?
2) What are the similarities and differences in the knowledge states of pupils from the three types of primary schools?

3) What types of errors made by pupils who were diagnosed with the knowledge state that has the highest percentage of occurrence (most common knowledge state) of each cognitive model?

1.5 Limitations of Study

Time given to solve the test is a limitation to the study. Pupils should be given sufficient time to solve the problems in the assessment. However, with the priority of not interrupting pupils' learning and school activities, the time given to pupils was limited to only 60-90 minutes for each school. Hence, this might caused anxiety in pupils which affected their performance and some pupils might not be able to complete the test. To reduce the impact caused by time constraint, extra time was given to selected pupils who did not manage to complete the test. To reduce the anxiety of pupils, a briefing was given to explain the purpose of the test, i.e. to identify their strength and weakness in the learning of time and not to rank them.

Apart from that, the findings of this study was not able to be generalized to all primary schools pupils in whole Malaysia as it only involved eleven primary schools in Penang. However, the results may be applied to some extent across other primary schools as it involved 544 Year Six pupils. In addition, the study only limited to the topic of "Time" involving dates which was taught in primary school mathematics syllabus.

The analysis on the types of error was done solely based on the pupils' responses in their script towards the items. Due diligence has been exercised in arriving at the analysis but there was possibility of misinterpretation about the errors made by the pupils as the researcher concludes the types of errors based on observation of the pupils' working. However, this analysis was validated by

mathematics expert to ensure the quality and to reduce the chance of misinterpretation.

Furthermore, during the analysis of the type of error in KS1 of CM 1 and KS3 of CM 4, it was found that there were pupils who did not show any working in all items they solved. Hence, it was not possible to identify the type of errors that this group of pupils had made. Thus, the type of errors identified in KS1 of CM 1 and KS3 of CM 4 were limited.

1.6 Significance of the Study

The findings of this study will be significant in the following ways:

First, the pupils will be able to know their strengths and weaknesses by knowing their knowledge states in the subtopic tested. The pupils will be able to get fine-grained feedback about their learning in the subtopic tested based on the knowledge state, generated for each individual. With that, they can take proper remedial action to help themselves to improve their weakness while continue to strengthen the area that they were good in.

Second, the teachers will be able to help each and every pupil using their knowledge state. Teachers will know the common knowledge state possessed by pupils and thus knowing the attributes that the pupils were good at and weak at. This will help the teachers in their instructional planning. Remedial work will be made easy for teachers as the knowledge state will provide information on the strengths and weaknesses of every pupil for each attributes in the knowledge state. The CDA used in this study can also be helpful to teachers as it will be a question bank for teachers when they carry out the SBA. Novice teachers can also make use of the hierarchy suggested in the CDA for each concept measured to introduce the topic of “Time” to pupils starting from the simplest to the more complex attribute. Teachers could also

adapt the sequence of the attributes as a reference in the instructional design when introducing the subtopic of dates to the pupils.

Third, the errors identified from this study will benefit the pupils as it can be guidance for pupils to avoid repeating the same errors. As the English proverb goes, "By others' faults the wise correct their own". Apart from that, the teachers, being exposed to the types of errors made by pupils in solving the problems involving dates would know which the common mistakes were. Novice teachers in particular, will gain a deeper understanding in the area where pupils are struggling or easily confused. This knowledge will help teachers in preparing their instructional planning as they could, in advance, think of ways to emphasize and enhance pupils' understanding on area where pupils do not understand. Hence, this will enable teachers to deliver mathematics lesson on the topic of "Time" involving dates more effectively. By knowing the types of error made by the pupils, teachers can also plan remedial work, focusing on tackling the area of common mistakes made by the pupils.

Fourth, research studies related to the topic of "Time" is still scarce thus the findings will be helpful for other researchers who are interested to further their research in the topic of "Time". This study provides some insight into the state of knowledge on the topic of "Time" that the pupils possessed and common knowledge state among the pupils from three types of primary schools as well as the errors made by pupils when they were solving the problems in the topic of "Time" involving dates.

Lastly, the strength and weaknesses of the topic of "Time" involving dates for the pupils from the three types of schools were identified based on their performance on the CDA and expressed in term of knowledge states of the pupils. These diagnostic results among the pupils from the three types of schools and the analysis on the pupils' types of errors provide an insight to the policy maker in designing the

curriculum. This information can also aid in the design and development of the textbook content by the textbook writers of the three types of schools.

1.7 Definition of Terms

(a) Knowledge state

Knowledge state refers to a pattern of attribute mastery formed by a defined set of attributes in a specific topic, for example duration of dates. In an assessment, a knowledge state is also known to be pupil's level of mastery of cognitive skills tested (Falmagne, Cosyn, Doignon, & Thiéry, 2006).

(b) Cognitive profile

The cognitive profile is a formal summary of an individual's strength and weaknesses in cognitive skills measured by a cognitive diagnostic test.

(c) Attribute

Attribute of an item means the knowledge, skills and process involved in solving a problem.

(d) Cognitive model

A cognitive model is defined by Leighton and Gierl (2007b) as a "simplified description of human problem-solving on standardized educational tasks, which helps to characterize the knowledge and skills students at different levels of learning has acquired and to facilitate the explanation and prediction of students' performance." (p. 6). Hence, in this study, cognitive model refers to the detailed descriptions of attributes which include knowledge, skills and processes needed to solve problems.

(e) Cognitive Diagnostic Assessment (CDA)

CDA is an assessment designed to model pupils' cognitive performance on task which aims to diagnose pupils' specific knowledge structures and processing skills for a particular topic. CDA yields specific information about pupils' strength and weaknesses in their learning for the topic (Leighton & Gierl, 2007a).

(f) Primary school

Primary schools in this study refer to elementary schools which offer formal education for children from age of seven (Standard 1) to twelve (Standard 6) in Malaysia.

(g) Schema

According to Rumelhart (1980, as cited in Sabella, 1999), schema is a method of organizing knowledge stored in memory into units of knowledge, which contain information about how the knowledge is to be used.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

This chapter reviewed literature related to assessment, particularly focusing on assessment system in Malaysia and Cognitive Diagnostics Assessment [CDA] as well as reviewed past studies on the learning of "Time" and knowledge states. Next, the theoretical framework discussed the theory underpinning this study. Finally, a conceptual framework was formed to guide this study.

2.1 Assessment

According to The Glossary of Education Reform, assessment (2015, November 10) in education refers to "the methods or tools that educators use to evaluate, measure, and document the academic readiness, learning progress, and skill acquisition of pupils" (para. 1). Defining from a mathematical perspective, the National Council of Teachers of Mathematics (NCTM), as cited in Shimizu (2005) specifies assessment in mathematics as "the process of gathering evidence about a student's knowledge of, ability to use, and disposition toward mathematics and of making inference from the evidence for a variety of purposes" (NCTM, 1995, p.3).

2.1.1 Assessment system in Malaysia

The Malaysian formal education system is divided into four levels: primary (Standard 1-6), lower secondary (Form 1-3), upper secondary (Form 4-5) and pre-university (Form 6 or Matriculation). At these four levels, there are two types of assessment commonly used by teachers to assess the knowledge and skills of their pupils: formative and summative assessment. Formative assessments are usually carried out by the subject teacher on daily basis as part of their classroom activity or

as monthly test to monitor on pupils' learning while summative assessments are carried out at two levels: school level and national level to evaluate pupils' learning. At the school level, summative assessments are carried out usually twice a year as midyear examination and final examination at the end of the schooling year. At the national level, it is compulsory for pupils at Standard Six, Form Three and Form Five (equivalent to Grade Six, Nine and Eleven) to take public national examination respectively at the end of their grade levels. Sixth graders take Primary School Achievement Test (*Ujian Pencapaian Sekolah Rendah* [UPSR]); Ninth graders take Form Three Assessment (*Pentaksiran Tingkatan 3* [PT3]); Grade Eleven students take Malaysian Certificate of Education (*Sijil Pelajaran Malaysia* [SPM]).

Mathematics is taught from pre-school to upper secondary level as a compulsory subject. The Malaysian Examination Syndicate also sets mathematics as one of the core subject in all the public national examination from UPSR, PT3 up to SPM (MOE, 2013a). Public examination has been given over-emphasis and resulted in examination-oriented teaching in the classroom. As addressed by Lim (2009), pupils' performance in the public national examinations is used as criteria to rank and classify the schools. This has resulted in "show and tell" (Lim, 2009, p. 3) syndrome among school teachers and "drill and practice" (Lim, 2009, p. 4) phenomenon among the pupils. Teachers teach for exam. These have resulted in mismatch between the National Educational Philosophy and the actual practices by the teachers.

The public national examinations are mostly summative assessments which aim to rank or compare examinees based on the total score they obtained. However, these assessment do not provide individualized feedback to teachers regarding test-takers' strengths or weaknesses in a specific content of the tested skills (McGloben, 2004). Moreover, total score given to the pupils "obscures important diagnostic

information about more fine-grained attributes that students use to solve problems within a given domain" (Briggs & Alonzo, 2012, p. 11). The items in the summative assessment measured the content areas rather than the cognitive processes in the examinee (Cui, Leighton, & Zheng, 2006). In addition, content-based assessment provides unclear evidence of the knowledge, skills and process used by the examinees in answering the items (Nichols, 1994). Furthermore, summative assessment provides only limited feedback to the educational stakeholders on how to improve on the performance of the examinees (Bailey, 1998).

Hence, to overcome the weakness of the summative assessment discussed earlier and to provide diagnostic information, there is an alternative form of educational measurement being introduced in recent years, known as Cognitive Diagnostic Assessment (CDA).

2.1.2 Cognitive Diagnostic Assessment (CDA)

Cognitive Diagnostic Assessment (CDA) is an educational test designed to measure examinees' cognitive process, learning, specific knowledge structures and skills for diagnostic purposes (Ketterlin-Geller & Yovanoff, 2009). CDA is a cognitive based approach with items designed to provide teachers with detailed feedback on the cognitive strengths and weaknesses of the individual examinee (Leighton & Gierl, 2007a). CDA also provides specific information about the examinees' educational needs (McGlohen, 2004).

CDA is commonly used in diagnosing reading skills and testing of languages (Jang, 2005; Royer & Sinatra, 1994), diseases and medical field (Engel, Greim, & Zettl, 2007), and mathematics (Roberts, Alves, Chu, Thompson, Bahry, & Gotzmann, 2014). In the context of mathematics, there were many researches done on mathematical procedures and concept by using CDA, particularly the domain of

mathematics. There are many area of mathematics that have been studied which include multiplication and division with exponents (Birenbaum & Tatsuoka, 1993), fractions (de la Torre & Douglas, 2004, 2008; Tatsuoka & Tatsuoka, 1992, 1997), algebra (Gierl et al., 2008; Gierl, Cui, & Zhou, 2009; Russell, O'Dwyer, & Miranda, 2009), mixed-number subtraction (Henson, Templin, & Willse, 2009; Sinharay & Almond, 2007) and pre-algebra (Ye, 2005). There are also applications of CDA in the field of science too.

In educational testing, CDA may help to overcome to limitation of the traditional assessment (Nichols, 1994) as CDA has several strengths: Firstly, CDA can provide summative inference of each individual pupil, specifying on the skills mastered and skills not mastered upon completion of the instruction. CDA can also provide formative inferences about what should be taught in the next lesson prior to knowing what has not been mastered by the pupils. These inferences help teachers in preparing the appropriate instructional material for the subsequent lesson (Alves, 2012).

Secondly, CDA provided fine-grained feedback on pupils learning in a form of attribute mastery profile which contains the diagnostic score, specifying "whether or not they have mastered each of a group of specific, discretely defined skills or attributes" (Huebner, 2010, p.1). The detailed feedback on the pupils' cognitive strengths and weaknesses in problem solving encourages them to work on their own weaknesses thus making CDA a tool for learning to these pupils (Jang, 2008).

Thirdly, CDA enhances the quality of the diagnostic feedback provided to pupils as CDA generates cognitive profile of an individual pupil based on the analysis done on pupil's response for the items designed in a CDA (Roberts, 2012). This score report provides detailed information on the knowledge, skills and process tested

in this assessment as well as the degree of mastery of pupils on the tested knowledge, skills and process. In addition, the individualized diagnostic inferences aid teachers in knowing what the pupils had mastered, detect inconsistent-mastery knowledge state and plan adaptive instruction to cope with pupils' need (Ye, 2005).

A complete model of CDA should have: (a) assumptions on how all the attribute assessed in a test interact with each other; (b) a reliable, accurate, and efficient statistical estimation method; and (c) effective implementation procedures for real data analyses (Hartz & Roussos, 2008; Su, 2013). These components of CDA were further elaborated in Gierl and Cui (2008) and Jang (2009) that the design of the items was guided by a cognitive model. Each item developed based on cognitive model is characterized by specific cognitive attributes that measure domain-specific structural knowledge, skill and process. A psychometric modelling is then employed to direct the statistical analyses on the item response patterns of the pupils to make inferences about their level of mastery on the tested attributes.

It is important that the assessment is designed based on a cognitive model because it provides an interpretative framework that bridging test result interpretation to cognitive attribute. Thus, pupils' test result interpretation can be linked to specific inference about pupils' knowledge and skills (Gierl, Alves, & Taylor-Majeau, 2010). According to Ketterlin-Geller, Jung, Geller, and Yovanoff (2008), the cognitive model "is composed of attributes that are domain specific prerequisite skills and knowledge needed to demonstrate mastery in the targeted task" (p. 4). Attributes can be identified by studying the knowledge, process and skills used in solving the task (Ketterlin-Geller & Yovanoff, 2009).

2.2 Past studies on the topic of "Time"

Friedman (1986) indicated that children start using their imagination to solve calendar-related task by age of 10. The study done by Levin (1977) found that the ability for the children to judge which duration of two synchronous events was longer followed by logic justification increased with age and was also dependent of the type and number of interfering variables. There are several studies (Boulton-Lewis, Wilss, & Mutch, 1997; Chung & Wang, 2007; Doig, Williams, Wo, & Pampaka, 2006; Sherman, Richardson, & Yard, 2009) done on the learning of "Time" which highlighted the pupils' difficulties when learning "Time". In the research done by Boulton-Lewis, Wilss, and Mutch (1997), the proposed sequence of time acquisition: hour, half hour, quarter hour, five minute, and minute times was found to be followed among the pupils in grade 1-3 but irregularities of this sequence was observed in Grade 4-6. Digital time has higher success rate of reading and recording compared to analog clock. The main cause for error in recording time in analog clock was the incorrect placement of the hour hand. Doig, Williams, Wo, and Pampaka (2006) used an age-standardized diagnostic assessment that integrate pupils' correct and incorrect ideas about topic of "Time" to describe a developmental 'map' of pupils' understanding and skills in the topic of "Time". Chung and Wang (2007) adopted Doig et al. (2006) study to assess the "Time" concept of Taiwanese school pupils and found that the two biggest misconceptions among the 9-12 years old pupils were: "the more distance moved, the longer time spent" and "when the clock stops moving, the time stops as well". Sherman, Richardson, and Yard (2009) analyzed a pupil's type of error in telling the time using Data Analysis Sheet (DAS) and recommended prescription for the types of errors as well as remediation to help the pupil.

There were a few studies (De Coster, 2004; Godard & Labelle, 1998; Labrell, Mikaeloff, Perdry, & Dellatolas, 2016) done on the learning of "Time" involving dates. Godard and Labelle (1998) examined the learning of conventional time system, the capacity to evaluate the interval of time between the present and some important events such as birthday and the capacity to make judgment of the relationship between two moments in time among 5 to 9 years old children. They found that the three factors which influence the learning of these examined concepts were: (1) the expansion of the conceptual span; (2) the ability to associate these concepts with mental images or personal experience; and (3) verbal mediation. In addition De Coster (2004) further studied into the acquisition on the concept of time and verified the three factors in Godard and Labelle (1998), concluding that construction of the concept "Time" and time representations arises from the contribution and the interweaving of multiple contributions: cognitive, emotional, environmental and language. Apart from that, Labrell, Mikaeloff, Perdry, and Dellatolas (2016) investigated the association between the numerical skills and the time knowledge in 6-11 years old children.

Kelly, Miller, Fang, and Feng (1999) examined the difference in time and strategy used by the Chinese speakers in China and the English Speaker in United States in solving tasks by naming the day or the month that comes before or after the specified time in the given day or month. Similarly, Zou, Wang, and Zhang (2009) investigated the difference between the representation of conventional time used by the Chinese speakers and English speaker. Their findings were consonant that Chinese speaker used arithmetic operation to solve the reasoning task related to conventional time whereas the English speaker resorts to reciting the names.

2.3 Past studies on knowledge state

Knowledge state is a term used in CDA to represent the pupil's unobserved latent variable. The term 'latent variable' refers to pupil's level of mastery on a subject matter which can be measured indirectly from the pupil's observed item response pattern in a test. Knowledge state also means patterns of attribute mastery (Cui et al., 2006). Birenbaum, Kelly, and Tatsuoka (1993) diagnosed pupils' knowledge states in algebra using 32-item test. Examinees were found to solve the items with two solution approaches, resulting in different knowledge states where pupils were then classified to. In the same year, Birenbaum and Tatsuoka (1993) also diagnosed pupils' state of knowledge about how the exponents behave in multiplication and division of quantity with exponents.

There were several studies (Birenbaum et al., 2004; Dogan & Tatsuoka, 2008; Tatsuoka, Corter, & Tatsuoka, 2004; Um, Dogan, Im, Tatsuoka, & Corter, 2003) which focused on using TIMSS released item to study the pupils' knowledge states. Um, Dogan, Im, Tatsuoka, and Corter (2003) compared knowledge states of eighth graders from Korea, Czech and America using TIMSS-R 1999 released item. Birenbaum et al. (2004) attempted to compare the knowledge states of eighth graders from the Unites States, Japan and Israel using TIMSS-Revised (TIMSS- R) item for the year 1999. In the same year, Tatsuoka, Corter, and Tatsuoka (2004) studied the samples of 20 countries on the patterns of diagnosed specific mathematical contents and process skill using TIMSS-R item in 1999. Dogan and Tatsuoka (2008) analyzed the knowledge states of Turkish pupils' mathematics skills using TIMSS-R 1999 released items.

Thus, in order to address the gap in the literature, a CDA diagnosing the learning of "Time" involving dates is needed. In addition, the difference in