THE DEVELOPMENT OF A YEAR FIVE CHILDREN'S ENGINEERING TEACHING MODULE FOR HOTS

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FACULTY OF EDUCATION
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ABSTRACT

Currently, there is a new push for early engineering to be included in the Science, Technology, Engineering and Mathematics (STEM) program. Activities integrated with early engineering foster Higher Order Thinking Skills (HOTS) among the children. Based on the previous research, it was clear that Malaysian children were lacking of HOTS. In line with that, this study has designed and developed Children’s Engineering Teaching Module (CETM) to help the science teachers to foster HOTS using the engineering elements among the Year Five primary school children. The theoretical foundation of this study was based on Gagne, Piaget and Vygotsky views. The process of developing CETM using the Isman model was carried out using the modified Delphi technique. The interviews with the experts were carried online. A total of 22 experts were involved in the CETM development. The email responses received from the experts were analysed and classified into four themes. CETM was designed and developed based on these four themes. CETM contains four activities whereby each of the activity represents a specific theme in the Year Five science syllabus. The CETM activities encourages children to use the engineering elements such as cyclic process and design thinking. Apart from that, the CETM activities also encourages children to produce a three-dimensional prototype as a solution for the given challenge. Once the CETM was developed and pilot-tested, the CETM activities were implemented in a primary school in Perak. The findings were based on the children’s sketches during the brainstorming session, written answers, verbal expressions, the ability in testing the prototypes and other interactions in the classroom. In addition, the children were interviewed and observed. Based on the analysis, it was found that children had the ability to justify and evaluate, offer different viewpoints and interacted intellectually either with their teacher or among themselves during the CETM activities. Children were also engaged in the reasoning process, creative thinking and participated in the intellectual discussions while designing the prototypes. In fact, they were able to create strategies which promoted ideas when they were designing the prototypes for CETM activities. Based on the reasoning skills test before and after the implementation of CETM, it was observed that there was improvement for some of the HOTS elements and reasoning skills among the children. Based on the test findings, it was found that the children’s ability to make decision, argue, reason deductively and mechanically has improved. One of the implications of this study is the usage of online interview to obtain the experts’ view from various countries. Apart from that, through the development of CETM, teachers were guided to produce activities which encompasses interdisciplinary fields such as technology, astronomy, ecology and sustainable engineering. Meanwhile children will also gain the experience of using the engineering and designing elements while learning science subject in the classroom.

PEMBANGUNAN *CHILDREN'S ENGINEERING TEACHING MODULE* BAGI MURID TAHUN LIMA UNTUK KEMAHIRAN BERFIKIR ARAS TINGGI

ABSTRAK

Sejak kebelakangan ini, terdapat usaha untuk memperkenal kejuruteraan awal dalam program *Science, Technology, Engineering* dan *Matematics* (STEM). Aktiviti-aktiviti yang disepadu dengan kejuruteraan awal menggalakkan Kemahiran Berfikir Aras Tinggi (KBAT) di kalangan murid-murid. Berdasarkan kajian lepas, ternyata bahawa murid-murid di Malaysia lemah dalam penggunaan KBAT. Sejajar dengan itu, kajian ini telah membina dan membangunkan *Children's Engineering Teaching Module* (CETM) untuk membantu guru-guru sains dalam usaha untuk menggalakkan KBAT dengan menggunakan elemen-elemen kejuruteraan di kalangan murid-murid Tahun Lima. Asas teori yang digunakan dalam kajian ini adalah berdasarkan pandangan Gagne, Piaget dan Vygotsky. Proses pembangunan CETM yang berasaskan Model Isman dijalankan dengan menggunakan teknik Delphi yang telah diubahsuai. Temu bual dengan pakar-pakar telah dijalankan menerusi talian internet. Seramai 22 orang pakar telah terlibat dalam pembangunan CETM. Maklum balas melalui e-mel yang diterima daripada pakar-pakar, dianalisis dan hasil dapatannya diklasifikasikan kepada empat tema. CETM telah dibina dan dibangunkan berdasarkan empat tema tersebut. CETM mengandungi empat aktiviti di mana setiap aktiviti itu mewakili tema yang khusus dalam silibus sains Tahun Lima. Aktiviti-aktiviti dalam CETM juga menggalakkan murid-murid untuk menggunakan elemen kejuruteraan seperti proses kitaran dan pemikiran reka bentuk. Selain itu, aktiviti-aktiviti dalam CETM juga menggalakkan murid-murid untuk menghasilkan suatu prototaip tiga dimensi sebagai langkah penyelesaian bagi cabaran yang diberi. Setelah CETM dibangunkan dan menjalani kajian rintis, aktiviti-aktiviti CETM telah dilaksanakan di sebuah sekolah rendah di negeri Perak. Dapatan kajian ini berdasarkan kepada lakaran murid semasa sesi

sumbang saran, jawapan bertulis murid, ungkapan lisan murid, pengujian prototaip oleh murid dan interaksi-interaksi lain di dalam bilik darjah. Murid-murid juga telah ditemuduga dan diperhati. Berdasarkan hasil dapatan, didapati bahawa, murid-murid mempunyai kebolehan menjustifikasi dan menilai, memberikan pandangan yang berbeza dan berinteraksi secara intelek sama ada dengan guru ataupun sesama mereka semasa aktiviti-aktiviti CETM. Murid juga terlibat dalam proses menaakul, pemikiran kreatif dan mengambil bahagian dalam perbincangan intelek semasa mereka bentuk prototaip. Malah, mereka berupaya untuk membentuk strategi-strategi yang menjana idea sewaktu mereka bentuk prototaip untuk aktiviti CETM. Tata laksana ujian kemahiran menaakul sebelum dan selepas CETM menunjukkan bahawa ada peningkatan dalam beberapa unsur KBAT dan kemahiran menaakul di kalangan murid-murid. Berdasarkan ujian kemahiran menaakul, didapati bahawa kebolehan murid-murid untuk membuat keputusan, berdebat, menaakul secara deduktif dan mekanikal telah meningkat. Implikasi kajian ini antaranya adalah penggunaan temuduga secara talian untuk memperoleh pandangan pakar dari pelbagai negara. Selain itu, melalui pembinaan CETM, guru-guru juga dibantu untuk menghasilkan aktiviti-aktiviti yang merentas bidang yang berlainan seperti bidang teknologi, astronomi, ekologi dan kejuruteraan mampan. Pada masa yang sama, murid-murid telah memperoleh pengalaman untuk menggunakan elemen-elemen kejuruteraan dan mereka bentuk semasa mempelajari subjek sains di dalam kelas.

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LIST OF ABBREVIATIONS

Abbreviation	Expansion
CETM	Children's Engineering Teaching Module
HOTS	Higher Order Thinking Skills
STEM	Science, Technology, Engineering & Mathematics
TIMSS	Trends International Mathematics & Science Study
PISA	Program for International Student Assessment
NGSS	Next Generation Science Standards
DDR	Design & developmental research
OECD	Organisation for Economic Co-operation & Development
IEA	The International Association for Evaluation of Educational Achievement
MOSTI	Ministry of Science &Technology Innovation
SRST	Science Reasoning Skills Test
TEE	Total Engineering Education
TSTS	Thinking Skills & Thinking Strategies
PEKA	Assessment of Laboratory Science Work
RBT	Revised Bloom Taxonomy
KBSR	Integrated Curriculum for Primary Schools
LOTS	Lower Order Thinking Skills
NEP	National Education Philosophy
EiE	Engineering is Elementary
KSSR	Primary School Standard Curriculum
NRC	National Research Council
VSA	Virginia Student Assessments

LLC	Learning Express
ID	Instructional Design
ADDIE	Analysis, Design, Development, Implementation & Evaluation
ARCS	Attention, Relevance, Confidence & Satisfaction
ASSURE	Analyse, State objectives, Select methods, Utilize materials, Require learner participation and Evaluate and revise.
NAE	National Academy of Engineering
NSF	National Science Foundation
ITEA	International Technology & Engineering Educators Association
ASEE	Award in American Society of Engineering Education
MOE	Ministry of Education
SPSS	Statistical Package for the Social Science
AERO	Alternative Education Resource Organization

CHAPTER 1: INTRODUCTION

Introduction

The world is becoming small due to the actions in certain parts of the world which uses powerful influence on other parts of the world. There is more engagement of individuals and communities from numerous parts of the world. These forces are difficult to obviate as they provide challenges for people in science education. Today's education must enable children to face challenges and working demands of daily living. Children not only need knowledge but at the same time, they also require higher level thinking skills in the coming years ahead. Next Generation Science Standards (NGSS) report revealed:

> Science, engineering and alternate concepts must be designed as a fundamental module of the criteria. The fundamental content for science must be acknowledged as part of the practices which presents a learning shift for instructional materials, science teaching and measuring learning outcomes. This presents an opportunity for both science and engineering in order to improve the curriculum, teacher development, assessment, accountability and most importantly, children's achievement.
>
> (NGSS, 2013)

The challenge in today's education is to teach children of diverse capacity and differing rates of learning. Teachers are expected to teach in a way that enable children to learn Science and Mathematics concepts while simulatenously acquiring higher level thinking skills and reasoning skills. Many teaching strategies have been encouraged in Science and Mathematics classrooms, ranging from teacher-centred approach to students-centred approach.

Education in Science and Mathematics has become a focus within government, industry and academic communities (Ali, 2012). Science and Mathematics education in primary school is an essential factor in developing an intellectual nation. According to

Ali, (2012) for future intensive economy, human capital must be more scientific and technical. The sustainance of competitive advantage in a nation depend more and more in science and engineering. However, the Malaysian primary schools are still not producing suffiencient number of children with high level of thinking skills, particulary in science (Ali, 2012).

In fact, one of the main obstacles for economic development faced by advanced firms in many countries is the lack of competent engineers and technicians (UNESCO, 2010). The lack of competent engineers and technicians must be addressed. Malaysia too is facing this challenge and the government is making the substantial efforts to overcome this challenge. The Ministry of Education (MOE) in Malaysia has estimated that the current number of engineers in the country is at about 140,000. This is projected to reach over 200,000 by 2017, based on an annual output of 15,000 new graduates here in Malaysia (Kieong, 2012). These new graduates will become engineers in fields such as mechanical, chemical, electronics and software. However, these engineers should be academically qualified with high level thinking skills, have the necessary training and experience in the technical area.

In equivalence with that, science must be imparted in an inspiring and thought-provoking manner to keep the inquisitiveness alive. Retaining children’s interest in primary science education is crucial because more children must be given the chance to select science in their secondary education (Cleaves, 2005; Lindahl, 2003) in order to pursue professions which are science and engineering related. Hamdan (2012) stressed that a carefully studied plan need to be implemented to increase the amount of children to take up science not only at university level but also at primary school level. Malaysia needs at least 500,000 children by 2020 who can think intellectually to continue the mission of becoming a developed nation (Hamdan, 2012).

Background of the Study

Science education is important in supporting the country's aim of accomplishing the status of a developed nation by the year 2020 (Karpudewan, 2012). Hence, numerous polices have been introduced by the policy-makers and MOE. These policies include the National Science and Technology Policy (STP I). STP 1 was first introduced in 1986 by the Science, Technology and Innovation Ministry (MOSTI). The vision of STP 1 is to become a nation that is proficient, self-reliant and inventive in science and technology, towards succeeding the goals of the nation's Vision 2020. Apart from that, this policy also aims to produce at least 60 researchers, scientists and engineers for every 10,000 workers in Malaysia. Over the years, STP I was revised and STP II was introduced in year 2003.

STP II addresses seven key significant areas. One of the areas concentrate on education, whereby there are calls for adoption of a 60:40 ratio of children pursuing science, technical and engineering disciplines in both upper secondary schools and universities. Achieving this target is crucial since we are left with four more years before we turn into an advanced nation in 2020.

However, the enrollment of children in science and technical areas at secondary school level in both government and government-aided schools fell from 22.8% in 1990 to 21.3% in 1995 (Higher Education Ministry, 1995). Since then, the enrollment of children in science and technical areas has not improved much. According to Nordin (2012), the situation further deteriorated in year 2012 as the children's enrolment into science stream decreased even more. At the rate things are going, it will be tough for the government to increase the number of capable research scientists and engineers in Malaysia. This can result in serious concern to the country's innovation and development plan since only children who enrol in Science and Mathematics are able to pursue further in science related professions.

Malaysia needs to devise more creative and effective strategies to address the concern of getting a larger proportion of Malaysians to be interested in Science and Technology (S&T). This is a huge challenge because interest in subjects such as Science and Mathematics will pave the way for the acquisition of greater S&T knowledge. Greater S&T knowledge will substantially determine the survival of Malaysia in scientifically and technologically inspiring 21^{st} era (MOSTI, 2008).

Malaysia is directly comparable to the United States of America (USA) on three issues that concern the latest developments or new findings in science, medicine and new technology (MOSTI, 2008). Nevertheless, Malaysia consistently registers lower numbers of interested citizens than the USA in all three S&T issues compared (MOSTI, 2008). Only 44.9% of Malaysians are interested in new science inventions or discoveries. In contrast, far more Americans (87.0%) and Europeans (78.0%) expressed an interest in this issue, exceeding Malaysians by 42.1% and 33.1% respectively. This proved that more than one third of the Malaysian population clearly expressed a lack of interest in S&T. These statistics make a compelling case that the Malaysian government needs to do more to reach out to those who appear to be indifferent to or uninterested in S&T (MOSTI, 2008).

Currently, Science, Technology, Engineering and Mathematics or also broadly known as STEM has emerged as USA development in science education. STEM has arisen as one of the most required in curriculum designs for incorporating science, technology, engineering and mathematics into the existing education (Meyrick, 2011). The benefit of integrating STEM curriculum into all content areas at all grade levels is that it delivers children with practices which employ creative ways to solve problems before they decide on a program of study for higher studies (Meyrick, 2011). In short, STEM education provides the children to develop higher level thinking skills during the problem-solving activities. Batterson (2010) revealed that policy makers often cry out for innovation as the basis of economic salvation and this situation made more emphasis in STEM education which is often followed by a move to have children take another math or science course. Batterson (2010) mentioned that this concept was wrong because innovation is the child of engineering-the “E” of STEM. Practicing innovation not only draws on Science and Mathematics but the engineering process itself (Batterson, 2010).

Every progressive nation knows that the way to economic success and global prowess starts with a STEM education (Putra, 2012). The perpetual discussion to increase the number of STEM children’s needs more than incentives offered to make it successful. According to Putra (2012), a transformation of the Science and Mathematics curriculum is essential to revive interest in STEM. In fact, the improved teaching pedagogy must also be flexible and be able to evolve with time. It needs to be more proactive to cope with the fast-changing world of science.

Putra (2012) adds on that improvements for transformation must address the current method of learning science and teaching by rote, as this is no longer effective in this era. However before addressing new transformations, it is vital to observe children’s achievement in Science and Mathematics from time to time with the intention of measuring numerous variables such as teacher’s role, children’s interest, children’s motivation, school’s conduciveness and many more. Thus, an international assessment is crucial to assess specific attention or concentration of relevant variables.

The Trends in International Mathematics and Science Study (TIMSS) is a comparative study designed in 1995 by The International Association for Evaluation of Educational Achievement (IEA) (Ghagar, Othman & Mohammadpour, 2011). TIMSS evaluated the quality of the teaching and learning of mathematics and science among the fourth and eighth graders across more than 60 participating countries (Ghagar et al., 2011). Children performing at the Advanced International Benchmark communicated an understanding of complex and abstract concept in Biology, Chemistry, Physics and Earth Science. Children also combined information from several sources to solve problems, drew conclusions and provided written explanations to justify their scientific knowledge.

Program for International Student Assessment (PISA) also aims to evaluate education system worldwide every three years. PISA assesses fifteen-year old's competencies in various subject matters such as mathematics, science and reading. PISA is administered by the Organisation for Economic Co-operation and Development (OECD) in over 70 countries, both OECD and non-OECD countries (Chapman, Loo, Kulasegaran, Chen, Mohsin & Goon, 2012). The PISA assessments have been conducted since 2000 with Malaysia taking part for the first time in 2009. Although Mathematics and Science were also a part of PISA's assessment, reading was the main domain of focus in PISA assessment (PISA, 2009).

Malaysian participants did not produce a positive result in both TIMSS 2011 and PISA 2009 assessments. Apart from these international benchmark assessments, there were also other compelling evidence regarding the lack of thinking skills among Malaysian children. Observational studies such as Malaysian Education Blueprint 2013-2025 and Yassin (2013), revealed that although there were several programmes carried out by Malaysia in order to enhance the higher thinking skills among children, there were still some points that were often overlooked. Hence, the following critical argument discusses the lack of higher thinking skills among the Malaysian children.

Problem Statement

Higher order thinking skills (HOTS) has been discussed increasingly in the science educational literature over the past few decades by researchers' worldwide (Beyer, 1988; Costa, 1985; Glaser, 1984; McLoughlin & Mynard, 2009; Pogrow, 1988, 1990;

Zohar, 1999, 2006; Zohar & Dori, 2003). Fostering children's HOTS in school has been an important aim of science education, whereby element such as reasoning play a vital role in engaging children in effective inquiry (Barak & Shakhman, 2008; National Science Teachers Association, 2003).

However, there is a strong recent concern in researching children's higher order thinking for reasoning in the science classroom because countries across the world such as USA, UK, Australia, Spain and Israel are facing with science students who are lacking HOTS (Alozie et al., 2010; Osborne, 2010). Contrary to previous studies which have indicated the importance of HOTS in teaching reasoning skills among science students (Anderson & Krathwohl, 2001; Barack & Shakhman, 2008; O'Brien, 2003; Papadouris, 2012; Santamaria, Tse, Moreno-Rios & Garcia-Madruga, 2012; Wang, Wei, Ding, Chen, Wang & Hu, 2012), Malaysian children are also lacking HOTS in science because Malaysian children were not successful in applying reasoning skill which is a crucial intellectual skill in science (Hashim, 2006; TIMSS, 2011).

The decline in Malaysian student's HOTS are highlighted by the results of TIMSS 2011 whereby Malaysia performed lower than the international average in all the cognitive domains except for reasoning in Biology (TIMSS 2011). In fact, Malaysia's reasoning in Biology is still lower than Singapore by 15%. TIMSS 2011 assessment also pointed out that Malaysian student could not recognize the basic facts of science and communicate an understanding of complex and abstract concepts in Chemistry, Physics and Earth Science domains because they were unable to master the reasoning skills. Malaysian science students performed very poorly in scientific reasoning skills since TIMSS 2007. This is because they were unable to apply scientific reasoning skills that are necessary for explaining science concepts (Abdullah & Shariff, 2008; Martin, Mullis, Foy & Stanco, 2012).

Malaysia's outcome in PISA 2009 is relatively alarming as TIMSS 2011 because 44% of Malaysian students were unable to recognise the main idea of the reading text and compare the information provided with everyday knowledge. This statistic is worrying since PISA is an assessment of students' HOTS and ability to solve problems in a real-world setting which are vital skills in the 21st century (Chapman et al., 2012). Despite the previous researchers have indicated the importance of HOTS in learning science, HOTS still remain as an unsolved issue. This is because the involvement of reasoning skills in science curriculum has not received sufficient attention and there is a need for more research in teaching attempts for promoting reasoning skills especially among the upper graders in the primary school (Fah, 2009; Papadouris, 2012).

One of the central goals of science education is to help children reason in science but most of the scientific inquiry processes are often taught separately from knowledge-rich contexts (Chin & Malhotra, 2002). At the same time, traditional science textbook-based instruction is in need of reform because textbook inquiry tasks rarely ask children to conduct multiple studies of the same basic procedure in order to explore a wider number of hypotheses and experiments which helps to reason a phenomenon (Chin & Malhotra, 2002; Haberman, 1991; Silk, Schunn & Cary, 2009; Waxman & Huang, 1995). The inquiry tasks in the textbooks not only predetermines many of the cognitively challenging decisions, but at the same time seldom ask children to consider the issue of controlling themselves. This does not help the children to develop an understanding of reasoning in science subject (Chin & Malhotra, 2002; Germann, Haskins & Auls, 1996; Silk et al., 2009).

Although textbook in Malaysia serves as a source for curricular document to inculcate values in realising national aspirations, recent study has revealed that an expert group achieved consensus on revitalizing the textbook content to be transformed and implemented among the teachers and the children (Rahman, Alias, Siraj & Dewitt, 2013). These researchers have indicated that text content should emphasize problem solving apart from testing multiple intelligences at all levels of learning. Children are not interested in reading science textbooks as the text is difficult to be understood and they only use the textbook when receiving assignments from the teacher to get the compact and correct facts (Guzzetti, Williams, Skeels & Wu, 1997; Jamaluddin, 2002).

Subsequently, numerous studies have not only shown that many primary school teachers and children display very limited science knowledge but also dislike science subject (Trumper, 1998). This is a significant problem because teachers' limited knowledge will employ didactic approaches rather than student-centred approaches (Appleton & Kindt, 1999; Bencze & Hodson, 1999). Malaysia Education Blueprint 2013-2025 reports that only 50% of the science lessons are being delivered in an effective manner. The lessons did not sufficiently engage students and followed a more passive lecture format of content delivery. In fact, these lessons focused only on achieving surface level content understanding, instead of HOTS. This statistic is distressing as an estimated 60% of today's science teachers will still be teaching in 20 years' time where they will be practicing the same teaching approaches for learning science (Malaysian Education Blueprint 2013-2025).

Yassin, Tek, Alimon, Baharom and Ying (2010) also pointed out that the questions posed by Malaysian primary science teachers were substantially 98.8% coded at the lower cognitive taxonomic categories such as remembering and understanding. These findings indicated that primary school children were engaged at a lower cognitive level in learning science because science teachers offer little opportunity to express ideas and ask questions. In fact, even if the teachers offered the opportunity, the teacher's questions were found to be focused on knowledge reproduction with the drive being towards an end that had been previously determined by the teachers (Anderson &

Contino, 2010; Barak & Shakhman, 2008; Kanuka & Garrison, 2004; Yassin et al., 2010). This is disappointing because higher order questions make students active and independent compared to lower order questions, which promote passiveness among the students and mute thought (Brualdi, 1998).

Other countries such as USA, UK, Australia, Spain and Israel were also facing the same situation as Malaysian children who are also lacking HOTS. These countries have carried out several researches from 2007 until 2012 with the purpose of enhancing HOTS among the science students. There is compelling evidence that the usage of technology such as digital media and web diagrams have increased the HOTS among science students (Anderson & Contino, 2010; Skillen, 2008). Recent research also found that HOTS has been fostered with the usage of teaching aids such as interactive white boards (Kershner, Mercer, Warwick & Staarman, 2010) and questioning materials based on authentic instruction (Preus, 2012). Tantalizing evidence suggest that critical reading of newspaper also enables the development of HOTS among students (Oliveras, Marquez & Sanmarti, 2011). Another recent study showed that a designed teaching module has given the platform for the children to develop their HOTS through their knowledge and understanding in learning science (Avargil, Herscovitz & Dori, 2011). Significantly, majority of these researches have employed a qualitative methodology in contrast to a mix-method study where the findings of these studies were gathered through interviews and classroom-observations.

The Malaysian education curriculum is also set to undergo a revamp to realign it with international standards, as well as to develop HOTS among school children especially in science subject (Malaysian Education Blueprint, 2013-2025). To produce HOTS children who can compete at international level, the Malaysian Education Blueprint (2013-2025) has detailed a host of changes, including strengthening the delivery of STEM education. Part of the plan to produce children with HOTS include the infusion of HOTS type questions into the local assessments such as Primary School Evaluation Test (*Ujian Pencapaian Sekolah Rendah)* and General Certificate of Education *(Sijil Pelajaran Malaysia)* which will require children to use analytical and evaluation skills. However, these local assessments not only place less emphasize on the elements that involve in HOTS but at the same time these assessments use the familiar materials to evaluate the HOTS among the children.

Parallel to that, it was observed that HOTS have been nurtured through early engineering among primary school children in all five continents around the globe (Jones, 2006; Hill, 2009; Jones & Compton, 2009; Lachapelle & Cunningham, 2012; Muchtar & Majid, 2009; Nwohu, 2011). Converging evidence also shows that, early engineering promotes HOTS in the application of science (Clark & Andrews, 2010; Tu, 2006). In fact, corresponding research indicates that children's engagement in early engineering allows them to explore scientific ideas in understanding the science context (Kolodner et al., 2003; Lachapelle & Cunningham, 2007; Lachapelle et al., 2011; Macalalag, Brockway, McKay & McGrath, 2008; Penner, Giles, Lehrer & Schauble, 1997; Sadler, Coyle, & Schwartz, 2000; Thompson & Lyons, 2008; Wendell, Connolly, Wright, Jarvin, & Rogers, et al., 2010).

Introducing early engineering in Malaysia could enhance HOTS and reasoning skills among children since Malaysia is moving towards fostering higher level thinking skills among primary school children in order to obtain 21st century skills and knowledge (Abdullah & Osman, 2010; Meeteren & Zan, 2010; Salih, 2010) Early engineering have demonstrated the ability to generate and reason over interpretive assertions within a well-defined scientific domain (Russ, Ramakrishnan, Hovy, Bota & Burns, 2011).

Early engineering is encouraged for primary school children because the development of problem solving skills among the infant or toddler years is related to children's reasoning domain and the ability to use scientific thinking to solve problems that are in their everyday environment (California Department of Education, 2012; Silk et al., 2009). Early engineering also promotes critical intelligence (Burghardt, 1999; Golanbari & Garlikov, 2008) and intellectual traits (Paul, Niewoehner & Elder, 2006) which are important component for reasoning in science (Duncan, 2003). It is observed that the fifth and sixth graders reason better through try and see approach in early engineering (Schauble, Glaser, Raghavan & Reiner, 1991; Silk, et al., 2009). When children are involved in early engineering, their goal is optimization which is to reason and produce a desired effect rather than determining which factors made a difference and which ones did not (Zimmerman, 2000). All the most successful educational systems in the world teach new knowledge in the early grades. During early grades, children are very receptive and with efficient teaching method, deficiencies in the first six grades can be avoided and improve the quality of later schooling (Core Knowledge Foundation Report, 2010). According to neuroscience perspective, children's dorsolateral prefrontal cortex, which is a subdivision of frontal lobe in the human brain perform better than adults (Kain & Perner, 2005; Krawczyk, 2012). Since dorsolateral prefrontal cortex supports the reasoning ability and problem solving process in a human brain (Morris et al., 2002), it is appropriate to introduce early engineering at a younger level as the human's reasoning ability increases from early childhood (Halford, Maybery, O'Hare & Grant, 1994; Richland, Morrison & Holyoak, 2006).

Hence, this study designed a teaching module called Children's Engineering Teaching Module (CETM) to promote HOTS among primary school children apart from guiding the teachers in fostering HOTS during the teaching and learning practice in science lessons.

Aim of the Study

This study aimed to develop Children's Engineering Teaching Module (CETM) to enhance Higher Order Thinking Skills (HOTS) among the eleven years old children in learning science subject. The content of the CETM was constructed based on the Malaysian science curriculum in the essence of helping the teachers to foster HOTS among the children.

Objectives of the Study

The objectives of this study are to:

1. Design CETM for Year Five primary school children in science subject based on the following elements:
    a) Characteristics of children's engineering.
    b) Reasoning domain of HOTS.
2. Evaluate the developed CETM based on its ability to enhance HOTS through the teachers' perceptions.

Research Questions

This study answered the following research questions:

1. What are the elements in teaching science that could enhance HOTS for the CETM?
2. What kind of activities embedded in the CETM in order to enhance HOTS in teaching science?
3. How does the developed CETM enhanced reasoning domain of HOTS in teaching science?
4. How do the teachers perceive the developed CETM?

Significance of the Study

The developed CETM focused in facilitating both the teachers and children. Apart from helping the children, CETM was also keen in helping and guiding the science teachers to implement HOTS during the teaching and learning science. The designed CETM was an alternative guide in accelerating the process of fostering HOTS while learning science in the classrooms.

As much as science is a practical discipline, it is equally a theoretical subject too. Science also involved thinking, having good ideas, simulating, and modelling (Wellington & Ireson, 2012). The developed CETM helped in this aspect of science as well since science is a practical aspect. Science is a design (Wellington & Ireson, 2012) because it involves children going beyond the hands-on and by utilising both theory and practical exercise. Parallel to that, CETM helped in learning the content and knowledge of science by using engineering thinking skills. These skills and processes were vital to science itself, apart from the overall science education.

Operational Definition

The operational definition of the terms used in this study is as following:

Children's Engineering Teaching Module (CETM)

CETM was the common name given to deal with the doing and making in the primary science classroom (Whiting & Hickey, 2009). Children's engineering or early engineering encouraged the integrated STEM education into the primary science education (Whiting & Hickey, 2009).

In this study, CETM was a teachers' guide that provided children with hands-on activities to foster HOTS. CETM was an effort to bridge the gap between memorization of facts and understanding of cognitive skills such as creating, evaluating and analysing through meaningful practical activities that often interest and motivate even the most reluctant children. Each of these cognitive skills which reflected the HOTS were evaluated based on the reasoning skill and other higher level thinking elements. The reasoning skills and other higher level thinking elements were embedded in the designed and developed CETM activities.

Higher Order Thinking Skills (HOTS)

This study defined HOTS based on the collection of opinion from various fields and expertise (Aguirre & Speer, 1999; Barack & Shakhman, 2008; Brickhouse, 1990; Nespor, 1987; Pajares, 1992; Prawat, 1992; Richardson, 1996, 2003; Zohar, 2006).

In this study, HOTS is defined as elements of higher level thinking skills which can be fostered during hands-on activities. The process of creating real-word prototypes in the classroom can enhance elements of higher level thinking skills such as strategic thinking, independent thinking, making decision and argumentative. HOTS in this study also defined as the ability of a child to justify their reasons using other subject matters such as Mathematics, Living Skills and Technology.

This study also referred HOTS based on the higher division of Revised Bloom Taxonomy (RBT) which includes creating, evaluating and analysing. This is because the CETM activities involved cyclic design which emphasizes analysing, creating and evaluating elements during the activities. The cyclic designing nature in CETM activities required children to think critically on their cyclical reflective process because these activities encourage children to improve their higher-level thinking skills (Lo¨hner, van Joolingen, Savelsbergh & van Hout-Wolters, 2005; Smith & Szymanski, 2013). Further more, this study shortlisted some experts and the criteria's in choosing the experts are discussed in Chapter Three.

Reasoning Skills

Reasoning skills is closely allied with other domains of inquiry in psychology (Kaufman & Sternberg, 2009). At the same time, reasoning skills also represent different but overlapping aspects of human intelligence (Kaufman & Sternberg, 2009). According to Kaufman and Sternberg (2009), reasoning skills also refers to the process of drawing conclusions or inferences from the given information. However, Bruner (1957) mentioned that reasoning skills always require going beyond the information that is given.

In this study, reasoning skills is defined as a thinking skill that depends importantly on knowledge. Children who have rooted in knowledge tends to reason differently when given problems during the lessons in classrooms (Feltovich, Prietula, & Ericsson, 2006). This study defines a good reasoning skill is nothing more than a good piece of knowledge. Everyday reasoning depends heavily on the efficacy of past reasoning processes (stored as knowledge) as well as the efficacy of present reasoning processes (Kaufman & Sternberg, 2009). An increasingly sophisticated knowledge base supports increasingly sophisticated forms of reasoning because a more sophisticated knowledge base has richer, more abstract associative connections between concepts and more metacognitive knowledge that links strategies to goals (Gobet & Waters, 2003; Feltovich et al., 2006; Horn & Masunaga, 2006; Proctor & Vu, 2006).

Apart from that, this study also defines reasoning skills as a major component within the Higher Order Thinking Skills (HOTS). For example, this study has referred creating, evaluating and analyzing in the Revised Bloom Taxonomy (RBT) as the main component in HOTS. This study has defined reasoning skills as a thinking skill within the components of creating, evaluating and analyzing. For example, in order to create, evaluate and analyze a prototype during the activities, children are given the opportunity and the space to use their reasoning skills while experiencing each of the HOTS component.

Science, Technology, Engineering and Mathematics (STEM)

According to DeJarnette (2012), there is a great need in USA for talented scientists and engineers. Numerous programmes abound for high school and middle school children in regard to STEM initiatives (Murphy & Mancini-Samuelson, 2012). Collaborative STEM studies often aimed at the primary education. Parallel to that, Murphy and Mancini-Samuelson (2012) mentioned that curriculum for primary science education must be involved with STEM education, especially to refine the present assessments and educational standards.

In this study, the concept of early engineering was derived from STEM education. In order to recognise the importance of science and engineering which is a rapidly growing field of knowledge, the early engineering idea was a crucial part of STEM education (Archer et., 2010). This study focused on Malaysia's need to take serious steps to increase the HOTS through STEM education apart from attracting more children to enjoy learning science. In this study, early engineering which is a subset of STEM education was investigated using the inter-disciplinary subjects such as Science, Technology, Engineeering and Mathematics.

Scope of the Study

This study focused on eleven years old children who studies science subject at primary school. The outcome of this study generalized a small population of Year Five children rather than the entire population in Malaysia. Two primary schools in the same state were used to implement CETM activities. The first school was where the CETM activities were piloted. The second school was used to implement the real study of CETM implementation.

Limitation of the Study

Five CETM activities has been designed and developed in this study. The five activities accommodated five themes for all the twelve topics in Year Five science syllabus. At the same time, the cost and time was also a crucial factor in designing and developing CETM since the hands-on activities has the needful sources which the researcher provided to complete the activities. Apart from that, this research discussed four out of five outcomes in Gagne theory. Motor skills was omitted because it is seen as a huge researching area and often involved in examples of physical science education as compared to science itself according to established journals and books.

Since this is a design and developmental research (DDR), the ultimate focus was to develop and evaluate the CETM in order to foster HOTS among the children. Hence, only one primary school was chosen where a total of 30 children participated in this study. Parallel to that, two teachers were guided and involved in implementing the CETM in the classroom. However, only one teacher used the CETM and implemented it in the classroom. The process of developing the CETM took almost a year because all of the experts who helped to design CETM were contacted through online interviews via e-mail which was time consuming. At the same time, during the photo-elicitation session, the children were asked a several relevant questions instead of interviewing them. This is because the children's responses were inconsistent and most of the time endeavoured the same responses.

Apart from that, experts suggested that a close-ended assessment should be embedded within each of the CETM activity. For example, after the children have created their prototypes, children can test their prototypes based these close-ended responses. The children's responses which was "Yes" or "No" in close-ended questions was analysed as descriptive analysis using frequencies and percentages. However, when asked upon the experts, how the close-ended question in testing the prototypes assesses children's HOTS, the experts mentioned that these questions were reflecting the analysing element in Revised Bloom Taxonomy (RBT). Analysing is the third element after creating and evaluating in RBT. Hence, this research used the close-ended descriptive analysis only to support the quantitative analysis, particularly for the Science Reasoning Skills Test (SRST) analysis which evaluated the children's HOTS before and after the CETM activities.

Summary

Based on Ministry of Science and Technology Innovation (MOSTI) 2008 report, Trends International Mathematics & Science Study (TIMSS) 2011 results, Malaysia Education Blue Print 2013-2025 report and the current status of science in Ministry of Higher Education (MOHE) 2012, it was summarized that children were lacking of Higher Order Thinking Skills (HOTS). According to Wellington and Ireson (2012), knowing about the problem is half the battle won. Hence, this study designed and developed Children's Engineering Teaching Module (CETM) to help the science teachers to foster HOTS among the primary school children. The following chapter discusses the literatures that justify the emerging importance of CETM in fostering HOTS among the primary school children.

CHAPTER 2: LITERATURE REVIEW

Introduction

This chapter discusses the literatures related to children's engineering, studies done to introduce early engineering, researches carried out to foster Higher Order Thinking Skills (HOTS) in other countries as well as in Malaysia and the analysis of Trends International Mathematics & Science Study (TIMSS) 2011. Based on the international assessment, curriculum analysis and literature reviews, it can be summarized that the Malaysian children are lacking of HOTS in learning the science subject. Parallel to that, the purpose of this study was to design and develop Children's Engineering Teaching Module (CETM) to promote HOTS among the primary school children.

Children's Engineering for Primary School Children

Children's engineering is an approach to infuse HOTS and reasoning capabilities among primary school children. Researchers have approved the positive effects of applying children's engineering elements for children.

The primary school level is to open to young children's mind to the diversity and ubiquity of engineering (Lachapelle & Cunningham, 2012). Apart from that, the fundamental of primary school is also to inspire the attitudes and habits of mind. This will lead the children for a change and not remain as consumers of their developing world (Lachapelle & Cunningham, 2012).

Children's engineering in primary schools incorporates 21st century skills such as HOTS, reasoning skills, creativity and innovation skills (Engineering Technology K-12 Standards & Curriculum, 2010). Since Malaysian children is lacking HOTS and reasoning skills, introducing children's engineering can overcome the current problem that the children are facing. Abdullah and Osman (2010) pointed out that Malaysia is moving towards fostering HOTS and reasoning skills among primary school children in order to obtain 21st century skills and knowledge.

In fact, children’s engineering also provides children with the opportunities to be motivated and genuinely interested in finding out if their own ideas would work during the science lesson (Meeteren & Zan, 2010). Apart from deficiency of HOTS, children in Malaysia are also demotivated and losing interest in pursuing science courses. Bringing in children’s engineering could enhance the enthusiasm for science and increase the awareness of science towards their future and nation.

Malaysian children must strive to generate HOTS and reasoning capabilities by getting engaged and involved in science (Salih, 2010). Hence, this study designed CETM in order to infuse HOTS among children.

Children are excited about learning when it comes to children’s engineering (Smith, 2006). According to Smith, children’s engineering has become one of the best practices where all children can succeed. In fact, Smith indicated that it is such a joy seeing children working together to find solutions that may be totally unlike anything we as adults and teachers might expect. Meanwhile, according to Regan (2010), children’s engineering lessons have become so popular that children are recalling what they have learnt during science lessons and talking about it at the dinner table. Children remember about children’s engineering lessons simply because they are interested once they have gained the experience.

Apart from experience, meaningfulness information also facilitates keeping data in the child’s memory (Schunk, 2012). Meaningful information or data can be straightforwardly related with the pre-existing information or data in the child’s memory (Schunk, 2012). By integrating children’s engineering into science lessons, children were allowed to manipulate the hands-on materials apart from interacting what they have learned and experienced throughout their life. According to researchers, it was observed that children not only employed the thinking skills but they remembered when they were asked to apply these thinking skills in the meaningful circumstances. Science teachers can help to enhance HOTS among the children when the teachers develop hands-on activities to assist the children in linking new information or data with the present knowledge in the children's memory (Schunk, 2012). Meaningful information is readily integrated into long term memory network (Schunk, 2012). Through children's engineering, children can develop an understanding of basic science concepts and how to make meaningful scientific observations apart from improving their reasoning skills.

Similarly practicing children's engineering in classrooms helped children gain experience in carrying out various type of roles in an activity. During the activities, children be distributing materials and tools, collecting and recording the findings emerged during the activities. These activities and experiences prepares children to work in small groups without demanding the continuous interference from the science teacher (Lachapelle & Cunningham, 2012).

Significantly, viewing an activity as too easy is not beneficial (Shunk, 2012). It is plausible that, children may become bored if the materials were not challenging. When lessons are not planned to meet the varying needs of children, the desired achievement behaviours will not be displayed. In working on one of the activities in children's engineering, some children would probably have difficulties to solve the problem in the activity. They may need to spend majority of their time learning facts and using manipulative skills to reinforce learning of new concepts. According to Shunk, (2012) success on these activities in a nonthreatening classroom environment builds hope for success and lowers fear of failure. Shunk (2012) mentioned that children become proficient in the activity given to them by mastering the steps, understanding the relationship between science concepts and the goal of an activity. Children were guided to practice challenging skills by giving them the brief review of the activity, which maintain the hands-on challenge (Shunk, 2012). This approach helped the children to set more challenging goals in science through CETM activities.

Past Studies on Incorporating Early Engineering

A number of countries in primary school have engaged with curriculum that introduced children to engineering design (Lachapelle & Cunningham, 2012). England, New Zealand, some provinces in Canada and a number of states in US have identified engineering learning standards for primary school children (Hill, 2009; Lachapelle & Cunningham, 2012).

At present, there is a new momentum for engineering to be more prominently encompassed in the national curriculum in England as part of a new national STEM programme (Lachapelle & Cunningham, 2012). Clark and Andrews (2010) revealed that engineering design activities promote HOTS using the application of science as compared to subjects such as Design and Technology.

Majority of the teachers in New Zealand reported that they use problem-solving and hands-on activities to attract the children's interest and develop their higher thinking abilities in classrooms (Jones, 2006; Jones & Compton, 2009). However, the primary school teachers voiced out that they need assistance with finding and purchasing materials for children to work with as guidance in implementing and assessing the present education curriculum (Lachapelle & Cunningham, 2012). In 2007, a new recognized curriculum based upon constructivist and sociocultural learning theories was released. This curriculum was built with input from international researchers and local educators (Lachapelle & Cunningham, 2012). The revised curriculum was organized into three strands which included technological practice strand (Jones & Compton, 2009). The technological practice strand was most closely corresponded to the elementary engineering for children in New Zealand (Lachapelle & Cunningham, 2012).

The push for what and how engineering education should be taught in the primary school (ages five-eleven) has been one of the main focuses of STEM education in USA (Lachapelle & Cunningham, 2012). In Virginia and Massachusetts where early engineering activities were introduced, children not only had fun but they were motivated and were engaged in the hands-on activities during the science lessons. The outcome convinced USA educators and curriculum implementers to precede the value of this endeavour (Lachapelle & Cunningham, 2012).

National organizations made a number of efforts by creating guideline and recommendation to advocate for engaging children in engineering activities. At the same time, efforts were also carried out to work with the teachers by providing materials to support them as these teachers implement early engineering in their respective classrooms (Lachapelle & Cunningham, 2012).

In fact, looking at the growing importance of engineering in primary schools across countries in Europe and USA, this study has also looked at Asia's current ideas and participation in engineering education for primary school children. Surprisingly, China has already encourged engineering education among primary school children through a project called Total Engineering Education (TEE). Tu (2006) highlighted the economic, political and socio-cultural aspects of engineering education in China. According to Tu (2006), TEE was proposed as one method to shape the future leadership of China. TEE encompassed the entire engineering education and profession preparation system, beginning from primary school programmes to high school graduation, post-secondary and finally graduate education. Through TEE, children for either engineering or non engineering professions must have a basic understanding of engineering approaches and have strong academic, technical and social skills in order for China to achieve a strong level of competitiveness in the global economy of the 21st century. Tu (2006) mentioned that children should be helped to go beyond independent learning to recognise the importance of all knowlegde including HOTS. These knowledge must be viewed in the context of acquiring information from variety of sources than relying on a narrow range of viewpoint.

Nwohu (2011) believed that engineering education must begin from primary school children in Nigeria. The rapid changes in global enviroment, new products development and advancement in science and technology (S&T), underline the imperative of finding new approaches and solutions to the problems of engineering education in Nigeria (Nwohu, 2011). Accoding to Nwohu (2011) the making of an engineer is a long process beginning from primary school but at the same time it does not end with the university degree. Nwohu (2011) highlighted that the education of would-be engineers should begin at the primary school level. This is because the education of would-be engineers have enhanced the higher level thinking skills among the children who have participated in engineering design activities.

German engineering is broadly admired globally as having outstanding class and great skill because their quality of designs is inventive and accurate (Muchtar & Majid, 2009). German engineers are well appreciated and demand great appreciation from their peers across the world. Their engineering skills can be the result of early engineering exposure, which has been inculcated at a very young age. According to Muchtar & Majid (2009), the children's higher level thinking is enriched by their experience, observation and teamwork while learning at the primary schools in Germany. The experience that the children had undergone has seen as an early engineering exposure in the primary schools (Muchtar & Majid, 2009).

The experience that they stumble upon in that environment helped them to improve their higher thinking skills. Through play at school which involved early engineering, children learnt to improve their social and emotional skills (Parten, 1932 & Vygotsky, 1978).

Malaysian Science Curriculum in Primary Science Education

The science curriculum has evolved over a period of more than a century (Wellington & Ireson, 2012). Malaysia too has undergone changes in science curriculum over the past years. Since Malaysia aspires to become an industrialised society based on science and technology, Malaysian education system is giving greater emphasis to science education (Curriculum Development Centre, 2006). Malaysia science curriculum has been designed not only to provide opportunities for children to acquire science knowledge, developing thinking skills and thinking strategies in everyday life but at the same time also to inculcate noble values and the spirit of patriotism among children in learning science (Curriculum Development Centre, 2006). Based on the Malaysian Curriculum Development Centre (2006), thinking skills are categorised into two main groups, named as critical and creative thinking skills. Figure 2.1 in the following page gives a picture of thinking skills and thinking strategies based on 'Thinking Skills and Thinking Strategies (TSTS) science model which was developed through several phases in Curriculum Development Centre (2006).

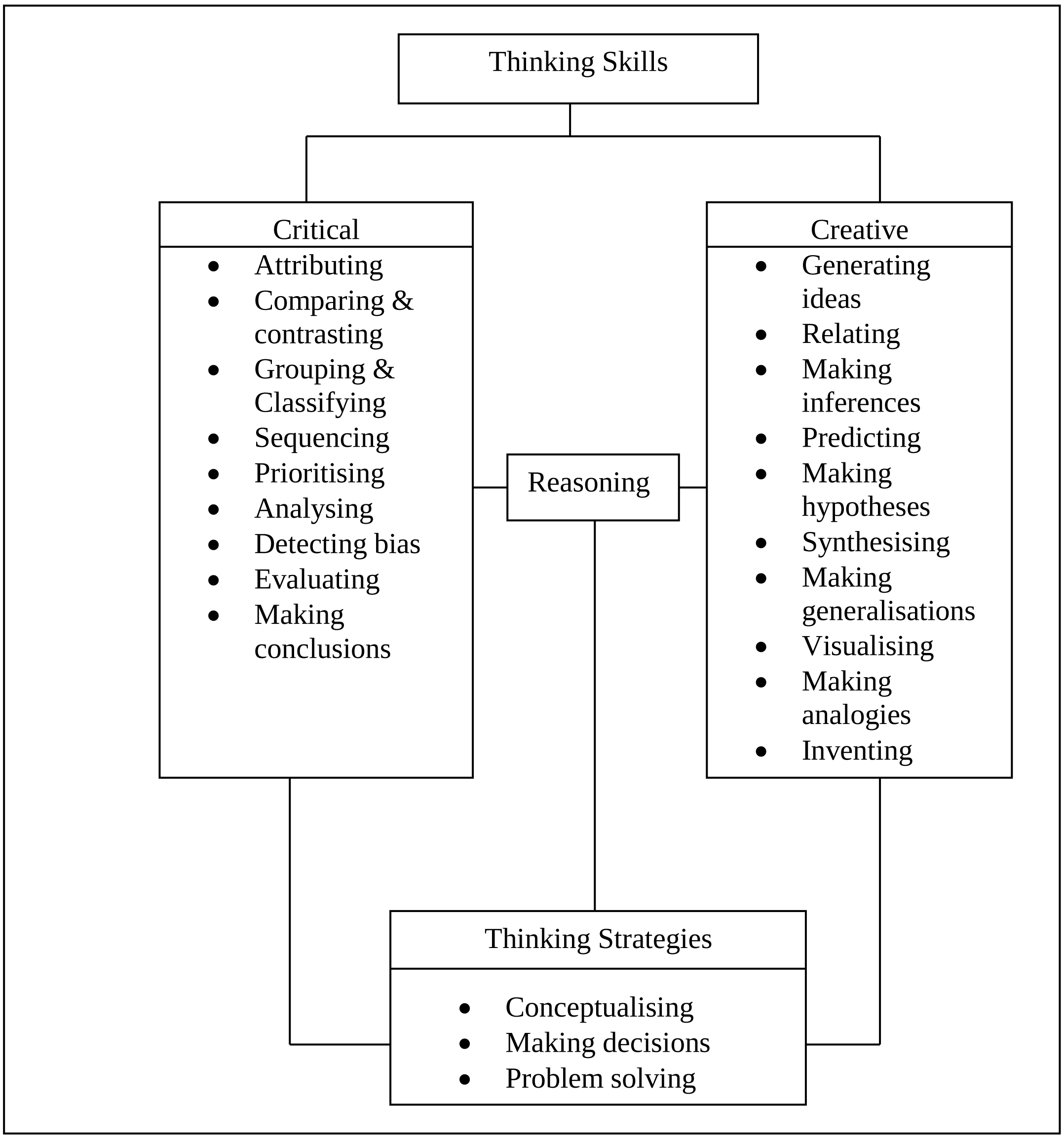


Figure 2.1: Types of thinking skills in primary Year Five science based on the thinking skills and thinking strategies (TSTS) science model (2001) guidebook

Reasoning is a skill used in making logical, just and rational judgements (Curriculum Development Centre, 2006). Thinking strategies are higher order thinking processes that involve various steps where each step involves various critical and creative thinking skills. Based on Curriculum Development Centre (2006), the ability to formulate thinking strategies is the ultimate aim of introducing thinking activities in the teaching and learning science process. Science process skills are required in the process of finding solution to a problem or making decision in a systematic manner. Mastering science process skills involve the mastering of the relevant thinking skills. The thinking skills related to a particular science process skill are shown in Table 2.1.

Table 2.1: Science Process Skills and Thinking Skills

No.	Science Process Skills	Thinking Skills
1.	Observing	Attributing Comparing and contrasting Relating
2.	Classifying	Attributing Grouping Comparing, contrasting and classifying
3.	Measuring and using numbers	Relating Comparing and contrasting
4.	Making inferences	Relating Comparing and contrasting Analysing Making inferences
5.	Predicting	Relating Visualising
6.	Using space-time relationship	Sequencing Prioritising
7.	Interpreting data	Comparing and contrasting Analysing Detecting bias Making conclusions Generalising Evaluating
8.	Defining operationally	Relating Making analogy Visualising Analysing
9.	Controlling variables	Attributing Comparing and contrasting Relating Analysing
10	Making hypotheses	Attributing Relating Comparing and comparing Generating ideas Making hypotheses Predicting Synthesising
11.	Experimenting	All thinking skills
12.	Communicating	All thinking skills

Source. Curriculum Development Centre, 2006

Science education for primary schools emphasizes the ability of children to use the processes of science and process skill learning which has been included as a component of science curriculum (Lan, Ismail & Fook, 2007). For children to demonstrate the integrated process science skills, assessment using hands-on procedures to determine skill acquisition by groups of children deems most appropriate (Lan, Ismail & Fook, 2007). This is because teaching science should not be based on the transmission of scientific knowledge but at the same time should stress on the process of inquiry and communication to build knowledge (Ford & Forman, 2006). However very little research that has been carried out into the effectiveness of practical work in Malaysia (Hofstein & Lunetta, 1982). Malaysian school science implements practical work, which is known as PEKA (Assessment of Laboratory Science Work) in the school science curriculum (Lan et al., 2007).

The Ministry of Education required teachers to conduct school base practical science or PEKA to assess children's acquisition of the science processes. This is because PEKA assess more nearly actual samples of the kind of behaviour in the integrated science process skills. Yet, the administration of the PEKA, which requires children to actually perform the task concerned, has the same problems like the Individual Competency Measures which is very time consuming and require a trained observer (Lan et al., 2007; Meerah, Osman & Halim, 2005). The problem of using such procedure can be a burdensome task to teachers as it is common to have 40 or so children per class in the science classroom (Lan et al., 2007). Besides, the question of reliability and validity of such big scale assessment is also a big concern (Lan et al., 2007) because the teachers found too confusing to adhere all the aspects and criteria which is provided in the PEKA scoring procedure (Meerah et al., 2005). Hence, each teacher has his or her own peculiar way of scoring before carrying out a directive experiment where no questions asked to the children (Meerah et al., 2005).

Despite numerous researches has indicated that science learners should be provided the opportunity to communicate and collaborate in the process of inquiry and discover new knowledge and develop scientific process skills (Etkina, Mestre & O'Donnell, 2005; Hogan & Fisherkeller, 2005; Kozma, 2003; Osbourne & Henessy, 2003), it does not seem to be the case in many schools across the nation. The ability to acquire thinking skills is the main concern for most teachers because it is crucial to produce effective thinkers so as to enable children to think critically and to solve problems (Salih, 2010).

Higher Order Thinking Skills (HOTS) and Reasoning Skills in Malaysia

The HOTS decline among Malaysian children was further highlighted by the TIMSS 2011. However, this problem has erupted since the introduction of Integrated Curriculum for Primary Schools (KBSR) in late 1980s as a mechanism to realize the National Education Philosophy (NEP). According to Hashim (2006), although the cognitive skills were from the lower rung of Bloom's taxonomy, which consists of the lower order thinking skills (LOTS).

In fact, teachers faced the same difficulties several years back in identifying suitable topics to teach HOTS (Hashim, 2006). Hashim (2006) revealed that the teaching of HOTS in schools were not effective and stressed that there's a need of preparing teaching module for thinking skills and to formulate critical and creative types of questions. This growing situation which took place several years back has proved that Malaysian children were weak in thinking skills and this has further resulted through TIMSS 2011 because there was a huge decline in fostering HOTS especially in science. A microanalysis in cognitive level of questions in TIMSS 2011 revealed that Malaysian children were weak in reasoning skills which is hugely stressed in upper rung of RBT, applying, evaluating and creating (Jayarajah, Saat & Rauf, 2013). The microanalysis also indicated the optimization of reasoning skills for developing HOTS in science education (Jayarajah et al., 2013).

Like many other countries, Malaysia too participated in TIMSS 2011 by sending eighth graders for both Science and Mathematics. Both Singapore and Malaysia are the neighbouring countries who have also participated in TIMSS 2011 assessment. However, Singapore has achieved much better results in all content domains as compared to Malaysia. Content domain assessed the knowledge for each science subject whereas cognitive dimension specified the thinking process in scientific inquiry that children used as they engaged with the content domain. Table 2.2 discussed the science assessment between Singapore, Thailand, Malaysia and International Average for both the content and cognitive domains.

Table 2.2: Comparison of Malaysian 8th grade (Form 2) Achievement at the TIMSS 2011 International Benchmarks of Science Achievement among International Average and Neighbouring Countries

	Content Domain							
	Biology		Chemistry		Physics		Earth Science	
Country	**Cognitive Domain (%)**							
	Apply	Reason	Know	Reason	Know	Apply	Apply	Reason
Singapore	92	75	91	64	73	45	83	22
International Average	83	57	85	35	58	32	63	18
Malaysia	69	60	73	18	53	16	49	5
Thailand	77	45	67	20	41	22	61	8

Source. TIMSS & PIRLS International Study Centre, Lynch School of Education, Boston College, 2011.

Each item in the science assessment was associated with one content domain and one cognitive domain, provided for both content-based and cognitive-oriented perspectives on children achievement in science. The content domains for the eighth grade were Biology, Chemistry, Physics and Earth Science meanwhile the three cognitive domains which were knowing, applying and reasoning.

Among the top-performing countries, Singapore performed better than Malaysia and most countries in science overall. Singapore was one of the highest achieving Asian countries for TIMSS 2011 for both fourth and eighth graders. Conversely, Malaysian participants performed lower than Singaporean participants in all the cognitive domains. In fact, Malaysian children also performed lower than the international average benchmarking in all the cognitive domains except for reasoning in Biology. However, Malaysia's reasoning in Biology was still lower than Singapore by 15% in difference. Most Malaysian children could only recognize some basic facts from the life and physical sciences. Children had some knowledge of Biology and demonstrated some familiarity with physical phenomena.

Malaysian children could not communicate an understanding of complex and abstract concepts in Chemistry, Physics and Earth Science domains. Malaysian children achieved lower than Thai children in reasoning domain for both Chemistry and Earth Science by 2% and 3% in difference. Moreover, Malaysian eighth graders were also achieved lower than Thailand eighth graders and International Average in Biology, Physics and Earth Science for applying domain. Apart from that, Malaysian children were unable to understand the structure of matter, physical, chemical properties and changes; and apply knowledge of forces, pressure, motion, sound and light. Malaysians did not achieve the advance international benchmark because they were unsuccessful in combining information from several sources to solve problems, draw conclusions and provide written explanations to communicate scientific knowledge. Even for knowledge domain, Singaporeans achieved more than Malaysians in Physics and Chemistry content domains. In short, Malaysia performed poorly in TIMSS 2011 assessment.

Both knowledge and applying domains which were stressed in TIMSS 2011 assessment were indeed cognitive domains that can be traced back to RBT (1956), where the RBT gives progression from remembering to creating (Pohl, 2000). The RBT

(1956) identified a hierarchy of six levels of cognitive function (Pohl, 2000). Table 2.3 described these levels alongside indicative learning outcomes.

Table 2.3: RBT (1956) and Indicative Outcomes

Bloom's Statement	Indicative Outcome
Remembering	Ability to recalling information. *Recognizing, listing, describing, retrieving, naming and finding.*
Understanding	Ability to explaining ideas or concepts. *Interpreting, summarising, paragraphing, classifying and explaining.*
Applying	Ability to use information in another familiar situation. *Implementing, carrying out, using and executing*.
Analysing	Ability to break information into parts to explore understandings and relationships. *Comparing, organizing, deconstructing, interrogating and finding*
Evaluating	Ability to justify a decision or course of action. *Checking, hypothesising, critiquing, experimenting and judging.*
Creating	Ability to generate new ideas, products or ways of viewing things. *Designing, constructing, planning, producing and inventing.*

Source. Pohl, 2000

In each of the RBT's taxonomy (cognitive, affective and psychomotor), lower levels provide a base for higher levels of learning (Bloom, 1956; Kauchak & Eggen, 1998; King, Goodson & Rohani, 2012). Applying domain form linkage using HOTS where the child uses meaningful information such as abstractions, formula, equations or algorithms in new application in new situation (King et al., 2012).

HOTS include analysing, evaluating and creating which require mastery of previous levels such as applying routine rules to familiar or novel problems (King et al., 2012; McDavitt, 1993). HOTS also involve breaking down complex material into parts, detecting relationships, combining new and familiar information creatively within limits set by the context and combining and using all previous levels in evaluating or making judgements (King et al., 2012).

Reasoning as a cognitive domain in TIMSS 2011 assessment is involved in a more complex task related to science (TIMSS 2011, Science Framework). A major purpose of science education is to prepare children to engage in scientific reasoning to solve problems, develop explanations, draw conclusions, make decisions and extend knowledge to new situations. Reasoning domain is assessed in TIMSS 2011 where solutions needed to break down a problem into component parts, each involving the application of a science concept (TIMSS 2011, Science Framework).

This resembles the indicative outcome of analysing in Bloom's taxonomy. Evaluating is also resembled by reasoning domain in TIMSS 2011 assessment. Reasoning is included as one of the major cognitive domain in this assessment because by using reasoning domain, children were expected to evaluate and make decisions (TIMSS 2011, Science Framework). Finally, the highest progression in RBT is creating where scientific reasoning was involved in children's ability to generate new ideas, products or ways of viewing things (TIMSS 2011, Science Framework). Based on TIMSS 2011 assessment and all the cognitive domains, it was noticed that Malaysian participants were weak in answering science questions and solving science problems because Malaysian children were lacking HOTS.

HOTS include critical, logical, reflective, metacognitive and creative thinking (King et al., 2012). HOTS are activated when children encounter unfamiliar problems, uncertainties, questions or dilemmas (King et al., 2012). Based on TIMSS 2011 report, Malaysian eighth graders were not successful to apply HOTS in reasoning that was valid within the context of available knowledge and other intellectual skills (King et al., 2012). At the same time, Malaysian teachers were also less effective at teaching the HOTS articulated in the written curriculum (Malaysia Education Blueprint 2013-2025).

According to King et al., (2012), HOTS are also grounded in LOTS such as remembering, understanding, application and other cognitive strategies which were not achievable by Malaysian children based on TIMSS 2011 report. Abilities in knowing, applying and reasoning are all components of HOTS that must be introduced at primary schools and further developed throughout science education in secondary school (TIMSS 2011, Science Framework).

According to Malaysia Education Blueprint 2013-2025 (Sept, 2012), providing equal access to quality education of an international standard is needed because the foundation for the success of a school system lies in its definition of what its children must know, understand, and be able to do. Despite of the importance of international assessment, it is inevitable that the outcome of the latest TIMSS 2011 was not satisfying since even neighbouring countries surpassed Malaysian children in cognitive domains. The findings of TIMSS 2011 were analysed in depth and the outcome was related to the RBT to justifying the lacking of HOTS among Malaysian children in science subject.

Efforts in Fostering HOTS among the Children

The term higher order thinking refers to skills such as comprehension, analysis, synthesis, evaluation and application because these skills involve the manipulation of information and not simply blind memorisation (McLoughlin & Mynard, 2009).

Lately there's an interesting development in fostering HOTS among children for primary schools. It is observed that HOTS have been nurtured through engineering education among young children in USA with the introduction of Engineering is Elementary (EiE) curriculum development (Lachapelle & Cunningham, 2012). EiE units increased children's HOTS, communication skills and teamwork problem solving skills apart from providing opportunities for children to study more about science and engineering (Lachapelle & Cunningham, 2012). EiE units were assembled based on

USA science curriculum, the four weather seasons and their contemporary culture. This curriculum development is a subject by itself for primary school children starting from Grade One until Grade Eight.

Malaysian researchers have also researched on thinking skills among local children in learning science. An analogical task for an abstract Biology concept in accelerating the thinking skills of Malaysian children in teaching and learning Biology was discussed in Salih (2010)'s research. The analogical task was given to 99 Biology participants and the task enhanced the various thinking skills such as creative and critical thinking skills (Salih, 2010). Salih (2010) revealed that as the participants strived to generate their respective analogies, their reasoning capabilities and thinking strategies developed significantly. In fact, engaging analogical reasoning in engineering design promotes creative thinking (Perkins, 1997). As Perkins articulated, analogy is "the creature that carries people's cognitive capacities across the desert of unworkable possibilities from the familiar to true innovations".

Parallel to that, HOTS were also developed by team commitment via group problem solving among a group of in-house engineers from the engineering faculty in INTI International University Malaysia (Vijayaratnam, 2012). This research has proven that adopting real world tasks for participants to work in small groups has not only helped the participants to relate theory with practice but at the same time unconsciously developed their HOTS (Vijayaratnam, 2012).

Tan, Aris and Abu (2006) have also improved HOTS among computer system learners by using a pedagogically-enriched web-based learning environment. The web-based learning environment was designed to incorporate the attributes of essential elements in generating HOTS which functioned not only as a knowledge acquisition tool but also a cognitive tool that improved HOTS among the undergraduates of University of Technology Malaysia (Tan et al., 2006).

Yassin (2013), the previous Malaysian Education Minister revealed that several initiatives were taken in order to increase HOTS among children in learning science. In fact, the Ministry of Education targeted for at least 20% of the Primary School Evaluation Test (local assessment for twelve years old children) and PT3 (local assessment for fifteen years old children) to be equipped with HOTS for the science students. Malaysian education system carried out the HOTS programme for a total of 31,000 Science and Mathematics teachers for Form One (thirteen years old children), Form Two (fourteen years old children) and Form Three (fifteen years old children) (Yassin, 2013). Programme i-Think was implemented in Science and Mathematics to increase the child's ability in HOTS and reasoning skills. Starting from early 2013, a total of 2,500 teachers and 500 schools were given training on HOTS and reasoning skills in this programme.

Malaysia Education Blueprint 2013-2025 (Sept, 2012) also aimed to benchmark the learning of Science and Mathematics to international standards. Every child was supposed to receive a strong grounding in numeracy of the foundational skills for all further learning especially Science. Children were taught a curriculum that has been benchmarked to the standards of high-performing education systems.

Launching a reviewed Primary School Standard Curriculum or *Kurikulum Standard Sekolah Rendah* (KSSR) in 2017 was also an important shift in the Malaysian primary school education (Malaysia Education Blueprint 2013-2025, Sept 2012). The curriculum at primary school levels will be reviewed to insert a composed set of information and abilities such as creative thinking, innovation and problem-solving skills. This curriculum will continue emphasize on the student-centred and differentiated teaching, but will have a greater prominence on problem-based and project-based work. The new curriculum will also encourage an amplified learning trail for higher order thinking children to complete Primary School Evaluation Test in five years rather than six years.

The preliminary report of the Malaysia Education Blueprint has already indicated a goal of being in the top third in the world for assessments like TIMSS and PISA. The question is how are we going to get there, with the same routine teaching and learning method ("or benchmarks") or staying true to the principles of providing all children with a solid and holistic education?

Why Implement CETM in Malaysia's Primary Science Education?

Children benefit from early exposure during early engineering activities (Lachapelle & Cunningham, 2012). In the following subsections, this study elaborated on the motives of introducing children's engineering among primary school children.

Children are naturally inclined to be thinkers and creators.

As Petroski (2003) pointed out, children were fascinated with building and they take things apart to see how buildings are made up. By inspiring such explorations among primary school children, teachers can keep these interests active (Petroski, 2003). By defining children's activities as 'engineering', children are engaged in the natural design process and teachers can help children in order to develop positive relations with engineering. In fact, children's engineering can continue to increase children's desire to pursue such activities in the future (Petroski, 2003).

Hence, bringing in children's engineering into Malaysian science curriculum can give the opportunity to enhance curiosity in science among primary school children besides helping them foster HOTS.

Engineering literacy is essential for the 21st century.

As societies across the globe increasingly depend on engineering, citizens need to recognize this field in order to make practical decisions about profits, expenses and the wisdom of putting new engineering tools in use (Katehi et al., 2009; Pearson & Young, 2002; Raizen, Sellwood, Todd & Vickers, 1995). Research pointed out that introducing early engineering will be an opportunity to increase the science literacy of primary school children and their teachers (Lachapelle & Cunningham, 2007; Macalalag et al., 2008; Thompson & Lyons, 2008).

Based on TIMSS 2011 report, 43% of Malaysian children failed to reach the minimum standard in science because children could only apply it to few familiar situations (Chapman et al., 2012). Furthermore, it was disconcerting to note that only 67% of the children could identify the chemical formula for carbon dioxide (Martin et al., 2012). At the same time, only 5% of the Form Two children could answer the science questions provided in TIMSS 2011 (Martin et al., 2012).

CETM could be the answer to improve our literacy in science starting from primary school because according to Malaysian Education Blueprint 2013-2025 report, children who were unable to master core intellectual skills such as literacy as well as HOTS, will be less likely to succeed in today's rapidly changing economy and globalised society.

Engineering activities hold the promise of improving science achievement by making science and engineering applicable to primary school children.

Engaging children in hands-on through real-world engineering experiences provided opportunities for children to practice thinking skills in science (Lachapelle & Cunningham, 2012). Children's engineering motivates primary school children to learn science concepts by illustrating relevant applications during the activities (Engstrom, 2001; Katehi et al., 2009; Pearson, 2004; Wicklein, 2006). Compelling evidence show that engagement in engineering design allowed primary school children to explore scientific ideas in context, which appears to improve their understanding in learning science (Kolodner et al., 2003; Lachapelle et al., 2011; Penner et al., 1997; Sadler et al., 2000; Wendell et al., 2010).

Lack of essential knowledge and skills are mental barriers to further science learning. This is because children's new learning depends on their prior knowledge: "Every new thing that a person learns must be attached to what the person already knows" (McLaughlin, 2005). According to Martin et al., (2012), 18% of Malaysian children have limited prerequisite knowledge and skills in science classrooms. Meanwhile 55% of them had limited prior knowledge in science. What might be a bigger concern to local educators and policy implementers is that over half of the Malaysian children mentioned that they were not confident in learning science.

Children's engineering could be the answer to overcome demotivated children in learning science, because motivated children show engagement during lesson and this could offer the chances of children fostering HOTS.

Children are capable of developing understanding in engineering at an early age.

Learning process and content must be carried out simultaneously (Lachapelle & Cunningham, 2012). Limiting science instruction to memorization of facts can impede children's learning over a period of time. Children need to be developing a rich knowledge structure through the engagement of complex ideas in discussion, reflection, investigation, experimentation and other disciplinary practices (National Research Council [NRC], 2000, 2007). Children can ask cognitive challenging questions where they were encouraged to connect previous knowledge to new information and, in so doing, develop new understandings (Gillies, 2011).

Apart from that, many of the activities outlined in science education challenges would be a part of good practice to improve the higher level of thinking skills among the children (Bailin, 2002). These include a focus on complex, scientifically significant problems; a focus on reasons rather than rules; a focus not on procedures but on conceptual tools; a focus on reasoning in specific contexts; and a focus on group as well as individual reasoning (Bailin, 2002).

Early engineering fosters HOTS through problem-solving activities.

In the modern world, problem-solving can be a complex process, including problem formulation, iteration, testing of alternative solutions, and evaluation of data to guide decisions (Benenson, 2001). Skills such as HOTS, reasoning skills and creative thinking skills are examples of twenty-first century skills which early engineering incorporates among children (Miaoulis, 2001; Partnership for 21st Century Skills, 2009).

Designing effective CETM goes beyond systematically executing various steps within an instructional model (McLeod, 2003). Hence, CETM took into consideration the theoretical base in which it was grounded (McLeod, 2003).

Early engineering promotes reasoning skills through sketches.

Emerging research suggests sketching should be explicitly recognized as a key element in science education. To show conceptual understanding, children must learn how to reason with multiple visual (Ainsworth, Prain & Tytler, 2011). As they select specific features to focus on in their drawing, children can reason in various ways, aligning their drawing with observation, measurement and emerging ideas (Ainsworth, Prain & Tytler, 2011). According to Ainsworth, Prain and Tytler, (2011), classroom research shows how children reason as they generate and refine models supported by expert teacher guidance. This creative reasoning is distinct from, but complementary to, reasoning through argumentation (Ainsworth, Prain & Tytler, 2011). The sketchings reflect children's expanding on previous work to reason about particle distribution and movement, energy exchange and time sequencing (Ainsworth, Prain & Tytler, 2011).

Tytler, Prain and Waldrip (2013) argued that complex informal reasoning through a mix of inscriptions and artefacts was a fundamental but unacknowledged characteristic of scientific discovery. In fact, Tytler, Prain and Waldrip (2013) revealed that sketchings are a powerful focus for reasoning and generation of meaning, provided the task is matched to a joint purpose and children are appropriately scaffolded.

Learning Theories in Educational Research

Learning theories do not give the solutions, but directs a researcher's attention to those variables that are crucial in finding solutions (Merriam & Caffarella, 1999). Learning theories does not offer answers in developing teaching module but instead, it offers clarity, direction and focus throughout the developing process of the teaching module (McLeod, 2003). There are three main learning theories, specifically behaviourism, cognitivism and constructivism addressed along with the opportunities and challenges for each learning theory presents to the instructional designers. This includes the extension theory of constructivism (Seymour Papert) which has been used in constructing mental models for children's learning in the classrooms.

However, this study did not employ the extension theory of constructionism (Seymour Papert) because Papert's emphasis lies almost at the opposite pole of Piaget's theory. Papert's research focuses on how knowledge is formed and transformed within specific contexts, shaped and expressed through different media and processed in different people's minds (Ackermann, 2001). While Piaget liked to describe the genesis of internal mental stability in terms of successive plateaus of equilibrium which is in line with this study. On the other land, Papert is interested in the dynamics of change because Papert stresses the fragility of thought during transitional periods (Ackermann, 2001). In fact, Papert always points toward the fragility, contextuality and flexibility of knowledge under construction (Ackermann, 2001).

Each learning theory offered benefits to instructional designers (McLeod, 2003). Combination and incorporation of the behaviourism, cognitivism and constructivism learning theories into an ID process provided optimal learning for children in classroom (McLeod, 2003). This study discussed the three learning theories and its relation with the CETM development.

Jean Piaget and Cognitivism Development

Piaget hypothesized four stages of cognitive development for children as they grow. Piaget believed that all people pass through the same four stages in exactly the same order. However only two stages were discussed since these two stages was related to this study. The stages are generally associated with specific ages, as shown in Table 2.4, but these are only general guidelines, not labels for all children of a certain age.

Table 2.4: Piaget's Stages of Cognitive Development

No.	Stage	Approximate Age	Characteristics
1.	Concrete Operational	Begins about first grade, to early adolescence, around 11 years' old	Can think logically about concrete (hands-on) problems. Understands conservation and organizes things into categories and in series. Can reverse thinking to mentally "undo" actions. Understands past, present and future.
2.	Formal Operational	Adolescence to adulthood	Can think hypothetically and deductively. Thinking becomes more scientific. Solves abstract problems in logical fashion. Can consider multiple perspectives and develops concerns about social issues, personal identity and justice.

Source. Woolfolk, A., Educational Psychology 2013 by Pearson Education, Inc.

Piaget noted that individuals may go through long periods of transition between stages and they may show characteristics of one stage in one situation, but traits of higher situations. Therefore, knowing the children's age is never a guarantee you will know what the child thinks (Orlando & Machado, 1996; Woolfolk, 2013).

In this research, the concrete-operational stage is emphasized since the CETM is taught for children whom aged eleven years old. Piaget coined the term concrete operations to describe this stage of hands-on thinking. According to Piaget, the ability to solve conservation problems depends on having an understanding of three basic aspects of reasoning which are identity, compensation and reversibility. With a complete mastery of identity, the child knows that if nothing is added or taken away, the material remains the same. For example, while creating the windmill prototype; children filled the water in different type of bottles which had different volumes. Some of the bottles were 1.5 litres whereas others were 0.5 litres. Both types of bottle helped to create a windmill. Children learnt that both the materials were same but the effectiveness of the windmill prototype differs since it depends on the height of the bottle.

At the same time, with an understanding of reversibility, the child can mentally cancel out the change that has been made. Children exchanged the bottles with one and another to produce different windmills to observe the effectiveness. These reverse actions also help children to understand how different type of water bottles influences the windmill.

Meanwhile, classification depends on the child's ability to focus on a single characteristic of object in a set (for example: screws, nuts and card boards) and group the object based on the characteristic. For example, while designing metal tin robots and plastic parachutes, children grouped the screws and nuts according to their physical outlook and the functionality. Children also grouped the pieces of cardboards that can be used to create the humanoid robots. These classifications helped children to focus on the characteristic of the materials while creating the prototypes.

Apart from that, classification is also associated to reversibility. The capability to reverse a process mentally permits the concrete-operational of the child to see that there is more than one specific approach to classify a group of objects. For example, the child understood that the screws and nuts can be classified based on the size and colour. However, the screws and nuts can also be reclassified by its functionality in designing prototypes such as metal tin robot and windmill.

In contrast to preoperational child, the concrete-operational children are able to understand that B can be greater than A but still lesser than C. For example, when children designed humanoid robots, they compared their prototypes with other groups. Each of the prototypes was different from one another, especially the size. Children concluded that the bigger the base was, the more stable the prototypes were. These sequential relationships gave the opportunity for children to construct logical thinking apart from understanding the stability concept in science.

How Piaget Related to Children's Engineering Teaching Module (CETM)?

Table 2.5 shows the linkage between concrete operation of Piaget's theory and CETM for primary school children. The teacher who guided the children to design the CETM prototypes, directed the children with concrete-operational in learning science.

Table 2.5: Teaching Children's Engineering using Piaget's Concrete-Operations

No.	Teaching the concrete-operations	Children's engineering and rationale
1.	Continue to use the concrete props and visual aids, especially when dealing with sophisticated material.	Facilitating inquiry-based learning can be demanding because it requires a lot of materials and time. However, children's engineering emphasized the need of concept development in learning science to enhance higher level thinking (Baine & Cox-Boniol, 2012).
2.	Continue to give children a chance to manipulate and test objects.	Children developed an understanding of the properties, position and motion of tools and how different tools and materials used in designing prototypes (Whiting & Hickey, 2009).
3.	Make sure presentations and readings are brief and well organized.	Children adjusted their spoken, written and visual language to communicate effectively for different purposes. Children carried out the CETM activities with enjoyment and countinous information exchange (Whiting & Hickey, 2009).
4.	Use familiar examples to explain more complex ideas.	Science teachers encouraged children to see the bigger picture, to ask questions and to be creative. Teachers empowered the children to think out of the box by starting with familiar examples (Roman, 2009).
5.	Give opportunity to classify, group objects and ideas on increasingly complex levels.	The action of solving problems opened up creative process for children. By enhancing children's engagement during classroom learning, the intensity of learning process increased (Baine & Cox-Boniol, 2012).
6.	Present problems that require logical, analytical thinking.	Children's brains could connect neurons to other areas of brain because children were challenged with complex problems. Children were required to think logically to establish a complex mind and interrelated neural pathways to facilitate logical thinking (Roman, 2010).

Lev Semyonovich Vygotsky and Constructivism Perspectives

Shayer (2003) pointed out that Piaget's main attention was in the child's current level of development, whereas Vygotsky was involved in the effects of intervention. Edwards and Mercer (1987) who regards knowledge and thought as fundamentally cultural also agrees with Vygotsky's principle. The implication of this view is constructed not only through processes operating on individuals such as the stimulation of senses or mediation of prior knowledge but also through the process of communication (Wellington & Ireson, 2012; Vygotsky, 1978). Building on the Vygotsky's work, Mortimer and Scott (2003) suggested that social communication could lead to dialogic communicative approach that teachers could use in classroom. Meanwhile Osborne (2009) indicated that dialogic approach could develop good habits in making critical judgements where children could construct stronger foundation for learning science.

How Vygotsky Related to Children's Engineering Teaching Module?

From the Vygotskian perspective, interactive dialogues comprised social interaction and scaffolding as children gradually developed thinking skills (Schunk, 2012). Table 2.6 reflects how CETM was integrated using Vygotsky's theory.

Table 2.6: Teaching Children's Engineering during science lessons by integrating Vygotsky's teaching techniques

No.	Vygotsky's Teaching Techniques	Children's Engineering
1.	Tailor scaffolding to the needs of children.	Experiencing CETM was close to the work carried out in real engineering activities. Children had opportunities to work and discuss with peers.
2.	Make sure children have access to powerful tools and materials that support thinking.	The tool and material that support the thinking gave the children the experience, freedom and choice on how to solve a challenge.
3.	Build on the children's cultural funds of knowledge (Gonzalez, Moll & Amanti, 2005; Moll, Amanti, Neff & Gonzalez, 1992; Woolfolk, 2013).	Children from various background was grouped together to avoid the differences between their home culture and the culture of learning because this could improve the achievement (Aikenhead & Jegede, 1999; Lee, 2003).
4.	Capitalize on dialogue and group learning.	Children worked in teams to brainstorm, create, design and test solutions. As teammates, children learnt to listen to each other, compromised and shared the responsibilities.

Theoretical Framework

The diagram below explained how learning theories was involved in designing the CETM for primary school children in learning the science lessons.

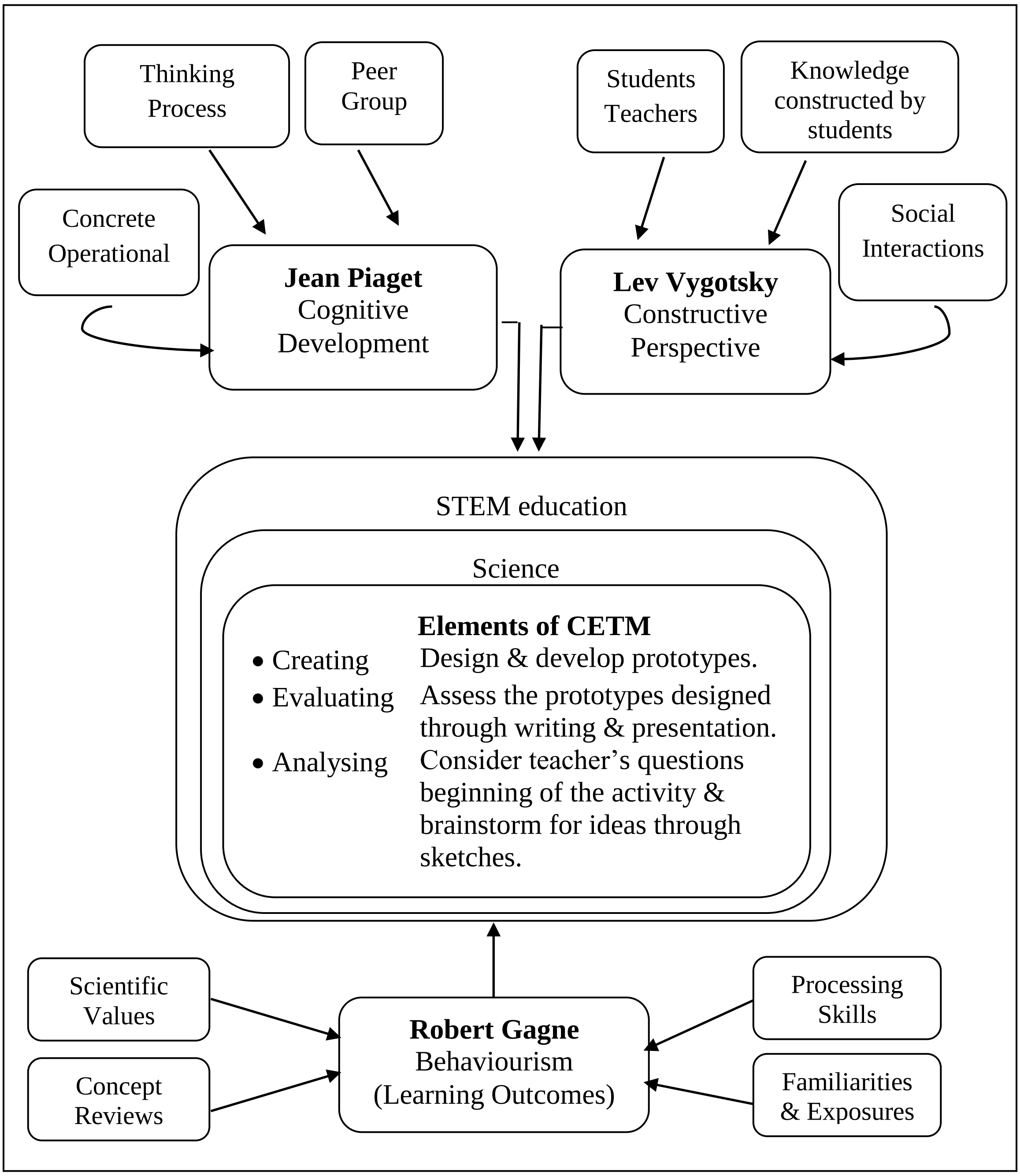


Figure 2.2: Theoretical framework based on the learning theories and its relation for the development of CETM.

The theoretical framework in Figure 2.2 encompassed three learning theories which are Jean Piaget, Lev Vygotsky and Robert Gagne. These theories were analysed in order to jive them into the design and development of CETM. Piaget and Vygotsky were used as the foundation of designing CETM whereas Gagne was utilized as an indicator to perceive the learning outcomes of CETM activities.

The learning theory, Piaget underpinned three main elements which are concrete operational, thinking process and peer group. Concrete operational is the third stage in cognitive development that involved the sample of this study which is Year Five or eleven years old children. At this age, Piaget revealed that children were able to think reasonably when it's concerning hands-on problems which support the CETM design and development. This is because CETM is embedded with five activities that involved practical doings. Teaching the concrete operational level during the science lessons also include the thinking process. Giving the children opportunities for manipulating and testing prototypes offered the development of thinking process during the CETM activities. The thinking process also referred to peer group when children were challenged to solve a complex problem in a team with various ideas and intellectual mentalities. However, emotion and intellectual capabilities required children to develop both the thinking and feeling aspects of the mind (Ferrett, 2010).

Parallel to that, Vygotsky reflected joint teaching and learning where children and teachers were involved in producing interactive dialogues which also leads social interactions. Interactive dialogue encouraged children in sharing views and producing critical judgements. Dialogue conversation which involves exchanging ideas assisted the children to be engaged either in joint activity or conversation between the children and teacher. Knowledge through ideas in designing the solution for problem solving activities in CETM were created and implanted into the minds of children indirectly. The interactions among children and teacher during CETM activities produced intellectual synergy of many minds to bear on a problem, and the social stimulation of mutual engagement in a common endeavor (Zhou & Tan, 2011).

STEM is a huge agenda that has been initiated by USA which is been explored and studied across the other countries as well. One of the STEM programmes is children's engineering. In line with that, this study designed a teaching module for science based on the characteristics of children's engineering within abroad and local context. Apart from designing, this study perceived the engagement of HOTS in reasoning domain through implementation of CETM activities. The activities in CETM consisted of HOTS elements which were creating, evaluating and analysing. Reasoning skills was also evaluated in each of the five activities.

Gagne's theory is discussed in depth in Chapter Three since Gagne was also used as an Instructional Design (ID) model in designing CETM. However, there are four learning outcomes anticipated to be achieved with the usage of the preferred teaching module based on Gagne. One of the outcomes anticipated was the ability of children to value which was included as intellectual skills in Gagne's learning outcome.

During the CETM activities, the concepts review using verbal information was an important influence. However, both verbal and nonverbal communications were vital in children's engineering approach (Engleberg & Wynn, 1995; 2013). Group members also often relied on the nonverbal behaviour than the words to interpret the meaning (Engleberg & Wynn, 1995; 2013). Processing skills in problem solving activities through children's engineering were part of the cognitive strategies that helped children in attending to new information apart from practising facts. The attitudes of children were perceived indirectly through familiarities and exposures which was also a positive learning outcome using CETM. It is important to manage children's positive attitudes, optimism, confidence and persisting skills (Ferrett, 2010).

Literature Review on Assessing HOTS and Reasoning Skills

Reasoning skill which is a higher level thinking skill is also an elemental dimension of scientific knowledge (Weld, Stier & McNew-Birren, 2011). Reasoning skills was also embedded in a definition for science learning promoted by the NGSS (NGSS, 2013; Weld et al., 2011). Researchers measured HOTS and reasoning skill using variety of instruments, each with limitation and restriction (Weld et al., 2011). The following tests were the common instrument used to assess HOTS and reasoning skill.

Science Reasoning Skills Test (SRST)

This study developed a SRST by adapting two different sources which were known as Virginia Student Assessments (VSA) and Challenging Logic and Reasoning Problems. The following explanation justified the reason for combining two different assessments to produce a SRST for this research.

Virginia Student Assessments (VSA)

VSA provides the feedback on children's progress towards the acquisition of HOTS during the instruction (Hintze, Keller, Lutz, Santoro, & Shapiro, 2006). Apart from that, VSA was designed to assess the children's HOTS because Virginia did not perform well in TIMSS and PISA as compared to countries such as Finland, South Korea and Singapore (Commonwealth of Virginia Richmond Report, 2013). This relates to the Malaysia's current predicament as well since Malaysian children did not perform well in TIMSS and PISA due to the lack of HOTS in science (Abdullah & Shariff, 2008; Martin, Mullis, Foy & Stanco, 2012). In fact, VSA assesses the children's thinking skills in order to provide the opportunity for the children to be involved in the growing STEM education (Commonwealth of Virginia Richmond Report, 2013). This is also in line with the Malaysian education system since Malaysia is also in need to assess a broader range of children's thinking skills, especially in HOTS. Apart from that, according to the Commonwealth of Virginia Richmond Report, (2013), other countries such as Holland has also used VSA to assess children's higher order thinking skills (HOTS). Subsequently, STEM education has been given the top priority by the Malaysian education ministry as an alternative to develop the children's HOTS, particularly in science subject.

This study employed a total of fifteen questions from VSA to evaluate the HOTS and reasoning skills among the children in science. The questions in VSA were chosen in this study because it revealed a significant focus on the higher order cognitive skills (Buoncristiani & Buoncristiani, 2006). Apart from that, VSA was also designed for primary school children since its reliability was adequate as compared to other established tests. The Cronbach alpha ranged between 0.84 - 0.85 indicated that VSA was a reliable assessment for children between nine to twelve years old (Virginia Department of Education, 2009). At the same time, the development of VSA involved the use of blueprints, item development specifications, multiple review committees, field testing and item banking (Virginia Department of Education, 2009).

Experts such as school teachers, administrators and content specialists took part in the development of VSA. They reviewed the test items to ensure that the test items measure children's knowledge precisely. The VSA was a multiple-choice test which distributed HOTS and reasoning skills apart from drawing on a deeper level conceptual structure in answering the questions (Virginia Department of Education, 2009). In line with that, VSA also evaluated the different type of HOTS and reasoning skills (Buoncristiani & Buoncristiani, 2006; Swartz, 2001). For example, VSA measures HOTS and reasoning skills item such as argumentative, inductive reasoning and deductive reasoning. These thinking skills are also embedded within the activites in Children's Engineering Teaching Module (CETM) to evaluate the children's ability in

HOTS and reasoning skills. Since VSA was aimed for primary school children in science subject (Shipman, 1997; Ennis, 1993), VSA was suitable for evaluating children's HOTS and reasoning skills before and after the CETM implementation because this study focused on eleven years old children.

Though VSA was intensively used in Virginia, other studies could use the VSA as well in order to evaluate the reasoning skills among children. However not all the released items or questions from the VSA have been used in this study since the usage of VSA must coincide with the research objectives. This study received the consent letter to use the VSA to assess the children's thinking skills (see Appendix 1).

Challenging Logic and Reasoning Problems Series

This book practiced different type of multiple-choice questions that appear on standardized test assessing logic reasoning, mechanical reasoning, analytical reasoning and making judgement skills. At the same time, the assessments in this book also contained cognitive domain such as creating, evaluating and analysing where each of this cognitive domain reflected on reasoning skills. A total of five questions have been used from this book because the questions were designed to evaluate types of reasoning skills for all ages, including primary school children. Since this book was a second edition and had the copy right of Learning Express (LLC) for year 2005, these questions were trusted to have the sufficient trustworthiness.

In fact, there were also some positive testimonials from other researchers who have employed the questions from this book. The SRST development which consisted of 20 questions based on Virginia Student Assessment (VSA) and Challenging Logic and Reasoning Problems Series book was conversed in detailed in Chapter Four. Though these questions were from reliable sources, the validation and reliability was still given sufficient importance in this research. Prior to that, the development of SRST for this study was discussed in Chapter Four.

Instructional Design (ID) Models

ID models are widely-acknowledged system of planning, implementing and evaluating instruction (Gagne, Wager, Golas & Keller, 2005; Reiser & Dick, 1996; Shelly, Cashman, Gunther & Gunther, 2006). ID is to make learning more efficient (Summerville & Reid-Griffin, 2008).

Isman Model

The major objective of Isman model is to reveal how to plan, develop, implement, evaluate and organize full learning activities effectively so that it will ensure children's competent performance by the children (Isman, Abanmy, Hussein & Al Saadany, 2012). The theoretical foundation of Isman model was based on behaviourism, cognitivism and constructivism. According to McGriff (2001), the learning process must be concerned with the experience and context that make the child willing to learn. This is one of the things that Isman model emphasized in instructional activities (Isman et al., 2012). The following explanations describes on how Isman model was integrated in the previous researches for the instructional activities.

A sample size of 100 graduate students at the education faculty of Eastern Mediterranean University in North Cyprus was used to find out academic differences between two instructional activities (Isman, 2005). The instructional model for the control group was designed by traditional instructional model meanwhile Isman ID model was used to design the instruction for the experimental group (Isman, 2005). Student's achievement was statistically analysed according to the experimental and control group. T-test results indicated that Isman instructional model was implemented successfully in the instructional activities in experimental group where the academic achievement produced positive results.

Isman et al., (2012) examined the effectiveness of Isman ID model in developing the sixth level students' teaching skills (planning teaching's domain) by redesigning "General teaching method course at teacher's college King Saud University. A total of 80 participants who enrolled in the university were divided into two groups of 40 participants each for experimental and control group respectively. The findings of this study revealed that the experimental group which implemented Isman ID model helped the participants to improve their planning teacher's domain. Isman ID model had significantly increased the participants's competencies in their lesson planning and learning.

The efficiency of Isman ID model was also examined in secondary educational setting in Malaysia by Alias and Siraj (2012). Two instruments were used to collect data of the effectiveness of Isman ID model in developing Physics module on learning style and appropriate technology. Pre-test, post-test and Felder Silverman's Learning Style Inventory was designed to identify the student's achievement score and to measure student's learning style. The findings suggested that Isman ID model was effective for visual, active and reflective learners apart from being focused on the instruction from the learner's perspective than the content perspective. Isman ID was suitable in designing and developing Physics module based on the learning style and appropriate technology in secondary school setting.

Based on all the mentioned ID models, it can be summarized that every ID model has strength and weakness. Although these ID models were widely used in the designing and developing research, no ID is free from limitations and setbacks. The following chapter discussed the type ID model employed in this research to design and develop the CETM for primary school children.

Why Thematic Analysis was used in Analysing Research Findings?

While statistical software can be extremely helpful to researchers, it does have a number of disadvantages. This study did not employ statistical software for coding process because thematic analysis was a better option. However, the qualitative researcher who does not employ a statistical software will be held up during the data analysis process in contrast with those who employ the statistical software (Miles & Huberman 1994). Some argued that the computer only needed to be used as a tool purely for data management and archiving and not for analyzing the research findings (Kelle, 2004). Therefore, in trying to make a choice about whether to employ a statistical software, it is worth bearing in mind what Gibbs (2002) recommended. Gibbs suggested that it is not the software that interpreted the text or transcript but the person or the researcher who's involved in the study (Bergin, 2011).

Thematic analysis is an initial technique for qualitative analysis (Braun & Clarke, 2006; Holloway & Todres, 2003). Thematic analysis was seldom acknowledged although thematic analysis was broadly employed as the qualitative analytic method within and beyond the academic fields (Boyatzis, 1998; Roulston, 2001). Thematic analysis is an independent qualitative descriptive method which identifies, analyses and reports the patterns within the findings (Braun & Clarke, 2006).

Thematic analysis offers a comprehensive, decently qualitative and nuanced research finding (Braun & Clarke, 2006; Vaismoradi, Turunen & Bondas, 2013). Thematic analysis also offers systematic content analysis apart from allowing the efforts to combine the meaning of analysis within specific viewpoint (Joffe & Yardley, 2004).

This study used a few qualitative data sources from CETM activities such as children's written answers, sketches, verbal expressions, testing stage, prototype presentation and classroom atmosphere to answer the third research question. Since there were no previous studies dealing on how CETM enhanced HOTS among children, the categories which was coded were derived from the transcript data (Hsieh & Shannon, 2005). This form provided an overall explanation of the research data and a more comprehensive analysis of the findings (Braun & Clarke, 2006). At the same time, it is not necessary for thematic analysis to be committed to stay within the theoretical framework (Sandelowski, 2010).

Hence, emerging data from the thematic analysis were welcomed, especially in corresponding the exact research tenacity and the current condition of science in the space of concern (Hsieh & Shannon, 2005). Subsequently, thematic analysis helped to generate unanticipated insights which can recapitulate main issues of a huge amount of data and provide a deep explanation of the findings (Braun & Clarke, 2006). Even though the thematic analysis is broadly employed, there was no clear understanding on how the researchers can analyse the research data using thematic analysis (Boyatzis, 1998 & Tuckett, 2005).

Hence, this study was in line with the Braun and Clarke's study since it showed the clear guidance of conducting thematic analysis. At the same time, other experts such as Vaismoradi, Turunen and Bondas (2013) have constantly used Braun and Clarke's study as a parameter in using thematic analysis in their research studies.

Summary

Learning theories, Instructional Design (ID) model, research objectives, Science, Technology, Engineering and Mathematics (STEM) education and the lack of reasoning skills were all associated to each other in producing effective Children's Engineering Teaching Module (CETM) for Year Five children. Since this study emphasized on the process of designing and developing CETM, the following chapter discussed all essential steps to design and develop CETM.

CHAPTER 3: THE CETM DESIGN AND DEVELOPMENT

Introduction

Design and development research (DDR) seeks to produce knowledge grounded in data steadily derived from practice (Richey & Klein, 2010). DDR defined as:

> The structured understanding of design, development and evaluation processes with the objective of creating an empirical base for the formation of both the instructional and non-instructional products, tools and enriched model which administer their development.
>
> (Richey & Klein, 2010)

Instructional Design (ID) models are practical summing of psychological as well as other researchers, for helping those who create educational and training materials (Suzuki, Nishibuchi, Yamamoto & Keller, 2003). The systemic process in ID models established the link between the educational research and practical application for the researches that employ DDR (Morrison, Ross & Kemp, 2007; Shellbecker, 1974).

Although classroom-orientated ID models have the potential to help the teachers plan and propose effective instructional model with tools, research studies have shown that ID models were not widely used (Lim & Chai, 2008). Generally, teachers hold favourable attitudes towards the ID models but teachers seldom plan instructional model due to the impracticability of the models in the complex school system (Mishra & Koehler, 2006; Smith & Ragan; 2005). In fact, Lim and Chai (2008) mentioned that the ID models that were developed were less organized and goal-oriented. These ID models have failed to initiate teacher's re-examination of their existing practice and investigation of alternate practices for effective instruction (Lim & Chai, 2008).

However, it cannot be denied that DDR using ID models not only leads to creation of information and complete understanding of the field but also the ability to make predictions (Richey & Klein, 2010). Since Science, Technology, Engineering and Mathematics (STEM) education has emerged as an important acronym in educational reform movement, meaningful integration of science emphasized in primary schools (Sciarra, Dorsey, Lynch & Adams, 2013).

Well known ID models such as ADDIE, ARCS, ASSURE and Dick Carey also has its own restrictions depending on the process these models were used in the research. Extensive literature reviews revealed that these ID models were either a conversational label for systematic approach or did not represent the true essence of an ID model. (Akbulut, 2007; Bello & Aliyu, 2012; Heinich, Molenda, Russell & Smaldino, 1999; Huang, Diefes-Dux, Imbrie, Daku & Kallimani, 2004; Khodabandelou & Samah, 2012; Molenda, 2008; Morrison et al., 2013; Reiser & Dempsey, 2012).

On the other hand, Isman model provided detailed steps for each major stage which guided the development of the CETM in structured and organized order. Based on the literatures, Isman model was also used to design and develop teaching modules for science subjects. After analysing these ID models, Isman model was chosen and adopted in developing Children Engineering Teaching Module (CETM). Since most strategies for presenting instruction were rooted in the instructional theory (Richey & Klein, 2010), this study also employed Gagne’s Nine Events of Instruction to provide the foundation knowledge in developing CETM for primary school children.

Isman Instructional Design (ID) Model Based on Learning Theories

Instructional theories represent recipe of rule and concept restraints that express the recommendations imposed by them on the final preparation of activities and wisdom resources (Sicilia, Lytras, Sanchez-Alonso, Garcia-Barriocanal & Zapata-Ros, 2011). According to Reigeluth (1999), instructional theories are exercise-orientated theories offering clear supervision on helping researchers develop educational materials.

Isman (2011) presented a new ID model in an article entitled "Instructional Design in Education: New Model". ID model was designed to point out on how to plan, develop, implement, evaluate and organize learning activities effectively in order to ensure competent performance by children. In this study, the theoretical foundation of Isman ID model underpinned views from behaviourism, cognitivism and constructivism.

Piaget's theory on cognitive development and Vygotsky's theory on constructivism were adapted in producing CETM. Cognitivism view supports the practice of analysing a task and breaking it down into manageable chunks, establishing objectives and measuring performance based on those objectives (Malik & Khurshed, 2011). On the other hand, constructivism is a philosophy of learning founded which reflects on children's experiences where children construct their own understanding of the world they live in (Malik & Khurshed, 2011). In a constructivism classroom, the science teacher not only provides the children with opportunities for thinking, interaction, prediction but at the same time, offers thought-provoking questions and creates an environment which reflects children-centred base (Malik & Khurshed, 2011).

Behaviorism is a learning theory that emphasizes the relationship between stimulus and response. At the same time, it is also used to motivate children to learn more in classroom (Isman, 2011). As for behaviourism, Gagne's theory was used in this research. Gagne's model behaviour addresses events that specifically talk about getting the children's attention, guiding their learning, eliciting information from the children and providing feedback (Gagne, 1970, 1985; Liaw, 1999). When these events are part of a lesson, it will keep children focused on the task given (Mountain, 2009). Gagne's model (1970, 1985) also includes informing the children about the lessons objective early in the process. The introduction of stimulating material attracts children's attention in continuing their interest and motivation to learn (Gagne, 1970, 1985). Hence keeping that in mind, this study aimed to foster HOTS through the designed and developed CETM.

The Five Step Isman Instructional Design (ID) Model in Designing CETM

Isman ID model described a five step systematic planning process which are the input, process, output, feedback and learning (Isman et al., 2012). These processes were used to plan a variety of instructional approaches, ranging from teacher to children centred activities. As a result of using this process, science teachers were able to develop effective instruction which helped children to learn more and be motivated during class activities (Isman et al., 2012).

The first step in Isman ID model is input which involves the needs; identify contents, goals objectives, teaching methods, evaluation materials and instructional media (Isman et al., 2012). The main objective of the first step is to identify factors for input. Later, goals and objectives were built. Then, instructional activities and assessments techniques were planned. After that, science teacher was ready to experiment and implement the planned instruction with the children. According to Isman (2012), the vital move in the instructional planning is input since this step not only gives the teacher the information about the effectiveness of instructions but identifies what and how the teacher should teach science.

The second step in Isman model is a process where it involves test prototypes and redesigning of instruction and learning activities. Isman et al., (2012) pointed out the direction of where children want to go, how they are going to get there and finally reorganize the instructional activities.

The third step is the output process that involves testing and analysing results which required the teacher to implement assessment tools in order to determine the demonstration skills, knowledge and attitude by the children (Isman et al., 2012). Apart from that, educational measurement and evaluation process was implemented by the teachers when it involved the children's learning. When teachers found out what children have learnt from the instruction, teachers analysed the given results and decided which direction the instruction led to (Isman et al., 2012).

The fourth step in Isman ID model is feedback which involved revise instruction based upon the collected data during the implementation phase (Isman et al., 2012). The teacher revised and reinvented some aspect of the instruction to enable the children to accomplish their goals when children were not enjoying the learning process.

Learning is the final step of Isman ID model. The teacher made sure that children not only learnt during the lesson but also accomplished their objectives in the CETM activities. Isman model described five major steps which has a total of twelve sub stages. The detailed version of design and development of CETM is described in Chapter Four. The summarized development of CETM is illustrated in Table 3.1.

Table 3.1: CETM designed using Modified Isman ID Model (2012)

The Step	The Stages	The Descriptions
Input	Identify Needs	• Derived from critical analysis of literatures, education reports and international assessments.
	Identify Contents	• Interview questions were built using the contents derived from literature review. The interviews with the experts was carried out using two rounds of Delphi.
	Identify Goals Objectives	• Based on the research questions and the expert's responses in designing the CETM activities, the objectives and goals for each of the CETM activity was identified. The Year Five science curriculum was also used to indentify the objectives for the activities.
	Identify Teaching Activities	• Based on the expert's feedback, all the activities were problem solving based. These activities were designed and carried out through group work.
Process	Test Prototypes	• The designed CETM was validated by a group of experts.
	Redesigning of Instructions	• The CETM was restructured based on the views of expert.
Output	Assessment (written feedback on how to further improve the designed prototypes)	• At the end of each of the activity, the children wrote their evaluations about their designed prototypes. Apart from that, while testing their prototypes, they also responded in an open-ended set of questions.
	Revise Instruction	• The activities were evaluated by same experts who helped to design the CETM activities. They gave suggestions on how to further improve the activities.
Feedback	Back to Related Steps	• The feedback process involved CETM revision based on the data gathered during the implementation phase where interviews were transcribed and themes were emerged.
Learning	Identify Instructional Media (Compact Disk)	• The final draft was documented into a CD containing all the five activities. • The CD with all the activities was an instructional media support for the teachers to administrate the activities.
	Long Term Learning	• Bartlett (1932) stressed that interest played a major role in human remembering (Schunk, 2012).

	• Hebb (1949) expressed that experiences were critical for learning. For example, experiences from the environment (eg: visual and auditory stimuli) and from one's own mental activities (eg: thoughts) were important for learning (Schunk, 2012). In short, brain imposed some structure on incoming information which is important to facilitate memory. • However, Conway, Cohen and Stanhope (1991) revealed that the level of interest taken by a child can influence long-term retention of knowledge. • Ferrett (2010) cited that a barrier to memory is disinterest. Ferrett (2010) also mentioned that children must want to remember. Children overcome the barrier of disinterest by creating a positive and curious attitude. In short Ferett (2010) summarized that when the teacher delivered an interesting lesson to enhance a point, children remembered the information easily rather than taking time to understand and apply it. • CETM can aspire to attract and motivate the children apart from enhancing HOTS.

Isman ID model supported an alternative method to design and develop the CETM. At the same time, Isman ID model also helped in generalizing the conclusions of CETM usage in teaching and learning of science for primary school children.

Instructional Design (ID) Theory

Learning theories were often confused with ID theories. According to Reigeluth and Carr-Chellman (2009), learning theories are descriptive because learning theories describe how learning occurs. Learning theories provided an understanding of why a certain method of instruction worked so well.

At the same time, an ID theory easily can lead to the development of learning theory as the learning theory can lead to the development of an ID theory (Reigeluth & Carr-Chellman, 2009). Thus, ID theory and learning theory are both important and like a house and its foundation, they are closely related (Reigeluth, 1999). This is because learning theories are useful for understanding why an ID theory works, and, in areas where no ID theories exist, learning theories can help a researcher to invent new methods or select known instructional methods that might work (Reigeluth, 1999).

In this study, Gagne Nine Instructional Events was used as an ID theory. Identifying the learning outcomes was crucial in designing CETM activities (Donnelly & Fitzmaurice, 2005). According to Reigeluth and Carr-Chellman (2009), apart from Bloom’s taxonomy, the next best taxonomy in the instructional arena is Gagne’s (1965, 1984) learning outcomes. Gagne’s taxonomy was specific in guiding the selection of instruction methods (Reigeluth & Carr-Chellman, 2009).

Gagne’s Theory and Children’s Engineering Teaching Module (CETM)

Instructional theory of Gagne resembled meaningful learning theory which focused on the expository where the teacher acts as a guide or moderator in the information processing theory (Babadogan & Unal, 2011). Gagne theory suggested a particular sequence of instructional activities that can be incorporated into a lesson to facilitate learning and transfer (Richey & Klein, 2010). Gagne’s theory was categorized into three main categories which were preparation for learning, acquisition and performance and transfer of learning. Gagne and Briggs (1979) specified types of instructional events with different phases as shown in Table 3.2.

Table 3.2: Instructional Events for Learning Phases (Gagne)

Category	Phase	Instructional Event
Preparation for learning	Attending	Informing the science class that it is time to begin
	Expectancy	Informing the lesson's objective, type and quantity of performance to be expected
	Retrieval	Asking class to recall subordinate concepts and rules
Acquisition and performance	Selective perception	Presenting examples of new concept instruction
	Semantic Encoding	Providing cues for how to remember information
	Retrieval and responding	Asking children to apply concept or rule to new examples
	Reinforcement	Confirming accuracy of children's learning
Transfer of learning	Cueing retrieval	Give short quiz on new material
	Generalizability	Provide special reviews

Source. Schunk, 2012; Gagne and Briggs, 1979.

During the attending phase, children concentrated on the stimuli related to the teacher's effort in introducing the activity. Teachers either used audio visuals, written materials or teacher-modelled behaviours to kick off the activity. For instance, teachers clapped both their hands and concurrently asked the children to be prepared for the CETM activities. The teacher indirectly informed the children about the expectation of CETM activities. Apart from reading aloud the challenge provided in each of the activity, the teacher motivated the children to design prototypes that fullfilled the criteria in the CETM activities. This effort increased the level of expectation that helped to familiarize children with the aim of each CETM activity. As for the retrieval phase, teachers brainstormed some questions especially on ways to overcome the given challenge in the CETM activities. Over a period of time, through practices of conducting the CETM activities, the level and type of questions asked by the teacher differed and escalated into higher stages. Hence, children remembered the triggering questions from the teacher for a long period of time. Parallel to that, children were encouraged to trigger the portions of topic relevance studied (Gagne & Dick, 1983).

Selective perception means that the sensory records significant stimulus features and transfers this spur structures to working memory. For example, the teacher acted out how the windmill prototype worked. The teacher can spread both the arms wide apart and tilt the body while moving both the arms simultaneously to display how the blades move in a windmill. By presenting this type of example in introducing new concept, teachers can offer hints on how to evoke information. For instance, during the humanoid robot activity in CETM, teacher asked children on strength and stability concept, indirectly comparing a table and a human being. A table stands with four legs and a human with two legs. By recalling concepts like these can help children to remember crucial information for a long period of time. During retrieval and responding phase, children reclaimed fresh data from remembrance and made a response representing learning. For example, children changed different brand batteries in the same prototype to observe any difference in function. Children learnt to apply the same concept by using different examples, such as the battery.

Subsequently, reinforcement referred to reaction that approved the accurateness of a child's reaction and offered corrective facts as required. Children's conversational dialogue between group members and teachers can indicate the accuracy of learning during the CETM activities. While creating the prototypes, questions and answers were one of the ways to perceive the children's precision in learning during the science lesson. Teachers can guide the children by provoking simple hints or tip-off in order to emphasize the children's focus in performing their CETM designs.

Relocation of knowledge phases included prompting retrieval and generalizability. In cueing retrieval, children accepted hints gesturing that earlier knowledge is relevant in that condition. When solving word difficulties, for example, the teacher informed children that their knowledge of language is applicable. While designing the CETM prototypes, children asked the teacher the meaning of simple words and how they differed from one another. For instance, words such as ‘fragile’ and ‘break’ was used as a short quiz in transferring new piece of knowledge while using delicate and vulnerable materials in designing the CETM prototypes.

Generalizability was boosted by providing children the chance to rehearse skills with diverse content and under different situations. Children spontaneously compared their designed prototypes between other groups. For example, the designed prototypes were contrasted on which one moves faster, flies longer or lights continuously. These observations helped children to draw inferences, whereby knowledge based on experience were transferred into their learning process.

The nine phases which were discussed in Table 3.2 was applicable for the five types of learning outcomes (Shunk, 2012). Gagne (1985) identified five types of learning outcomes which were intellectual skills, verbal information, cognitive strategies, motor skills and attitudes (Schunk, 2012). The learning outcomes of Gagne’s theory were shown in Table 3.3.

Table 3.3: Learning Outcomes in Gagne’s Theory

Learning Outcomes	
Type	**Examples**
Intellectual Skills	Rules, procedures, concepts
Verbal Information	Facts, dates
Cognitive Strategies	Rehearsal, problem-solving
Motor Skills	Hitting a ball, juggling
Attitudes	Generosity, honesty, fairness

Source. Schunk, 2012; Learning Theories

This study scrutinized four out of five learning outcomes in Gagne’s theory. Motor skills were omitted since motor skills were developed through steady enhancements in the quality of muscular movements attained by the children. Apart from that, rehearsal motor skill practice involved replication of the same muscular movements which the development of CETM does not intend to research on. This study focused on the intellectual skills, verbal information, cognitive strategies and attitudes.

Intellectual skills included procedures, methods and formations. They were forms of procedural facts or productions. This form of knowledge is engaged in talking, writing and reading, resolving problems and applying scientific values to difficulties. For instance, in CETM activities, children worked on an on-going project to determine just what it is an engineer does find solutions to a problem. Children designed a solution for an existing problem (Draeger, 2006).

Verbal information involves facts or importantly related style recalled verbatim. During the CETM activities, children can either write about it or share orally with peers. As children can do oral presentations on their design, other children can get a review of concepts (Berry, 2006).

Cognitive strategies are exclusive control processes. Cognitive strategies include information processing skills such as attending to new facts, deciding to practice facts processing, using problem-solving strategies. For example, in CETM activities, by determining a problem to be solved, an interest can be peaked and a challenge can be born. In order to solve this problem, children can become self-motivated engineers (Goll, 2006). Buggs (2010) added that when children become motivated and engaged, children can improve their thinking skills on what they have experienced during the CETM activities.

Attitudes are inner views that influence actions and reflect individualities such as generosity, honesty and commitment to healthy living. Teachers can organize circumstances for speaking information and cognitive approaches. However, in CETM activities, attitudes can be learnt indirectly through familiarities and exposures to live and symbolic models. For example, during CETM activities, children can sketch symbols such as arrows, shapes and other figurative expressions.

Batterson (2010) revealed that children's engineering completed a continuum of education ranging from the pure theory of science to the almost purely hands-on trades. While trades prepare the child to build and repair existing systems, children's engineering prepared the child to design and fabricate new system which brought new value to society by developing solutions to real-world problems (Batterson, 2010). Apart from that, children's engineering also helped children to become critical, creative thinkers and problem solvers (Smith, 2006).

Conceptual Framework of the Study

The major purpose of this study was to design and evaluate CETM as an alternative approach for teachers to foster HOTS among children who were learning science at primary school. Although Malaysia is taking several steps to increase the level of HOTS among the children, this research also revealed the importance of inculcating higher level thinking process starting from primary school children. The learning theories were also displayed on how does the designed CETM affects the children who have learnt science by using CETM in the classroom. Revised Bloom Taxonomy (RBT) was involved in testing the children's level of HOTS.

The present level of children's existing HOTS was tested based on the higher division of HOTS which included creating, evaluating and analysing. Each of these intellectual skills which reflected HOTS were assessed based on reasoning domain or skill. The design and development of CETM were summarised, whereby ID model and instructional theory were also illustrated in the conceptual framework in Figure 3.1.

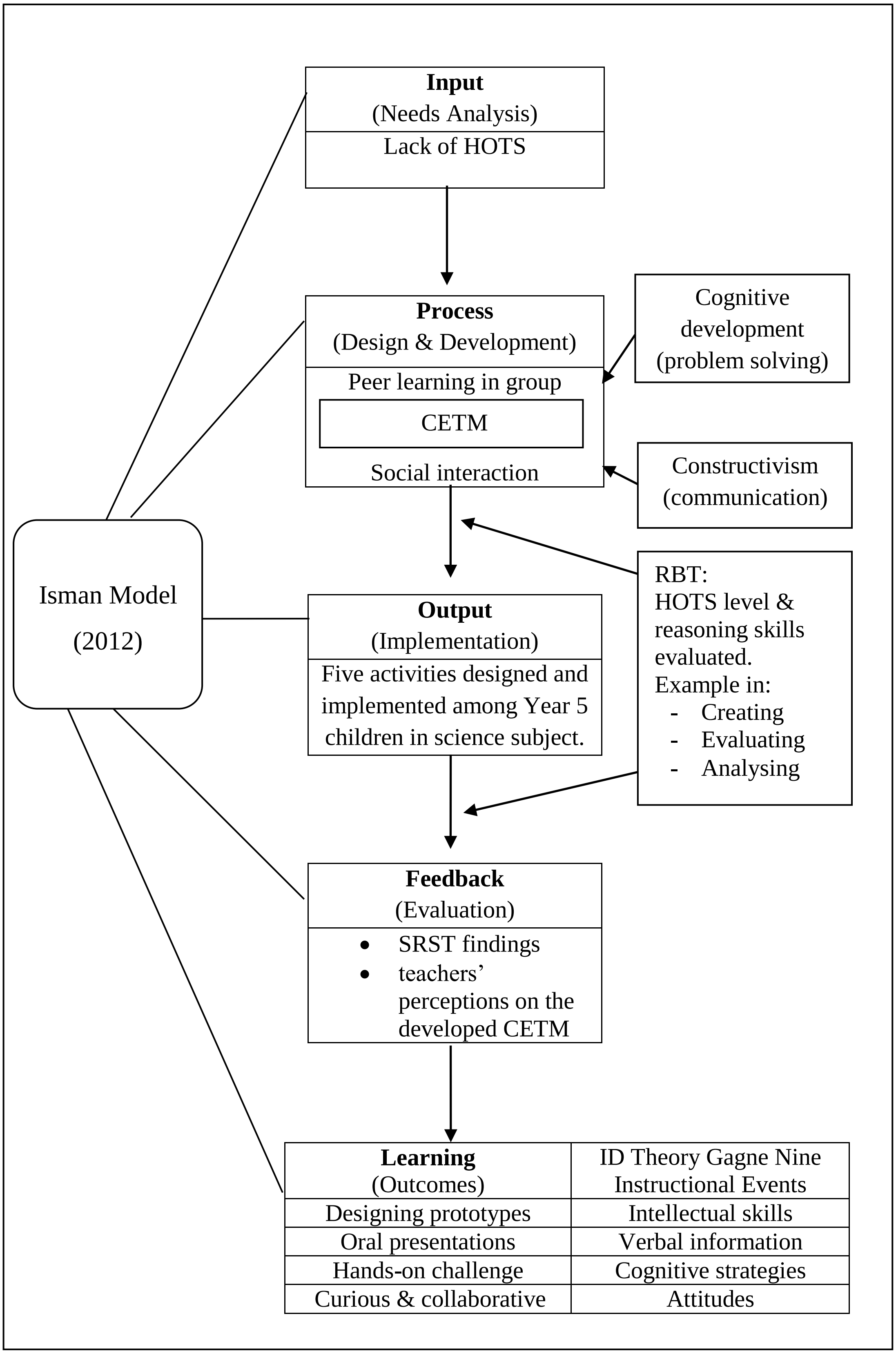


Figure 3.1: Conceptual Framework of CETM

This study envisioned to foster HOTS among children through CETM by encouraging the children to carry out activities that involved HOTS and reasoning skills. In order to achieve that, this study proposed to design and develop CETM based on ID model, instructional theories and learning theories. This study employed Isman model as an ID model because Isman model provided the detailed steps for each of the major stage starting from the need analysis until learning. The theoretical foundation of Isman model underpinned views from cognitivism, constructivism and behaviourism. McLeod (2003) indicated that the consolidation of cognitivism, constructivism and behaviourism learning theories and integration of them into an ID such as Isman model provided optimal learning for children in learning science.

Piaget's theory on cognitive development and Vygotsky's theory on constructivism were adapted in designing and developing the CETM. Children were able to develop critical problem solving skills as they worked in groups to meet the criteria for an activity. According to Malik and Khurshed (2011), cognitivism encouraged the practice of analysing a task and breaking it down into manageable chunks before establishing the objectives and measuring the objectives. In this study, teachers were asked to deliberately point out to children the strategies, steps, rules and directions needed to tackle the problem given in a CETM activity. When the teacher drew the guidelines which the children were supposed to work, it helped the children when they were working on their problems as well as in evaluating their prototype (Costa, 1984; Ghosh, 2003). The children learnt to plan their tasks by estimating the time required to complete the task given, organising the material available and sequencing the necessary procedures (Blakey & Spence, 1990; Ghosh, 2003).

Apart from Piaget, this study was also in line with Vygotsky's perspective where Vygotsky encouraged social interaction between the teacher and children. The dialogic communicative approach between teacher and children helped to make critical judgement during the implementation of CETM. The CETM activities involved hands-on approach, which did not have the right or wrong answers. However, the teacher helped children to develop an interest by encouraging them to ask themselves questions before they begun the activities. When children generated their own questions, it helped them comprehend better on what they were reading or doing. This made the children pause to think about whether they understood a concept or if they have linked what they have learnt to their prior knowledge. In fact, they contributed their own examples. By questioning themselves, children became more self-regulated and took conscious control of their own learning (Ghosh, 2003; Sanacore, 1984).

CETM was designed and developed to connect the science knowledge with the engineering concept. Connections are the hallmark of deeper thinking (Wellington & Ireson, 2012). Questions asked in CETM activities allows children to justify, explain, hypothesise, predict, reframe and sum up because these are higher order thinking questions which allowed the children to think beyond the superficial (Wellington & Ireson, 2012).

Besides learning theories, Gagne's theory was used in this study as an instructional theory. Gagne's theory addressed five types of learning outcomes which were intellectual skills, verbal information, cognitive strategies, motor skills and attitudes (Schunk, 2012). However, this study analysed all the learning outcomes except for motor skills. Motor skill was omitted since motor skills such as hitting a ball or juggling involved muscular movements which the designed CETM does not intend to research on. Thus, four out of five of the learning outcomes in Gagne's theory were discussed in Conceptual Framework (Figure 3.1). The developed CETM activities produced learning outcomes such as designing solution, oral presentations, hands-on challenge and attitudes such as curious and collaborative. Apart from curious and collaborative attitudes, children can learn to abandon the notion of "I don't know" or "I don't understand" the moment they see a task that was different or unfamiliar. With the teacher's guidance, children can break down the task into smaller components. Children can see clearly what information and skills required to complete the task.

The Designing Process of CETM

The design and development stage which employed Isman ID model started from needs analysis until feedback (evaluation). However, this chapter discussed the phase from needs analysis (input) until implementation (output) of the CETM activities. The evaluation (feedback) phase or the end product of the CETM design process will be discussed further in Chapter Four. The following phases also included the modified Delphi technique which was employed in this study.

Input: Needs Analysis (Phase One)

This is the first phase of designing the CETM. Based on the microanalysis of TIMSS 2011, it was certain that Malaysian children were lacking of HOTS in science. Literature reviews indicated that Malaysian children were poor in reasoning skills. Meanwhile, based on the science curriculum analysis and literature reviews in Chapter Two, questioning and reasoning skills were not given much priority as compared to other countries that have excelled in TIMSS 2011. Since this crisis was also faced by other countries, researchers around the globe have studied about introducing early engineering for primary school children to overcome this problem. Need analysis revealed that there were gaps in the current science education which needed close attention. These gaps were discussed in Chapter One and Chapter Two.

Selected experts were interviewed (audio recorded) to be parallel with the current state of science education in the education system. A total of five experts were interviewed. Two of them were science lecturers in Teaching Training College. Another two experts were secondary school teachers who taught Physics and Biology. The final expert was a primary school teacher who taught science subject. These respondents had nine to sixteen years of experience in teaching science. The interview questions are attached in Appendix 2.

Though they had substantial amount of knowledge in science education, when answering about HOTS and reasoning skills, they gave vague answers. The concept of higher level thinking skills was not emphasized in their teaching because they were too exam oriented. One expert mentioned that higher level thinking skills were groomed using multiple choice questions. Meanwhile, another expert revealed that HOTS can be fostered through science competition such as robotic or solar energy which was held once a year, either at the school level or district level. They fail to understand that not all the children can participate in these competitions because only three to four children will be fortunate to experience such competition.

Another expert was aware about the government's intention in promoting HOTS among children but did not agree that HOTS is as important as the knowledge in learning science. This expert claimed that the facts and formulas must be memorized by the children in order to excel in science. At the same time, some experts misunderstood the concept of HOTS and reasoning skills itself. They stated that HOTS can only be fostered from secondary level onwards because it is difficult to promote higher level thinking at a younger age. Similarly, an expert mentioned that HOTS was difficult to teach a child since HOTS is a complicated academic material.

Looking at the responses from these experts, it was clear that there was a need to guide the teachers in promoting HOTS and reasoning skills among the children in learning science. It is a bitter truth that we must succumb into since years of experience and levels of expertise alone does not justify the awareness of an academician in promoting HOTS and reasoning skills.

Process: Designing Teaching Module (Phase Two)

This phase employed modified Delphi technique to gather the elements required for CETM. After designing the items through Delphi technique, the phase continued to develop CETM which was validated by several experts who were selected as the appropriate respondents.

The Modified Delphi Process

This study employed modified Delphi technique because modified Delphi technique has the ability to produce certain level of information or findings for a research study (Miller, 2001). At the same time, this study employed modified Delphi technique because many other researchers have employed this technique since it is seen as efficient especially in gathering information for important current issues (Kerlinger, 1973). The modified Delphi method is a moderation process for allowing multiple participants to work together towards a solution and this technique also helps to minimize the collaboration bias (Paul, 2008). Apart from that, the time and cost of participants travelling to meetings is saved, while still enabling their participation in this research. Moreover, through modified Delphi technique the anonymity of the participants is preserved. This anonymous collaboration relieves peer pressure and other performance anxieties that are common to group collaboration methods and allows participants to focus on the problem (Paul, 2008).

In-depth interviews with the experts were used in this study as an alternative to questionnaires because interviews provide the flexibility which is absent in the questionnaires (Gordon, 2007). Gordon mentioned that interview provides the opportunity to probe the reasons behind the forecast, to search for biases in the forecasts and to follow up on unexpected hints dropped by the interviewees.

Selecting Delphi Experts

Keeney, Hasson and McKenna (2006) cited a range of definitions of 'expert' including 'informed individual' or 'someone who has the knowledge about a specific subject'. In short, an expert is a person who is very knowledgeable or skilful in a particular area (Soanes & Stevenson, 2003). An expert must be selected based on the characteristic of knowledge (publication), experience and ability to influence the policy (Campbell & Cantrill, 2001; Keeney, Hasson & McKenna, 2006). This study employed five measures in choosing the right experts for gathering consensus to design CETM (see Appendix 3). The measures were academic background, research areas, professional services, years of experience and honours, awards and contribution

Academic Background

One of the characteristic often identified was knowledge (Baker, Lovell & Harris, 2006). The possession of a qualification means that an individual has achieved a certain predefined knowledge base (Hardy et al., 2004, Williams & Webb, 1994). Many authors including the experts in this study cited their professional qualification in their definition of expertise. This study has incorporated a range of experts with a variety of academic level such as professor, associate professor, scientific programmer and senior researcher.

Research Area

It is crucial to investigate the research area of an expert. In this study, experts were screened through the articles written and published in well-known academic journals. The panellist in this study has published papers in fields pertaining to STEM education, engineering design, early engineering and engineering is elementary (EiE) in high impact journals. The experts' publications were searched and selected in established journals such as International Journal of Science and Mathematics Education, International Journal Technology and Design Education, Review of Educational Research and British Educational Research Journal. Soon after that, the corresponding authors for the respective authors were contacted by e-mails to ensure the originality of their research area and their availability to provide their opinion. All the experts also sent their complete curriculum-vitae to indicate their agreement in assisting this study. They were prepared to provide their consensus on how to design CETM activities. The research areas in children's engineering has been scrutinized and agreed upon. The experts were specialist is STEM education, science inquiry and early engineering, mechanical engineering and engineering design, science, mathematics and primary school education, design practice and design thinking in teaching and research Engineering is elementary (EiE), brain and cognitive sciences, reasoning thinking skills and neuroscience of complex learning.

Professional Services

Knowledge or publication alone does not equal the expertise of an expert (Keeney et al., 2006). Graham, Regehr & Wright (2003) revealed that selecting policy makers as experts were also a vital component in gathering consents. In view of that, this study has also looked into the proficiency and policy influence of the experts in research fields. Experts' professional services were also an indicator to judge how vast was their involvement in the research areas.

Years of Experience

The experience of an expert in their areas is an important measure in justifying their expertise (Hardy et al., 2004, Jeffery, Hache & Lehr, 2000). The range of experience that the experts had in this study was between 7 to 43 years. It is impossible to predict whether experts will retain the necessary attitude, knowledge or skills if the overall years of experience were the sole criterion upon in which they were judged (Baker, Lovell & Harris, 2006). It was unconvincing to suggest that a certain number of years of experience mean an individual can be considered as an expert in their corresponding fields (Baker *et al*., 2006).

Honours, Awards and Contribution

In addition to the measures of selecting an accurate expert, this study looked into the expert's impact in their respective research fields. Experts' nobility and righteousness was analysed before asking their consent to be an expert in this study. There were several startling contributions that the experts have achieved.

Expert Panel Size

Concerning the appropriate number of experts to involve in a study, Delbecq, Van de Ven and Gustafson (1975) recommended that researchers should use the minimally sufficient number of experts and should seek to verify the consents through the follow-up explorations. Delbecq et al (1975) suggested that ten to fifteen experts should be sufficient in a study concerning gathering consents and opinions. Meanwhile, according to Ludwig (1997), majority of the studies have used between fifteen to twenty experts as an expert panel size. Hsu and Sandford (2007) revealed that the sample size of experts must not be too small or large because the consequences of findings could either be unrepresentative or inherent drawback from large blocks of time.

Therefore, a collection 22 precise experts from various countries was grouped together in this study. Though most of these experts (a total of fifteen) were based in United States of America (USA), they differed from various states within USA. Three experts originated from Massachutes and two of them from Virginia. The rest of the

USA came from other states. Apart from that, there were five experts from Norway, Denmark, Russia, Israel and Australia participated in this study. Another two experts who agreed to participate in this study originated from Malaysia and India. All of these experts were involved in the development of CETM for the Malaysian children in fostering HOTS and reasoning, particularly in science subject.

The Final Experts and Responses

A total of 61 experts were chosen and they were sent an e-mail asking their consent to be interviewed. Some experts were interested n the research as one of them replied;

> …Your research sounds very exciting. We certainly do not have enough work in this field. I will be glad to meet with you. I'm also attaching another recent paper you may find interesting.
>
> (Expert 1)

However, some of them declined to be interviewed. Meanwhile a few of them did not respond to the e-mail that was sent. After a series of e-mails, an agreement was achieved between the researcher and a total of 42 experts. Yet some of these experts did not respond to the follow up mails. These experts were also screened and shortlisted based on their field of expertise, years of experience and their relevance towards the current research. Finally, a total of 22 experts from various countries agreed to answer a written response through the e-mail. Keeney et al., (2006) indicated that there are no universally agreed criteria on the minimum or maximum number of experts on a panel. In fact, according to this group of researchers, the total numbers of experts were related to the common sense and practical logistics. These experts agreed to send their written answers within two weeks. Even though they agreed to respond within the agreed time frame but some of the experts needed a reminder and responded;

> …I'm sorry for the delay in my response. It sounds like you are undertaking some interesting work that relates to ours. I would be happy to respond to a written interview about your instrument—can you e-mail it to me?
>
> (Expert 2)

Data from e-mail interviews were generated within an average of four weeks and these experts were willing to participate in additional discussion. Some of these experts were cautious and they were particular in certain aspects before they agreed to be a part in the first round of Delphi. One of them reacted;

> …I'll gladly give an interview for your work, under one condition: Before you publish any of the data from the interview, I want to approve the parts of the text where the interview is quoted or where I am listed as contributor. This is just to ensure that the views expressed in the interview are not taken out of context.
>
> (Expert 3)

After the first round, these experts agreed to be involved in the second round of Delphi. In fact, most of them had the similar respond as this particular expert who replied; "…I'll be happy to be included in the next round". Hence, the written responses were analysed into initial codes before suppressing them into categories and finally themes. Certain answers from the experts were vague. Since all of the experts agreed to be involved in the second round, these doubts were mailed back to the respective experts and they cleared the uncertainties. One of the inexplicit responses for Q13 was; "…The HOTS of transfer, certainly engaging creativity". The expert received a mail during the second round of the Delphi technique and after two days to four days, a feedback was received. The explanation for the vague response was much more prominent;

> …In my perspective, the fundamental part of HOTS lies under 'remember' in Bloom's taxonomy. I believe that one can very quickly move or transfer the focus to the HOTS during learning, as kids around 10 years are believed (and it's showed in various studies) to be more

> generative, meaning that they already are very capable of 'creating' so what they need training in is more to evaluate and analyse.
>
> (Expert 4)

Based on the responses which were collectively gathered by two rounds of Delphi technique, CETM was developed. CETM was validated by several experts based on their qualifications. Ludwig (1994) pointed out that solicitation nominations of well-known and respected individuals from within the target groups of experts are recommended. Thus, this study also targeted several experts or positional leaders who were related to children's engineering. The developed CETM was validated twice by these experts until it was ready to be implemented. Each of the experts gave concrete validation and a depth outcome of the designed CETM. Figure 3.2 summarized the modified Delphi process in this research.

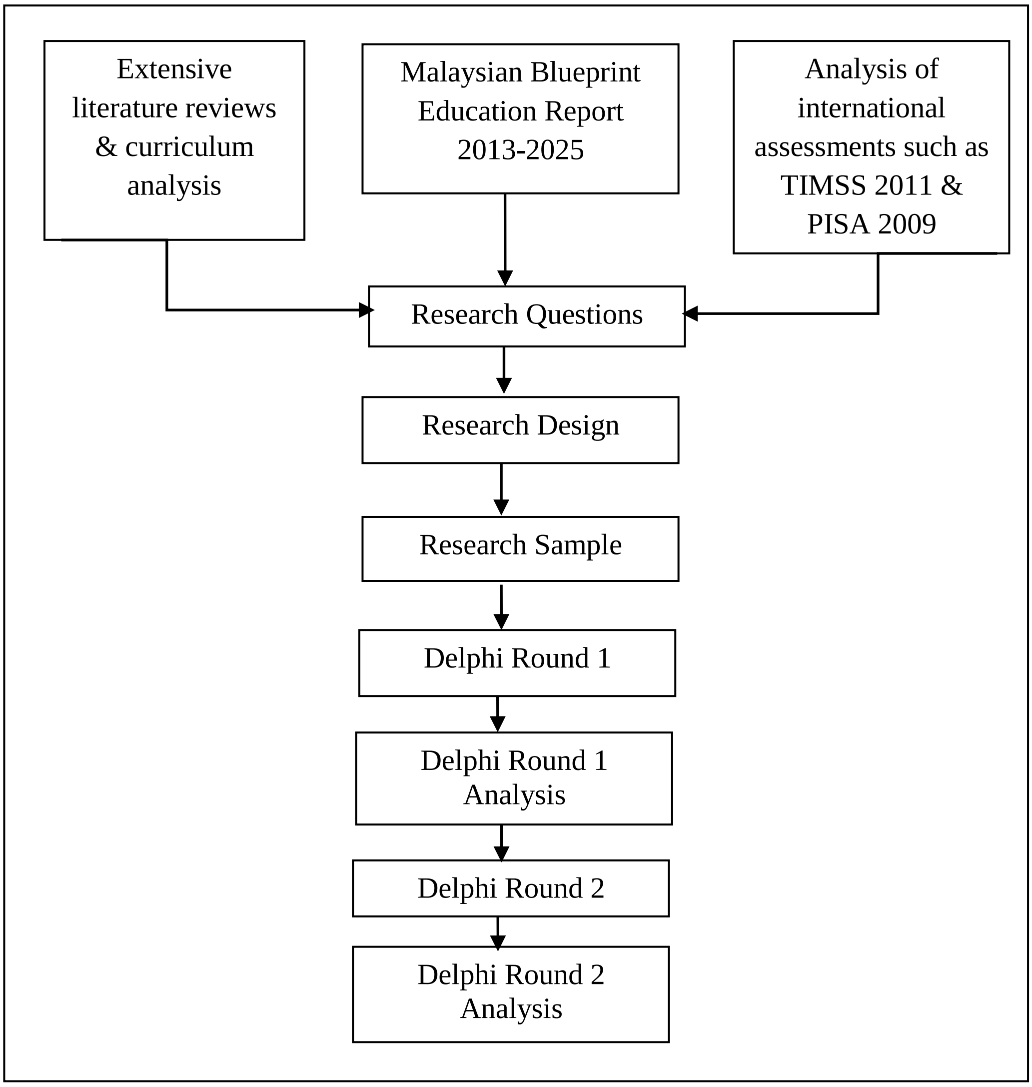


Figure 3.2: Modified Delphi process (Skulmoski, Hartman & Krahn, 2007)

During the Delphi round One, interview questions were e-mailed to the experts who agreed to participate in designing CETM. Online interviews were used to gather expert's responses. At the same time, during the Delphi Round Two, further clarification of the expert's response in Delphi Round One was elucidated. Online interview was the main method used to gather feedback from the experts who participated in designing CETM. The process of interview on conducting the online interview is described in the following pages.

Interview

This study employed semi-structured interviews where an open-ended response was expected from the interviewees. This study employed interviews in gathering data because according to Creswell (2012), interviews provide useful information and have better control over types of information received. The interviewer can ask specific questions to elicit information (Creswell, 2012). For interviews, qualitative inquiry use designed protocols to record information during the conversations.

This study employed a designed interview protocol where a list of open-ended questions was built (see Appendix 4). The interview questions were built based on literature reviews and research questions in Chapter One. There were thirteen interview questions designed in this study. These questions were validated by lecturers and teachers as to observe and substantiate the relativity between the content of the questions and the HOTS issues in the education system. Apart from that these questions were also piloted at the needs analysis stage during the early stage of CETM development. Experts during the needs analysis stage and CETM evaluation were interviewed face to face whereas the experts in designing CETM were interviewed using internet connection. Majority of the experts were interviewed online via e-mail.

Online Interview to Garner Opinions of the Experts

Online interviews can be divided into two main types: asynchronous and synchronous (Mann & Stewart, 2002; Ayling & Mewse, 2009). This research employed asynchronous online interviews which do not require both researcher and participant to use the Internet at the same time and these interviews were usually conducted via e-mail (Hunt & McHale, 2007). E-mail interviewing allowed more extensive communications (McCoyd & Kerson, 2006) and in fact this study managed to receive eleven to nineteen pages' transcripts in average. Subsequently, although this type of interviews often had an extended period of time over which e-mail interviews could be conducted, e-mail interviews yielded detailed and rich data (McCoyd & Kerson, 2006). Since the participant's responses were in writing, an accurate transcript is immediately available with no loss or inaccuracy in transcription (Salmons, 2010). It obviated the need for tedious transcription apart from allowing the respondent's to 'clean up' their own messages and the researcher does not modify the respondent comments by deciding which verbal tics and stuttering to remove, but obtains responses needing only a cleaning of spelling errors (McCoyd & Kerson, 2006).

Online interview also viewed as having the added advantage of reducing the transcriber's potential 'bias' when translating an audio recording into textual form (Ayling & Mewse, 2009). Parallel to that, Chen and Hinton (1999) also highlighted that online interviewing has the potential to be the 'great equaliser', as participants may be unable to judge their interviewer based on gender, age, race and other factors.

Apart from that, this study trusted online interview using e-mails because of its ability to overcome the barriers faced by the conventional 'in-person' interview such as geographical distance, the time and the cost involved in travelling to meet participants (Chen & Hinton, 1999; James & Busher, 2009; Mann & Stewart, 2002). According to Holbrook, Green & Krosnick (2003), people interviewed by telephone or face to face preferred another mode of interviewing most often because it would allow them more time to think about the question.

In line with that, this study invited large participation and geographically dispersed samples by sending them e-mails individually rather than making long-distance telephone calls, or traveling to the location of experts. For some of the experts when skype and video conference were tried, they were not successful because of the timing, poor internet connectivity and experts from isolated venues. However, for thematic analysis data, skyping did work.

The interview questions were mailed simultaneously to all experts during local daylight. However, each of the interview response was received at different period of time. These questions were e-mailed from the university campus. The entire process of interview for all the 22 experts was completed approximately in seven months, which was in July 2014. The stages of Delphi rounds varied because each expert sent their feedback at different dates. The interview proces were on-going because the mail box was checked everyday to observe whether any mail was received from the experts.

In regards to the expert's unease during the interview, the experts were assured that the entire message will be copied from the electronic mail response without identifying any information. Later, the responses were pasted into a word document with no identifying information other than the assigned code number. Likewise, the original e-mail was also deleted and in fact removed permanently from the recycle bin as soon as a response was sent. In fact, it managed to strive for more complete, complex and reflective nature of the data derived from expert's responses.

The Codes Emergent in Developing the CETM

Once saturation or redundancy occurred when the expert's answers began to be the same or similar, the sampling was terminated since no new information was coming. Thus, the written transcripts in the e-mails from the interviews were compiled in Microsoft Word for easier analysis. The specific thematic analysis process used in this study incorporates open coding and categories which are used in qualitative studies.

Experts's written responses were thematically analysed using three stages of coding stage. During the open coding, reading through the entire interview and highlighting the key words and phrases were the first run at coding and conceptualizing the data. This was followed by specifying rigorous emerging codes which leads to generating a list of descriptors based on the key words and phrases in the open coding.

For example, for the first research objective (What are the elements in teaching science that could enhance HOTS for the CETM?) as shown in Table 3.4, one of the codes was opportunity. The following interview responses from the different experts were examples of how the code opportunity was emerged.

Expert 1:	…I use Children's Engineering to allow children the **opportunity** to apply what they are learning in the core areas.
Expert 2:	…The children must have the **opportunity** to make and present mock-ups and prototypes of unique solutions.
Expert 3:	…What children are doing should be situated in a larger context and then they should have the **chance** to engage in engineering practices and the engineering design process.
Expert 4:	…I think reformed teaching practices are important. That allowing children the **opportunity** to engage with content prior to being graded.

The descriptors with common meaning were then grouped to develop categories. Based on the Table 3.4, apart from opportunity, many other codes such as mechanical reasoning skills, leaps of knowledge, critical thinking skills and logical thinking emerged from the transcripts. However, descriptors with mutual connotation such as motivating discoveries, bridging the gap, connecting ideas and exciting challenges were grouped with opportunity to form a category called empowerment of mind-boggling thinking. In the same token, other categories were also formed based on the codes emerged from the transcripts.

Once the grouping was completed, the list of categories was mailed to approve the consensus from the experts. The lists were modified for the experts that disagreed with the categories. Although the data given by the participants were comprehensive, it was a cumbersome process for the researcher to select the description responses. This is because the researcher has to fully reflect an overall viewpoint of all the interview responses through the coding process. According to Gall, Gall, and Borg (2003), this reduced the researcher biases within the research study, mainly when the interviewing process involved numerous participants. Apart from that, local lecturers were also involved in ensuring the compressing the codes to form themes. Many researchers recommended the necessity to use a third party consultant who can review the codes or themes. This step is to determine the quality and efficiency of the review based on their assessment of the interview transcripts (Creswell, 2007). This helped alleviate researcher biases when the over-analyzing of research data take place.

More connections were made between the categories to form themes. For example, the five categories such as empowerment of mind boggling thinking, mastering inter-disciplinary paradigm, grooming abductive reasoning, branding conditional reasoning and displaying mental endurance displayed in Table 3.4, was suppressed to develop a theme called building a genius brain. The following responses from the experts on a theme called building a genius brain for children is revealed here:

Expert 1: …Basically, on a **neurological level**, one could hope for building of new associations connecting analysis, evaluation and creation which could lead to stronger reasoning skills.

Expert 2: …I believe HOTS is related to theories about cognitive load and the sequence of processes necessary for particular **brain process**.

These themes, categories and codes were scrutinized to ensure that each is fully elaborated and outlined. Once all emerged codes were all grouped together into categories and themes, it was mailed once again to receive the final consent from the experts. Finally, using high level of specificity and abstraction, these emerged themes, categories and codes are unified to identify the key issues emerging from the data. In order to increase the enhancement of trustworthiness of the findings, the coding also underwent peer review. Each research question generated two themes. For the first research objective (What are the elements in teaching science that could enhance HOTS for the CETM?) as shown in Table 3.4, a total of two themes, nine categories and 38 open codings were emerged from the data.

Table 3.4: Themes, second coding and first coding of the first research objective which encompassed the elements to promote HOTS in CETM

No.	Themes	Category	Codes
1.	Building a genius brain	Empowerment of mind-boggling thinking	Opportunity Motivating discoveries Bridging the gap Connecting ideas Exciting challenges
		Mastering inter-disciplinary paradigm	Leaps of knowledge Transferable skills Divergent mode thinking
		Grooming abductive reasoning	Mechanical reasoning Practical reasoning Deductive reasoning Inductive reasoning Engaging creativity
		Branding conditional reasoning	Strategic thinking Assessing Measuring intelligence Analytical thinking
		Displaying mental endurance	Synthesis Critical thinking skills Articulation skills Epistemology Argumentative Making decision Informal reasoning Formal reasoning Logical thinking Flexible thinking Independent thinking
2.	Engineering design thinking	Infusing engineering teaching and learning	Engineering design Systemic thinking
		Conceptualising design learning	Designing process Designing goals
		Basic necessary HOTS	HOTS fundamental HOTS paradigm
		Imperative engineering skills	Problem solving skills Open-ended problem Ill-structured problem Application

For the second research question (What kind of activities embedded in the CETM in order to enhance HOTS in teaching science?) as shown in Table 3.5, a total of two themes, ten categories and 28 open codings were emerged from the data.

Table 3.5: Themes, second coding and first coding of the second research objective which encompassed the activities that promote HOTS in CETM

No.	Themes	Category	Codes
1.	Embracing beyond basics using STEM education	Cyclic process	Understanding problem Brainstorming solutions Creating the best solutions Testing solutions Evaluating solution Redesign prototype
		Building aesthetically and technically	Engaging engineering activities Features of sustainable green design engineering, electrical engineering and mechanical engineering
		Authentic assessment	Optimizing alpha brain waves Recording ideas
		Tailoring engineering synergy	Collaborative learning Cooperative learning Emphasizing team work
		STEM initiatives	Integrating alternative perspectives Systematic effort for coherent framework
		Bridging designing loop process and guided portfolio	Engineering constraint Prompt ideas Safety measures
		Correlating the curriculum	Teacher's role Student's role Flexible guide
2.	Discovering never ending possibilities through engineering design	Relevant solutions beyond market logic	Exploring future technologies Transforming ideas into practical situations Sustainable engineering
		Democratic reasoning	Nurturing thought provoking atmosphere Expressing own words
		Balancing flabbergast vibes	Encouragement Fostering curiosity

Justifying CETM Codes with the Literature Reviews

Each theme from both research objectives has been elaborated using extensive literature reviews with additional illustrative quotes used in the text.

The elements to promote HOTS in CETM

Theme 1: Building a genius brain. Engaging children in children's engineering activities can lead towards building a genius brain. Experts revealed that the brilliance of a child can be produced based on well planned children's engineering activities.

Parallel to that, Darlington (1969) defined genius as a person who modifies the surroundings of others for his own and subsequent generations, for his own species and for the entire living world. Meanwhile Thomas Carlyle defined genius as countless ability for taking pains (Overholser, 1961). Hence, this study concluded that being genius is a person who tries to make positive changes to make a better world by using both mental and physical attributes where deep thinking and hands-on activities were required. However, while we cannot modify our genetic inheritance, a lot can be done to steer engineering practice on a progression towards building a genius brain. According to Nithy (2009), geniuses can be born but they can be made too. Nithy continued that it is important to grab the golden opportunity of expanding the child's potential to become a genius at an early stage of their lives.

This theme was developed from a compression of five categories, which were empowerment of mind boggling thinking, mastering inter-disciplinary paradigm, grooming abductive reasoning, branding conditional reasoning and displaying mental endurance. These five categories were in line with building a genius brain for primary school children in learning science.

Empowerment of mind boggling thinking. Mind boggling thinking is defined as being mentally or emotionally exciting or having overwhelming thinking during an organized challenge in a classroom (Jensen, 2008; Moore & Hibbert, 2005; Saxe & Young, 2013). Overwhelming thinking which can be produced during an aesthetic and technical activity such as an engineering design activity has the potential to build a genius brain, especially among the children (Gallagher & Freeman, 2016; Hooker, 2000). The powerful effect of mind can be yielded among children during the prepared design activities by the teachers (May, Albers, Dooley, Flint & Holbrook, 2015). At the same time, experts indicated children need HOTS in order to be competitive in today's world since careers today's world is not only constantly changing but also challenging.

Hence children need HOTS in order to adapt, change and remain challenged. Experts believed that children need ample opportunity to develop HOTS. Though science naturally interest's children through inquiry based lessons, children should be given enough chance to develop HOTS while learning in the classroom. One of the experts agrees with this view, stating; "…the children must have the opportunity to make, present mock-ups and prototypes of unique solutions while learning science."

Yet, in spite of call for investment in promoting innovation, design and production of new knowledge, there are few opportunities for young students to innovate and design (Webb, 2010). Meanwhile, focusing on motivating discoveries, experts believe that, distinguishing, analysing, and classifying are a few HOTS that are used for higher order learning in both inquiry and discovery task. They also revealed that if children' practices over time, children can be helped to discover bigger things while learning science. An expert mentioned;

> …when motivation is secured, one can very quickly move the focus to HOTS, as kids around 10 years old are believed to be more generative, meaning that they already are very capable of creating.

Although the teachers might be aware of the significance of motivation for discovering something new, these teachers might not have committed themselves in doing so. According to Casakin & Kreitler (2010), one of the reasons why the teachers might not be involved in motivating the children is because teachers themselves might be lacking the understanding and skills of how to increase and stimulate motivation for discovery among the children during the lessons in the classrooms.

Mastering inter-disciplinary paradigm. Interdisciplinary research can deliver substantial assistances to the researchers, experts and strategy creators. Since, interdisciplinary researches are increasingly become important, is anticipated to be one of the fields that incorporate the future of educational studies (Bridle, Vrieling, Cardillo, Araya & Hinojosa, 2013). A growing body of research in the futures field, and elsewhere, has described the characteristics and quandaries of interdisciplinary research, including the crucial question of how to build interdisciplinary capacity (Bridle, Vrieling, Cardillo, Araya & Hinojosa, 2013).

The integration of varied knowledge at different stages is crucial since traditional methods of reasoning are not enough as the situation is radically different from classical optimization and modelling (Le Masson, Hatchuel & Weil, 2011). One expert supported the fields of knowledge is important in increasing HOTS using engineering design. This expert stated;

> …if you cannot reason about why something does or does not work you cannot create your own thinking and knowledge. Engineering by definition is applying knowledge from disciplines and creating new knowledge.

Divergent mode thinking is also often seen as an underlying factor for complications concerning societal organization, communication and broadcast of the data (Viale & Pozzali, 2007). This is because the concept of diversity mode runs through every stage of the teaching (Ling, Hengyang & XianYing, 2012).

As designers are impossible to be all-knowing, they have to figure a systematic model to give consideration to both rational and innovative, for co-working with experts from diverse fields from time to time (Schon, 1983). However, with the variety of cross disciplines, how to develop a design based project to harness various knowledge and integrate the divergent mode thinking process to accomplish the education goal still remains unclear (Hong & Choi, 2011). The importance of divergent mode thinking is inevitable since another expert echoed stating; "…different levels of reasoning or thinking in representing about science and engineering constructs are crucial."

Subsequently, engineering education lay emphasis on the transferable skills rather than learning by heart (Chong & Ng, 2013). An expert revealed that; "…HOTS are fundamental to this strategy (engineering design) as it is all about transfer of knowledge and skills to new situations." Since transferable skills are essential especially in building a forthcoming occupation for the children, teachers should ruminate on integrating transferable skills into the children's daily lessons (Chong & Ng, 2013).

Grooming abductive reasoning. Abductive reasoning is an ability to predict intellectually. Abductive reasoning can be fostered through engineering design (Lu & Liu, 2012). Abductive reasoning helps to provide the good ideas to solve a problem, especially in an unanticipated challenge (Peirce, 1931-1958). Peirce also argued that abductive reasoning skills can be nurtured in a scientific and technical environment. For example, CETM activities promotes both scientific and technical elements and there are possibilities where children can be cultivated in abductive reasoning skills.

Abductive reasoning is a rational interpretation which flows from an opinion to a theory. In fact, abductive reasoning stresses on the observation, particularly in pursuing for the simplest clarification in coming up with a conclusion. An expert agreed by indicating that;

> …they (children) see that making a "perfect" solution is not possible: there are only different kinds of optimization that reflect different values for what is most important about the solution. These types of thinking can lead towards abductive reasoning which helps them for final conclusion in an activity.

Similarly, Gonzalez, Broens and D'Ottaviano (2007) revealed that abductive reasoning does not guarantee about its correctness. By the same token, Lu and Liu (2012) also indicates that abductive reasoning can lead to multiple possibilities because children are encouraged to guess the various types of solutions to overcome a challenge. According to Gonzalez, Broens and D'Ottaviano (2007), the guesses or the possibilities created by children are actually the hypotheses that emerge in their thinking.

Parallel to that, deductive reasoning is also needed to confirm the probability of the hypotheses or the prospects that emerge in children's ideas during the activities. These hypotheses could help children to predict the right solutions apart from explaining the original or initial idea that appeared during the activities. An expert too trusted that children's prediction is required in making decision; "…they (students) must make decisions based on their knowledge and predictions". Deductive reasoning is related to abductive reasoning since it consists of deriving the conclusions from the given evidence to form the best solution (Jøsang, 2008). An expert concluded; "...the most effective solution creates the type of learning activities that encourages students to function at a higher cognitive level."

Abductive reasoning is also subjected to generalizability because according to Lu and Liu (2012), different types of abductive reasoning pattern can be initiated in wanting to solve the various encounters during the designing process. The applicability of abductive reasoning can be viewed from an elusive idea to a tangible idea to support a broad-spectrum design activity. An expert warned that;

> …but if there is too much doing and no explaining, then students aren't likely to learn the more generalizable ideas and practices that would be beneficial to them in other situations.

Creativity is defined as the children's capability of how they use the information around them, especially the information that revolves around their routine life to reflect their thinking process (Greene, 2013). In line with this view, children who involve in activities addressing science, engineering or mathematics could lead towards their creative thinking skills, especially when they yield the unique or different outcomes or prototypes. Similarly, abductive reasoning could not only engage creativity but also stretch the creative mind among young children. According to Gonzalez, Broens and D'Ottaviano (2007), abductive reasoning helps the children to practice the creative thinking skills which lead towards various types of feasible and practical solutions for the given challenge in an activitiy. An expert suggested;

> …by emphasizing their ability to come up with something novel (P-creativity wise), you could then move to an analysis of the creation, and finally an evaluation. In this way, the students could (perhaps) immediately foster HOTS, based on existing knowledge level.

Meanwhile, Hall, Mayer, Wuggetzer and Childs (2013) mentioned that since abductive reasoning is influenced by incentive and the outcome of a designer based on the values, one could consider high level creative thinkers as having the ability of imagining the futures that divert from the predictable to develop new solutions.

Mechanical reasoning skills encompasses the broad-spectrum of the reasoning skills and precise understanding of the machineries (Cronbach, 1984; Hegarty, Just & Morrison, 1988). Converging evidence showed that the mechanical reasoning processes are fundamental to numerous real-life responsibilities. For example, mechanical reasoning skills can be nurtured by encouraging the children to understand the explanations of how the machineries work, how the machinery operate, how to diagnose the errors in the machines and how to design and develop new machineries (Hegarty & Just, 1989; 1993; Kieras & Bovair, 1984; Rouse & Morris, 1986; Williams, Hollan, & Stevens, 1983). An expert discovered; "…i find mechanic reasoning and argumentation overall are good predictors of learning HOTS." The involvement of mechanical ability in abductive reasoning is acceptable to an extent since mechanical systems such as designing windmills and robots develop abductive skills, especially when the children can employ meaningful ideas in designing the technical prototypes (Gonzalez, Broens & D'Ottaviano, 2007).

Branding conditional reasoning. Conditional inference plays a central role in logical reasoning, and is used in a wide range of applications (Jøsang, 2008). Jøsang continued that the truth value of conditionals can be evaluated in different ways, for example as binary true or false, as a probability measure or as an opinion. In fact, Jøsang revealed that the conditionals are complex propositions because they contain an antecedent and a consequent that are also propositions with truth values that can be evaluated in the same way. An expert recommended;

> …to encourage kids to practice evaluating a situation, the curriculum and teaching must focus on creating solutions where kids feel a need to evaluate and have the support to conduct a good evaluation.

Conditional reasoning operates for multinomial opinions (Jøsang, 2008). Conditional reasoning can be described as the multidimensional process that involves complex forms of thinking which are proficient in nurturing the strategic thinking, negotiation, literacy and numeracy (Ezziane, 2007). Strategic thinking is about making the best use of the given materials and tools and accomplishing the ideal results for a given challenge in an activity. Strategic thinking also helps the children to figure out on how to adapt, adopt and implement their ideas in designing the prototypes for the given challenge (Sarason, 1990; Verduin & Clark, 1991). An expert said; "...it (engineering design) involves metacognition and self-regulated learning, critical thinking and strategic thinking." In fact, children should be encouraged to think systematicly about the topics they read about in class and their everyday lives (Barber & Buehl, 2013).

The conditional reasoning items in an instrument can focus on the assessment of inherent understandings (Bowler, Bowler & Cope, 2013). Conditional reasoning helps to measure the children using a set of reasoning problems by asking the children to pick the best reasonable clarification for each of the reasoning problem (Qiu, et al., 2007). Hence conditional reasoning could also function as an evaluating reasoning skill. The importance of evaluating also agreed by another expert, who mentioned;

> …to encourage kids to practice evaluating a situation, the curriculum and teaching must focus on creating solutions where kids feel a need to evaluate and have the support to conduct a good evaluation.

Qiu, et al. (2007) mentioned that conditional reasoning activities support the children's reasoning skills because conditional reasoning does not encourage an integrated situation but it is sensitive towards the content in a substance. The combination of data or knowledge from numerous sources is crucial in addressing the conditional reasoning problems (Qiu, et al., 2007). In sum, the cingulate cortex in the brain can be stimulated by conditional reasoning activities with intellectual materials and tools (Qiu, et al., 2007) and hence it can be indicated that conditional reasoning tasks has the possibility of measuring one's intelligence (Reis, et al. 2007). This is in line with an expert who had faith that; "…i believe HOTS is related to theories about cognitive load and the sequence of processes necessary for particular brain process." However, "practice makes perfect" is still an undeniable phrase that we need to succumb to. Conditional reasoning can be mastered well by practicing designing activities (Qiu, et al., 2007).

Displaying mental endurance. There is compelling evidence that mental endurance or mental toughness has been defined as a capability cope pressure, stress and hard times (Goldberg, 1998; Gould, Hodge, Peterson & Petlichkoff, 1987; Williams, 1988). Apart from that, mental endurance also helps to overcome or rebound from failures since it encourages children from quitting (Alderman, 1974; Goldberg, 1998; Gould et al., 1987; Taylor, 1989; Tutko & Richards, 1976; Woods, Hocton & Desmond, 1995). Displaying mental endurance is the tenure of greater intellectual abilities (Bull, Albinson & Shambrook, 1996; Loehr, 1982, 1995). Mental endurance encourages the higher order thinking skills (HOTS) that retain the children's performance of mental endurance in a competitive atmosphere, especially in the classroom during the activities (Demetriou & Raftopoulos 1999; Jones, Hanton & Connaughton 2002).

The skills to assimilate numerous viewpoints with a diversity of evidences and to decide the best action is known as critical thinking skills (Flores, Matkin, Burbach, Quinn & Harding, 2012). Critical thinking skills allow the children to view their reasoning processes. Parallel to that, the emphasis of education must shift to teaching children how to become critical thinkers from just teaching the content in a subject (Flores et al. 2012). An expert quoted; "…critical thinking is an essential element in learning science and engineering."

Epistemology is one of the fundamental basis for HOTS and its pedagogy (Demetriou, Spanoudis & Mouyi, 2010). Although the epistemology is linked to higher grade children, but at present, epistemology is increasingly becoming important among the primary school children (Daniel & Gagnon, 2011). According to Amiel and Reeves

(2008), epistemology is also defined as the way of knowing or how knowledge is derived and it should be validated and tested. Since epistemology is also involved logical thinking and acts as a part of fundamental philosophy (Toohey, 2007), epistemology requires a collection of interaction in order to reveal the truth when a problem is given. An expert is in line with that and the statement of agreeing sounded;

> …yes, these HOTS skills are especially important for learning science since science and engineering have typically a high level of interactivity involved in a given problem setting.

Apart from that, argumentation makes communication more efficient. Reasoning is the cognitive mechanism that makes argumentation possible. When it is used to produce arguments, reasoning's function is to find arguments that convince an audience. Arguments that support the speaker's point of view are more likely to achieve this goal (Mercier, Benard & Clement, 2013).

An expert also stressed the concept of argumentation in designing process during early engineering activity in the classroom. This expert said; "…being able to compare between different explanations is part of the process of design and thus more accessible while in use." Decision making in design is crucial (Hall, Mayer, Wuggetzer & Childs, 2013) since at the end of any arguments, a decision has to been at the end of the conversations or dialogues.

Oaksford and Chater (1998) indicated that judgement and decision making leads to a much more unified field of higher mental processing. Meanwhile, Stanovich, West and Toplak (2011) revealed that reasoning skills is much involved in a judgement and decision making. The following statement is in parallel with the expert's answers;

> …engineering is a purpose driven discipline and requires student to make decisions based on reasons derived from research and experience.

Theme 2: Engineering design thinking. Engineering design is a systematic and intelligent thinking where the children generates, evaluates and specifies their ideas while satisfying some specified restrictions during the activities (Dym, Agogino, Eris, Frey & Leifer, 2005). This definition promotes engineering design as a meaningful process that depends on the cyclic process and the specifications that help the children to design the prototypes as the solution for the given challenge.

This theme evolved from a compression of four categories, which are infusing engineering teaching and learning, conceptualising design learning, basic necessary HOTS and imperative engineering skills. These four categories are in line with engineering design thinking.

Infusing engineering teaching and learning. Engineering or design thinking reveals the multifaceted practices of inquiry learning where the children can work together in a social process and interact with various types of interactions in the classroom. An expert described; "…engineering thinking has to be cantered on using higher level reasoning." Engineering design activities are often carried out with certain limitations, criteria or objective to design a prototype that does not have to be a perfect prototype. An expert concurred;

> …Bottom-Up and Top-Down engineering design activities are examples of engineering design activities where the content will require children engage in HOTS.

Design thinking is reflected as the dominant or one of the main characteristics in the engineering design activities. In fact, design thinking is observed as the sequence of endless revolutions from experiencing the learning process of concept domain and addressing the knowledge domain (Dym et al. 2005). The understanding and practice of engineering design allows for behaviours that enhance engineering design thinking through divergence and convergence, the use of abductive reasoning, experimentation and systemic thinking (Hall, Mayer, Wuggetzer & Childs, 2013). An expert stated that; "…science and engineering students should be taught in a systematic hierarchy, from simple or straightforward concept to complicated/sophisticated understanding".

Conceptualising design learning. Design has many different meanings depending on domain and view point (English, Peter, Hudson & Les (2012). Design thinking is the set of mental processes that enable design and a prevalent in design business and practice. Design learning has identified a series of distinct characteristics that occur during the design process (English et al. 2012). One of the experts exposed the features of design process. "…ideally, children would design, build, test cycles in which they learned from their failures and improve their designs."

A number of iterative design processes plays a major role in engineering design activities (English et al. 2012). Engineering design activities such as constructing bridge requires the iterative design process where the design criterias and the constraints are crucial in constructing the bridge (English et al. 2012). An expert explained that; "…HOTS help you "run" your processes – research or design, problem solving – so that sub-goals can be related to main goals."

Basic necessary HOTS. Skills required for reasoning are fundamental to the design and construction process (Dunn & Larson, 1990). Children to get to the heart of design thinking (Roozenburg & Eekels, 1995) by making an allowance for the reasoning pattern behind the design, by looking at the central design practices of framing and frame creation (Dorst, 2011). Design thinking is also viewed as separate from other modes of thought and valued in practice (Brown, 2009; Cross, 2011). Design thinking can be implemented using different fields in order to be valued, especially in promoting HOTS. An expert explained on how to foster science and engineering;

> …science and engineering need to be taught on how to identify, highlight and categorize the key concepts to enable them understand the critical features that underlying the fundamental principles. HOTS can serve as the fundamental element to nurture such capability.

HOTS have been nurtured through children's engineering among the primary school children in all five continents around the globe (Hill, 2009; Jones, 2006; Jones & Compton, 2009; Lachapelle, Sargianis & Cunningham, 2013; Muchtar & Majid, 2009; Nwohu, 2011). In fact, corresponding research indicates that children's engineering which encourages engineering design thinking allows the children to discover scientific ideas which can increase their understanding in learning science (Cunningham, 2007; Kolodner et al., 2003; Lachapelle et al., 2011; Macalalag, Brockway, McKay & McGrath, 2008; Penner et al., 1997; Sadler et al., 2000; Thompson & Lyons, 2008; Wendell et al., 2010).

Imperative engineering. Engineers are known as the people who can solve problems (Denayer, Thaels, Vander & Gobin, 2003; Mourtos, Okamoto & Rhee, 2004; Winkelman, 2009). Children can be encouraged to be engineers who has the ability to solve problems whether they are involved in analytical situations or design activities. An expert quoted that; "…children need to be actively engaged in problem solving."

However, the real-life challenges are not very similar from the most engineering design activities. Real-world design problems are generally open-ended and ill-defined, lacking complete information about problem constraints. Children should be encouraged to develop open-ended problem solving skills since open-ended problem solving skills is central to the engineering design activities. An expert cited that;

> …to do this there must be a focus on open ended activities that require children to think and reason and to show these reasoning skills to others either through the drawing of a representation or through discussion of their reasons.

Meanwhile, ill-defined problems involve conflicting assumptions, evidence or opinions that could lead to different solutions for a given problem or challenge in the engineering design activities. Kumsaikaew, Jackman & Dark, (2006) argue that ‘real world’ (ill-structured) engineering problems are information-rich and thus require problem solvers to be able to reason effectively about what information is relevant to the task at hand. An expert differed before concurring that;

> …however, if you were to ask me whether students should be encouraged to engage in complex questions, and in scientific practices, so as to encounter “messy problems” and answer “messy questions”, I would say, YES!

The solutions to ill-structured problems are somewhat arbitrary and must be justified by the problem solver. As such, Voss (2006) emphasises that the knowledge, beliefs and attitudes of the problem solver play an important role in solving ill-structured problems. Ill-structured problems are faced more frequently in everyday and professional practice. This is because ill-structured problems are not inhibited by the content domains studied in the classrooms since the solutions are not anticipated (Douglas, Koro-Ljungberg, McNeill, Malcolm & Therriault, 2012).

Relating to the first research objective (What are the elements in teaching science that could enhance HOTS for the CETM?), experts have provided the feedback that has developed two themes in conjunction to promoting the HOTS elements in teaching science. Looking into the attributes that are crucial in promoting elements of HOTS, it is interesting to know that HOTS could be the one of the major fundamental towards building a genius brain among children. The following themes and codes are the findings of the second research objective (What kind of activities embedded in the CETM in order to enhance HOTS in teaching science?).

The kind of activities embedded in CETM to enhance HOTS

Theme 1: Embracing beyond basics using STEM education. STEM education is the study or professional practice in comprehensive parts of science, technology, engineering, and mathematics. Although the products or the prototypes produced during the engineering design activities has greatly influenced everyday life of human being, for many of the educators, STEM education simply means as Science and Mathematics. In order to improve the educators's perception on the STEM education, the fundamental of STEM education should encourage the children's cognitive synthesis for engineering and technology as well. Children should experience engineering design activities within the STEM framework by applying the higher level thinking skills related to the design process (Hernandez et al, 2012).

This theme evolved from a compression of seven codes, which are cyclic process, building objects aesthetically and technically, authentic assessment, tailoring engineering synergy, STEM initiatives, bridging between designing loop process and guided portfolio and finally correlating the curriculum. These seven codes are in line with embracing beyond basics using STEM education.

Cyclic process. The cyclic processes in children's engineering or engineering design activities started when a given problem in an activitiy being is interpreted. Firstly, the initial ideas for solving the given problem or challenge are brainstormed. Secondly, a likely track to design the prototypes is selected and expressed in an investigational method. Third, the likely track of ideas is tested and the consequent data analysed and employed to review or discard the ideas. Fourth, the revised or a new idea is articulated in an investigational method. The fifth step is when the cyclic process is reiterated until the idea of designing sees the restrictions indicated in the given problem or challenge (Zawojewski, Hjalmarson, Bowman & Lesh, 2008; English et al. 2012). Two experts revealed; "…specific to engineering, children should recognize that the process is cyclical, design, test and build and then repeat." Similarly, another expert mentioned;

> …children's engineering requires a great deal of reasoning. They are brainstorming and then using reasoning skills to decide which solution is the best.

Building objects aesthetically and technically. The engineering designing process can be practiced with the elements of aesthetics and technical to allow the children to search their ways to produce the prototypes that are visually and practically able to function (Nohl, 2001; Crilly, 2010 & Brophy, 2013). Engineering design not only relies heavily on knowledge about art and artistic perspectives but also the need to be aesthetically pleasing (Liu, 2003; English et al. 2012). Subsequently, it is essential to link engineering design with different interpretations by using both aesthetical and technical aspect in a relevant phenomenon (Murphy, Ivarsson & Lymer, 2012). Higher order thinking skills (HOTS) should convey not only the approaches required to meet the demands of the activities, but at the same time also address the aesthetic experiences and the new insights.

In line with that, HOTS should convey the pleasures taken in familiar recognitions and other manifestations of what it looks and feels like to engage in the children's engineering activites (Brophy, 2013; Nohl, 2001). Some of the experts came to an agreement by saying; "…together in teams to design and create a physical artefact with the essence of aesthetical." Meanwhile another expert said;

> …there is always the challenge of finding the equipment that will allow you to engage students in sufficient practice so that they develop the specific technical skills to perform proficiently.

Authentic assessment. The process of searching and interpreting evidence for use by children, especially to acknowledge where they are in their present learning, where they are required to go and how best to get there is called assessment. On the other hand, authentic assessments encourage the methodical probe, creation of higher level knowledge and the values beyond the curriculum (Newmann, Secada & Wehlage, 1995). Newman et al. (1995) mentioned that methodical probe is signified by persistence, deep inquiry into the desiging processes and the STEM discipline itself.

However, it is perceived that the authentic assessment offers opportunities for children to participate in various kinds of learning styles (Hassanpour, Utaberta, Abdullah, Spalie & Tahir, 2011). Children have the prospect to create higher level knowledge to generate new strategies to overcome a given problem or challenge, especially in the children's engineering activities (Hassanpour et al. 2011). Documenting and reflecting on the engineering design processes is also an essential section of an authentic assessment and this is in line with some experts who revealed that; "…Engineering Design Process applied to a Design Brief or Activity Outline documented through a design portfolio or engineer's notebook."

> …reasoning activities in science must require children to document the reasons that justify their answers to particular questions. This documentation could be in the form of a drawn representation or through discussion that requires each student to explain the reasons that they have used to form a particular hypothesis or conclusion.

When the alpha brain waves are semiconscious and deeply relaxed state, the right brain functions in optimal condition (Wolfe, 2010). Children's alpha brain waves are often observed to be in this state and hence trusting the alpha brains wave's function is important (Green, Green & Walters, 1999). According to Yellin (1983), alpha brain waves are important in learning and using the information taught during the hands-on activities. Hickein (2008) believes that the more a child is encouraged to access the right brain, the more genius like capabilities can be retrieved. Alpha brain waves which are the largest brain lobe has the possibilities in enhancing the children's reasoning skills and creative thinking skills (Kaufman, Kornilov, Bristol, Tan, & Grigorenko, 2010). Pable (2009) has indicated that creativity and sketches go hand in hand. In fact, if a child can't sketch, the high level of creativity which stimulates the alpha brain waves is not there (Pable, 2009). Hence since sketches operates in the space between the real and the imaginary of a child, it is important to include drawing or sketching section in an assessment. An expert mentioned; "…i believe it is important for designers to be able to communicate their design intent with hand drawings."

The ease of freehand sketching offers a calm and free flow interaction which gives the confidence among the children in an engineering design activity (Laseau, 2004). Another expert concurred by indicating; "…i also like children to draw representations of their learning so that I can see how their thinking and reasoning is changing over time." Children who are not given the opportunity to sketch are actually being omitted from most of the ways in which they can understand the real-world challenges (Cohn, 2012). Sketching ideas helps children to think, express themselves and develop a memory which can be significant in demonstrating the children's brains plasticity. By sketching, children's brain can rewire itself to produce stronger connections (Kolb & Whishaw, 1990).

Tailoring engineering synergy. Synergy means teamwork and empowerment that could indicate the survival of mankind (Campbell, 1996; Hamilton, 1995 &

Huijsman, 1995). This corresponds with the following statement; "…we must all hang together, or we surely will all hang separately." (Benjamin Franklin, 1706–1790).

The cooperative process that allows the children to produce solutions or prototypes during the hands-on activities such as children's engineering is known as teamwork (Scarnati, 2002). The children in the groups have mutual objectives where the group members can develop active interactions to accomplish mutual goals, especially during the engineering design activities (Harris & Harris, 1996). Teamwork depends on the children who work together in a cooperative atmosphere to accomplish the mutual goals through joint understanding and thinking skills. An expert echoed;

> …engineers almost always work together in teams in the "real world", so I'm a strong proponent of team-based activities of all types. First of all, we spend one entire class period discussing the importance of diverse teams, and use a variety of techniques to form teams based on gender, social styles, technical skills, etc.

Group members experience how to be flexible in order to work in a cooperative setting where the objectives are attained through collaboration effort rather than personalized objectives (Luca & Tarricone, 2001). An expert corresponded; "…there are many ways that a solid, well-designed early engineering content could help children to practice important skills such as collaboration."

STEM initiates. Different STEM awareness can analytically differentiate, analyse and integrate patterns within vast amounts of unstructured data. At the same time, STEM education awareness can also creatively produce new knowledge, questions and ideas to shape the children into higher level thinkers (Marshall, 2010). Hence it is necessary to have alternative options such as engineering design activities or children's engineering which can increase the higher order thinking skills (HOTS) among the children using STEM education. An expert mentioned;

> …I do not instruct science per se, but use engineering design pedagogy in STEM, so science is included. We have developed and use the informed engineering design pedagogy which includes just in time learning of STEM knowledge and skills necessary to solve a design challenge.

Apart from that, organized energy is also equally important since a few experts have mentioned about the systematic coherent efforts in designing a framework in a particular discipline. They quoted that:

> …I do not teach in the science area but as a general expectation, all programs should incorporate the necessary teaching strategies and learning engagement that will prepare children to think critically and creatively. This is also the expectation in science education. The new NGSS recently published in the U.S integrate engineering design into all three of the science disciplines (life sciences, physical sciences, earth/space science) at all grades levels K-12.

Bridging between designing loop process and guided portfolio. Design loop is defined as the sequence of concentrating at various measures for the iterative investigation of engineering design activities (Currano, Steinert & Leifer, 2012). An activity outline, engineering constraint and safety measures are part and parcel of the various scales in a design loop process. During the design loop feature, the children relates to an activity outline but the teacher provides most of the material and support general outline of the activity (MacLeod, Gopie, Hourihan, Neary & Ozubko, 2010). An activity outline can be created using prompt ideas relating to the science topics because the activity outline does not have to be complicated for the teacher to design the children's engineering activities. An expert mentioned;

> …I use design briefs in my engineering lessons. With a design brief, students are given a challenge, and are given the criteria for meeting the challenge. A design brief can be written on nearly any topic in the science curriculum.

According to Stapelberg (2009), safety in engineering design activities begins by recognizing the possible hazards that could occur in the classroom during the activities. At the same time, teachers can help the children to avoid an accident or incident during the engineering design activities. Safety in engineering design is crucial says an expert; "…children talk about what they are learning and should be given a safe, learning environment". However, the engineering design parameters cannot be manually selected all the time because the optimal designing process should be accomplished within the design criterias and restraints (Stapelberg, 2009).

Correlating the curriculum. Design-based approaches to identify and solve engineering problems can enrich the broader school curriculum in that they: (1) are highly iterative; (2) are open to the idea that a problem may have more than one possible solution; (3) provide significant contexts for learning mathematical, scientific and technological concepts; (4) provide a stimulus for appreciating and dealing with complex systems, including engaging in mathematical modelling and analysis (Katehi et al. 2009, Borgford-Parnell, Deibel & Atman, 2010). There can be different approaches to implementing engineering design processes within schools (English et al. 2012). An expert concurred that;

> …a good early engineering content (curriculum) will scaffold children to think about how their solutions work, what doesn't work, how they can figure out why different aspects of their designs are working or not working.

Theme 2: Discovering never ending possibilities through engineering design

Engineering design is an ongoing practice. Petroski (2010) mentioned that engineering design does not truly lead towards a final decision because engineering design process has many stops, back tracking and redirections in producing the prototypes. According to Petroski, an inventor or designer must be of two minds: thinking about the immediate problem at hand, while at the same time looking into the future for unexpected, undesirable consequences. Hence, engineering design assists to discover the never-ending possibilities to come up with solutions to solve a problem.

This theme progressed from a compression of three codes, which are relevant solutions beyond market logic, democratic reasoning and balancing flabbergast vibes. The thress codes are in line with discovering the never-ending possibilities using engineering design.

Relevant solutions beyond market logic. Although engineering design feats and exploits are really never-ending, it is still difficult to satisfy or persuade the manufacturing investors in spending their money on a certain designed invention (Petroski, 2000). In fact, some of the design inventors take years of development and marketing to continue attract investors. Petroski (2000) stressed that not all potential competitors look for new patents as a mean of venturing into the market. Hence, it is crucial to design the engineering activities consists of exploring new technologies and transform the children ideas into practical situations before producing a sustainable engineering solution.

The Brundtland Report of the World Commission on the Environment and Development outlines the sustainable development as follows; "…humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their needs." (Macomber, 2011). Since that time, this definition has not been challenged, but it has also not found application in engineering practice (Krumdieck, 2013). The kinds of learning activity that integrate STEM content are an awareness of sustainable development is only limited by our imagination (Lang et al. 2012). An expert described about example for a sustainable development by explaining;

> …an example for workable solution is, in addition to knowing that moving air and water can influence the shape of a landmass (erosion), 4th grade children are also required to develop a technological solution that impacts the influence of moving air and water on a landmass.

Stables (2008) pointed out that engineering design activities addresses the sustainability which is significant in making the best with what the children are given with. Stables continued that engineering design activities should be introduced especially in the problem-solving context for the primary school children. Once the children understand how engineering applies to the world around us and that engineers play a vital role within the sustainable development movement (Lang et al. 2012).

Democratic reasoning. According to Vedder-Weiss and Fortus (2013), children are allowed to make more choices about their learning in the democratic classrooms. This is because children can select what subject content they want to learn, with whom they want to learn and how much they want to learn. Democratic classroom coincides with children's engineering activities because children can be allowed to decide what prototype of science model to build, which who they want to work with and to what extent they want to complete the prototype (Vedder-Weiss & Fortus, 2013). In fact, in most of the democratic classes science teachers seldom use textbooks and generally no assessment is administrated to the children (Vedder-Weiss & Fortus, 2013). Instead, similar to the children's engineering activities, the teachers have to be self-sufficient in designing the engineering design activities to counterpart the children's desires and needs (Vedder-Weiss & Fortus, 2013).

Concrete examples of the democratic teaching are the questioning skills where it has helped the teachers to make their classroom atmosphere to be more thought-provoking atmosphere (Fook & Gardner, 2007). By using questioning skills, the children can be actively participating in the thought provoking activities such as engineering design activities (Cortazzi & Jin, 1996; Jackson, 2002; Tsui, 1996; Zou, 2004). An expert confirmed that; "…I never give those answers, only questions that they are able to answer."

During the hands-on activities, which encourages engineering design, the teacher uses the productive type of question which calls for reflection and analysis (Ramnarain, 2011). These types of questions can promote a view of science as a dynamic search for answers (Ramnarain, 2011). Questions by the teacher can provoke some unique thoughts and at the same time, can encourage the children to justify their answers or responses during the children's engineering activities (King, 1994).

At the same time, during the designing activity, children are requested to do some clarification of an idea presented. This is to allow the group members to have some opportunities to explain their concepts in full apart from provide and seek reasons for any decision (English et al. 2012). Two of the experts agreed that children should be given the chance to express themselves during the design activity. They stated that; "Show them, let them explore, and then listen to what they say." At the same time, another expert said;

> …I also believe strongly in tests against nature. That is, when students test their ideas (whether designing a physical mechanism or a mathematical relationship), they ought to test them against how well they work for the actual problem, not based on an authority-figure's judgement about whether they are correct or not. I think requiring students to explain and justify their design choices in an engineering task is critically important.

Balancing flabbergast vibes. Flabbergast vibes involve wondering through surprises in an atmosphere where the children could get motivated and passionate over something that they learn during the lesson in a classroom (Ainley, Hidi & Berndorff, 2002; Casakin & Kreitler, 2010; Hernandez, et al.,2012). However, balancing the motivational or flabbergast ambiences are crucial because teachers would not wish to see their children get carried away from the learning objectives (Ainley, Hidi & Berndorff, 2002; Casakin & Kreitler, 2010; Hernandez, et al.,2012).

One of the fundamental of science education is to integrate various type of external motivators (Ainley, Hidi & Berndorff, 2002; Casakin & Kreitler, 2010; Hernandez, et al.,2012). Parallel to that, some teachers frequently use words of inspiration for struggling children (Wiesman, 2012). Children's questions during the hands-on activities such as children's engineering are significant indicator of their thinking (Jelly, 1985; Watts, Gould & Alsop, 1997). Teachers are constantly guided to boost children to ask questions during the activities in the classroom (Harle, 2001).

According to Meyrick (2011), STEM education offers the encouragement to design solutions for problems throughout the science curriculum in an inquiry based learning atmosphere. An expert expressed; "…too many so-called "engineering" activities are really just crafts activities that help kids "feel good" about engineering because they're having fun." While incorporating children's engineering into the classroom, Resnick (2007) added that children were able to think critically and creatively to exhibit their understanding of science conceptions during the children's engineering activities. This promoted an opportunity to foster HOTS among children during engineering activities. Curiosity is a must for almost all of the hands-on activities which encourages designing process (Kashdan, et. al., 2013). This is because children's curiosity fosters thinking skills such as creative thinking, decision making and social relations (Kashdan, et. al., 2013). An expert succumbed and mentioned;

> …to me, the key must lie in making it interesting and directly relevant for their everyday life. Another thing is role models, the kids need to see 'cool' adults who make use of engineering to make 'cool stuff'. How can principles from engineering, and an understanding of these, be interesting for everything in their life?

By being fully involved in the hands-on activities, a curious child is assured of intensifying the higher level of thinking skills and competence (Kashdan, et. al., 2013).

Experts has provided the response that has developed two themes in concurrence to the kind of activities embedded in the preferred CETM in order to enhance HOTS in teaching science. It is inevitable that the introduction of early engineering could be a huge discovery in promoting HOTS among children. In this digital age of innovation, the child's mind needs to adopt the nature, quality of how they think and what they think about (Garrison & Kanuka, 2004). In fact, Westley and Antadze (2010) mentioned that cross disciplinary fields which include designing process is the new alternative for sustainable innovation, radial partnership and transformative large scale of worldwide alteration. Based on the expert's views, this is in line with the second theme which is discovering never ending possibilities through engineering design.

Translating the elements in developing the CETM

The codes which emerged from the findings in developing the CETM is referred as elements. The activities in CETM was created based on the documentations of Children's Engineering Educators, STEM education and Engineering is Elementary (EiE). Each of documentation has the features of activity guidelines and emphasized the cyclic process in designing the prototype. The design process guided the children through a systematic problem solving procedure that encouraged a clear understanding of a problem and challenged children to brainstorm multiple solutions. It was an organized approach to help children work through designing, creating, testing and evaluating prototype. In an overall design, CETM consists of features of the activity guidelines, cyclic process and classroom atmosphere. The following Table 3.6 shows the detailed elements that have been infused into the designed teaching module.

Table 3.6: Structure of CETM activities and learning environment

CETM		
Features of the activity guidelines	**Cyclic process**	**Classroom atmosphere**
Activity outline Scenario Design challenge Criteria Materials Tools Safely considerations	Understanding the problem Brainstorming solutions Creating the best prototype Testing prototype Evaluating prototype	Presentation (Collaboration)

The features of the activity consist of seven stages, the cyclic process consists of five stages and the classroom atmosphere has one stage involved. Each of the stage is described with examples apart from showing how the embedments of the research findings were infused into the CETM. The cyclic process and classroom atmosphere were the sequence carried out by children while designing the prototypes in the classroom. The cyclic process and classroom atmosphere were abstract since they were experienced by the children and not an instruction to be followed by the children. Meanwhile, on the other hand, the features of the activity guidelines were mentioned in each of the activity. Table 3.7 displays the embedment of elements for research questions one and two for seven stages involved in features of the activity guidelines.

Table 3.7: Features of the activity guidelines in CETM

CETM		
Features of the activity guidelines	**Elements of research question one**	**Elements of research question two**
Activity outline	Leaps of knowledge and systemic thinking	Prompt ideas
Scenario	Motivating discoveries, flexible thinking, open-ended problem and problem solving skills	Flexible guide
Design challenge	Critical thinking skills and designing goals	-
Criteria	Logical thinking	Sustainable engineering
Materials	Strategic thinking	Fostering curiosity
Tools	Engineering design	Engineering constraint
Safely considerations		Safety measures

Each of the features has at least one element embedded either from research question one or two, or from both the research questions. Each of the element embedment into the features of the activity guidelines is described using relevant examples in CETM activities.

Activity Outline

Many disciplines are integrated into each activity through the activity outline. In fact, the activity outline has been repeatedly mentioned by the experts in the findings. The activity outline in each CETM activity is guidance for teachers of how an activity is being displayed. For instance, an activity outline also slots in, the curriculum learning outcomes for each of the theme. All the five activity outlines in CETM are basic assistance for teachers to create and design their own activities in the future. Each activity outline in an activity consists of scenario, design challenge, criteria, materials, tools and safety considerations. The emerged elements that were embedded into activity outline are leaps of knowledge, systemic thinking and prompt ideas.

Each activity outline encourages incorporating inter-disciplinary fields in STEM education to develop leaps of knowledge in all the CETM activities. Each activity can have knowledge of science, technology and mathematics. For example, while designing a windmill prototype, children have to ensure the 1.5 litres of water bottle is filled with water. However, children will learn that the higher the volume of water in the bottle, the more stable the windmill stands independently. This step helps to incorporate the mathematical knowledge into the renewable energy concept of science while developing the windmill prototype. At the same time, while designing a metal tin robot, children are indulged into the technical aspects of improving the prototype, little realizing that their design integrated machinery appliance.

Systemic thinking which is embedded into the activity outlines can be taught from simple or straightforward concept to complicated or sophisticated understanding or vice-versa. Systemic thinking can be taught from idea to example concept or example to idea concept. Children can be guided to realize about two categories which are human made and nature created. Teacher can help the children to recognize the difference between nature and engineered materials. For instance, while reading aloud the problem or given challenge, the teacher can question how materials such as manila cardboard, newspaper and tissue paper were manufactured. On the contrary, the teacher can also reverse the situation by prompting the children by asking how natural resources such as trees, water and wind can be engineered into useful things or beneficial situations for the mankind.

Prompting ideas in creating activity outlines is a prerequisite embedment into the activity outline section. Teachers are encouraged to prompt simple and spontaneous ideas in creating activity outlines for CETM activities. For example, teachers could impulsively create an activity outline without channelling much energy and time because the idea of CETM is also not to give a burdening perception towards teachers.

Scenario

The first section of the activity explains the background of the challenge. The scenarios are covered in the class where they can be derived from a particular fact.

During this section, teachers will leave to the floor on how to solve the given situation. Children are encouraged to think and voice out their suggestions on how to solve the problem. Unexpected answers or discoveries that come from the children must be followed by praise and encouragements. The scenario includes five elements which are open-ended problem, problem solving skills, motivating discoveries, flexible thinking and flexible guide.

As facilitators, teachers do not solve or answer children's questions, but instead give open-ended problem or ask question to promote problem solving skills. These problem and open ended questions are embedded in the scenario. Similarly, each activity in CETM has an open-ended problem to promote the problem solving skills. For example, in order to come up with a solution for designing a plastic parachute, children were poised with questions such as "What is the best way" and "How could it be done". These questions give an opportunity for children to increase their capability in problem solving skills.

Challenging children with a restricted or given situation helps in motivating discoveries because discoveries can be inspired by combining everyday things in unusual combination and to add new ones too. For example, each scenario in the CETM activity consists of real life challenge faced by people across the globe. These real life challenges allow the children to be motivated and discover solutions using their own thinking. Real life challenges such as the need of an alternative energy, the need to explore minerals from other planets in space and the increasing chores for mankind that requires an unusual route in this modern era.

Every activity in CETM required the children to develop their flexible thinking to keep an open mind in facing the new truth about the world. For example, while designing the plastic parachute, children were aware that their knowledge and skills can be stretched to save other things or species apart from human alone. At the same time, children proposed a different solution such as designing a helicopter or a plane as a substitute to parachutes. Either way, children are encouraged to display balanced thinking for each of the scenario in the CETM activities.

The science curriculum should be one of the fundamental basics for scenario in the CETM activity. The curriculum should be a flexible guide in correlating the curriculum so that when the children are completing the challenges they are reinforcing skills taught and striving for mastery. Concepts such as renewable energy which are naturally replenished on human being such as sunlight, wind and waves are embedded in the science curriculum. Apart from renewable energy, other correlating science curriculum concepts such as saving the extincting species and enforcing stability using man made things were also encouraged in the scenarios.

Design challenge

Design challenge gives an overall view of the problem for children to solve where the varied means and norm are provided for each activity. Design challenge tells children what type of solution they can design to complete the activity. Design challenge was embedded with two elements which are designing goals and critical thnking skills.

Designing goals are mentioned in the design challenge of a prototype in an activity apart from being a platform for developing ownership for essential knowledge. For instance, in designing challenge of windmill prototype, children must create a windmill that stands independently and produces light. In designing challenge of metal tin robot, children must create a prototype that moves freely.

Critical thinking skills are also enhanced when children organize the ideas prototype because students will try to answer questions of ‘how’ and ‘why’ from either the teacher, group members or the design challenge itself. Critical thinking skills are an essential component to understand the challenge. Therefore, critical thinking skills in this section are a natural growth of presenting the challenge.

Criteria

Criteria in the activities represent specific detail about the finished designed prototype. There are three to four criteria in each activity. These criteria must be fulfilled using rational thoughts. There are two elements embedded into criteria section. These elements are logical thinking and sustainable engineering.

Based on the criteria, children must use their logical thinking in adapting the given scenario or circumstance. By moving into the logical paradigm, children must succumb to the fact that their solutions or prototypes must be based on their common sense as well as their thinking skills, knowledge and experience in the classroom or outside the classroom. For example, in order to design a plastic parachute that able to fly without floating left to right or otherwise, the plastic has to be big apart from having a small or balanced weight of supplies such as food and drink. Similarly, in order for having the windmill produce light, the logical criteria of ensuring the connections tightly fixed must be fulfilled.

Criteria in designing the prototypes also involve sustainable green design engineering. Children who have the interest in saving the world will be interested in sustainable green design engineering. In order to achieve this, children must be aware that they must design a prototype with a restricted environment by using recycling resources to achieve earth friendly prototypes. For instance, children have to design a plastic parachute using a recycled plastic, design a noisy metal tin robot by adjusting the cover cap of the recycled tin can and design firm windmill by using a used 1.5 litres mineral water bottle instead of 750ml mineral water bottle.

Materials

Materials are things that can become part of the finished design. For example, when a plastic is used in designing a parachute, the plastic becomes part of the completed design. It is not necessary to use all materials for the CETM activities. In this section, two elements are incorporated; they are strategic thinking and fostering curiosity.

Children are encouraged to use strategic thinking when considering how to use materials in new and different ways. The preparation of design challenge before the lesson helps to train the children to solve the problem in the CETM activities using tactical skills which draws towards strategic thinking. Strategic thinking assists children in adapting the existing challenge in each activity to ensure the most effective use of provided resources through organization. Teachers must provide for choices, time on task, conservation of materials, and smooth transitions from a traditional lesson to a hands-on lesson. For example, children could consider how to fulfill the plastic parachute design challenge which must be able to carry food and water without falling to the ground. Children can be seen not entirely using all of the materials and tools provided, instead strategically using things around them such as pencil, eraser and ruler. For example, given two types of mineral water bottle with diferrent volumes, the children are required think intentionally which bottle will fulfil the criteria of designing the prototype. In the same way, when children are provided with different sizes of cardboards, they must think critically with which cardboard size the end product of humanoid robot will stand firm.

Every designed activity has the possibility in fostering curiosity among children with the provided resources. Children will be inquisitive in holding, meddling and using the provided things because they don't see often these things in their classroom. For instance, children seldom get the opportunity to design windmills and metal tin robots since these prototypes involve mechanical and technical materials. Hence, children will be curious to use these materials to produce prototypes that they might rarely have the feel of designing themselves.

Tools

Tools are items used when creating the prototype but cannot become part of the prototype. For example, when a scissors is used to cut a plastic in designing a plastic parachute, the scissors doesn't become part of the design. This section has embedded one code which is engineering constraint.

Every activity deals with engineering constraint to alert the children in designing prototypes with the given resources. Children are encouraged to make the best prototype with the given resources. For example, in some activities, children might utilize the scissors to screw when the screw drivers were not enough. This is simply to observe what will be the reaction of the children when a tool was not enough for all of them. In short, children will be encouraged to make the best with what they have.

Safety considerations

Teachers must always use the tools correctly and follow safety procedures as mentioned in-detail in the designed CETM. Safety measures must be discussed openly with the children because it is an integral part while using the materials and tools in designing prototypes. For instance, while using sharp tools such as scissors and screw drivers, children must be reminded of the using these tools responsibly.

Children should design a prototype or solution for each activity. Children are encouraged to use the cyclic process during the design process. Table 3.8 exhibits the embedment of elements for cyclic process in CETM activities.

Table 3.8: Cyclic process in CETM

	CETM	
Cyclic process	**Elements of research question one**	**Elements of research question two**
	Opportunity and bridging the gap	Correlating the curriculum
Understanding the problem	Independent thinking	Recording ideas
Brainstorming solutions	Transferable skills, inductive reasoning and argumentative	Engaging engineering activities, optimizing alpha brain waves and emphasizing team work
Creating the best prototype	Deductive reasoning, mechanical reasoning, designing process and divergent mode thinking	Transforming ideas into practical situations and exploring future technologies
Testing prototype	Measuring intelligence and making decision	Encouragement
Evaluating prototype	Assessing	Building aesthetically and technically

Cyclic process

A cyclic process is the underlying principle for an engine or locomotive machine instrument. The same standard applies in CETM activities, especially while creating prototypes. While creating a prototype in CETM activity, children are stimulated to go through cyclic process. In this subdivision, two elements are incorporated and they are opportunity and bridging the gap.

Designing each prototype using cyclic process is an opportunity for empowering mind boggling thinking among children. Every cyclic process in the CETM is a chance to enhance the children's intellectual skills by manipulating their emotional and psychological overwhelm. For example, cyclic process allows children to spread out the workload of the group more evenly. At the same time, cyclic process allows the children to encourage user feedback, so as to elicit the prototypes' real requirements.

Cyclic process also emphasizes in bridging the gap between memorization of fact and the understanding of skills and processes through expression in difference of opinion. For instance, children can recall the renewable energy concept which they learnt during science lessons to produce the windmill prototype. Subsequently, cyclic process enables the group members to leverage lessons learned, and therefore to continuously improve the designing process.

In the cyclic process, designing a CETM prototype starts and returns to the inital state. However, the cyclic process undergoes five stages to complete the designing process of a prototype in the CETM activities. The cyclic process consists of understanding the problem, brainstorming solution, creating the best prototype, testing prototype and evaluating the prototype.

Understanding the problem

The first step in applying the cyclic process is to make sure that children understand the problem. The teacher can observe at each group and listen to the children' ideas. The teacher may also choose to have the children dictate their ideas so they can be recorded. Understanding the problem section involves two elements embedments which are independent thinking and recording ideas.

Children must try to restate the problem in their own words by using their independent thinking. For example, children can write what comes to their mind especially other than what's stated in the given scenario. The response can be simple yet shows their independent thoughts in their feedbacks. This is because an autonomous situation is achieved when children use their independent thinking in solving the given challenge. At the same time, children are supposed to write using their own mind without referring to their group members.

One of the most important efforts in understanding the problem is documenting the work, clearly communicating the solution to the design problem so the teacher can understand what the children have written. The explanation and reasons are assessed by looking into what the children are trying to say in regards with the problem given to them. In order to achieve that, children must be recording ideas by writing down their thoughts. Verbal expressions are crucial but black and white written evidence is equally important for the teachers to assess. Hence, in order to make sure that the children understand the problem, children are encouraged in recording ideas by restating the problem in their own words.

Brainstorming solutions

The second stage in cyclic process is brainstorming solutions. Brainstorming solutions involves accepting all ideas. Visualizing the materials allows children to grasp the limitations of the problem they need to solve. They are not to begin building solutions yet. However, children should be encouraged to generate as many possible solutions as they can. There are six elements incorporated into brainstorming solutions and these elements are engineering design, transferable skills, inductive reasoning, being argumentative, optimizing alpha brain waves and emphasizing team work.

Engineering design is an important component for brainstorming solutions because notion of engineering design represents that there are multiple ways to solve a problem. Different solutions fit different collective needs at different times. For example, children are encouraged to design various types of humanoid robots based on the given scenario. The design of each humanoid robot shall not be the same sincee they will be based on the imagination of each child in a group. Hence, each humanoid robot could not only represent the child's different solutions but also symbolizes the solution for the future of a developing nation such as Malaysia.

Transferable skills such as the ability to use stationary utensils help to incorporate children's sketches into learning outcomes of the activities. Children's ability to use rulers for measurement and pencils for sketches provided the platform for transferable skills. Apart from that, children's imaginations and experiences through observations also can be transferred into their sketches while brainstorming solutions. For instance, some children displayed their handy skills in sketching prototypes using proper measurements meanwhile others can exhibit their knowledge based on observations into their sketches.

While brainstorming for solutions, children can discover that no solution is a perfect solution. Inductive reasoning encompasses on trial and error since a perfect solution is not possible in a convincing design prototype. This is because solutions to engineering design problems do not magically appear. Ideas are generated when children are free to take risks and make mistakes. For example, when the sketched design does not appear to be answering the solutions, it does not mean that the child has failed. On the contrary, this helps the child to reason inductively to design the prototype that fulfils the criteria.

Argumentative is an evidentiary protest raised in response to a question which encourages a child to draw inferences from facts of the CETM activity. Being argumentative among children comes in handy when their different explanations are observed while brainstorming the solutions in their respective groups. These arguments could lead to different thoughts of mind that enhances higher level thinking among children. For example, children can disagree, provoke or even create a friendly dispute among group members because this could display their argumentative abilities in reasoning especially when they either agree or disagree with the solutions.

Optimizing alpha brain waves in a child's brain can be evident in brainstorming solutions while designing CETM prototypes. Sketching ideas helped children to visualize how different sketches parts or ideas are combined; resulting in a better design. Every activity in CETM inspired the children to make sketches. These diverse solutions can be represented through design sketch by the children. Sketching and describing some possible solutions were brainstormed in this section. Children were given a chance to sketch their imagination design through visualization. They discussed and observed on each other's design. Hope added that sketches act as a bridge between the inner world of imagination, reason and outer world of communication which reflects sharing ideas. Meanwhile Bartel (2010) mentioned that sketches help to develop the mental abilities of children because the mind is always thinking during the sketching process.

Brainstorming at this stage is often a team effort in which people from different disciplines are involved in generating multiple solutions to the problem. Emphasizing team work was integral to the success of the entire group members in designing the prototypes during the activity. Each child brought different strengths to the team, without which the team can't function as efficiently. Every activity was participated by at least six children. Communication skills and patience were valuable assets when working with a team of children.

Creating the best prototype

While creating a prototype, children with various abilities can express their skill acquisition through design process. Children can try to master the skills from other group members and move forward to the next level in CETM activity. Teachers are able to reach different ability learners such as linguistic, visual, audio and social. Hence, apart from infusing reasoning skills, these skills could also be observed as not all children come with the same set of skills or background. Through designing process, these skills can be assessed. There are seven elements embedded into this section. These elements are designing process, deductive reasoning, mechanical reasoning, engineering thinking, diversity mode thinking transforming ideas into practical situations and exploring future technologies.

Designing prototype involves the process of designing the prototype during the teaching and learning in the classroom. Designing process encourages a clear understanding of a problem and challenges children to brainstorm multiple solutions. Both understanding of a problem and brainstorming solutions must finally lead to a decision in creating the best prototype for an activity. Apart from that, while designing the metal tin robot and windmill prototypes, children can also display the ability of technical skills by using screw drivers and scissors.

Deductive reasoning works through the use of guidelines, prototypes and characterizations (Fisher, 2005). This is parallel with the notion of creating prototypes during the CETM activities. At the same time, deductive reasoning also allows children to make inferences logically between the more general and the less general (Costa, 1990). For example, when creating the humanoid robots, children can observe for themselves the creation that stands firmly are the ones with balanced cardboards as compared to the imbalanced arrangements. Hence, this experience of creating prototypes can help them conclude logically. Similarly, deductive reasoning also helps the children in deriving the conclusions from the given evidence to form the best solution in designing the prototype. For instance, based on the sketches and arguments, children can emerge with a conclusion of using specified way to design the best prototype for their group.

Mechanical reasoning involves power-driven concepts using motors (Petroski, 2003; 2010). The idea of how the prototype machines work is fundamental to the real-world tasks (Petroski, 2003; 2010). For instance, designing a windmill emboldens the assimilation of mechanical reasoning because windmill represents machine functions and the type of energy it produces. Correspondingly, creating a metal tin robot also involves the assemblement of technical gadgets such as motors and wires apart from dissecting the cause which hinders the prototype from functioning (Petroski, 2010).

Engineers make things that work or make things work better (Regan, 2010). Engineering thinking encourages the children not be afraid to try different ways of designing until they find one they like because engineering thinking give the prospects of endless possibilities (Petroski, 2010; Regan, 2010). This idea is similar in the CETM activities because these activities provide possibilities in creating the right solution for each challenge. For example, different types of plastics and different weights of wooden beam are provided to children to design a plastic parachute. The different materials offer the alternatives in creating the best plastic parachute since it has to fulfil the given criteria as well.

While creating prototypes, children can be involved in divergent mode thinking since it gives the prospect of generating many different answers. For example, designing humanoid robots using cardboards produces endless type of prototypes. All of the prototypes share the same criteria which are to stand independently. However, divergent mode thinking helps children to realize that when wide varieties of minds work together, the possibility to create more detailed and better designs is higher. Over a period of time, teacher can help to make sure that children can have divergent thinking skills so that they can help each other in creating many different answers or prototypes especially by using the same materials.

In fact, according to Runco and Acar (2012), divergent mode thinking or different viewpoints also often lead to originality and originality is the central feature for stimulating creative thinking skills. For example, children come out with unexpected solutions and alternatives during the CETM activities that revolved around different viewpoints. These unexpected solutions and alternatives were indicators for creative thinking because Hocevar (1981) had identified different viewpoints as one of the indicators that enhance creative thinking skills.

Children can act like engineers by transforming ideas into practical situations by coming up with specific designs. Children could feel appreciated because they have come up with a solution to solve the given problem in the activity. For instance, when children try to create a prototype that produces light, noise and movement; children have the belief that they have transmuted raw materials and tools into a useful product for the use of all mankind. Children are also stimulated to think beyond classroom walls and use their knowledge in overcoming a certain scenario in real life.

Some of the most amazing inventions on the market today can exist because exploring future technologies are crucial be initiated at an earlier stage of learning (Petroski, 2010). Though the teacher would have prepared the materials and tools to design an unfixed or irregular solution, the teacher must also be open to children's way of solving issues because there are possibilities that their way could be better than the teacher themselves. For example, children might fall short of their potential because they grab at the first idea or solution that presents itself. However, first ideas can be a common trite. Through CETM activities, children are able to explore future machinery equipments since prototypes such as metal tin robot and windmill help children to move beyond their ideas apart from considering alternatives before making decisions.

Testing prototype

The stage of testing a prototype is a fully operational production of the complete design solution (Stapelberg, 2009). The purpose of the testing prototype is to test the design solution under the given criteria for each of the CETM activity. A total of three elements such as measuring intelligence, making decision and encouragement are embedded into the testing prototype section.

Children in groups may have already preformed informal tests along the way as they worked through the design process. This prototype testing takes place as a way to determine if the design needs to be altered. Testing the prototypes does involve measuring intelligence. The sequence of testing their solution does inspect the HOTS allied cognitive loads which are related with the children’s brain process. For example, a windmill design would first be tested as a scale model by turning the blades using fingers. Turning the windmill blades without getting it attached to a mineral bottle, would generate information to be used in constructing a full-size prototype of the windmill. After testing the CETM prototypes under expected and unexpected operating conditions, the prototypes are brought into full creation.

This testing takes place as a way to determine if the designs need to be altered and children must decide whether their solution is good enough or still in need for a repair work. Making decision at the end of testing prototype stimulates children’s higher mental processing for each of the CETM activity. Children should come to a consensus about which criteria that has hindered them from creating the prototype. For instance, when metal tin robots move without vibrating and making noise, the children should decide on which section of the prototype that needs to be altered. They should be jugde this unanticipated situation by extending their thinking apart from making a decision on what can be done to overcome this surprising challenge.

Each time the children test their designed prototype, the encouragement of getting involved further into the design or future design activities can be boosted. Binet (1908) who was an early psychologist believed that children with adequate encouragement could be trained to become more intelligent in their thinking. For example, when a prototype is tested, children could see a light in windmill prototypes feel the vibration and hear the noise of metal tin robot prototypes and observe the movement of plastic parachute prototypes. These responses from designed prototypes can create further interest that could lead an intrinsic satisfaction among children.

Evaluating prototype

After the testing process, children can be brimming with ways to improve on their design. In this section, two elements are involved and they are assessing and building aesthically and technically.

Having the children assessing their prototype provides space to reflect over the activity. Children discuss what they would change, what they would keep the same and if there is something they might add if they were to build it again. For instance, though the purpose of metal tin robot is to transfer the minerals from Moon to Earth, this prototype does not come with a carrier or basket. Hence, children could add a basket or transporting equipment into the metal tin robot. At the same time, children beautified their designs by shading on their designed prototypes.

The CETM prototypes involve the features of sustainable green design engineering, electrical engineering and mechanical engineering. For example, windmill prototype reflects on electrical engineering, metal tin robot prototype reflects on mechanical engineering, plastic parachute and humanoid robot reflects in sustainable green design engineering. In fact, building a prototype aesthetically and technically provides the idea of how the responsibilities of engineers and architects often overlap.

Children can have the opportunity to act as an architect and engineer while assessing a prototype (Petroski, 2010; Stapelberg, 2009). Architects design the space to meet client needs, as well as the aesthetic appearance of the inside and exterior of the building (Petroski, 2010; Stapelberg, 2009). Engineers' main responsibility is to ensure the design is safe and meets all appropriate building elements (Petroski, 2010; Regan, 2010; Stapelberg, 2009). A child can assess a design using the sketches created. At the same time, another child can go over the design and decide what materials must be added or removed to make the prototype to completion and fulfill the criteria in the activity outline.

With this step, the cyclic process is completed, depending on the prototype and group members. On the other hand, the learning processes in the classroom during the CETM activities are equally crucial. Table 3.9 demonstrates the embedments of elements for the classroom atmosphere in CETM activities.

Table 3.9: Classroom atmosphere in CETM

CETM		
Classroom atmosphere	**Elements of research question one**	**Elements of research question two**
Presentation	Connecting ideas	Expressing own words, nurturing thought provoking atmosphere, cooperative learning and collaboration learning

An overall classroom atmosphere should consist of expression of own words, connecting ideas, nurturing thought provoking atmosphere, cooperative learning and collaboration learning.

After evaluating their prototypes, children present their design by expressing own words in an oral presentation. Children can present their designed prototypes by speaking clearly and confidently. Freedom of speaking is crucial because it could lead to democratic learning in the future.

While a group is presenting, other groups should observe on how to connect the ideas between the design process and the final prototype. Children can continue to improvise their designs while simultaneously looking at the presentation of other groups. For instance, children can improve their designs by absorbing the design ideas from a different group. These chains of idea can be connected between what they observe from other groups and discussion with their group's members to continue the invention of their prototypes.

Nurturing thought provoking atmosphere is the role of the teacher because it leaves the options open for children to explore and learn while presenting their prototypes. Teacher listens and shares their comments in the form of questions. For example, teacher can provoke the children to ask questions during the presentations. Spontaneous questions that test the children's response can be asked. Questions such as how does the windmill blades move, why have you inserted a tin can into a metal tin robot, how can you create movement in humanoid robots and how to make a plastic parachute fly longer can trigger the children's mind.

Cooperative learning involves the use of small groups so that children work together to maximize their own and each other's learning. When a child is presenting the prototype, the other group members can support and help the child to either hold the prototype or answer some of the questions poised to them. Children can conclude that each group member can only succeed if all the group members succeed in which the teacher facilitates small groups of children toward achieving the group goal. Children work together towards a common or shared objective. Meanwhile the teacher can observe the children and take anecdotal notes while they the present.

In a collaboration learning environment, children can agree on fundamental issues of the CETM activities. All children can strive to be well mannered and disciplined apart from working continuously within the science time period. When children are interested and engrossed with these activities, children can encourage each other not to make unnecessary noise during the science lesson. Children can also support and help other group members from different groups in solving their challenges. For example, children who are skilful in screwing the nuts can help other group members to fix the connections for their prototypes. Children can also help to answer the questions raised regardless from which group they are from.

Embedding the elements into the designed CETM

Some of the elements embedded into the CETM were print screened and attached in Appendix 5. These elements were suppressed and arranged through a structured sentence to rationalize the embedment process for the entire CETM advancement. Others were mentioned individually with some explanation about the embedment into the CETM activities. In line with that, some of these elements embedment was suggested by the Delphi experts based on their expertise. Meanwhile some of the elements were suggested by the researcher based on the literature reviews. Some of the suggestions were accepted by the experts whereas some did not reach mutual consent. These embedment stage was carried out in a cautious manner though it was time consuming since each of the expert's response had to be taken into consideration. Supervisors of this study also gave some crucial feedback and their opinions were useful since they themselves are experts in the science education curriculum.

CETM Rubric Assessment

This study used holistic rubric for assessing children's performance in CETM activities. Holistic rubric gives the teacher and children a summary evaluation of an activity (Maurer, Pleck & Rane, 2001). Holistic rubrics are ideal for evaluating children because holistic rubrics can be done quickly apart from reflecting a clear criterion (Maurer, Pleck & Rane, 2001). This is in line with the Malaysian Education Blueprint 2013-2025 since Malaysia aspires to educate and evaluate the children holistically. In fact, Malaysia intends to develop the children holistically in order to have the necessary values, knowledge and thinking skills to succeed particulary in the STEM education.

The rubrics in this study were designed using references from literatures reviews, EiE programmes and suggestions from experts (see Appendix 6). Teachers or researchers can write their own rubrics or select a rubric for use from among the many that are available on the Internet or in curriculum materials (Brookhart, 2010). The rubrics in this study has five scales whereby they measure whether or not the children meet the criteria and if they do, how far have they met the criteria in an activity. Wiggins (1993) says that scoring rubrics need to be able to discriminate between performances and performances of different degrees of quality. Therefore, these scales for the rubrics were designed based on scales offered in early engineering references.

This study also selected and wrote rubrics that describe qualities (e.g., "reasoning is logical and thoughtful") rather than count things (e.g., "includes at least three reasons") because it was helpful when the same general thinking or problem-solving scheme was applied to other CETM activities. According to Brookhart, children will learn that the thinking and reasoning qualities described in the rubric as their "learning target" and can practice generalizing them across the different activities as in the CETM. Brookhart added that the advantage of using such a general framework as the basis for scoring all kinds of work is that children will come to see the types of thinking expected in the general rubric as learning goals. Similarly, children will be able to practice and work consistently in CETM activities toward these achievement outcomes.

Once the rubrics and scales for the CETM activities were designed, they were sent to two experts for refinement and improvement. These experts are professional in designing rubrics for children's assessments and they were well aware of the CETM's intention in promoting HOTS and reasoning skills among the children during the science lessons. The detailed version curriculum vitae is attached in (see Appendix 7). The experts involved in looking into the rubrics for CETM assessment offered constructive ideas in developing the set of rating scales for the CETM rubrics. The first expert mentioned that a rubric contains details in each cell that help the teacher decide which cell to use for each judgment. This was parallel to the rubric in CETM.

The first expert gave examples of rubrics and scales but she did express that rubrics can't be 100% perfect but still they should lead towards reliable judgements. Meanwhile the second expert agreed that adapting rubrics and scales based on reliable articles and references are acceptable as long as the existing rubrics meet the specific purposes for CETM. In fact, the second expert also mentioned that evaluating the rubrics qualitatively by seeking verbal feedback was sufficient for in designing the rubrics for CETM assessment. However, the first expert advised to pilot test the rubrics in CETM assessment before investing a lot of time using the rubrics. Consequently, the designed rubrics for CETM assessment were pilot tested in a primary school to gain further feedback in improving the rubrics and scales for the CETM activities. Once these activities were piloted and the shortcomings were noticed, some improvements had to be adjusted both in the content and the CETM rubrics.

Developing Five Activities in Children's Engineering Teaching Module (CETM)

All the five CETM activities were designed based on the Malaysian curriculum in science subject. Table 3.10 shows the themes, selected topics, learning outcomes and the CETM activities.

Table 3.10: A summary of themes, topics, learning outcomes and activity

No.	Themes in science syllabus	Topic	Certain examples of point form learning outcomes	CETM activities
1.	Investigating living thing	a) Survival of species	i) The importance of species survival	Plastic parachute
2.	Investigating force and energy	a) Energy b) Electricity c) Light	i) Various sources and forms of energy. ii) Renewable energy iii) Examples of appliances that make use of energy transformation	Windmill
3.	Investigating materials	a) Three states of matter b) Changing states	i) Matter that can be classified into solid, liquid, gas.	Soap bubbles
4.	Investigating the earth and universe	a) The earth, the moon and the sun	i) Moon and its importance	Metal tin robot
5.	Investigating technology	a) Strength and stability	i) Shapes of objects in structures ii) Factors that affect the stability and strength of an object and structure	Humanoid robot

Be noted that, not all of the learning outcomes mentioned in the above table. For every theme in the syllabus, a CETM activity was designed to fulfill the learning objectives of the theme apart from promoting HOTS. Each activity was aligned with the syllabus and curriculum to ensure that the engineering design activity is within the context of teaching and learning science.

The designed CETM consists of five activities because Year Five science syllabus has five themes and each activity here is designed to accommodate each of the themes in the current syllabus. Besides than that, based on the needs analysis, curriculum analysis and literature reviews, most primary school teachers were unfamiliar with the children's engineering. It was observed that teachers will be gaining their first-hand experience with CETM activities and design challenges. In both content and structure, CETM activities differ substantially from most traditional science textbooks. Hence this was the reasons as to why this research has planned to develop five activities. This is to ensure that the teachers are thoroughly familiar with the five activities that their children will be doing in the classroom.

Each of the activity in the CETM was initiated with different levels of difficulties. The activities were labeled as easy, medium, difficult and challenging problems. All the five activities have been embedded with different learning outcomes and the amount of learning outcomes vary from one activity to another activity. The activities which incorporate more learning outcomes has been labelled as challenging problems, followed with difficult, medium and finally easy.

For example, Activity Four (metal tin robot) has been labelled as the challenging problems because it includes Four different learning outcomes. Activity Four encourages children to have the following learning outcomes at the end of activity:

a) Children learn the source of electricity.

b) Children learn the various sources of energy.

c) Children learn some aspect of technology concept.

d) Children learn the importance of minerals in the planet Moon.

The other activities have fewer learning outcomes that need to be taught or learnt. Hence, the sequence of difficulty in CETM activities is displayed in Table 3.11

Table 3.11: Sequence of difficulty in CETM activities

Sequence of difficulty		
No.	**Activity**	**Level of difficulty**
1.	Metal Tin Robot (Activity Four)	Challenging problem
2.	Windmill (Activity Two)	Difficult
3.	Plastic Parachute (Activity One)	Medium
4.	Humanoid Robot (Activity Five)	Medium
5.	Soap Bubbles (Activity Three)	Easy

Apart from learning outcomes, each of the activity has different level of difficulty because the activities have different level of technicality. Some activities can be completed faster whereas some takes time to be completed. For instance, designing humanoid robot takes lesser time as compared to designing the windmill prototype. The least amount of time used by children is while carrying out Activity Three. Meanwhile, designing metal tin robot is the activity that takes the most amount of time to be completed. Parallel to that, the tools and materials used to design the prototypes also differ for each of the activity. Some activities employ simple and light utensils whereas some activities need more practical and mechanical utensils. For example, in order to design the humanoid robots, card boards were the fundamental materials needed. On the other hand, in order to design the windmill prototype, materials and tools such as nuts and screw driver were encouraged to be used. In the nutshell, the sequence of difficulty among the activities were based on the learning outcomes, duration to design the prototype and the type of tools and materials used to design the prototypes.

Piloting the developed CETM

A classroom of 24 children in a primary school was chosen in a state called Selangor. However, only two from the five CETM activities were carried out in this sub-urban school because the purpose was to just get some feedback on the overall CETM activities, including the rubrics. The pilot test stage was carried out within two weeks. Activity One (plastic parachute) and Activity Two (windmill) was piloted among the children during the science lesson. These activities were carried out by the researcher himself in order to check for any limitations or drawbacks that the developed CETM activities had. On the other hand, the science teacher of that school observed and went through the rubrics developed in CETM activities. The teacher gave some ideas and feedback on rating the rubrics and scales after the pilot testing.

Test Reliability of CETM Rubrics

All the five CETM activities has developed similar rubrics to assess the children's performance in HOTS and reasoning skills. CETM activities come up with alternative prototypes but has similar pattern of assessment task to complete with the same scoring rubrics. After the pilot testing, the researcher and the teacher concerned gave their respective evaluations for the first activity. The score ratings were compared. In the same way, the second activity was carried out in the second week and the score ratings from the teacher and the researcher was compared. Since both the activities involved the same process, there was a similarity in the ratings. There was no major difference in both the evaluations for both the CETM activities. The rubrics for CETM assessment were concluded to be a broadly reliable measure for the children's performance in the activities.

On the contrary, every assessment instrument has an error measurement or fluctuation in scores depending on testing conditions, the mood of the child and even interpretations of the activity questions (Maurer, Pleck & Rane, 2001). For instance, it is reported that research performances assessments have about the same error variance as that reported for standardized tests (McTighe & Arter, 2001). In line with that, CETM rubric assessments could also differ especially from the lenses of different perspectives across various fields in science education.

Validating the CETM Rubrics

A predictive validity was incorporated in this study by asking experts what he or she would expect in all other CETM activities based on the designed rubrics. Consequently, two foreign experts and two local experts from secondary schools provided some constructive feedback. Further improvement in CETM rubrics were prepared based on whether the rubrics reflected the thinking skills necessary for HOTS, did the rubrics emphasized significant knowledge and important concepts and were the rubrics adequately differentiates between superior, adequate and substandard performance.

Although using rubrics can be a positive experience for teachers and children, the use of rubrics does not substitute for one on one dialogue or conversations teachers have with children to explore understandings or misconceptions (Butler & McMunn, 2006). In short, rubrics are not the answer to everything in a teaching and learning process because eventually a teacher's personal judgment on how a child progressed in an activity is also important, especially for an authentic reflection in assessing HOTS and reasoning skills during CETM activities.

Once the rubrics for all the five CETM activities were considered as reliable and valid in a general outlook, the elements which merged from both the first and second research question were embedded into the activities to complete the overall design and development of the CETM.

Comprehensive CETM Validation

After all the elements were embedded into the activities, CETM underwent an overall validation to ensure that the entire CETM is valid and useable. CETM was validated using content validity and face validity. Wiggins (1993) mentioned that the need of content validity was important because a well-designed performance assessment such as CETM must not only cover the objectives and learning outcomes but also display the contexts and the 'feel' of real world challenges. The designed CETM and along with the learning outcomes that was wished for the children to master was given to a few experts to further verification.

Almost all the experts involved in designing CETM gave some feedback about the overall CETM design. However, there were four experts who gave detailed response in validating the completed CETM. Two of the experts were involved in designing the CETM during the online interviews. Meanwhile the other two experts were not involved in designing the CETM but they were specialists in STEM education and science education field. Their curriculum vitae was attached in the Appendix 8. Some of the examples on how the content of CETM was validated are conferred here. After looking into the CETM, the experts were satisfied with the learning outcomes and the context of CETM in an overall view. Still a local expert questioned on the understanding of the children in one of the CETM activity;

> …I am not sure how a primary school child would be able to relate the soap bubbles with the black holes. Do primary school children know what a black hole is?

Activity 3 was still designed and implemented despite of the experts' criticism and opinion because the number of experts who gave negative feedback on Activity 3 was not many. Apart from that, some of the online experts suggested that Activity 3 was high level since CETM activities also aspires to increase the inter-disciplinary knowledge among the children while doing science in the classrooms.

Another feedback from an expert in another CETM activity was;

> …give mileage to the moon (Activity 4) and have children guess how long it might take to get there.

If the assessment looks as though it measures what it promises to measure, the assessment has face validity (Butler & McMunn, 2006). The same experts gave some feedback in holding the children's attention and motivation for CETM activities. The experts raised a few doubts in matters involving the design of CETM. Some of the qualms were similar with one another. For example, an expert mentioned that;

> …the designs you came up with for the kids to build are cute. Do they enjoy following your instructions?

The same concern was raised by another expert when the response was;

> ...why do you provide very detailed step by step instructions? You have removed most of the design work and thinking. Leave much more of the task open for the children.

These experts suggested that the activities in CETM must be designed entirely on open-ended basis without any type of aid through directions on how to design the prototype for a challenge provided in the activity. Subsequently, another similar response derived from the local expert was;

> …this module can be considered well designed and it has good potential to be applied in our education. It integrates various type of thinking skills and the STEM education approach to science education. However, I wonder why don't you give open-ended questions to explore more on the students thinking?"

Meanwhile, one of the comments that was brought up by an expert;

> …very nice activity! You really have a great product here. However, you might want to think about adding some pre and post assessment questions. These would be different from your brainstorm session that the teacher is facilitating rather this would almost be a like pre and post quiz.

Not all the views and ideas were taken into consideration in improvising the developed CETM. This is because, other issues such as time management, local curriculum context and the atmosphere in teaching and learning at classrooms also must be taken into reflection. Since this study could be a maiden attempt in local education system, the other well organized ideas are kept in mind for further development of CETM in future.

In order to alert the higher education representatives, this study gained the approval from the Ministry of Education (MOE) (see Appendix 9). Subsequently, the official letter from the education department in the state of Perak was also received (see Appendix 10). Finally, the school where the CETM was implemented also gave the approval to allow this study to be carried out among the teachers and children during the science lessons (see Appendix 11).

The Final Outlook of the Developed CETM

This study is in line with design layering and ID of Gibbons (2004) who describes a set of layouts derived from the functional properties of virtually all IDs. Gibbons has explored issues surrounding the knowledge educational designers' use and how that knowledge is represented, drawing from diverse fields of design practice, especially engineering and architecture (Boling & Smith, 2012). Hence, the outlooks of CETM layouts are based on content, strategy, message, representation, media-logic and data management.

Figure 3.3 displays the front cover of CETM. There are three main elements in the front cover and they are the copyright of CETM, the title along with the abbreviation and the year. The title was designed with the largest font size to advertise its importance to the teachers. Meanwhile the university logo is in colour to address the recognition needs of the exclusive rights.

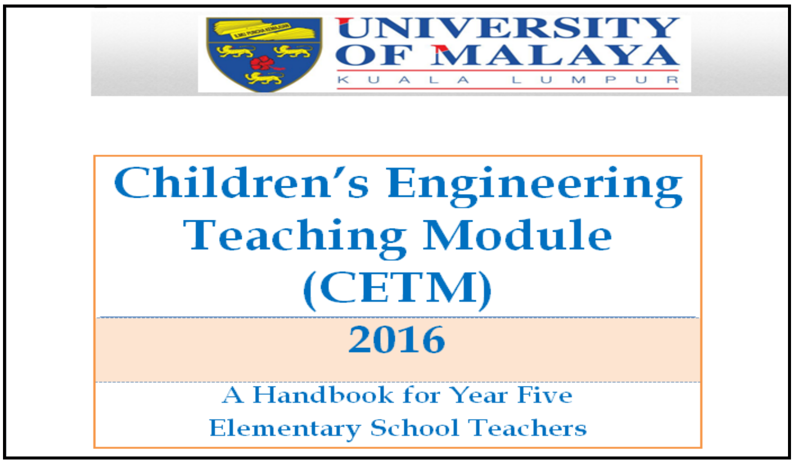


Figure 3.3: Front cover

Figure 3.4 shows the table content of CETM. The structures of CETM subject matter was specified in the table content and the pages. The content was divided into three main units which are background, implementing children's engineering activities and children's engineering activities. This division is to help the teachers in describing how elements of subject matter made available to instructional functions performed by other sublayouts which are in bullet forms. These sublayers represent specialized CETM design that result from the breakdown by functionality of the entire CETM ID.

Table Content

Content	Page
A. Background	2
• What is Children's Engineering Teaching Module (CETM)?	2
• How do children benefit from Children's Engineering Teaching Module (CETM)?	2
• The design process	2
• Understanding the cyclic process	3
• What is the problem?	3
• Brainstorm solutions?	3
• Creating the solutions you think the best	3
• Test solution	3
• Evaluate your solution	3
• Present your solution	4
B. Implementing Children's Engineering Teaching Module (CETM) Activities	4
Introduction to writing design briefs	4
What is a design brief?	4
Hints for choosing topics for everyday design briefs	4
Assessment	4
• Authentic assessment	4
• Rubrics	4
• Deciding criteria	5
• The elements of higher order thinking skills (HOTS) and reasoning skills embedded in the CETM for the teacher to evaluate	7

Figure 3.4: Table content

Figure 3.5 demonstrates the early stages CETM content. CETM used tactical yet simple language of message structure. According to (Morrison, Ross, Kalman & Kemp, 2013), translating the design into an effective instructional unit requires more than simply 'writing' the instruction. The message layouts throughout the CETM were designed to allow the communication between the content derived information and the teacher in a formal practice. Each important heading was bolded in black to emphasize the significance before giving the structured and organized explanation.

Children's Engineering Teaching Module (CETM)
Kamaleswaran (PHA110042) University of Malaya

A. Background

What is Children's Engineering Teaching Module (CETM)?

CETM is a teaching module that helps the teacher to encourage the children to deal with the doing and making in the elementary science classroom. CETM encouraged the integrated STEM education into the elementary science education.

How do children benefit from Children's Engineering Teaching Module (CETM)?

Based on the research findings from this research, three conclusions can be made. The conclusions are:

(a)	CETM enhanced Higher Order Thinking Skills (HOTS) and reasoning skills among children.
(b)	CETM features has encouraged the children to improve their HOTS and reasoning skills. The CETM features were: i) practice of cyclic process in designing a prototype, ii) the variety of features in an activity to express children's answers, iii) the essence of learning beyond curriculum content and iv) the involvement of sustainable engineering design in the activities.
(c)	CETM enhanced children's motivation and interest in learning science.

Figure 3.5: Content layout

Figure 3.6 exhibits the diagram which explains the cyclic process in CETM. Although the written explanation has been narrated in CETM, diagrams are also embedded into CETM. CETM highlights the media logic layout whereby the design processes such as cyclic process is described in a simplified sequence. This layout shall make things easier for the teacher's understanding. In fact, teachers can save time in digesting the core of CETM in implementing the designed activities. The usage of colours and shapes such as rectangles and arrows help the teacher to remember the information for a long period of time.

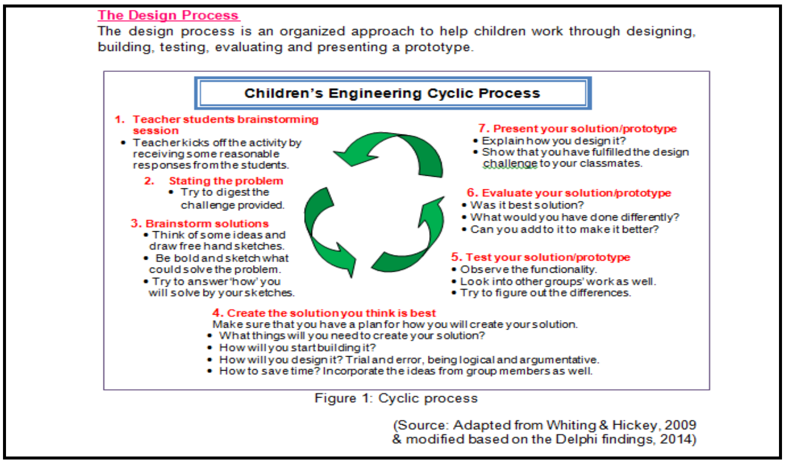


Figure 3.6: Coloured media-logic layout

Figure 3.7 describes the data management layout in CETM. Data management layout in CETM helps the teacher to display the specified data that can be captured, archived, analysed, interpreted and reported during the CETM activities. This stage is in line with instructional theory of Gagne because it helps the teacher to reinforce the acquisition and performance by children apart from confirming the accuracy of children's learning. At the same time, the expected performance while preparing the activity outline can be observed and evaluated using the data management layout.

The elements of higher order thinking skills (HOTS) and reasoning skills embedded in the CETM for the teacher to evaluate

No.	Checklist for CETM rubrics (Based on early engineering articles, Engineering is Elementary (EiE) program, Children's Engineering journals, HOTS rubrics (Allen, 2006) & Delphi findings 2014)	Elements of HOTS based on Delphi findings (based on emerged themes), literature reviews & HOTS rubrics (Allen, 2006)
A.	**Teacher students brainstorming session**	
1.	Argues with teacher or with classmates or little or nothing to do the discussion.	a) Argumentative
2.	Offers some ideas to the group but the ideas are not original, are not presented in sufficient detail, or are only vaguely related to the problem being considered. Generally respects other are ideas.	a) Argumentative b) Transforming ideas into practical situations
3.	Offers reasonable ideas based on everyday experience and respect the ideas offered by others.	a) Argumentative b) Transforming ideas into practical situations c) Motivating discoveries
4.	Offers unexpected, creative or unique ideas relevant to the task and respects the ideas offered by others.	a) Argumentative b) Transforming ideas into practical situations c) Motivating discoveries d) Exploring future technologies

Figure 3.7: Data management layout

Figure 3.8 displays the CETM activity given to the children during science lessons in the classroom. The pattern is the same for each of the other activities but the content differs to yield a different solution for every challenge provided. During the brainstorm session, teacher can give short quiz on the challenge given to gather the children's responses. This effort is parallel with the instructional theory of Gagne which cues the retrieval of children's previous knowledge through their ideas in producing the appropriate solutions. Teacher can help children to transfer their learning in the CETM activities.

Activity 1: Plastic Parachute

During class, we have talked about animals need food to survive. Currently country X is having a horrible dry season. The panda species in country X is suffering, in fact many have died. Panda's main food is bamboo shoots and when there is less bamboo, the panda population will be affected. What is the best way to send bamboo shoots to the panda species? How you can help to send bamboo shoots and water to save the panda species from extinction?

(Source: Fox, 1984)

- Teacher helps to create brainstorm session to gather student's responses. Teacher should leave the answers open by not restricting students suggestions.

(5 minutes)

Design challenge (One of the design ways)

Design and build a parachute that can fly at least for 10 seconds from place it is floated. Supplies such as food and water must be tied to the parachute without falling to the ground.

Criteria:

Your parachute must:

- Consists of the plastic.
- Be able to fly without floating from left to right or otherwise.
- Be able to fly with the supplies even with the increase of the wind speed.

Materials: *(What can you use?)*

(Your teacher might give you the materials you can use in a paper bag to help you track of them)

Figure 3.8: First layout of Activity One

Figure 3.9 refers to the second page of the CETM worksheet after introducing the design challenge, criterias, materials and tools. The blue colour which is the brighter colour as compared to the black colour font highlights the necessity of response from the children. The underlined words also show that it is crucial to encourage independent thoughts from the children. This layout is corresponding with the Piaget's theory of presenting the problems that require logical and analytical thinking. Children's feedback could be one of the ways of presenting the challenges given.

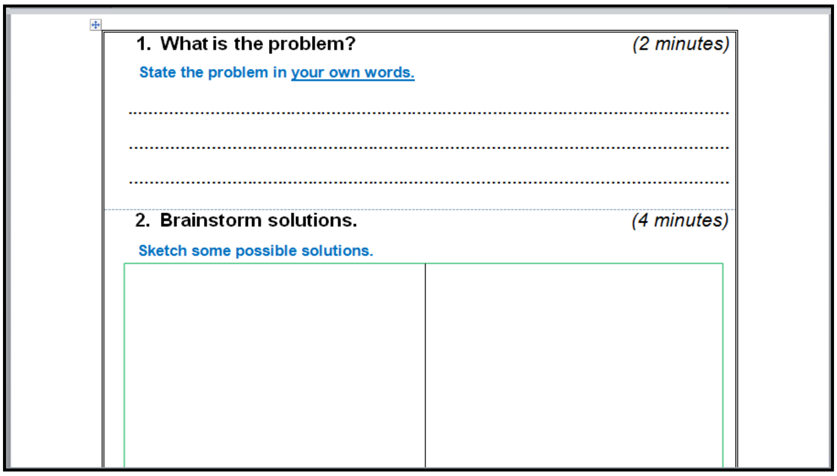


Figure 3.9: Second layout of Activity One

Figure 3.10 exhibits the following layout of the first Activity. The third layout is designed to provide the children a chance to manipulate and test the prototypes. This aim is parallel with the Piaget's theory since children can create and test their prototypes during the CETM activities. Teachers can also guide the children to fulfil the number of minutes. Teachers can easily observe children's ability to test their designed prototypes since these questions are close-ended. Teachers also can take note that the most amount of time allocated for each CETM activity is for creating the prototype.

3. Create the prototype you think is best. *(40 minutes)*

4. Test your prototype. *(3 minutes)*

Circle your answer.

a.	Does your plastic parachute fly freely when there is wind?	YES	NO
b.	Does the height of where the plastic parachute floated influences the total time the plastic parachute flies?	YES	NO
c.	Does all the supplies such as food and water flies without falling to the ground?	YES	NO
d.	Can the plastic parachute fly better if bigger plastic is used?	YES	NO
e.	Can the plastic parachute fly further if heavier supplies are tied to it?	YES	NO
f.	Does the wind speed important for the plastic parachute to fly?	YES	NO
g.	Does every supply which you tie to the plastic parachute take the same time?	YES	NO
h.	Are you confident your plastic parachute will reach country X with all the supplies?	YES	NO

Figure 3.10: Third layout of Activity One

Figure 3.11 shows the fourth layout of the Activity One in CETM. Teacher can observe children's ability to use familiar examples to explain more complex ideas while evaluating their prototypes. Apart from that, teachers are also reminded to allow children to present their prototypes after evaluating them. The time allocated for each section is for the teacher in trying to ensure that the entire open-ended lesson completes within the science lesson. The presentations can be brief and organized as the CETM design is parallel with the concrete-operations of Piaget theory.

5. Evaluate your prototype. *(2 minutes)*

a. Was it the best solution? Would one of your other ideas have been better? Why or why not?

....

....

b. How can you make your parachute design better? What will you do?

....

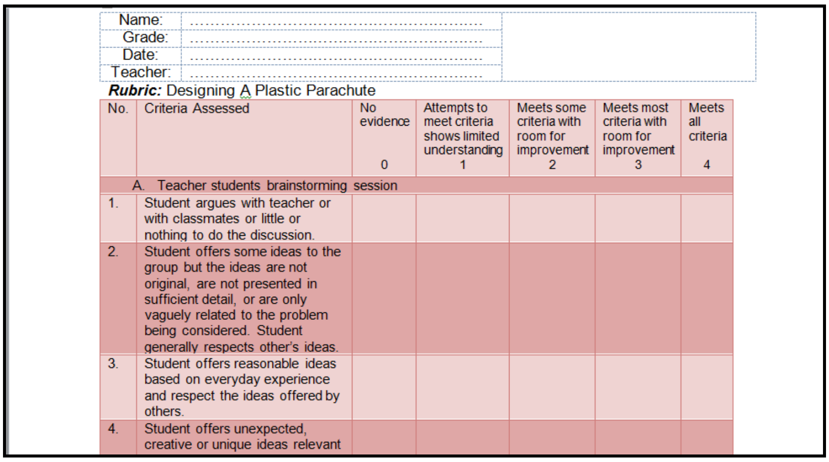
....

6. Present your prototype. *(4 minutes)*

Well done!

Figure 3.11: Fourth layout of Activity One

Figure 3.12 demonstrates the fifth and final layout of the first activity. In this layout, teachers can generalize children's ability in improving their HOTS while carrying out the CETM activity. Teachers can detect whether or not any transfer of learning has taken place during the activity. The generalizability concept is in line with the Instructional theory of Gagne. This layout is also designed based on the learning outcomes of Gagne's theory whereby teachers can evaluate children's intellectual skills, verbal information, cognitive strategies and attitudes. For example, in order to evaluate children's intellectual skills, children's ability to generate solutions using sets of criterias or rules for each CETM activity can be observed. Meanwhile, as for verbal information, these layouts also help the teachers to assess children's capability to understand, recall and state some information pertaining to the CETM prototype. As for cognitive strategies, teachers can use this coloured layout to generalize children's ability to reflect on their designed prototype. Attitudes such as tolerance, teamwork and leadership can be also observed by the teacher. The pattern of this layout is the same throughout all the other CETM activities. Hence through practice, or repetitions of subsequent CETM activity, teachers will be used to these layouts.



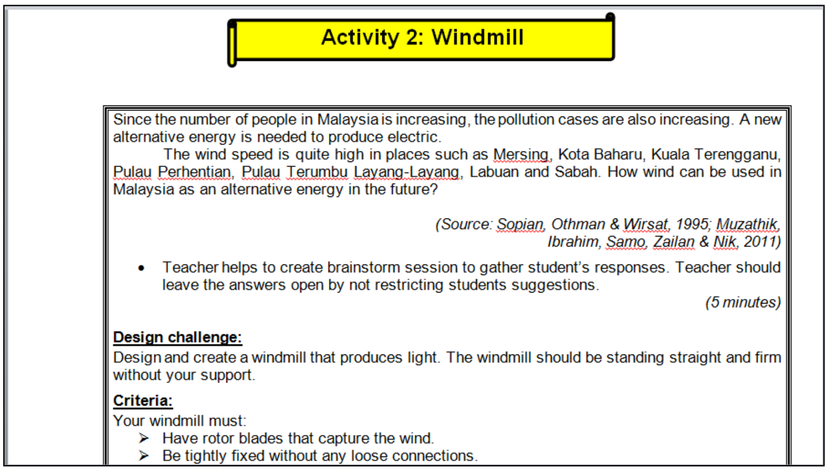
Name: ....
Grade: ....
Date: ....
Teacher: ....

Rubric: Designing A Plastic Parachute

No.	Criteria Assessed	No evidence 0	Attempts to meet criteria shows limited understanding 1	Meets some criteria with room for improvement 2	Meets most criteria with room for improvement 3	Meets all criteria 4
	A. Teacher students brainstorming session					
1.	Student argues with teacher or with classmates or little or nothing to do the discussion.					
2.	Student offers some ideas to the group but the ideas are not original, are not presented in sufficient detail, or are only vaguely related to the problem being considered. Student generally respects other's ideas.					
3.	Student offers reasonable ideas based on everyday experience and respect the ideas offered by others.					
4.	Student offers unexpected, creative or unique ideas relevant					

Figure 3.12: Fifth layout of Activity One

Figure 3.13 exhibits the first layout of the second activity in CETM. Each activity has the same pattern though the content varies from one another. Each CETM's has been designed using the Vygotsky theory or teaching techniques, which is the make sure that children have excess to powerful tool that support thinking. In this case, the tool that could enhance the thinking is the brainstorm session, writing the problem, sketching the ideas, testing and evaluating the prototypes. These outfits in CETM guide the teachers to foster and evaluate the HOTS among the children while designing the prototypes.



Activity 2: Windmill

Since the number of people in Malaysia is increasing, the pollution cases are also increasing. A new alternative energy is needed to produce electric.

The wind speed is quite high in places such as Mersing, Kota Baharu, Kuala Terengganu, Pulau Perhentian, Pulau Terumbu Layang-Layang, Labuan and Sabah. How wind can be used in Malaysia as an alternative energy in the future?

(Source: Sopian, Othman & Wirsat, 1995; Muzathik, Ibrahim, Samo, Zailan & Nik, 2011)

- Teacher helps to create brainstorm session to gather student's responses. Teacher should leave the answers open by not restricting students suggestions.

(5 minutes)

Design challenge:

Design and create a windmill that produces light. The windmill should be standing straight and firm without your support.

Criteria:

Your windmill must:

- Have rotor blades that capture the wind.
- Be tightly fixed without any loose connections.

Figure 3.13: First layout of Activity Two

Figure 3.14 displays the first layout of the third activity in CETM. Each activity has its own scenario, design challenge, criterias, materials and tools. Apart from that, since each of the CETM activity involves group work, the classroom atmosphere is expected to be busy. Hence, teachers can capitalize on dialogues and group learning between children once the lesson begins.

Activity 3: Soap Bubbles

A spaceship was lost when it was travelling to Mars planet. 10 astronauts disappeared in the space. A professor known as Dr. Vitor Cardoso informed that the spaceship has been pulled into a black hole in space. The black hole absorbs everything including light because it has a strong gravity force. Dr. Vitor Cardoso revealed that the process of investigating black hole in space is complicated.

However, he was confident that the soap bubbles can be used to study the characteristics of black hole in space. How can you help Dr. Vitor Cardoso to produce soap bubbles? How can you help in investigating the black hole in space?

(Source: Cardoso, 2006)

- Teacher helps to create brainstorm session to gather student's responses. Teacher should leave the answers open by not restricting students suggestions. *(5 minutes)*

Design challenge:
Create soap bubbles consisting of different forms of them.

Criteria:
The soap bubbles must:
- In a bubble chain or.
- A bunch of bubbles.
- Be produced bubble in a bubble form.

Figure 3.14: First layout of Activity Three

Figure 3.15 explains the fourth activity in CETM. This layout involves a technical effort from the children. Teachers can facilitate the concrete-operations by encouraging the usage of sophisticated materials or seldom used tools. This development of CETM layout is consequently in line with the Piaget's theory, which is to encourage higher level thinking among children. This layout also exposes the technical materials and tools involved in creating the metal tin robots. Teachers can come to know about the utensils used to create this three-dimensional prototoype. The following layout shows that children can be ready for more challenging materials but requires the appropriate scaffolding.

Activity 4: Metal Tin Robot

Mineral such silica, aluminum and calcium oxide getting reduced on Earth. All these minerals are vital for mankind. Astronomers at National Space Centre has identified moon is rich with silica, aluminum and calcium oxide. However, we cannot dig these minerals in moon because the oxygen level is not enough for us to breathe.

Imagine yourself as an astronomer. How you will dig these minerals in moon? How you can help in getting silica, aluminum and calcium oxide for human use on Earth?

Source: (Moon. (2014, October 3). Wikiversity)

- Teacher helps to create brainstorm session to gather student's responses. Teacher should leave the answers open by not restricting students suggestions. *(5 minutes)*

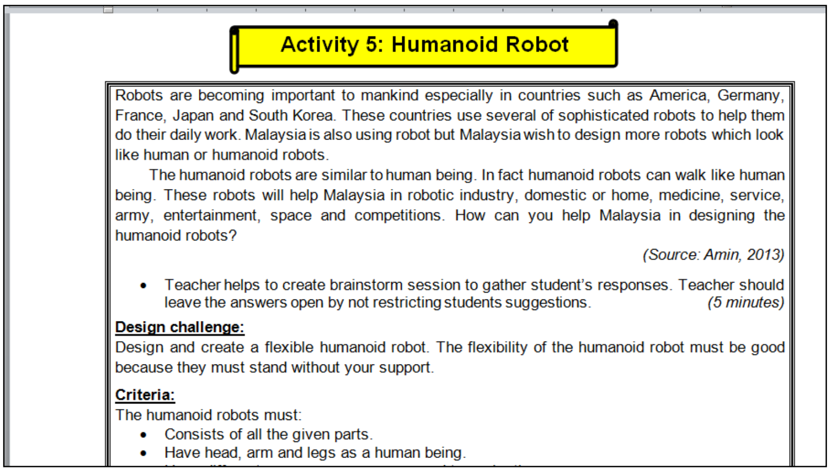
Design challenge:
Design and create a metal tin robot. Your metal tin robot has to be moving freely without your help.

Criteria:
The metal tin robot must:
- Produce sound when it vibrates with the metal tin.
- Be able to stand vertical and horizontal without any support from you.

Materials: *(What can you use?)*
(Your teacher might give you the materials you can use in a paper bag to help you track of them)
- 1 body plate
- 2 plastic legs

Figure 3.15: First layout of Activity Four

Figure 3.16 refers to the final CETM activity. This layout continues the effort of introducing the machinelike prototypes. The design of each activity is similar because the teachers must get used to the pattern and the structure of the CETM itself before exploring to other possibilities of creative layouts. The designed CETM aims to be simple, adaptive and user-friendly with fewer complications for the teacher’s benefits.



Activity 5: Humanoid Robot

Robots are becoming important to mankind especially in countries such as America, Germany, France, Japan and South Korea. These countries use several of sophisticated robots to help them do their daily work. Malaysia is also using robot but Malaysia wish to design more robots which look like human or humanoid robots.

The humanoid robots are similar to human being. In fact humanoid robots can walk like human being. These robots will help Malaysia in robotic industry, domestic or home, medicine, service, army, entertainment, space and competitions. How can you help Malaysia in designing the humanoid robots?

(Source: Amin, 2013)

- Teacher helps to create brainstorm session to gather student’s responses. Teacher should leave the answers open by not restricting students suggestions. *(5 minutes)*

Design challenge:

Design and create a flexible humanoid robot. The flexibility of the humanoid robot must be good because they must stand without your support.

Criteria:

The humanoid robots must:

- Consists of all the given parts.
- Have head, arm and legs as a human being.

Figure 3.16: First layout of Activity Five

The example of how an overall CETM activity looks like is attached in Appendix 12.

Output: Implementation of the CETM (Phase Three)

The designed teaching module was implemented in a primary school in the state of Perak. This primary school is located in a sub-urban place where the children here were not academically exposed, at least as compared to the children in urban the schools. Apart from that, this study aspired in ensuring all races are given the opportunity to involve in the activities designed in CETM. Sedlak, Doheny, Panthofer and Anaya (2003) research study revealed that the diversity and cultural competence provides the opportunities in keeping an open mind. These group of researchers also added that the collection of different beliefs and culture increased the possibility of children in demonstrating critical thinking skills during teaching and learning. This was also parallel with Malaysian government's aspiration which has been stressed in the Malaysian Education Blueprint 2013-2025 that providing equal access to quality education to all children in the nation in crucial in producing intelligent children. Hence this study involved Malay, Chinese, Indian, Sri Lankan and Punjabi children.

The implementation of the developed CETM was carried in the school chosen by the researcher. A science class of Year Five primary school was selected to introduce the developed CETM. The syllabus of Year Five consists of five themes and twelve topics. However not every topic was chosen in designing the activities for CETM. This is because themes such as Investigating Force and Energy has four topics such as energy, electric, light and heat which coincides and jives well in the elements of children's engineering as compared to other topics. Moreover, topics such as electric and light was merged to design one activity to be embedded in the CETM. So, it is not necessary to choose the themes and topics in the syllabus.

The science teacher was trained by the researcher and the researcher did the observation during the implementation of the teaching module. This was to prevent the effect of bias while conducting this study. Although only one science teacher was involved in carrying out the activities during the real study, there was another science teacher who was also interested to know about the CETM activities. This teacher also joined the training sessions during the school holidays. The training sessions was carried out for four days in the science lab at the school where the science teachers teach. The science teachers were asked to understand the CETM activiites and carry out the activities without much materials given. The researcher guided the teachers throughout the activity. The researcher answered the teacher's questions and discussed with the teachers on how to facilitate the children in the classrooms. Apart from that, the discussion during the training sessions also included on how to brainstorm for ideas during the beginning of the activities, how to handle the children when they claim that they have limited materials and how to evaluate the children during the activities.

During the implementation, children were observed on how the CETM enhances the HOTS during the science lesson. These observations were carried out five times since there were five activities embedded in the CETM. Each of the activity in CETM consisted of an assessment. These assessments were designed based on higher order thinking questions which underpinned the three high levels cognitive in Revised Bloom Taxonomy (RBT) which are creating, evaluating and analysing. Questions based on this high level thinking will indicate how the children foster the HOTS using the developed CETM in learning science. These questions were validated and revised until it was ready to be implemented. This proposed assessment was validated by science teachers, lecturers and master teachers. Children's answers were recorded and analysed as to how the CETM enhanced HOTS during the science lessons in the classroom.

Although the learning outcomes in the Isman Model was perceived to be the last stage of design and development, this study focused on the first four stages as the Gagne learning outcome were discussed in the following chapters. The final stage of designing involving the evaluation phase (Phase Four) was discussed in Chapter Four.

Summary

This chapter demonstrated the creation of a constructive learning environment using thoughtful planning at module level. Developing Children's Engineering Teaching Module (CETM) using learning outcomes, teaching methods, materials, activities and assessment were given intensification. The design and development of CETM is never a completed process, but rather a continuing process of reflection and review.

CHAPTER 4: METHODOLOGY

Introduction

This chapter will discuss the continuation of Children's Engineering Teaching Module (CETM) development, particularly the Type II design and development research (DDR) which was employed in designing the CETM. In line with that, the CETM evaluation process will be explained in this chapter to complete the cycle of Isman model. Apart from that, this chapter also outlines the methodological framework and the methods used to gather the data collection for designing the CETM. Experts' responses were quoted in evaluating the CETM. Subsequently, this chapter also discusses the thematic analysis to review the findings.

Design and Development Research (DDR)

This study adopted DDR design in developing a teaching module for science subject. Richey and Klein (2010) indicated DDR, as with all research endeavours, leads to knowledge production, a more complete understanding of the field and the ability to make predictions. DDR accomplishes these goals through two large categories of research projects which were product and tool research and model research (Richey & Klein, 2010). There are two types of DDR methods, Type I and Type II. Table 4.1 illustrates the summary of participants and research methods in developmental research studies.

Table 4.1: Participants and research methods in developmental research studies

Developmental Research	Function/ Phase	Type of Participant	Research Methods
Type I	Product design & development	Designers, developers, clients	Case study, in-depth interviews, field observation, document analysis
Type I	Product evaluation	Evaluators, clients, learners, instructors, organizations	Evaluation, case study, survey, in-depth interview, document analysis
Type I	Validation of tool or technique	Designers, developers, evaluators, users	Evaluation, experimental, expert review, in-depth interview, survey
Type II	Model development	Designers, developers, evaluators, researchers, theorists	Literature review, case study, survey, Delphi, think-aloud protocols
Type II	Model use	Designers, developers, evaluators, clients	Survey, in-depth interview, case study, field observation, document analysis
Type II	Model validation	Designers, developers, evaluators, clients, learners, instructors, organizations	Experimental, in-depth interview, expert review, replication

Source. Richey, Klein & Nelson, 2004.

Model development in Type II was used as a guidance to design and develop CETM activities. This is because the features of model development represented the appropriate participants and research method to develop the CETM. Model development encouraged Delphi technique and collection of literature reviews. This study employed using both qualitative and quantitative paradigm where interviews, observations and one group pre-test and pro-test were used to design and develop CETM. The participants in this study were parallel with Jones and Richey's (2000) Type II study where the children displayed the role as designers, developers and evaluators while designing the prototypes in CETM activities. Moreover, according to Robinson (2014), model development in Type II developmental research uses an external consultant who takes the role of modeller and then someone in house to act as model user. This scenario is parallel with this study whereby the teacher acted as the modeller and children were the model user since they used the materials and tools to design the CETM prototypes.

Model development research is the most generalized of DDR (Richey & Klein, 2010). The ultimate objective of this study was to produce new knowledge in a form of a new (or an enhanced) design and development model. This research emphasized comprehensive model and particular design technique. The model utilized in this study was Isman ID model meanwhile the design technique used was a mixture of both quantitative and qualitative. However qualitative was used in a broader spectrum in both gathering and analysing the data.

This study chooses Type II developmental research because it focused on design, development and evaluation model. Apart from that Type II involved constructing and validating design models and processes as well as identifying those conditions that facilitate their successful use. In fact, this research focused on the models and processes themselves, rather than their demonstrations. Isman model which underpinned input, process, output and evaluation was employed in developing CETM. The process of developing CETM was discussed in-detail in Chapter Three.

Sampling

This study employed purposeful sampling or also known as judgement or judgmental sampling (Babbie, 1990; Jones, 1955). The qualitative sampling (Creswell, 2012; Barbie, 1990) helped this study in selecting a sample "on the basis of your own knowledge of the population, its elements, and the nature of your research aims" (Babbie, 1990) where the population is "non-randomly selected based on a particular characteristic" (Frey, Carl & Gary, 2000).

This study developed an in-depth exploration of a central phenomenon by using a total of 30 children to participate in this study. Purposive sampling is useful if a researcher wants to study "a small subset of a larger population in which many members of the subset are easily identified but the enumeration of all is nearly impossible" (Babbie, 1990).

Parallel to that, this study required children with some particular characteristics. These anticipated characteristics were necessary because according to MacNealy (1999) the individual characteristics are selected to answer necessary questions about a "certain matter or product". Although this study preferred positive characteristics of a child, this study did not have any biasness towards the weak children's in terms of academic level. Weak children were also welcomed to participate in the CETM activities. In fact, this study allowed the science teacher to select the participants and the teacher selected most of the children in her class. This study also reflected a need for parental or guardian's consent for the under aged children to participate in CETM activities (see Appendix 13). However, the parents were positive in their children's involvement for CETM activities during the school hours in science subject. The example of parents/guardian consent is attached in Appendix 14. Meanwhile the parents consent for the use of photographs in the final write-up is attached in Appendix 15.

Despite the Type II development research formulates a generalized conclusion, yet this study did not generalize the outcome of the research to the entire nation of Year Five children. Hence, the central phenomenon of this study observed the outcome of the designed CETM's implementation on Year Five children in one particular primary school. Since this study concentrated on the design and development of CETM itself, the purposeful sampling provided useful information regarding the usage of CETM and guided the teachers to acquire the skills of implementing a teaching module that anticipated in enhancing HOTS among the children during science learning.

The Procedure of the Study

This study emphasized on developing the CETM. The first two research questions focused on designing CETM. These research questions were answered by using the modified Delphi technique which involved 22 experts from various different fields.

Although extensive literature reviews and international assessments has indicated that Malaysian children lacked HOTS, this converging evidence was focused to a range of different ages, especially Trends International Mathematics and Science (TIMSS 2011) which assessed Form Two children. Since this study concentrated on Year Five children in primary school, it was crucial to identify the level of cognitive skills specially to detect whether the findings of TIMSS 2011 tallied with the present level of HOTS among these children. Hence, the refined Virginia Student Assessment (VSA) was provided to assess the cognitive skills among the eleven years old children in science.

The developed CETM was implemented in a classroom where a science teacher was trained on the usage of the module. The third research question answers on how the developed CETM enhanced HOTS among the children. During the implementation, the groups of children who carried out the hands-on activity were observed and their group conversations were recorded. The final research question helped to validate the developed CETM by perceiving the teachers' opinion. The employed CETM was also validated by VSA as whether it has influenced the children's cognitive skills in learning science. Figure 4.1 explained the procedure of collecting data in this study.

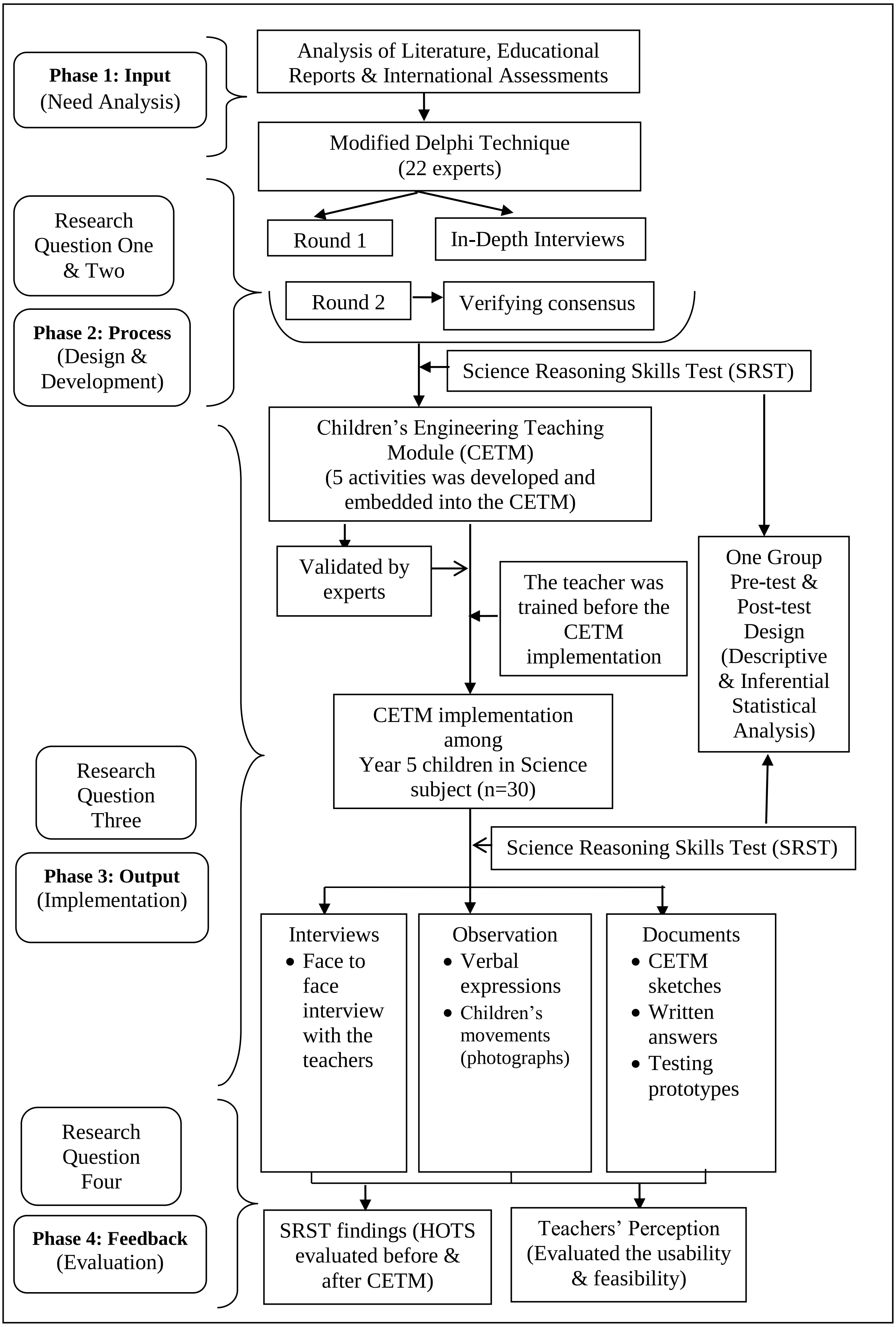


Figure 4.1: The procedure of collecting data

Data Collection

In order to gather detailed information to establish the complexity of the central phenomenon, this study proposed a varied nature of qualitative forms data. The data collection forms in this study were placed into the following categories:

a) Interview

b) Observation

i) Verbal expression

c) Documents:

i) CETM sketches

ii) Written answers (problem and evaluations)

iii) Testing prototypes (close ended responses)

d) Science Reasoning Skills Test (SRST)

Interview

The teacher who implemented the activities and her colleague was interviewed face to face to gather some feedback about the usability and feasibility of CETM. The interview questions (see Appendix 16) for evaluating the CETM were based on the teacher's evaluations from the following criteria:

a) Module aim
b) Subject content
c) Learning outcomes
d) Teaching strategies
e) Assessment strategies

Subsequently, these criteria were parallel with module designing experts, Donnelly and Fitzmaurice (2005) who have researched on constructive content alignment in designing modules for teachers.

Both the teachers were not comfortable to have their voices recorded since the teachers were involved in the district level of science education for primary school division. Although the teachers were aware with the term HOTS, TIMSS and PISA, they declined to have their opinions recorded because some of them were inconsistent when they gave their personal views on ways to improve the present education system. Hence, the responses were written on different set of papers as the interviews were held at different period of time. The teachers were interviewed once and after two months, they were interviewed again which was after the SRST administration for the second time, soon after the CETM implementation.

The interview was held at the science lab because the science lab was not occupied by any children or teacher and it was quiet. The teachers were interviewed in the morning and the duration of the interview was almost 150 minutes. The total sheet of transcripts with the teachers' responses was sixteen. The teachers gave their responses for the interview questions based on their experience, knowledge and working environment. Although the interview session was held in a professional, structured and organized manner, the interview session was in joyful atmosphere with laughters from the teachers.

Observation

This study conducted a non-participant observer where the researcher and an experienced science teacher sat at the back of the classroom to observe and record the general view of atmosphere during the CETM activities. Descriptive field notes were recorded during the observation. The description during the science lessons conducted by the teacher with children was be recorded by using an observation instrument.

An observation protocol was designed to ensure an organized means for recording and keeping observational field notes (Creswell, 2012). This observation instrument has been designed after a major refinement from Quality Learning Instrument (QLI) (Walsh, 2000; Walsh & Gardner, 2005). The observation instrument (see Appendix 17) was refined and adapted according to the needs and prerequisites of perceiving the process of fostering HOTS during the CETM activities. The observation instrument included a total of fifteen elements of perceived actions displayed by children during the implementation in the classroom. In an attempt to reduce observer subjectivity and bias, this study was parallel with O'Leary (2014). This study used fifteen elements to reduce the ever-increasing of detailed assessment criteria. Apart from that, the observations during the CETM activities emphasized on children and the learning process rather than the teaching (see Appendix 18).

The observation instrument was used in order to garner the actions displayed by the children during the CETM activities. Both the teacher and the researcher wrote their responses on what they saw and heard for each of the CETM activities. The teacher wrote in English and Malay language. Some of the written responses in Malay language were translated into English. Once translated, the researcher went through the translations with the teacher to ensure the teacher's denotation was not altered. The translated data was accepted because the teacher not only performed as a collector of descriptive data but also used her own intuitive judgment in providing the observation (O'Leary, 2014).

Observing communicative tasks while maintaining reasonable noise levels and keeping children on task is often see as a complex balancing act (O'Leary, 2014). In order to manage the observation for peer work management, this study employed a simple rubric for observing the children during the CETM activities. The teacher and the researcher used their eyes, ears, perspective and proximity for observing the children in action. The researcher walked around the classroom during the activities to focus in one group and followed by another group. The researcher also paid attention in the children's conversations apart from listening for individual voices that stood out. Subsequently, the teacher either stood for a wide-angle view or looked from the corner of the eye. The teacher also paused and observed what was happening without participating in the CETM activities. Although the researcher moved front to back and moved side to side in the classroom, the movements were restricted in purpose to allow the natural interaction setting between the teacher and children.

One of the ways to increase the reliability and equity of the classroom observation process is to allow the observer to see the observational instrument before the field work. In this study, the teacher was given the observational instrument to help the teacher to familiarize with the elements need to be observed. However, the teacher was told not to only look for the things that the study wanted to know about but play the role as a collecter of descriptive data. The teacher wrote the observation for most of the fifteen elements in the observation instrument. In fact, the teacher used the field notes column to jot down quickly what the eyes and ears captured during the implementation of the CETM activities. Soon after that, the teacher wrote some expanded notes by giving some examples of the children's actions. These observational feedbacks from the teacher were checked and some of the repetition was compressed. The teacher tried the level best in order to write what the teacher perceived during the science period. Some of the teacher's responses were not align with the elements in the instrument. The researcher's response was also compared with the teacher's response, simultaneously.

Each of the activity had five observations from each observer. The total number of observations was ten for all the activities. However, two of the observations were omitted since the responses from the children were not in line with the purpose of Activity Three in CETM. Hence, eight of the observations were analysed and coded.

This study also used video besides the observation instrument. The video was placed in the classroom in order to record the process of learning using the designed activities in CETM. Children's communication skills, teamwork capability, expressions were all recorded and analysed to determine whether the designed CETM helped to enhance children's engagement in during science class. Photographs were also snapped by using a digital camera during the process of implementing the developed CETM. Audio-visual materials helped to answer the research question on enhancing children's HOTS in learning science using CETM. These varieties of form of data collection increased the credibility of the findings. However, since the participants of this study were eleven years old children and still under aged the consent from guardian or parents were needed before involving the children. This study used a consent form in order to receive the permission of the children's parents or guardians.

In order to analyse the photographs, this study was parallel with Patton (2002) because it captured the children's feelings, thoughts, intentions and behaviours in which the children organize their mental understandings and then connect these understandings to their world. Photograph content is one of the concerns in analysing the setting related to people (Richard & Lahman, 2015). Hence this study analysed the photos using photo-elicitation where some of the photos were showed to the children and asked them to reveal their gestures and thoughts. By showing the photos, children were encouraged to interpret their actions because according to Stokrocki (1985), photographs do not speak for themselves and they need elaboration to include the intrinsic sense of the children. The children involved in activities gave some feedback by observing the photos shown to them.

At the same time, Stokrocki indicated that reliability increases with inter-subjectivity. Therefore, apart from the researcher, the teachers who were involved in the CETM implementation were also involved to examine and affirm the interpretation of the photographic series in CETM activities. However, it must be remembered that an interpretation is never final and they might differ from one reflection to another by different observers (Stokrochi, 1985). Photographs were captured from beginning of an activity until the completion of the prototype. The children's actions were natural during the activities. The photographs were randomly selected and photo-elicitation method was carried out among the children.

Children's Verbal Expressions during the CETM Activities

Apart from observing on children's conversations during the observations, a voice recorder was placed on the desk in each group of children. The conversations between the group members were transcribed into sheets of transcripts and were analyzed. Each group produced almost six sheets of transcript for each activity. Similarly, the children's presentation was followed by question and answer session. This question and answer session also produced some dialogic conversations between the children. The dialogic conversations between children were analyzed sentence by sentence when each sentence was matched with structural components such as a decision, valid grounds and rebuttal. This analytical argument pattern is in line with the study of Sampson and Clark's (2008) where rebuttal is the most significant quality indicator in an argument (Foong & Daniel, 2012). All the recorded conversations for all the five groups for each activity were transcribed and coded. In order to establish reliability for the coding results, for the first round, all the arguments were coded by the researcher and the teacher. The coders discussed and resolved the discrepancies until they researched a consensus. In the second round, two teachers from different schools helped to code independently for two activities prior to children's arguments. The two rounds of coding (involving different coders) were aimed at minimizing coders’ personal belief of solving an open-ended problem issue. There was also some interesting conversation between the teacher and children was recorded and transcribed (see Appendix 19). Additionally, the conversations between the teacher and children during testing the prototypes were also observed. Some of the conversations were unique as these dialogues reflected the elements of children’s engineering itself (see Appendix 20).

However, some of the activity did not yield much dialogic exchange between children. For instance, Activity Three which involved soap bubbles did not have much conversations exchange because children completed the task sooner than the given time. Children were excited in completing with one another with team mates from different groups. For another activity, children spontaneously placed their prototype on the floor for further design and evaluation. They did not return to their normal positions in the classroom where the voice recorder placed. Hence, some of the discussion between the children was heard and jotted down by the researcher. Most of the groups were noisy with screams and yells in excitement. The transcript focused mainly on children’s exchange dialogues with one another during the CETM activities, especially while creating the prototypes. These conversations were analysed based on the children’s questions among themselves, captivating answers and other interesting responses. When the results of this study was reported and typed in the transcript, the children's name or any other personally identified information was not used during the analysis data. Instead, a pseudonym (fake name) was employed for the children who participated in the activities. In order to maintain the research ethics, the child’s name was not revealed.

The second stage of evaluating the prototypes was presenting their prototype in front of their classmates. The presentation by children was flexible because the children were allowed to use their own words to express. The teacher did not have to persuade or force the children to speak out about their prototypes since all the representatives stood and spoke willingly. It was noticed that, the children had the similar pattern of presentation because each of them spoken about why they design it and how they created it before proving to the classmates about the functionality of their prototype. At the end of the presentation, each of the child showed that the windmill produced the light, the plastic parachute could fly, the metal tin robot was noisy while moving and the humanoid robots could stand firmly on a hard surface. The interesting part was when the child mentioned some working ethics in coming with the design. The presenters used the word 'We' each time they spoke and introduced working ethics such as tolerance, helping each other and cooperating.

Documents Analysis (Children's Sketches and Written answers)

Documents can be a valuable source of information in qualitative research (Creswell, 2012). The documents which was analysed in this study was CETM sketches and the written answers by the children during the CETM activities. The following document analysis was based on the experts who were specialist of analysing and examining the children's sketches.

Children's Sketches in the CETM Activities

In this study, the children's sketches in the CETM was used as the documents to be analysed. The designs which the children sketched was scrutinized and evaluated based on the answer sheets designed during the development of CETM.

In order to assess the children's sketches in each activity, a need for experts in children's sketches was crucial. A total of three experts agreed to validate and give some input on how to evaluate these sketches, especially in evaluating the HOTS and reasoning skills. These experts agreed to assess the children's sketches in CETM activities once they were informed about the objectives in this study. The expert's curriculum vitae is attached at Appendix 21. These experts were shortlisted from their level of expertise or research interest in children's sketching, number of publications in established journals and years of experience in art and design fields.

Apart from that, the willingness of these experts to authenticate the children's sketches via e-mail was also important factor in analysing these sketches. In fact, these experts also attached useful articles pertaining to children's sketches when they replied the mails. The expert analysis was helpful in grading the sketches according to how well the designs address the problem. After looking into the sketches, the experts offered some comments and they suggested that the general theme for these sketches touches upon technical skill versus creative originality. However, they came to an agreement that the opinion of the researcher himself or herself is also crucial in identifying whether HOTS can be fostered in using the CETM activities.

At the same time, these experts advised that the researcher is the person who captures what elements are regarded as indicating HOTS. The first expert was in line with the second expert when it came to the role and opinion of the researcher in analysing the sketches. Consequently, the first expert hinted that HOTS could be also linked with creativity than expression. As a matter of fact, some of these sketches were uploaded in the first expert's website to gather additional information and once the website http://children.chi.ac.uk/ is finalised, experts from other universities will also give their feedback. Therefore, based on the three-expert's analysis, the following facets were used to analyse the children's sketches in the activities: (a) shapes, (b) symbols, (c) being expressive, (d) being imaginative, (e) unexpected solutions, (f) measurement numbers, (g) improvising existing ideas, (h) different types of solutions and (i) displaying relationships or events.

These facets were used to analyse the children's sketches in all the CETM activities since these reliable experts were well aware of the research purpose. At the same time, this facet also broadens the horizon of HOTS definition. Subsequently, this study has defined HOTS based on the collection of opinion from several fields and expertise as one of its means in HOTS classification.

For example, some children justified their sketched prototypes using symbol which involved mathematical units such as kg (kilogramme), m (meter), cm (centimetre) and s (seconds). Children had used these symbols to justify and strengthen their ideas as they reasoned their plan of action using a structured and organized method of sketches. These sketches were evaluated as having the element of transferable skills as children used their Mathematics knowledge in reasoning their ideas.

For example, while brainstorming ideas to find a solution for Activity Two, a child used written notes and symbol of wind to justify the windmill sketches (see page 207). Another child used relational symbols, such as arrows and spatial relationships to explain the child's understanding on how the windmill idea could work (see page 208). Meanwhile during Activity One, a child has used the fire symbol learnt during the science lesson with the plastic parachute because she has decided her plastic parachute designs need energy to float and fly in the air (see page 236). Another sketch in Activity Four showed a robot without head but with a weighing device which has the 'on' and 'off' switch (see page 215). Children's sketches which reasoned using these symbols was evaluated as a better sketch as compared to other sketches.

At the same time, some of the children justified their sketches by using different type of shapes. Some of them used the rulers, some of them sketched using free hand. For example, the sketches which involved free hand was evaluated as the element of flexible thinking as they expressed their sketches in different patterns which involved different type of measurement. Some of the sketches involved specific measurement numbers because children wanted to justify their answers in an organized and structured response. These sketches reflected the element of designing process.

These sketches have number of variables and these variables addresses the variety of answers to the problem. The experts suggested that the children had the possibility of enhancing the HOTS by explaining the usage of key features such as symbols and units apart from placing their own ideas of improvements for each of the prototype during the brainstorming session.

Written answers in CETM Activities

Children wrote their responses in stating the problem and evaluation section. These responses were analysed based on the children's logical consistency, children's ability to provide adequate examples, the clarity of their argument and other interesting feedback from the children. It was noticed that some of the responses were beyond the teacher's expectations. The examples of written answers and how they were analysed is discussed in Chapter Five. The responses in the activities were randomly chosen. Children used both English language and Malay language to express their thoughts. All the expression in Malay language was translated in English language (see Appendix 22). These translations were validated by local primary school teachers. Each of the written expression for every activity was described and narrated.

Meanwhile the evaluating stage comprised of two questions. The questions were: a) Was it the best solution? Would one of your other ideas have been better? Why or why not? b) How can you make your design better? What will you do?" The written evaluation for each question in every CETM activity was observed. Some of the children wrote their answers in English whereas others wrote in Malay language (see Appendix 23). The answers written in Malay was translated and checked by the primary school teachers. The subsequent answers were randomly chosen based on the child's argument and hesitancy in agreeing that the designed prototype was the best solution. Most of the selected responses were derived from children whom did not quite agree with the solution they came up with. The reluctance that the children posed intrigued some unique thoughts because children also provided different types of solutions for each of the CETM activity.

Children's Feedback in the Close-Ended Questions

These close ended-questions were convergent questions by its nature has a more narrowly defined correct answer since it required children's thinking and some original thought while testing their designed prototypes. The "Yes" or "No" responses from the children were the first step of analyzing their designed prototypes before they provided the written responses on how to improve their prototypes. Children were encouraged to analyse their designed prototypes while testing according to the testing measures asked in the close-ended questions.

There was a total of 24 testing measures in all the CETM activities (see Appendix 24). Out of the 24 testing measures in the CETM activities, nine of the testing measures represented the third stage of Revised Bloom Taxonomy (RBT) which was analysing. According to the CETM experts, these nine testing measures gives the teacher to evaluate the children who can distinguish between parts, compare and constrast, classify and relate all these elements to the overall structure and purpose of each CETM activity.

Analysing skill in RBT requires children to use reasoning skills in order to produce the appropriate answer for the testing measures. Each of the analysing skill was embedded into the testing measures for each of the CETM activity. Children were encouraged to use the analysing skill to answer the close-ended questions because they simulatenously manipulated the prototypes. The notion gave the children to think and decide before answering the close-ended questions in the CETM activities.

The rest of the testing measures were measuring children's basic thinking skills such as remembering, understanding and applying which was not used to support the quantitative findings. The nine testing measures were analysed using descriptive analysis. Children's responses were analysed through frequencies and percentages. This descriptive analysis for the nine testing measures in close-ended form is described in Chapter Five.

Science Reasoning Skills Test (SRST)

This study adapted 20 multiple questions from the Virginia Student Assessment (VSA) and Challenging Logic and Reasoning Problems book. Designing multiple-choice tests are labour intensive especially in construction and revision of the tests because it requires a series of revisions and try outs. It is also more expensive and Ennis (1993) argued that there is no inexpensive critical thinking testing.

Subsequently, multiple choice questions are able to measure the achievement of children at the cognitive levels such as evaluate and analysis (Flateby, 2010). In fact, Flateby stressed that the evaluation of validity and reliability of the multiple-choice questions is possible as compared to subjective assessment. Ennis (1993) also indicated that multiple-choice questions can assess the specific aspects of cognitive level despite of having a greater structure apart from saving time to grade the answers.

Since this study planned for diagnosing the level of children's cognitive skills, SRST was employed to figure out what are the present cognitive levels of the child. Besides that, this study also aimed to evaluate the specific areas of strength and weakness in respect of reasoning skills which is also an important division in HOTS. SRST emphasized on testing the children's ability to apply aspects of reasoning skills.

Validation of Science Reasoning Skills Test (SRST)

The SRST was validated using content validity and face validity. According to Mark (1996), the content validity is the sampling adequacy of the content, the elements involved in the substance, the matter and the topics of a significance instrument. Meanwhile Mathew (2000) indicated that different sub units of the content should be carefully examined to ensure the content validity and items included. The content which is the reasoning skills and HOTS were identified and listed in line with the number of items for each question. The table 4.2 displays the listed content for HOTS and reasoning skills assessed before and after the CETM implementation.

Table 4.2: HOTS and reasoning skills in SRST

No.	**HOTS**	**Question(s)**	**Derived from**
1.	Predicting	9	Virginia Student Assessment (VSA)
2.	Analysing	13	
3.	Argumentative	11 & 17	
4.	Making judgment	2	
No.	**Reasoning skills**	**Question(s)**	**Derived from**
1.	Logical reasoning	1, 7 & 10	Virginia Student Assessment (VSA)
2.	Practical reasoning	20	
3.	Inductive reasoning	3 & 12	
4.	Deductive reasoning	15	
5.	Numerical reasoning	18	
6.	Case-based reasoning	8 & 19	
7.	Mechanical reasoning	14	Challenging Logic and Reasoning Problems Book
8.	Conditional reasoning	4 & 6	
9.	Correlational reasoning	5	
10.	Probability-based reasoning	16	

The refined Science Reasoning Skills Test (SRST) was mailed to a group of experts consists of researchers and college professors who have published articles pertaining reasoning skills and HOTS. These experts examined the relevancy, appropriateness and the representative of the thinking skills that were tested. Since it is recommended that expert panels should comprise at least three persons (Polit & Hungler, 1999), the adapted SRST had the opportunity to get validated by three different experts since nine others did not respond to the mails. Based on the expert's judgments, some amendments have to be made especially in making the language simpler and diagrams well understood.

Soon after the experts have reviewed and validated the adapted SRST, the language in SRST was translated into Malay language to incorporate with the Malaysian curriculum. Hence apart from content validity, SRST was also validated based on face validation. Beanland, Schneider, LoBiondo-Wood and Haber (1999) defined face validity as a sub-type of content validity. Thorndike and Hagen (1995) identified the following five components for an analysis of effective expression for face validity. The five components that was employed to validate the SRST are (a) arrangement of ideas in logical ways, (b) subordination of details to main ideas, (c) paragraphing well to bring out the organization of ideas, (d) adapting the style of message exposition, narration and (e) adapting the form to audience in word choice.

All these five components were used as an indicator to validate the refined SRST. Local experts such as primary school teachers were identified to approve the clarity and readability of SRST in Malay language to ease the administration during the pilot testing.

The SRST in this study was carried out in one-group pre and post-test design. According to Shadish, Cook and Campbell (2002), there are internal and external threats in one-group pre and post-test design. The internal threats which the researcher must be aware are the history, maturation, testing, instrumentation and statistical regression meawhile the external threat is the interaction effects of selection biases and the experimental variable (Shadish, Cook & Campbell, 2002). Although, both external and internal threats can cause some minor effect in a study, both threats cannot be used to generalize the findings of an untested population such as in this study (Creswell, 2012; Shadish, Cook & Campbell, 2002).

Reliability of Science Reasoning Skills Test (SRST)

This study used Cronbach alpha to measure the reliability of the SRST in designing the CETM. According to Brown (2002), Cronbach alpha is a flexible tool that can be used to generate the reliability of a test results. Cronbach alpha is also used to estimate the proportion of variance that is systematic and consistent in a set of test scores.

Piloting SRST was carried out to not only confirm the acceptable readability, clarity of content and writing but also to measure the reliability of SRST. A total of 192 children from three different primary schools in Selangor sat for the SRST (see Appendix 25). The school names were disclosed but the regions in Selangor were displayed in the Table 4.3.

Table 4.3: SRST pilot test

No	Region in Selangor state	Number of classes	Number of children
1.	Klang Valley	1	31
2.	Sabak Bernam	3	74
3.	Bestari Jaya	3	87
Total number of children participated in answering SRST			192

All the children from these schools were eleven years old and studied science subject. SRST was piloted at the same time because according to Nunnally and Bernstein (1994), pilot sample should be representative of the eventual target population in terms of range, level of ability and time limits. In fact, the children who participated in pilot study were not involved in the true research as samples.

This study used Statistical Package for the Social Science (SPSS) Student Version 21.0 to analyse the reliability of SRST by employing Cronbach alpha. The Cronbach alpha determined for SRST was α =0.679 and the rounded α figure becomes α=0.70 where this shows that the adapted SRST is reliable instrument. Since a reliability coeffiecient of 0.70 or greater is considered acceptable (Beanland, et. al. 1999; Polit & Hungler, 1999), the SRST in this study is reliable based on the average correlation among items within a test.

However, in order to achieve that reliability of SRST, items such as Question 1, 5, 12 and 16 had to be replaced. These items were either extremely difficult or easy to be answered by the children. Apart from that, these items measured more than one type of thinking skill which was not feasible because these items measured more than one particular content area. Therefore, these four items in the SRST were replaced by using different items with the same content of thinking skills.

At the same time, reliability of translations in this study means that the translations from Malay language to English language and vice versa accurately represent the originality and detailed aspect of the interpretation. There were five different renditions that needed translation and they were the SRST, children's written answers in CETM activities, children's written notes in sketches, teacher's written observation during the CETM activities and teacher's interview on how they perceive the developed CETM. These renditions were translated in easily readable English language.

According to Robinson (2007), there are various types of textual reliability but there is no single touchstone for a reliable translation, certainly no single simple formula for translation. This study employed translation that follows the original word for word from the source text. In fact, the translations were accessible and readable for the readers as they were like in the original source text. At the same time, the teacher's responses from their written observations and interviews were translated to unfold the hidden complexities of the original source text as this study explores the teacher's opinions in implementing CETM activities among the children.

The translations were carried out by two teachers and the researcher. The teachers recognized the source of text that required professionalism besides straight accuracy in translations. They were attentive to the details, sensitive to the research's needs and checked closely on the translations. In fact, the teachers worked together to list as many different types of translations as they could before the researcher discussed with them and finalized the translation.

Data Analysis

Type II DDR employed qualitative and quantitative strategies to help gather findings in designing the CETM. Though this study employed both the paradigm, qualitative design was given more weight as compared to quantitative design. This was to answer the research questions which focused on the process of development and in what manner the HOTS were fostered among the children. Interviews, observations and analysis documents were employed to gather the sufficient data to design the CETM.

The data analysis in this study has two stages, stage one and stage two. The stage one data analysis starts with interviews followed by observation and analyses of documents. The second stage of data analysis involves data processing where the data were reduced and clustered. The second stage data analysis was analysed using thematic analysis. The series of interviews and the observation were transcribed into transcripts by using hand analysis of qualitative data. Hand analysing helped the researcher to be close with the data apart from having the hands free without the intrusion of a machine (Creswell, 2012).

The sketches that the children have done during the activities were also analysed. These sketches were analysed based on the experts' who were specialist in children's sketches. Their feedback on how to assess the HOTS and reasoning skills through sketches were taken into consideration.

Besides that, the refined Science Reasoning Skills Test (SRST) which has a total of 20 multiple-choice questions was analysed by using SPSS Version 21.0 before and after the implementation of CETM. The second stage of data analysis continued where the transcripts of interview data were coded. These elements are collapsed into the categories and finally the themes which were used to form major ideas in the database of this study.

One theme was produced and interpreted during the analysis data. At the same time, statistical data were collected by using ANOVA in order to analysis the significant difference between cognitive skills and content domains as discussed in the following segment. Apart from that, children's repsonses in close ended section was analysed using descriptive analysis. Frequency and percentage was used to explain children's responses in manipulating variables during CETM activities. Both the qualitative and quantitative findings were interpreted and justified using the literature review and theories.

The findings were described in depth in Chapter Five once the process of developing the CETM was completed, validated and implemented. The framework of data analysis is illustrated in Figure 4.2.

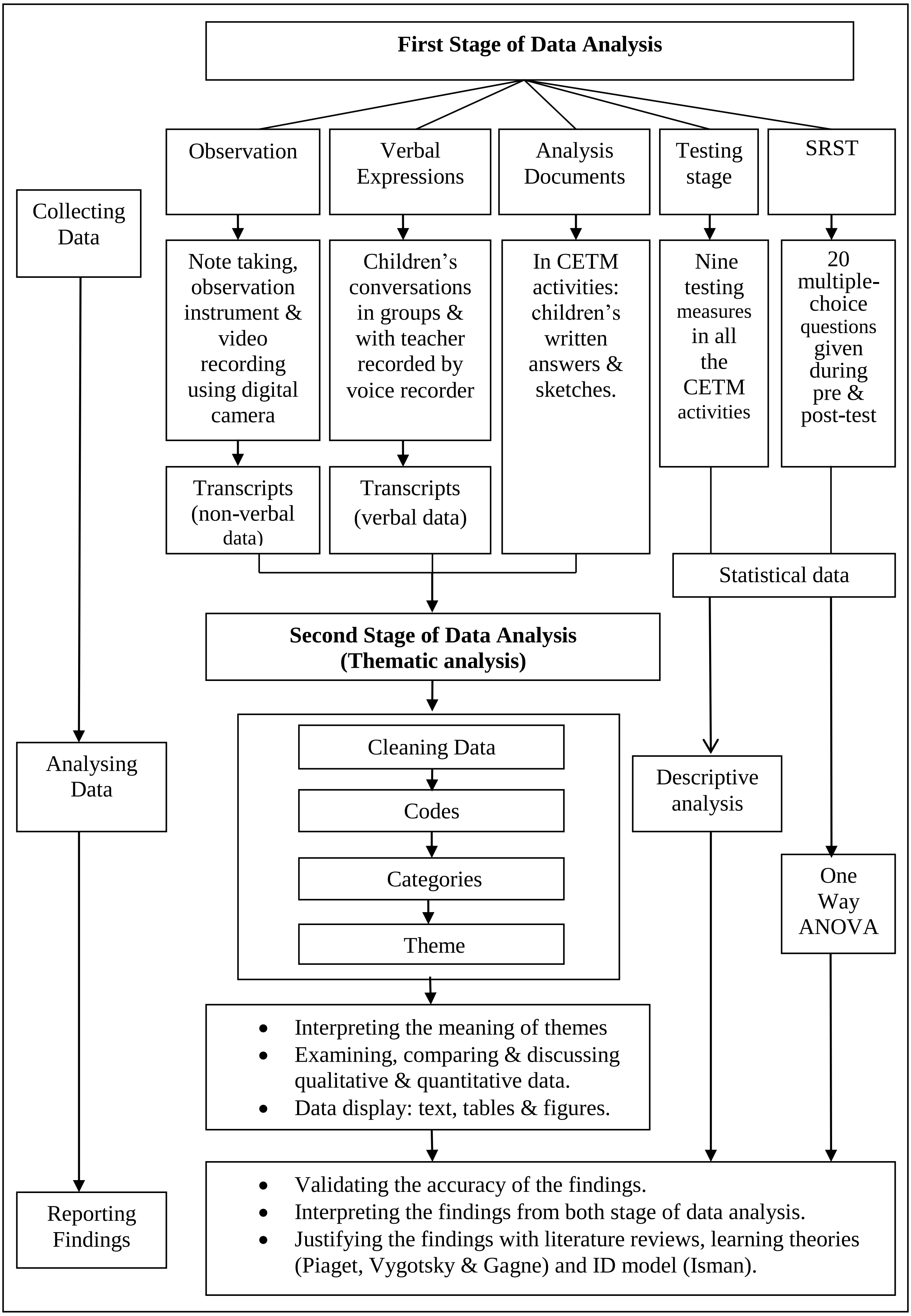


Figure 4.2: The framework of data analysis

One-Group Pre-Test and Post-Test

Before the designed CETM was implemented in the school, an evaluation test called Science Reasoning Skills Test (SRST) was given to the children to test and evaluate their present Higher Order Thinking Skills (HOTS).

The SRST was carried out in one-group pre-test and post-test design where a single classroom of 30 children was employed in order to assess and analyze the cognitive skills in science. The one-group pre and post-test design was practiced in this study because the one-group pre and post-test design does not require a large number of participants and it requires only one group for the study (Creswell, 2012). At the same time, it is better than one-short case study since any changes that take place will be known by the researcher (Fraenkel, Wallen & Hyun, 2012). Apart from that, this design has the advantage of providing data on single individuals, such as learning and behaviors of children (Creswell, 2012).

SRST was given to the children not only before the implementation of CETM but also after the implementation of the CETM. The pre-test (SRST) was administrated a week before the implementation of CETM whereas post-test (SRST) was carried out after three weeks of the implementation. This is because there were five activities in CETM that needed to be carried out during the three weeks' time.

The findings of the SRST were interpreted using both descriptive and inferential analysis. The descriptive analysis involved mean and standard deviation of the SRST whereas the inferential analysis involved the analysis of variance (ANOVA). Each of the cognitive skill was measured based on reasoning domain and HOTS questions. Allowing the researchers to include as many conditions as possible in one test was one of the advantages of ANOVA (Perry, Brownlow, McMurray & Cozens, 2008).

According to Perry et al., (2008), the one factor independent measure design in ANOVA is for situations where the scores in each condition come from different participants and the repeated measures design is for situations where the scores in each condition come from same participants. Since this study used the same children as samples, one-way ANOVA where repeated measure design was used to determine the cognitive domains that could have significantly different means on cognitive skills achievement.

Validation of Research Findings

Validation of the research findings was mainly divided into three divisions which are content validation, face validation and predictive validation. These validations were emphasized in designing the CETM, SRST and children's responses in the activities. These validations helped to confirm the components and processes of designing and developing the CETM. The validation stage encompassed expert reviews through online interviews using modified Delphi and face to face interviews. Expert reviews were used in designing the CETM to evaluate the content and face validity of the activities apart from predicting the outcome of the CETM.

Validation in this study was also used to confirm the elements in the CETM by verifying its components and documenting the impact of the teaching module's use. This study received feedback of CETM based on the teacher who has implemented it in the classroom. The feasibility and usability of CETM was validated by the teachers' perception.

This study also carried out triangulation to validate the research findings. Triangulation of different data sources was used to enhance the validity of this study. In this study, triangulation corroborated evidence from different individuals such as teachers and children. Types of data used such as observational field notes and interviews also helped to determine the validity if the findings. Data collection such as document analysis, observation, interviews and audio-visual materials are triangulated in order to interpret the descriptions and themes accurately.

Using Thematic Analysis to Review the Findings

In order to answer the third research question (How does the developed CETM enhanced reasoning domain of HOTS in teaching science?), thematic analysis was employed to develop the codes, categories and themes from the findings. Children's written answers in writing the problem and evaluation, verbal expressions between the children and the teacher and prototype presentation were used as the qualitative data source. These qualitative data feedback during the CETM activities were analysed using thematic analysis. For example, children's presentations (see Appendix 26) were transcribed into words as in Figure 4.3.

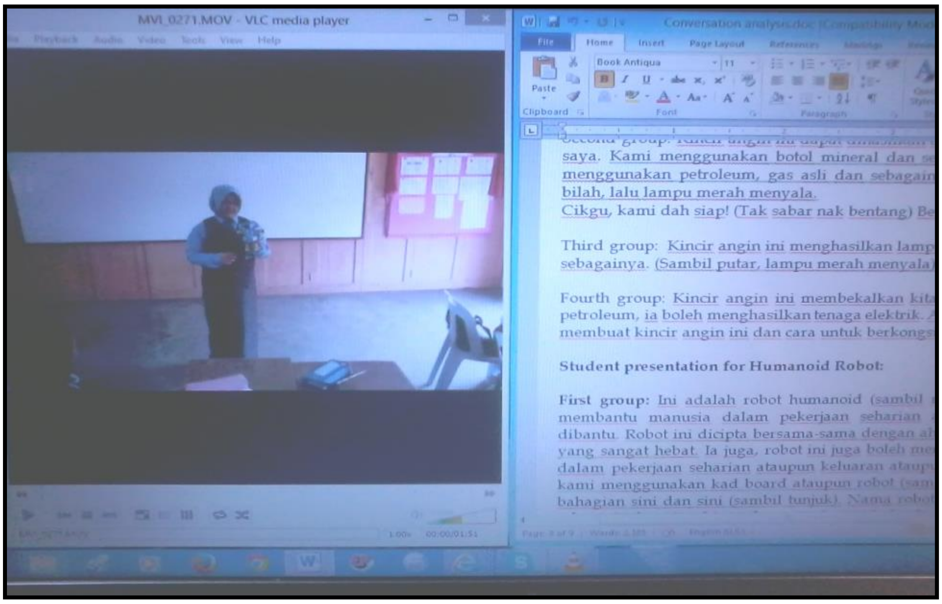


Figure 4.3: Children's presentation transcribed into words

Soon after the presentation, the children asked questions to the presenter. The questions were asked in random and this situation was not influenced or even started by the teacher. This question and answer session kicked off naturally when children started to raise their hands to ask questions. These sessions in every activity was recorded, transcribed and analysed (see Appendix 27).

Children's written answers were categorized into two sections which were writing the problem and evaluations. Subsequently, children's verbal expressions were also divided into two sections, which were exchange dialogues between the children and children and teacher. At the same time, children's presentations and questions answers session were also transcribed into words. Finally, the classroom observations using observation instrument and video were transcribed into words.

However, the detailed steps on how the thematic analysis was carried out in order to generate the codes, categories and themes is discussed in the following discussion. The thematic analysis was carried out in three steps, which are familiarizing with the data, generalizing initial codes and merging the developed codes to form categories.

Familiarizing with the Data

First foremost, all the gathered findings were transcribed and repeatedly read and re-read to note down the initial codes. It was important to familiarize with all the aspects of the data. The process of transcription in this study was time consuming, but according to Riessman (1993), it is an excellent way to start familiarizing with the data. According to Braun, Clarke and Terry (2014), it is vital for the researcher to immerse into the data to the extent that the researcher is familiar with the depth and breadth of the content. Hence, the transcribed data was read through five times before the coding process as the ideas and identification of possible patterns was shaped. The time spent in transcription was not wasted, as it informed the early stages of analysis and developed more understanding of the data through having transcribed it. The close attention to transcribe data facilitated the close reading and interpretative skills were needed to analyze the data (Lapadat & Lindsay, 1999). Apart from spending more time familiarizing with the data, the transcripts were also re-checked against the original audio recordings for data accuracy. These actions increased the overall data reliability.

Generating Initial Codes

The following analysis was in line with Boyatzis (1998), Miles and Huberman (1994) and Tuckett (2005) who are experts in thematic analysis. In this research, the process of coding was part of the analysis as the collection of data was organized into meaningful groups. These codes identified features of data that appeared to be interesting and referred to the most basic segment, element of the raw data that can be assessed in a meaningful way regarding the phenomenon.

The coded data differed from the units of analysis or categories and themes which has a broader definition. The emerged codes were data driven and supported by theories such as Piaget, Gagne, Vygotsky and Revised Bloom Taxonomy (RBT). The coding process was carried out manually since it gave the space and opportunity to observe the repeated patterns that arose in the data. The coding process in this research was also in line with Given (2008) because it was best to keep an open mind and look for concepts and ideas that directly correlate to the research objective.

Further discussion about why coding was carried out manually in this research was explained in Chapter Two. Since the coding was carried out manually, the data was coded by written notes on the text, using highlighters and coloured pen to indicate the potential patterns and using post it notes to identify the segments of data. Initially the codes were identified and they were matched with the data extracts that demonstrated that code. However, all the actual data extracts were coded and then collated together within each code. Many potential codes were coded since the researcher might never know what might be interesting later. Apart from that, the codes extract of data were carried out comprehensively.

There were seven experts who were involved in the coding process whereby four of the experts were from abroad and three of them were locals (Appendix 28). Once these experts agreed to be part of this research, children's responses in CETM were e-mailed to them. Some of the experts took around two weeks to respond meanwhile others took approximately a month to give their feedback. A list of suggested codes with proper definitions and evidences were also mailed to these experts. Meanwhile the local experts were met face to face in order to agree on the codes selection. For example, after looking into the children's responses in written answers, the experts listed out a few intial codes. One of the codes suggested by the experts were 'convincing statement'. However, this code was not finalized since the other experts who are not local also gave their feedback in finalizing the initial codes.

After looking into the listed codes and CETM evidence from the children, one of the experts requested that the code 'convincing statement' needed to be altered and referred as the 'marginal statement'. The similar process was carried out for all the other emerged intial codes. The other initial codes were also changed and altered based on the expert's opinion and judgment. After the second round of coding alteration, the experts mentioned that the sorting of coding process has improved and the initial codes were systematically presented as one of the findings.

After the initial coding, some patterns that started to form were recognized because the initial coding's primary goal was to find these patterns as documented in the data. It was time to refine, synthesize and explain the larger segments of research data. Meanwhile, some of the experts were asking to provide a better definition for most of the codes since it was a need to differentiate one code and another. While mailing the codes from time to time, after the alterations, a few experts were concern on the clearity and consistency of the codes. These feedbacks raised by the experts are placed at Appendix 29.

The coding process and the data were reviewed as they were grouped together. Subsequently, the codes were further compressed. Focus reading kept the researcher checking the preconceptions by constantly reviewing and comparing the previous findings of codes and data. The codes were recoded to better fit the data, new categories and new concepts or ideas. The experts gave constant feedbacks on developing the codes.

After the second coding stage, it is time to place them in the bigger picture. Consequently, refining the codes and improving categories helped analysis and constructed an overview of relevant information and their connections. Some of the codes were redefined and additional data was added. For example, based on the children's sketches, the experts identified initial codes such as shapes, pattern, symbols, numbers and being expressive. These initial codes were supressed into second coding known as "explaining using key features". At the same time, looking into children's written answers, experts identified another code known as "adapting logical examples". This is because experts mentioned that children have used logical examples to justify their answers. However, both these codes were grouped together since the experts believed that both the codes were parallel with the children's style of justifications. Subsequently, other experts gave their testimonials on other codes.

Merging the Developed Codes to Form Categories

Categorization is a process that develops along with the coding. As patterns became visible among the codes in this study, certain codes that fit together were grouped to form categories. These categories were explicit since an enumeration of codes was not sufficient. Parallel to that, a coherent scheme of sub categories was developed to facilitate the broader concepts and research as a whole. Sub categories were developed inductively by approaching the data without a pre-set list of categories and identifying units that conceptually match the phenomenon in the data. For example, based on children's written answers and verbal expressions, experts had suggested that children were offering unexpected solutions. The experts concluded that the children used different viewpoints while experiencing the CETM activities. Hence, different viewpoints, justifications, evaluation and constructing engagements were sub categories suggested by the experts.

Based on the description and examples (children's responses) for the sub categories, the experts merged the sub-categories into categories. For example, sub categories such as justifications, evaluation and different viewpoints was merged into a category called engaging reasoning skills. Apart from the descriptions and examples, the experts agreed that engaging reasoning skills was also in line with the research question of how the CETM can enhance HOTS.

However, along the process of merging the codes and categories, there different ideas from the experts. Some experts had different names the bcategories. For example, when developing categories using a collection of sub-categories, an expert suggested the category called 'interactive thinking'. However, another expert revealed that 'engaging reasoning skills' would be a better category since it's aligned with the research question. When majority of the experts agreed that 'engaging reasoning skills' was better that 'interactive thinking', the category was named as 'engaging reasoning skills'. At the same time, this description and examples from children suited the engaging reasoning skills idea as compared to interactive thinking.

Subsequently, other categories were also developed deductively, from prior studies, relevant literature, research question, expert's knowledge or experience. In this study, the key element of categorization was either to cluster groups of coded data or as an intermediate step of separating and connecting units of meaning. At the same time, while merging the developed codes into categories, the process of evaluating internal integrity (the definitions of sub categories) and external integrity (how do categories relate to other categories) was continued as codes and categories were more refined and apparent in terms of the connectivity. Once all the codes were placed in a relevant sub category and all major categories were compared and consolidated with each other, the progress towards the thematic, conceptual and theoretical was transcended.

According to Braun and Clarke (2006) and Bryman (2001) no data set is without contradiction and a satisfactory thematic code that will eventually produce an overall conceptualization of the data patterns. However, relationships between them do not have to smooth out or ignore the tensions and inconsistencies within and across data items. It is important to retain accounts that depart from the research question in the analysis, other codes which are relevant must not be ignored the coding process.

In line with the inter coder reliability, this study has employed nine different experts to categorize and verify the coding process. The coding process using the predefined codes, supervisors as local experts and other experts were invited to check and review on the codes as well. The results were compared and some modifications were made to the predetermined code template. A few researchers have questioned whether experts are the best judges of what is valid in the coding process. Member checks can become the participant's response to a new phenomenon, namely the researcher's interpretations (Sandelowski, 2002). However, because of the pure qualitative nature of thematic analysis, peer checking of inter coder reliability is not always possible since there is skepticism about the value of such testing. It has been discussed that one researcher merely trains another to think as she or he does when looking at a fragment of text.

Thematic Framework

A theme captures something important about the data in relation to the research question and represents some level of patterned response or meaning within the findings (Braun, Clarke & Terry, 2014). The theme that was produced in the thematic analysis was promoting idea-generating strategies as shown in Figure 4.4.

Parallel to that, the theme in this research was developed on its own space and time by collapsing codes and supressing the categories. Furthermore, the key of this theme was not entirely dependent on quantifiable measures but rather on whether it captured something important in relation to the overall research question (Clarke & Braun, 2013). According to Braun and Clarke (2006), the names need to be concise, punchy and immediately give the reader a sense of what the theme is about. Hence, the theme in Figure 4.4 displayed the intention of answering how CETM enhanced HOTS among children while learning science.

The Figure 4.4 also shows how the children used sketches, written answers, verbal expressions, testing prototypes and other various interactions to enhance the HOTS. For example, by using sketches in CETM activities, children explained their ideas using key features such as symbols and units. Apart from that, children also placed their own ideas of improvements for the prototypes by using the sketches.

Meanwhile children accepted criticism, provided unexpected solutions, manipulated variables, reflected on previous knowledge and experience, argued and placed their own ideas of improvements while having verbal expressions and testing the prototypes. However, some codes such as placing own ideas of improvements emerged for all the platforms on how the children enhanced HOTS during the activities. In other words, codes such as placing own ideas of improvements emerged from children's sketches, written answers, verbal expressions, testing prototypes and various interactions in the classroom. Similarly, other codes such as unexpected solutions, manipulating variables and argumentation also emerged twice from different platforms of CETM activities.

A total of eight codes emerged from the various platforms during the CETM activities. The codes were gathered from qualitative forms of data in CETM activities to explore children's HOTS enhancement while learning science in classroom. Each of these codes were grouped together to form four sub-categories. These sub-categories are justifications, evaluation, different viewpoints and construct engagements. In other words, children had justified their answers by explaining using key features and adapting logical examples. At the same time, children had also evaluated by placing own ideas of improvement and accepting criticism. Similarly, children provided different viewpoints by showing unexpected solutions and manipulating variables. Finally, children had constructed engagements by argumentation and reflection.

These four sub-categories were collapsed into three categories called stimulating creative thinking, engaging resoning process and practicing intellectual discussion. For instance, what can be said is that, children had stimulated their creative thinking skills by using justifications and showing different viewpoints. Similarly, children had engaged reasoning process by using justifications, evalution and showing different viewpoints. Finally, children practiced intellectual discussion by constructing engagements.

In line to that, the three categories which were engaging reasoning process, stimulating creative thinking and practicing intellectual discussion were collapsed into one theme called promoting idea-generating strategies. Therefore, in a broad view, CETM activities enhanced HOTS by promoting idea-generating strategies which allows the children to engaging in reasoning process, creative thinking and practice intellectual discussion.

Many researchers believe that both descriptive and interpretative approaches entail interpretation, even if the interpretive component is downplayed or masked in discussions of its broader narrative and exploration (Sandelowski, 2010). Meanwhile each of the codes developed from the findings were recognized as HOTS elements prior to the interpretation process.

The coding process was carried out simultaneously with expert's feedback and agreement on its practicability and significance based on the children's response in CETM activities. The value of codes, categories and theme description lies not only in the knowledge that can originate from it, but also because it is a vehicle for displaying and treating research methods as living entities that resist simple classification, and can result in establishing meaning and solid findings (Giorgi, 1992; Holloway & Todres, 2003; Sandelowski, 2010).

Figure 4.4 displayed how the developed CETM enhanced reasoning domain of HOTS in teaching science. The definition of codes and subcategories in Figure 4.4 was shown in Appendix 30.

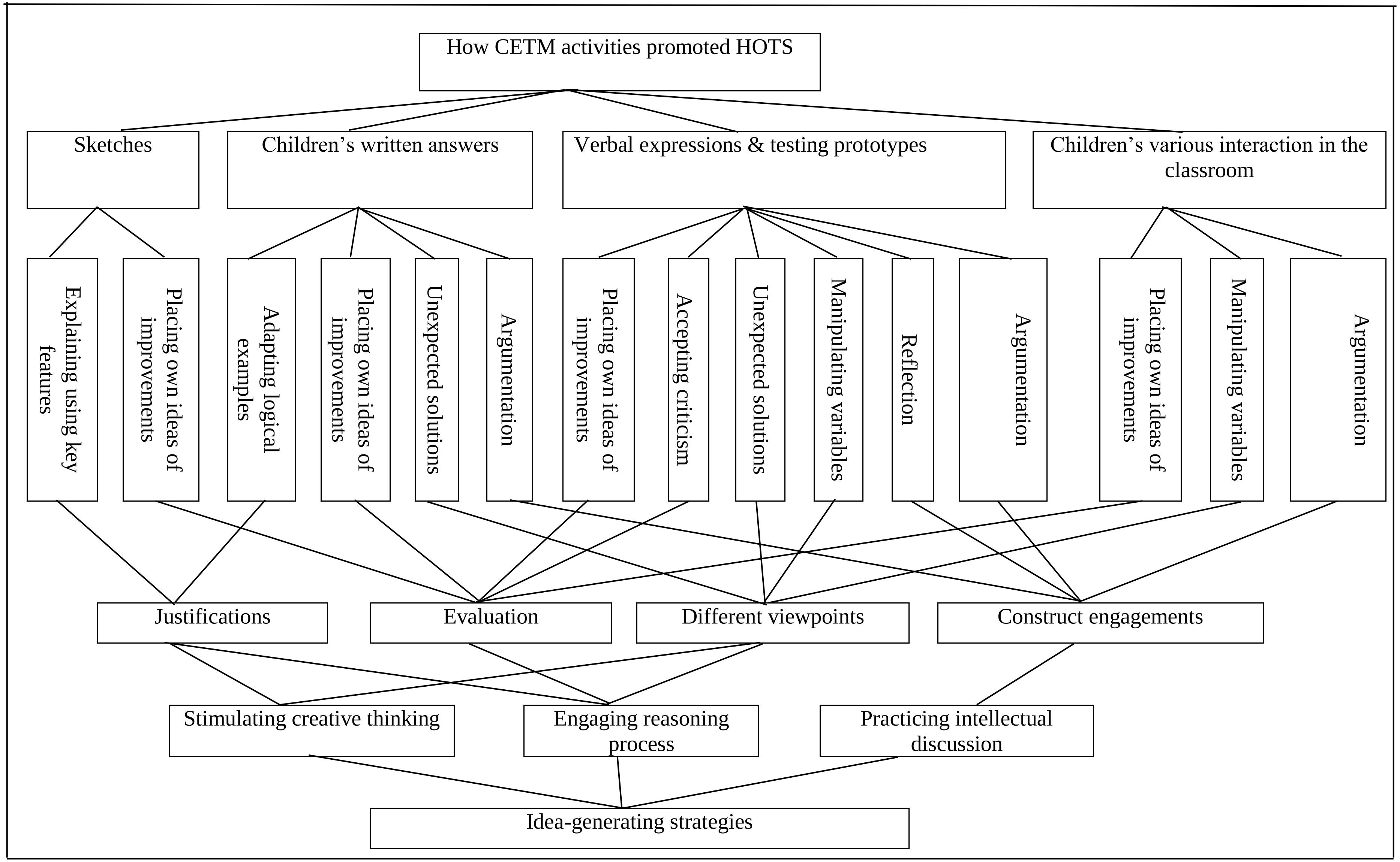


Figure 4.4: Thematic analysis for findings

Researcher's Bias and Assumptions

Facilitating primary school children with engineering design is a new approach of teaching in most Malaysian schools (Phang et.al, 2012). Hence, the researcher took the initiative to guide the teacher on how to assist the children during the activities. The researcher is also novice in engineering design. With extensive research in early engineering, children's engineering and EiE programmes, the researcher was well versed in the knowledge of engineering design. However, it was not enough as practical experience is equally important in delivering the activities, confidently.

In order to gain more hands-on activity in engineering design, the researcher attended a workshop. The workshop was on early engineering design held during the International Conference in Science and Mathematics Education in the northern province of Malaysia where the researcher took part and become a 'student' along with the other academicians. The workshop was carried out by an American primary school teacher called Rebecca Petersen. She was a STEM education specialist in training teachers and currently working closely with the schools in Thailand for primary school children. Equipped with both research knowledge and hands-on experience, the researcher was confident in guiding the teacher to implement the CETM activities developed by the researcher.

Summary

This chapter discussed the research designs, sample, data collection instruments, procedures and ways of interpreting the findings. Through this detailed direction for each part of the research process, the research questions were believed to be answered from the findings of both design and development chapter and the methodology chapter.

CHAPTER 5: FINDINGS

Introduction

This chapter will discuss the research findings that emerged in this study. This chapter outlines the findings based on qualitative and quantitative approach. There are two major parts in this chapter, whereby the first part discusses the qualitative findings. In this part, children's responses such as written answers and conversations were quoted. Some explanations were provided using inverted brackets. Apart from that, sketches and photographs were also provided in justifying the findings. The photographs used in this study have received the permission from the parents or guardians (Appendix 13). In some of the sketches, children included some written notes in Malay language. These written notes were translated into English language, at the bottom of the sketches. Subsequently, teacher's view on the Children's Engineering Teaching Module (CETM) was also narrated here as the final part of the qualitative findings. Pseudonym names were used for the children and teachers who participated in the CETM activities. Consequently, the second part of this chapter discusses the quantitative findings. In this part, the analysis of pre and post-test using Science Reasoning Skills Test (SRST) was discussed. The results of the descriptive analysis and significant difference for each test item were also presented in this chapter. Finally, descriptive analyses for testing the prototypes were discussed using percentages and frequencies.

Strategy, Technique and Skills Used by Children in CETM activities

Based on the analysis, it can be revealed that children employed certain strategy, technique and skills in responding towards CETM activities, particularly in HOTS and reasoning skills. Figure 5.1 shows the relationship between strategy, techniques and skills used by children in the CETM activities. The strategy used by children was idea-generating strategy, followed by three techniques such as engaging reasoning process, stimulating creative thinking and practicing intellectual discussion.

The research outcomes revealed that children had used four types of skills and three types of strategies in generating their ideas. Children used skills such as evaluation, justifications, different viewpoints and constructing engagements throughout the CETM activities. Apart from that, children employed techniques such as engaging reasoning process, stimulating creative thinking and practicing intellectual discussion while creating the prototypes. Each of these techniques assisted the children to produce ideas in creating the prototypes for the given challenge.

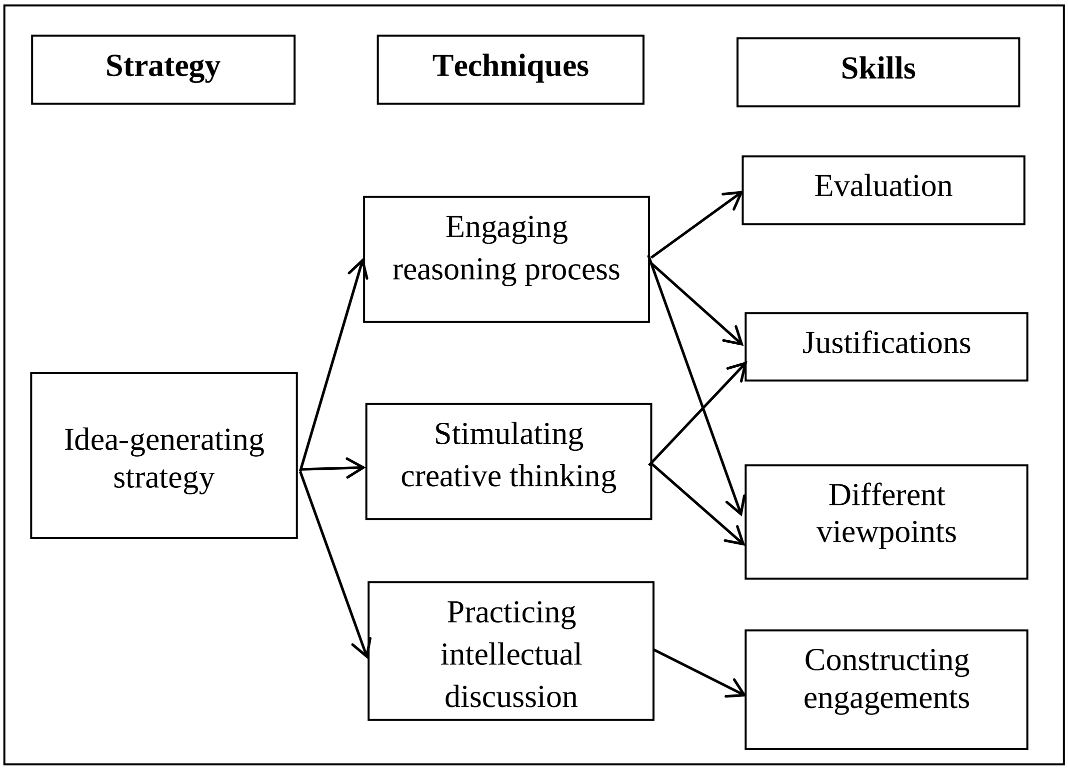


Figure 5.1: Schematic diagram on how children demonstrated HOTS and reasoning skills during CETM activities

Idea-generating strategy.

Idea-generating strategy is a plan of action children created to achieve an overall aim in designing a prototype during CETM activity. Idea-generating strategy required some sort of planning before making decisions during the CETM activities. Children used idea-generating strategy while brainstorming for ideas, drawing sketches, testing and evaluating the designed prototypes.

Based on the findings, children were able to generate as many ideas as possible within the given time frame. The more idea they generated, the better the solution they came up with. During the CETM activities, children worked in groups to overcome the given challenge. For example, during Activity One, children came up with an idea to design a plastic parachute in order to send bamboo shoots and water supply to rescue the pandas, which were stranded in the drought season. It was observed that children were discussing in groups. Meanwhile some of the children were shouting out their ideas loudly. One of the them mentioned; "…Use cloth instead of plastic". The usage of cloth is also an alternative material to design a plastic parachute. When asked upon, why he mentioned cloth when its known as plastic parachute, the child said that; "…As long as it can float in air". In real-life, there are parachutes designed using cloth because it floats longer in the air. As children were discussing, they also continued to brainstorm for ideas to design the parachutes which can float in the air with bamboo shoots and water supply. It was observed that children sketched different patterns of plastic parachutes. For example, children drew plastic parachutes with different amount of strings attached to the plastic.

In one of the groups, a child called Asri was observed to be sketching different amount of strings for each of the plastic parachute. When asked Asri why was the amount of strings varied for each of the sketch, Asri mentioned; "…In case the plastic parachute (once it's designed) does not fly properly, more strings can be added". At first, Asri and his group members designed the plastic parachute with three strings. Soon after that, when they evaluated the plastic parachute, they noticed that it was not floating properly in the air. Hence, Asri and his group members modified the plastic parachute by adding two more strings and the plastic parachute was observed to be floating better than the first attempt. Figure 5.2 shows how Asri and his group members added more strings to their designed plastic parachute.

Figure 5.2: Asri and his group members added more strings to design a better plastic parachute prototype

Apart from Asri and his group members, other children from different groups also created various types of plastic parachutes. There were a range of different plastic parachutes designed since the children created six types of plastic parachutes. Some of the plastic parachutes were designed with either more strings or lesser strings. Meanwhile, some of the plastic parachutes had either bigger plastic bags or smaller plastic bags. Children also managed to create plastic parachutes which could withstand heavy weight, with more bamboo shoots or water supply.

By the same token, for Activity Two and Four where children designed the windmill and metal tin robots, children came up with a number of ideas to produce the solution for the given problem. Children created windmill prototypes to experience the usage of renewable energy which came from natural resources which are replenished on a human timescale, such as the wind energy.

During Activity Two, children created different designs of windmill. The windmill designs had both bigger plastic bottles and smaller plastic bottles, which indicates that either more water was filled in the bottles or lesser water was filled in the bottles. While designing the prototypes, Jason from one of the group mentioned; "...The taller and heavier, the better (the windmill prototype)". When asked upon why he thought it was better, Jason said; "…It (the windmill prototype) functions better". When asked Jason, why it functions better, he said that; "…can get more wind and can resist tsunami". In short Jason described that when the windmill is taller, the possibility of it to receive more wind is higher. On the other hand, when the windmill is heavier, the possibility of it to withstand the strong wind or bad weather is also better.

Five days later, children participated in Activity Four, whereby they designed a metal tin robot. Children came up with the metal tin robots to dig the essential minerals in the Moon since these minerals were decreasing on Earth. After they have created the metal tin robots, children tested their designed prototype with other groups. While children were testing the prototypes, Lucy from a group of children mentioned; "…Use the plastic bottle, its lighter!" This is because while testing the designed metal tin robot, the metal tin robot moved slowly but Lucy and her group members wanted the metal tin robot to move faster. Hence, by replacing the metal tin can with a plastic bottle, the metal tin robot prototype moved faster. This type of idea-generating strategy reflected how children think during the CETM activities. Children managed to layout and recognize the patterns of creative ideas that could lead towards better solutions.

Promoting idea-generating strategies were carried out using three different techniques. Technique is a procedure or structure for children to complete a CETM activity. Based on the findings, children have used these techniques to create the prototypes. However, by using these techniques, it was obvious that some of the prototypes were unexpected since they were unique and creative. The techniques used by children were:

a) engaging reasoning process

b) stimulating creative thinking

c) practicing intellectual discussion.

Engaging reasoning process.

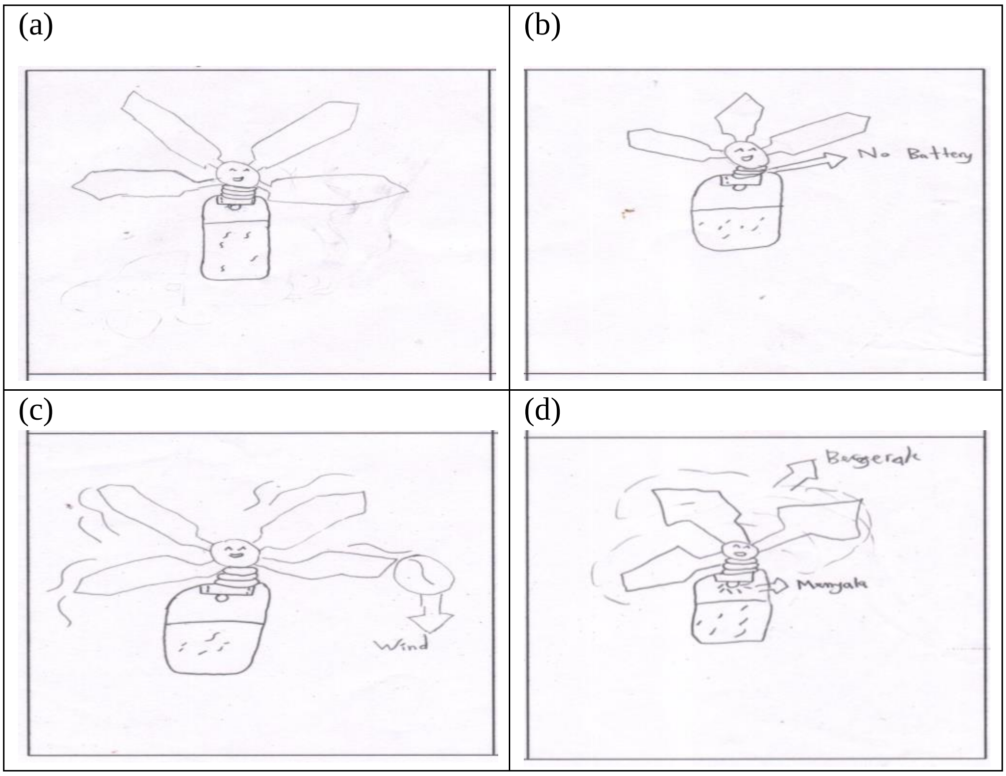
Engaging reasoning process is a thinking process that children experienced throughout the CETM activities. Based on the findings, children were engaged in reasoning process by using justification, evaluation and different viewpoints. For each of the activity, the teacher created a brainstorming session to gather the children's ideas on how to overcome the situation. Later, the children wrote the problem using their own words. Children not only wrote their answers with proper justifications and evaluations, but they also offered different viewpoints either while writing the problem or while evaluating the prototype once it was designed.

For example, in Activity Two before the children created a windmill prototype, they were encouraged to write the problem first. Based on their written answers for the necessity in finding solution, it was apparent that the children displayed the ability to justify their answers. In Activity Two, children experienced the process of finding a solution to use clean energy, such as the wind energy. While writing what was the reason at the first place for them to design a windmill, one of the children named Kenny wrote the problem as; "…There are few windmills in Malaysia, that's why humans use petroleum and produce pollution". Kenny justified the reason on why pollution is a problem and indirectly mentioning that more windmills should be built to overcome the use of petroleum by humans. By looking at Kenny's written answers, Kenny was asked how does the windmill reduce the pollution. Kenny responded that; "…. Windmill uses wind, (which can't be observed) but petroleum is liquid (can be observed), it burns". Kenny was indicating that wind does not have an outlook meanwhile petroleum is in the form of fluid and it can create combustion. These responses from Kenny indicates that he has not only differentiated the physical outlook of wind and petroleum, but at the same time, he could have imaged the process of combustion when the petroleum burns and produces smoke.

Concurrently, after writing the problem in each activity, children brainstormed their ideas using sketches. Some of the children sketched different types of prototypes. Meanwhile, other children either sketched the process of designing one particular prototype or sketched the overall process on how to solve the given problem.

It was observed that the children justified their sketched prototype using symbols, arrows, short notes and mathematical units. The children reasoned their plan of action using a structured and organized method of sketch. According to Uttal, Scudder and DeLoache (1997), symbols are difficult to teach the children who have not grasped the concepts the symbols represent. However, while brainstorming the ideas in the CETM activities, children had used symbols to justify and strengthen their ideas.

For example, while brainstorming ideas to find a solution for Activity Two, Jasmine sketched her ideas on creating the windmills prototypes. It was observed that, Jasmine used written notes and symbol of wind to justify her windmill sketches. Jasmine also used relational symbols, such as arrows and spatial relationships to explain her understanding on how her windmill idea could work. Several experts who looked at Jasmine's sketch in Figure 5.3 gave positive feedback, especially in regards to higher level thinking skills. One of the experts who helped to analyze the children's sketches mentioned; "…I believe that the child has rationalized the entire process of brainstorming. It is a step further in promoting engineering and architectural skills". Based on Jasmine's sketches and the expert's testimonial, it can be said that Jasmine has justified her ideas using notes and relational symbols while brainstorming for solutions in Activity Two.

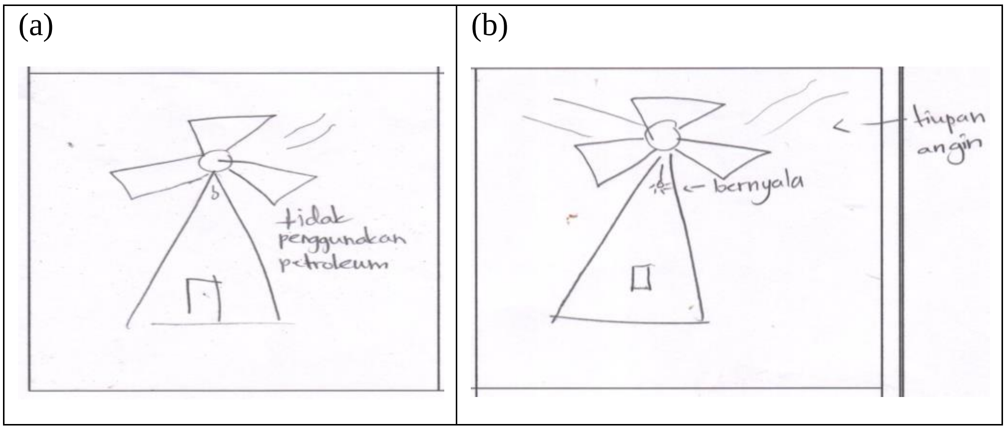


- *'bergerak'* means moving and *'menyala'* means light is burning

Figure 5.3: Jasmine's windmill designs

Parallel with Activity Two, it was observed that different groups of children sketched in different ways in expressing their ideas to create a windmill. Other groups of children were also simulatenously creating a windmill prototype to solve the given problem. Daisy who was from a different group, also sketched her windmill prototype using short notes and symbols, parallel with Jasmine's sketches. Based on Daisy's sketches in Figure 5.4, it was observed that Daisy has justified her ideas by writing short notes and using symbols of wind and light in designing the windmill.

However, Daisy's sketches were different as compared to Jasmine's sketches because it was noted that Daisy has different type of blades and sketched a door in her sketches. When asked Daisy, why was there a door sketched, Daisy mentioned that; "…people can stay inside it (windmill)". When probed her further, she justified that "…(windmill) can generate light and fan, so (people) can stay". It can be said that, Daisy has displayed the ability to share her different viewpoints as compared to her other classmates apart from evaluating her sketches to sketch a more productive windmill. Daisy has also articulated the structure of windmill over its superficial details with proper additional justifications.



- *'tiupan angin'* means wind is blowing
- *'bernyala'* means light is burning or 'illuminating'
- *'tidak menggunakan petroleum* means not using petroleum.

Figure 5.4: Daisy's windmill designs

In another situation, children began to use the information or knowledge from previous CETM activity to design their prototypes. For instance, when children sketched designs to design a metal tin robot for Activity Four, they began to justify their ideas by employing earlier facts from previous activities. Children were encouraged to design metal tin robot prototypes to dig the minerals in Moon because these minerals were essential for the mankind on Earth. Hence, one of the child named Awang sketched a few metal tin robots during Activity Four and one of the sketches is as displayed in Figure 5.5. All his sketches had legs to stand except for the one in Figure 5.5 because it was the only sketch which was sketched with blades on the head. When asked Awang why this particular design had blades and no legs, Awang mentioned that; "…(I) want it (metal tin robot) to fly". When probed him further, he explained; "…It (digging and transporting the minerals) can be faster since it uses the wind energy. It (wind energy) is free and it is everywhere". Awang offered different viewpoints in designing the different types of metal tin robot prototypes. Awang began to think on the economic issue when he mentioned that wind in free and it can be found everywhere. Awang was trying to say that his prototype can cost cheaper, yet function faster and better.

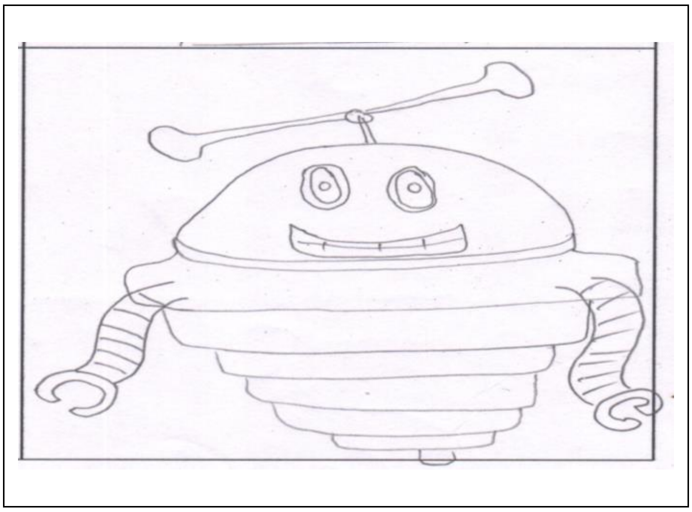
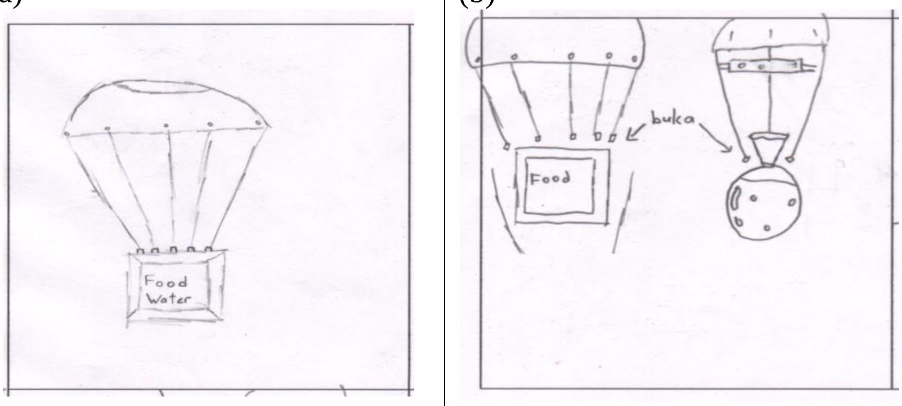


Figure 5.5: Awang's metal tin robot design

Similarly, children also sketched the plastic parachute in their first activity while brainstorming ideas to find a solution. The sketches in Figure 5.5 was an example of how the children began to justify their ideas using written notes, symbols that represents water and relational symbols, such as arrows and spatial relationships. It was observed that children have included symbols and short notes to explain their ideas in designing plastic parachutes. Children have also conveyed deep understanding on how the proposed plastic parachute works. William, who produced the sketches in Figure 5.6, illustrated his plastic parachutes as strong and stable.

(a) (b)



- *'buka'* means open

Figure 5.6: William's plastic parachute designs

However, it was observed that William had modified his sketches while creating the plastic parachute. When asked why he modified his sketches and sketched two different plastic parachutes as shown in Figure 5.6 (b), he said; "…I think one (plastic parachute) is not strong enough to withstand the weight of food and water to save the pandas. He continued; "…It is (plastic parachute) keep falling (not floating). That's why I did (sketched) two (plastic parachutes)". Without him realizing, William had actually engaged in the reasoning process, while thinking about the relationship between the weights that the plastic parachute need to withstand and the force of gravity.

Parallel to that, William also sketched some bubbles of water reflecting the symbols learnt during Year Four science lessons. According to the science teacher, children experienced to sketch water bubbles when they were in Year Four (ten years old). Children learnt the standard of measuring tools for volume in Unit Measurement in

Year Four Science. Children were introduced to beakers and cylinders where they learnt to sketch bubbles which represents water. Hence, it was found that William has justified his ideas using what he had learnt in Year Four Science in Activity One to design his plastic parachute.

Subsequently, after creating and testing the prototypes, children were encouraged to write evaluation regarding their designed prototypes. They were free to write their own assessment using their own words. For example, in Activity One, the question that required written answers is; "…Was the plastic parachute the best solution for the problem given?" It was noted that not all of the children agreed with the idea of designing the plastic parachute. Some of the children thought otherwise. For example, Rosninah mentioned; "…No, because it's a dangerous idea especially if the string gets snapped". Rosninah justified on why the idea of designing plastic parachute was dangerous, since the heavy load (food and water) can affect the strength of the strings.

Subsequently, other groups of children also evaluated their designed plastic parachutes after creating it. The atmosphere in the classroom was noisy because children were flying their plastic parachute while trying to improve their design. Meanwhile Zeti and Uma who represented different groups, disagreed that designing a plastic parachute was the only way to overcome the problem in Activity One. Both of them expressed their disagreements in written words when answering the question in the evalution stage. Zeti wrote; "…No, we can use bicycle". Similarly, Uma mentioned; "…No, it moves smoothly if we used hovercraft."

Zeti and Uma preferred to use bicycle and hovercraft instead of parachutes for rescuing the pandas from the horrible dry season. Both the answers were justified with suitable examples such as bicycle and hovercraft because the location of country where the pandas were stranded was not mentioned in the context. It was simply mentioned as country X in Activity One. Hence, the justification which Zeti and Uma gave was feasible because the support could be provided either by travelling on land (bicycle) or by water (hovercraft).

The word ‘hovercraft’ was not mentioned by anyone in the classroom and it came only from Uma. This could mean that it came from the child’s own observation through media or by reading a book. When asked Uma, why hovercraft and why not the plastic parachute, Uma lifted up the designed plastic parachute and displayed that it swayed towards the right and left. She was trying to say that the plastic parachue did not fly smoothly. Uma also mentioned; “…Faster”, reflecting that that it would be faster to send food and water using hovercraft rather than the plastic parachute. When asked how Uma came across the word hovercraft, Uma revealed that hovercraft was like a boat *(sampan)* that moves fast on water. According to Uma, she watched the hovercraft on the television.

This showed that Uma has used her personal knowledge and observation to reason out that hovercraft could be a better option than the plastic parachute. The children used the real-world application outside the classroom to reason and justify their explanations. By engaging in reasoning skills, they began to realize that CETM activity does not provide just one right answer. Every activity encourages children to experience the cyclic process of creating the solution for the problem given. Similarly, after five days of completing two activities, children created the metal tin robot for the problem given in Activity Four. After writing the problem, brainstorming for ideas and creating the metal tin robots, the children tested their designed prototype.

Based on the observation, it was found that in one of the groups, children were figuring out why the designed metal tin robot was not producing much noise when it was switched on. Figure 5.7 (a) showed two different gestures while testing the prototype on the classroom floor. It was observed that, Hartini was scratching her head by using an index finger while looking at the designed prototype. Hartini was observed to be thinking on why the metal tin robot was not producing much noise. Meanwhile, Lavin and Hamzah were pointing at the prototype. Lavin mentioned; "… Why is it not loud enough?" Hamzah echoed and responded similarly saying; "…Yes, Why ar?". This group of children evaluated their prototype during Activity Four.

The group of children were also trying to reason out while testing the prototype. These children were giving some insights and ideas on how to improve the prototype. They were puzzled on how to create more noise from the prototype. Hence, from the classroom floor where they tested their prototoype, the group of child rushed towards their normal position in the classroom to figure out the reason behind the default as displayed in Figure 5.7 (b).

Figure 5.7: Hartini and her group members figuring out how the designed metal tin robot can produce more noise when it's switched on

It was observed that, they reopened some of the structures in the metal tin robot. Subsequently, the children made some tiny holes on the metal tin can and filled the holes with screws. When the metal tin robot vibrated, the screws in the metal tin can were vibrating as well. After that effort, the metal tin robot made louder noise. The prototype produced louder noise and most importantly fulfilled the criteria that were mentioned in Activity Four. The criteria for Activity Four were to design a metal tin robot that produces sound when it vibrates. Children also increased the number of screws on the metal tin can because they realized that the more screws fixed into the metal tin can, the louder the noise produced when the metal tin can robot vibrates.

It can be said that the children were engaged in the reasoning process in a natural classroom setting without the interference of the teacher. Children justified and evaluated their prototype in a cooperative effort. Making tiny holes and filling it with screws in the metal tin can was an idea that they figured out within their group. They observed the problem and made an inference that having extra engagements between the metal tin can and the increasing number of screws can produce louder noise when the metal tin robot vibrates.

Based on the children's efforts, it can be said that the children had used the mathematical knowledge in creating a better prototype. Though the mathematical concept was basic, it was still important to create a productive prototype. The numbers of screws were prominent in creating louder noise. Hence, children were engaged in the reasoning process when they were rectifying the problem and finding the solution. The solution was something unexpected, since they carried out extra effort in producing a metal tin robot that produces noise when it vibrates.

Like other CETM activities, before creating the metal tin robot prototype for Activity Four, children were encouraged to brainstorm their ideas by sketching their designs. It was evident that, children incorporated mathematical knowledge into their sketches. This is because based on the sketches in Figure 5.8, it was observed that Awang's sketches were structured, organized and complex. Awang had used a ruler to measure and sketch his metal tin robots.

In fact, Awang has also incorporated a robot without head but with a weighing device which has the 'on' and 'off' switch as shown in Figure 5.8 (a). A numerical value with a weighing unit kilogramme (kg) demonstrated that Awang has infused the knowledge of Mathematics into the prototype. The usage of interdisciplinary relationship between Science and Mathematics revealed how Awang has justified the proposed metal tin robot prototype in Activity Four.

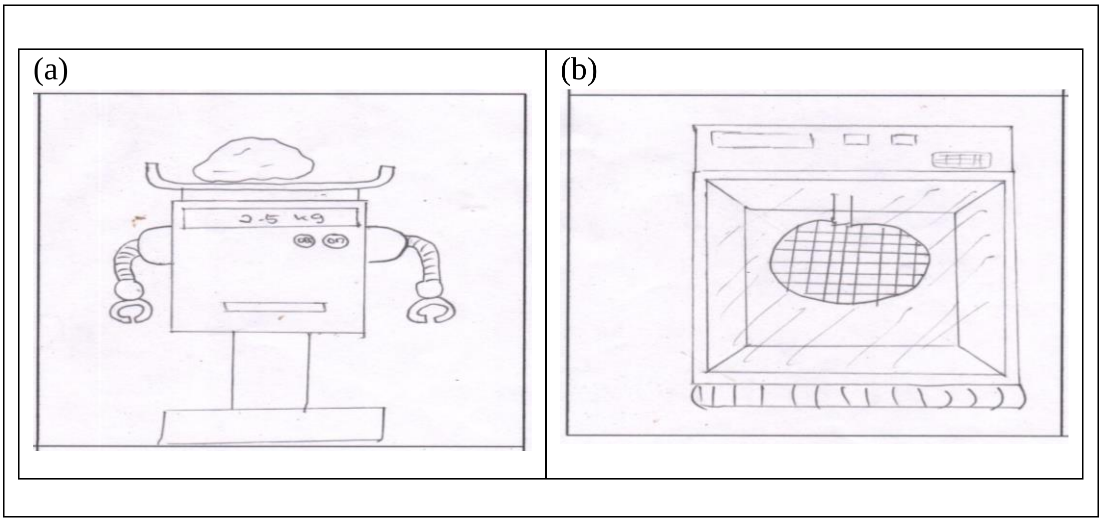


Figure 5.8: Awang's metal tin robot designs

Apart from that, Awang also sketched another sketch as displayed in Figure 5.8 (b). When asked Awang why the sketch does not look like a robot, Awang revealed it is a mineral sensor which detects the location of the mineral on the Moon. It is the image of how the mechanical system looks like inside the sketch in Figure 5.8 (a).

The usage of Mathematical knowledge in the sketches and the justification for each of the features sketched on the metal tin robot showed that Awang has reasoned his ideas before creating the prototoype. Awang has not only imagined how the prototype should be designed but at the same time, Awang has also prepared his prototype to locate the minerals on the Moon and dig them out to send it to Earth. Based on the findings, Awang has indulged deep into the process of preparing the best prototype by engaging in the reasoning process, particulary in justifying his idea in solving the problem for Activity Four. In short, Awang has examined and evaluated all the aspects of the problem or situation before he started to create the metal tin robot.

In another instance, once the metal tin robot was created, children were asked whether the metal tin robot was the best solution for Activity Four. Some children supported the idea of designing metal tin robot as the best solution to dig the essential minerals on the Moon. For example, Ramdan wrote the evaluation for the designed metal tin robot as "…Yes, because it can move without any support and it did not need oxygen at the moon". In the same activity, Nasri from a different group agreed with Ramdan. Nasri justified the usage of robot on the Moon by writing the following evaluation; "…Three types of minerals are decreasing on Earth. We need to take from the Moon. We need to use robots because robots don't need oxygen".

The written answers displayed by Ramdan and Nasri were demonstrative answers since both of them explained that machines don't require oxygen to breathe. It was observed that both of them gave some expressive information that supported his arguments. In short, children were observed to be engaged in the reasoning process because their written evaluations were well justified with correct knowledge, apart from demonstrating the ability to accurately construct their viewpoints.

Meanwhile, in another group, children were observed to be completing their designed metal tin robot with other groups of children. They wanted to test and complete the speed of each prototype. However, there was a group which did not produce a fast metal tin robot. The prototype was not moving fast enough as compared to other group members. Hence, the children removed the empty tin can from the design to check on any default that could have taken place. Children figured out independently and did not ask the teacher on how to overcome the problem. Finally, they figured out the default which was the wiring connectivity because they did not fix it correctly.

Hence the children tried to understand the parts of the metal tin robots because they reopened the entire prototype to figure out the problem. In order to understand the metal tin robot as a whole, they analyzed on how the metal tin robot parts can be fixed together. This effort can be related to scientific thinking since science takes a decomposition approach to things, breaking them down into parts, atoms and smaller matters. In short, this group of children reasoned and managed to overcome the problem by themselves. Figure 5.9 displayed the gestures of how the children tested their designed metal tin robot.

Figure 5.9: Testing the motor and tyres without the empty tin can

The process of designing the metal tin robots were carried out simulatenously with other groups of children in the class. In another group, children were trying to improvise the designed prototoype. Figure 5.10 showed that a child named Amirul was completing the final stage of designing the prototype, while another group member named Kar Fei was slanting his body to witness the effort portrayed by Amirul. Apparently, Amirul was trying to justify to Kar Fei that there was a need to use all the given screws. Amirul mentioned that; "… It's not like this. Use all the screws. Let me show". Amirul then screwed and showed Kar Fei that the connections became tighter and the prototype could move better after his effort. The metal tin robot functioned better after that.

Based on the observation, it can be said that children reasoned their explanations apart from predicting what will happen, especially when they try to fix the metal tin robot using all the screws. They listened and helped other group members who were unable to solve the same problem.

When Amirul explained the cause and effect in using all the screws, Kar Fei was reassured that Amirul's justifications were indeed reasonable. This is because Amirul described to Kar Fei about the possibility and necessity of using all the screws in fixing their metal tin robot. Both of them experienced the relationship between the usage of all the screws and the possible chances of an improved metal tin robot. Children found it easier to justify using hand-on gestures rather than trying to imagine and explain. Based on the findings, it was perceived that the children not only used justification skills in creating the metal tin robots but at the same time they also validated the reasons provided by their group members. Figure 5.10 showed that Amirul and Kar Fei were improvising their metal tin robot.

Figure 5.10: Amirul and Kar Fei improvising the metal tin robot

Parallel to the justification skills, children displayed some logical ideas supported with reasonable explanations in their written evaluation after they have created the prototypes. For example, in Activity Five children were encouraged to design humanoid robots using cardboards. Prior to that, Activity Five was the final activity in the CETM and Activity Five was carried out on the second week, two days after Activity Four was carried out.

In Activity Five, while evaluating the designed prototype, Sabrina gave a written evaluation; "…I can create more legs to the humanoid robot so it can stand independently". The idea given was creating more legs and followed by the justification which was the possibility of standing independently. Consequently, the children were able to justify their opinions by using simple sentences and yet, at the same time, they managed to validate their opinions using coherent ideas.

Similarly, Zairul also gave his written evaluations, especially on how to improve the designed humanoid robots in Activity Five. Based on his written evaluations, it was prominent that some of the children including Zairul preferred to design a machine which could transform into different shapes. Parallel to that, Zairul wrote his evaluation as; "…Machines that can change itself like us changing ourselves, following our needs". While Zairul and his group members were evaluating the humanoid robots, it was observed that Zairul kept mentioning the names of the robot characters from the Transformers movie. Zairul kept mentioning names such as *Transformers*, *Optimus Prime* and *Megatron*. Subsequently, Zairul has justified his written answers by using previous knowledge, either from his readings or observations. In fact, Zairul's testimonial displayed his ability to think and reason beyond classroom walls because Zairul has transferred the attributes from the matching domain (robot characters) to the target domain (humanoid robot).

Parallel with evaluating skills in Activity Two, some of the children could not create a windmill that produced light. One of the groups which could not create a windmill that produced light was Jasmine's group. It was observed that Jasmine was curious to know why her group's windmill could not produce the light. Jasmine was eagerly asking the teacher; "…Why ours not functioning? Why!" In fact, her group member, Aliya critized Jasmine's sketches; "…that's why, who asked you to sketch the windmill with the light?" This is because Jasmine had sketched her windmill ideas that have produced light. Some of the children thought the designed prototype must be more or less similar with the sketches which was sketched earlier during the brainstorming session. Nevertheless, Jasmine and her group members were constantly trying to figure out what went wrong. Finally, Jasmine's group member, Kuhan managed to figure out why their designed windmill did not produce the light.

Kuhan who was quiet and spoke less as compared to the other group members, proved to Jasmine and Aliya that the connections between the motor and the blades were not tight enough for the electric energy to flow and ignite the bulb.

Figure 5.11 displayed that Kuhan was holding tightly the motor of the windmill while turning the blades. The teacher, who did not answer Jasmine, questioned Kuhan why he was doing that. Kuhan answered; "…The light (from the bulb) was not coming (igniting). When I held the motor connections tightly and turn the blades, then I noticed the light".

Figure 5.11: Kuhan holding tightly the motor connections of the windmill

Kuhan has observed that the bulb was not producing the light. Hence, he tried to hold the motor tightly and made the inference that when the connections were tight, the light from the bulb can be observed. By figuring out the problem, Kuhan helped his group members to design a windmill that produced light. He rectified the problem by holding tightly the motor connections of the windmill. Based on the findings, Kuhan, Jasmine and Aliya were engaged in the reasoning process because they were not only figuring out the problem but at the same time, they have found a solution for the problem after the joint efforts of trial and error.

Engaging in reasoning process was a technique that emerged based on the collective findings in this study. Children justified and evaluated their ideas while creating a solution for the given problem in each of the CETM activities. Children were also observed to be examining and relating the possible solutions during the cyclic process. In short, children were engaged in reasoning skills by thinking through the problems and applying the strategies for solving the problems given to them.

Stimulating creative thinking.

Based on this study, stimulating creative thinking is about producing a series of actions or process which create new ideas, thoughts and physical objects that is original, unexpected and imaginative. During the CETM activities, children were engaged in creative thinking by coming up with reasonable design that fulfills the criteria fixed for each activity. For example, in order to design a metal tin robot and humanoid robot, children were encouraged to work towards creating the prototypes that have various appearances and have some room for improvisation based on their imagination.

During Activity Four and Five, before the children created the metal tin robots and humanoid robots, children brainstormed their ideas through sketches. Based on the sketches shown in Figure 5.12, sketched by a child named Alfred, it can be said that Alfred has offered different viewpoints for each of the prototypes.

According to Alfred, the features sketched in Figure 5.12 (a) had its own purpose. He explained that the hooks in the hands were to dig out the minerals, the satellite was to alert the human (scientist) on Earth and the pooping out eyes was to have a sharp and wide coverage of sight on the planet Moon. The metal tin robot should be equipped with proper features as displayed in Awang's sketches. These features can be used to find and dig the essential minerals on the Moon for the benefit of mankind on Earth. At the same time, the sketch features for Activity Five, as shown in Figure 5.12

(b) was less complicated as compared to the sketch in Figure 5.12 (a). However, the satellite was sketched on the head of robots for both of the prototypes. When asked Alfred why did he give emphasis to the satellite, he said; "…it (satellite) saves time and can communicate with other robots". Alfred not only knows the existence of the satellite but he has also justified the usage of satellite for his prototypes. Eventhough the functionality of the satellite was not taught by the teacher; Alfred has used his additional knowledge from his observation since he said he had seen a documentary about satellite on the television. Based on Alfred's sketches as shown in Figure 5.12, it can be summarized that, Alfred had used different viewpoints to stimulate his creative thinking before designing the metal tin robots and humanoid robots.

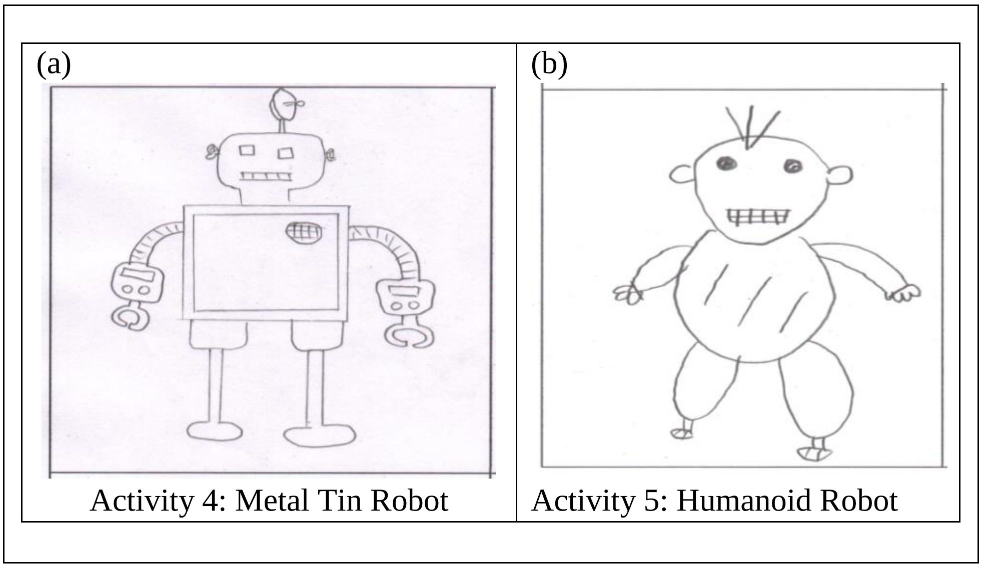


Figure 5.12: Alfred's different patterns of humanoid robot design

After brainstorming for ideas in Activity Five, the tools and materials were provided and the children started to create their humanoid robots in groups. Figure 5.13 (a) and (b) shows the different humanoid robots created by children during Activity Five in the classroom. Based on the humanoid robot sketches in Figure 5.13 (a) and (b), it was evident that the children have expressed their creativity and displayed some insightful thoughts in designing the humanoid robot prototypes.

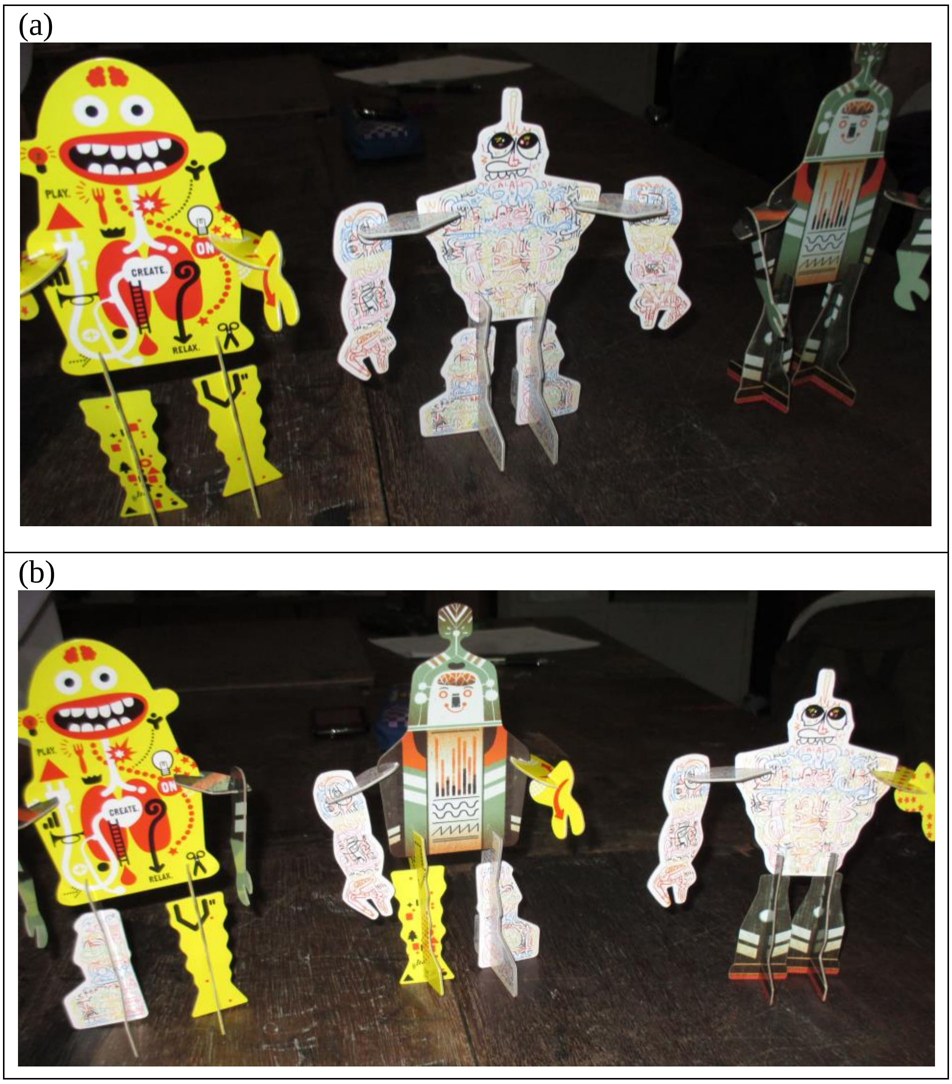


Figure 5.13: Modified humanoid robot design

This is because children have modified their prototypes using different source of cardboards with different sizes. However, the modified prototypes still stand firmly without tumbling. It can be said that the children have used skills such as making connection and different viewpoints in order to stimulate their creative ability while designing the humanoid robots.

In fact, children have creatively merged other group member's ideas to create different prototypes using the same type of cardboards provided. At times, children used the ideas of other group members as a stimulus for their own group. By creating the humanoid robots in a collective effort, creative thinking was stimulated to develop new ideas. These techniques forced the development of a wide range of ideas to spark off new thoughts and processes in producing different types of humanoid robots.

Creative children were good at marshalling their brains into bilateral mode and they become dual-active (Bronson & Merryman, 2010). Parallel to that, the design in Figure 5.13 (b) was unanticipated since children have originated different alternative designs as solutions. Other groups of children began to modify intensely after observing the group which has created humanoid robot designs such as in Figure 5.13 (b).

Every child in the group did a follow up for the initial idea they created. However, they altered the initial idea to generate new ideas. It was observed that children came up with more free-flow of unconnected ideas that was grouped and was created as a whole. This allowed for the initial ideas to be explored in a more detailed and accepted manner to enhance the unlimited creations.

Meanwhile in a different group, during Activity Five, children were observed to be modifying the designed humanoid robots. Children used the scissors to cut some extra cardboards which was not provided to them. Later, they began to fix the extra cardboards to create a bigger yet a stable prototype. It was perceived that the children had the ability to create, manipulate and transform the design into a workable prototype. They figured out that the best way to have a good humanoid robot is to generate lots of small humanoid robots. At the same time, children also discarded the impractical and inappropriate humanoid robots before completing the final and the best prototype. Figure 5.14 (a), (b) and (c) shows the process of children modifying the humanoid robot.

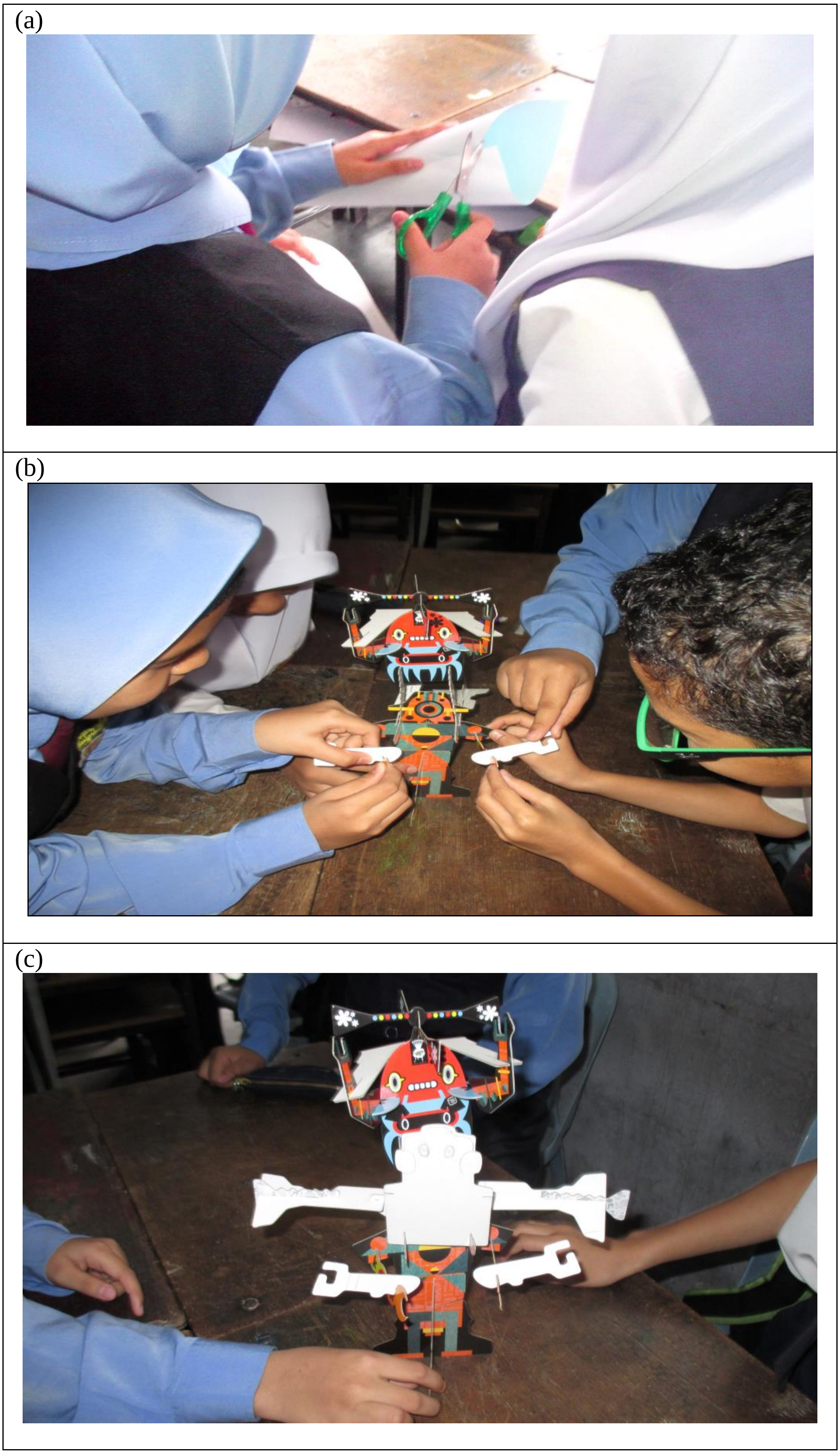


Figure 5.14: Process of modifying humanoid robot design

There is no scientific formula for the number of ideas children need to generate to find a good one, or even a guarantee that children will be able to find a good one at all. It was important to brainstorm for solutions and keep exploring even when the child has thought that he or she has found a good idea. This is because children's first idea in creating the humanoid robots was very seldom the best. According to the children, they have learnt how to paint and colour during the Art lesson. They wanted to apply the skills of painting and colouring while decorating the humanoid robots. In another example, children wanted to decorate the humanoid robots with emotions such as love and passion. Although most of the children wanted to decorate the humanoid robots as their main way in improving their prototypes, the way they wanted to decorate it differed from one another. Table 5.1 shows the different viewpoints used by children in their written evaluations.

Table 5.1: Different viewpoints among children in the same group for Activity Five

Children	**Children's responses in written evaluations**
Halijah:	Decorate it and add colour.
Sue Fen:	Do attentively and decorate it with love and passion."
Yasotha:	We can paint it.
Zubeda:	Decorate it well and correctly.
Nadesh:	If we add decorations, it will become heavy.
Sivam:	No decoration. It would be broken (detached) easily. It would add too much weight and will not stand.

Conversely, some of the children wrote unexpected evaluations on how to improve the humanoid robot. When most children gave positive feedback in decorating the humanoid robot, Nadesh and Sivam did not agree to decorate the humanoid robot. Their answers differed from other children. They reasoned that decorating the humanoid robots will add more weight on it and the designed prototype will not be able to stand. This answer represented that the children have thought about the impact of decoration on the humanoid robot designed. Both Nadesh and Sivam have reversed their perspectives to create not only a new idea but at the same time a productive idea as compared to the other children. Based on these findings, it can be said that children used their creative thinking in producing different ways to improve their prototypes.

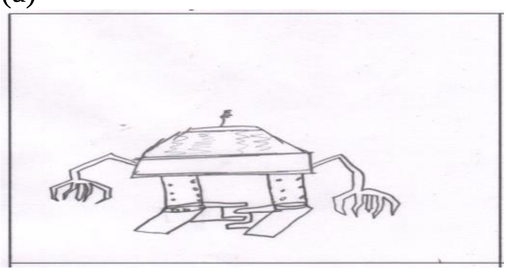
Based on the children's ideas in the process of modifying humanoid robot design and written evaluations, it can be said that the children were encouraged to use their creative thinking. This is because they have made several collective efforts to originate alternative designs in order to create different types of humanoid robots during Activity Five. Meanwhile in another example, for Activity Five, children have expressed various opinions while writing their evaluations after designing the humanoid robots. The written patterns of answers derived from each group had different type of ideas to improve their prototypes. Most of the answers were reasoned using clear observations and personal experiences.

Similarly, children also expressed their creativity in sketching metal tin robots while brainstorming for ideas in Activity Four. Children sketched the types metal tin robots that they wanted to design to overcome the lack of mineral problem on Earth. Figure 5.15 shows the types of sketches sketched by Rahman and Victor displaying on how the designed metal tin robots should function. During the brainstorming session, most of the children sketched the outer and inner features of the prototype they wanted to create.

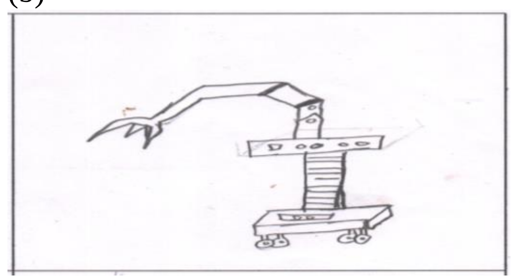
Figure 5.15 (a) and (b) demonstrated Rahman's sketches of metal tin robots for Activity Four in CETM. His sketches showed a variety of different metal tin robots that Rahman has brainstormed during Activity Four. Some of the sketches illustrated machine like robots with different features to dig the minerals on the Moon. The level of complexity for each design in Rahman's sketched increased. This is because each of his design was intensified with design had expressive details.

For example, each of the design focused on the arms, whereby the arms were sketched like a fork or drilling machine. The legs of the sketched metal tin robots were also different. The complexity of designs increased when (b) was embedded with wheels or tyres to allow the robot to move by itself. Meanwhile, the other sketch (a) had structured form of legs with screws and with ordinary limbs. The sketches from (a) to (b) became more structured, organized and advanced. When asked Rahman what was he thinking when he sketched different type of prototypes, Rahman said that; “…after sketching the first sketch (a), I thought how would it be if there was only one fork (drilling machine). Later I thought of controlling the robot using a remote, that’s why there were tyres (b)”. Based on his sketches and verbal explanations, it can be said that Rahman had used different viewpoints to connect his ideas through the sketches shown in Figure 5.15 (a) and (b).

(a)

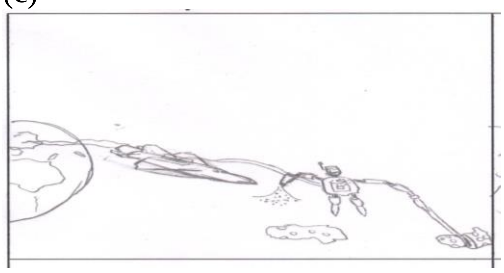


(b)

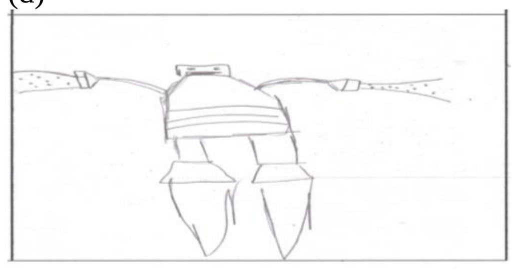


Rahman’s different sketches of metal tin robot design

(c)



(d)



Victor’s different sketches of metal tin robot design

Figure 5.15: Different viewpoints in Activity Four

However, Victor's sketches were different and creative because Victor wanted to design and develop a robot that can fly to the Moon in order to gather the essential minerals and transport back to Earth. When asked Victor what he was thinking when he drew these sketches in Figure 5.15 (c), Victor responded; "…I wonder how the prototype designed will be sent to the Moon (since Moon has the mineral wanted by humans on Earth), that's why I thought of this (sketch)." At the same time, Victor's sketches in Figure 5.15 (d) also showed that the metal tin robots were transported using a rocket. Some of the other sketches showed that the metal tin robots had the ability to fly to space using different types of launchers.

Based on the sketches and verbal responses, it can be summarized that Victor was thinking one step further on how to transport the designed prototype to the Moon. Victor reasoned on how to do it by sketching his idea while brainstorming solutions for Activity Four. It was evident that Victor used his creative thinking skills in expressing his ideas through his sketches as displayed in Figure 5.15 (c) and (d).

Both the sketches from Rahman and Victor who were from different groups showed the ability to imagine or invent something new by combining, changing and reapplying existing ideas. Some creative ideas from the children were brilliant because these ideas portrayed the robot evolution for the benefit of mankind.

After the children, have sketched their ideas, they created the metal tin robots using the tools and materials provided and later tested it. For example, in Activity Four, children should be able to create a metal tin robot that moves and produces sound. Based on the observation, it was found that two different groups of children were trying to compete with each other's prototype. While testing the designed metal tin robot, one of the groups was not satisfied with the speed of the prototype. They wanted their prototype to move faster. Figure 5.16 (a) displays how they were manipulating the materials and tools in order to create a faster prototype. After analysing the prototype, they concluded that it might be the length of the straw that was delaying the movement of the prototype.

Hence, the children tried to bend the straw into a different design where the straw will not touch the surface of the classroom floor or the table. They bent the straw according to how they wanted as shown in Figure 5.16 (b). Soon after that, they raced their modified prototype to compete with other group's prototypes. It was observed in Figure 5.16 (c) that their prototype moved faster than before but still slower than other group's prototypes. Figure 5.16 (a), (b) and (c) showed the process of modifying the metal tin robot.

(a)

(b)

(c)

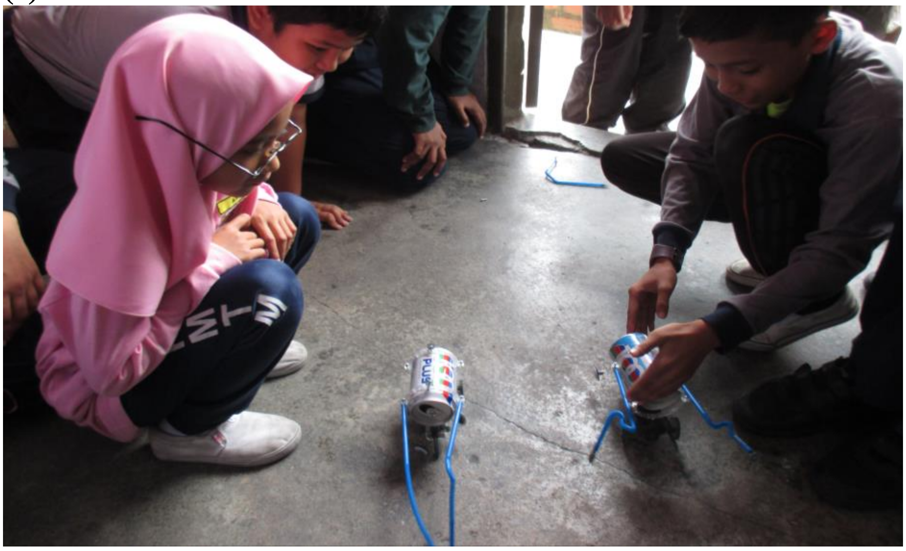


Figure 5.16: Process of modifying metal tin robot design

Based on the findings, it was found that, children were thinking in various ways to improve their design. At the same time, they were creative in bending the straw to allow the prototype to move faster. In fact, the children managed to find new possibilities in order to produce a faster metal tin robot. They refined their existing idea and evaluated their prototype using the criteria provided in the activity. In line with that, the children also experienced connections between old ideas and new ideas which can produce something new or better.

However, even after improvising the straws in the metal tin robot, it still struggled to move faster as compared to other group's prototype. Hence, the children continuously were working on the prototype as they kept trying to improvise it despite the fact they have fulfilled the criteria of the designed metal tin robot which was the ability of the prototype to move with some noise. The metal tin robot was making noise when it vibrates as it moves on the classroom floor. It was observed that the improvised prototoype did not move as fast as the children wanted.

Figure 5.17 displayed the children's gestures while improvising the metal tin robot. Although all of the children displayed various pattern of body structure, all of them were actually concentrating on how to improve their prototypes. One of the children who placed both the hands on the floor to have a closer look at the prototype was very much engrossed in improvising his designed metal tin robot.

Finally, after some time, they managed to find the cause of its default. The connection between the metal tin robot and tyres were weak since the plastic structure has cracked. Hence, the tyres in the metal tin robot were not able to move faster. It was observed that one of the children in the group quickly cut an eraser into small pieces and stuffed into the plastic cracks of the metal tin robot. Children used their creative thinking in an unstructured manner because there was no worry of failure, since there were no right or wrong answers in creating the metal tin robot.

Figure 5.17: Improvising the designed metal tin robot

After creating and testing the metal tin robots, children wrote their written evaluations, as it was the next step in the CETM activity. As designing metal tin robots was their fourth activity, they were used with the CETM activity pattern. Children experienced the cyclic process and gave their written evaluations on their designed metal tin robots.

For example, in Activity Four, children from various group responded on how to improve the metal tin robot by using different viewpoints. For every CETM activity, including Activity Four, evaluations were written after the children have tested the prototypes. These different viewpoints showed that the children generated many ideas on how they wanted to improve the designed metal tin robots. Table 5.2 displayed the examples of different viewpoints used by the children from various groups during the Activity Four.

Table 5.2: Different viewpoints among children in various groups during Activity Four

No of group	**Children**	**Children's responses in written evaluations**
Group 1	Yogen:	We can add two more tyres on the robot.
	Alvin:	Add more batteries.
Group 2	Kamil:	I will put more tyres and engine for a more useful robot.
	Yusof:	I am thinking of using the more power (batteries).
Group 3	Rose:	Basket can keep metals and other materials.
	Hisham:	Add more batteries and body size.

Based on their answers in Table 5.2, it can be mentioned that while evaluating the metal tin robot, children had the idea of manipulating the variables and create some unanticipated solutions. For example, the children wanted to manipulate variables such as tyres, basket, engine and other materials in creating a better metal tin robot. Based on these written evaluations, it was evident that the children have unconsciously yielded the creative thinking process by using different viewpoints skills. This is because children's ideas were different and sensible but most importantly some of the written evaluations for Activity Four were justified with solid reasons.

Parallel to that, children have compared and contrasted the designed humanoid robot in Activity Five and metal tin robot in Activity Four. During the humanoid robot activity, children used the metal tin robot as an example to express and reflected their previous knowledge while writing their evaluation. For example, Richard wrote an evaluation for humanoid robot as; "…The limitation of movement and sound for a robot is one of the problems and so is functionality". This is because Activity Five represented a humanoid robot that doesn't move and produce sound as compared to Activity Four which represented a metal tin robot that moved and produced sound. Based on the findings, Richard had made two different connections. The first connection was the comparison of the both prototypes between the two activites. Meanwhile the second connection was the prototype's functionality and the ability of the prototype to move. Richard managed to address his creative comparison between the prototypes by using the key features of a productive robot such as the ability to move and simultaneously create some machinery noises.

Providing written evaluations opens up the creative possibilities on how to improve the designed metal tin robots. Children's creative thinking was allowed to flow freely because CETM activities encouraged children to expand the possibilities of improving their designed prototypes especially in criticizing the prototypes for weaknesses and translating the flaws into actions of improvement.

Apart from expressing creative ideas through the written answers, children also used different viewpoints in brainstorming for solutions during the CETM activities. Figure 5.18 (a) and (b) displayed the children's various viewpoints which were evident in Activity One throughout the brainstorming session in yielding the plastic parachute designs.

Figure 5.18 (a) represented Rachel's sketches with different symbols of fire and with different pattern of design on the plastic parachute. Based on these sketches, it can be said that Rachel showed the relationship between the fire and the entire design as a key feature to allow the plastic parachute to fly. Rachel's sketches displayed the importance of using energy since she reasoned her sketches with the symbol of fire learnt during the science lessons. When asked Rachel about the symbol of fire used in her sketches, she revealed that the she learnt the symbol in Chapter Two during the Science lesson. When the Science teacher taught Rachel and her classmates the uses of energy in Investigating Force and Energy topic, Rachel had sketched a candle with fire in her Science exercise book. In fact, while discussing with the Science teacher after the first activity, the teacher showed the examples of how children sketched the candles with fire. The children had sketched symbol of fire around three months before the maiden CETM activity was implemented. Hence, Rachel has remembered what she has learnt and applied it to her plastic parachute sketches during the CETM activities.

Based on the findings, it was also evident that Rachel has transferred her scientific knowledge into the plastic parachute sketches by making the connections between what she has learnt and how she has imagined the plastic parachutes should be designed. Rachel has used the fire symbol learnt during the science lesson with the plastic parachute because she has decided her plastic parachute designs need energy to float and fly in the air. Rachel has creatively synthesized and refined her scientific knowledge to create a new learning material in Activity One.

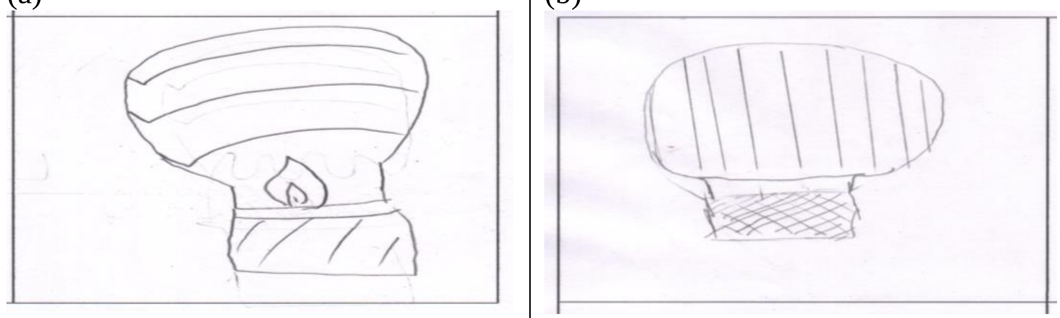


Figure 5.18: Rachel and Maximus’s different patterns of plastic parachute design

Meanwhile, Maximus who was Rachel’s group member, sketched the plastic parachute sketches as similar pattern with Rachel. Maximus’s sketches in Figure 5.18 (b) were decorated with different design though the pattern of the entire plastic parachute was the same. Although Maximus's sketches focused on the decorative pattern, it also displayed that Maximus had the capacity to quickly focus on the best solution to create a plastic parachute. This is because Maximus was the fastest to sketch his ideas because he was eager to start the process of designing the plastic parachute. Even though the pattern of his idea was different as compared to Rachel's, Maximus showed the ability to sketch a broad range of solutions to the problem given in Activity One.

By looking at the sketches of Rachel and Maximus, it was evident that, the children's collective creativity was superior to an individual creativity. Children's ability to visualize and accept many ideas related to the tasks in the CETM activities improved their efforts in using their creative thinking skills to solve the given challenge

Parallel to that, Figure 5.19 also displayed Mei Lan's plastic parachutes sketches during the Activity One. These sketches were sketched during the brainstorming session and they showed an overall situation in a generalized and structured array. This is because Mei Lan did not write the problem faced for Activity One. Hence, Mei Lan sketched how she intended to solve the challenge while brainstorming for ideas. In fact, Mei Lan has creatively described the entire process of why there was a need to create a plastic parachute in the first place.

When asked Mei Lan, why she did not write any answers instead sketched her ideas, Mei Lan replied; "…I thought (imaged) of it (process of rescuing the panda as well). Rescuing the panda was more important (to me), that why (I sketched the panda eating the food and drinking the water)". Mei Lan was the only child who explained her opinions through the sketches. Her justifications showed that she emphasized on the sustainability of pandas instead of the plastic parachute itself. Apart from that, based on her sketches, experts also revealed that Mei Lan has reflected her artistic ability and incorporated them into the plastic parachute designs as displayed in Figure 5.19.

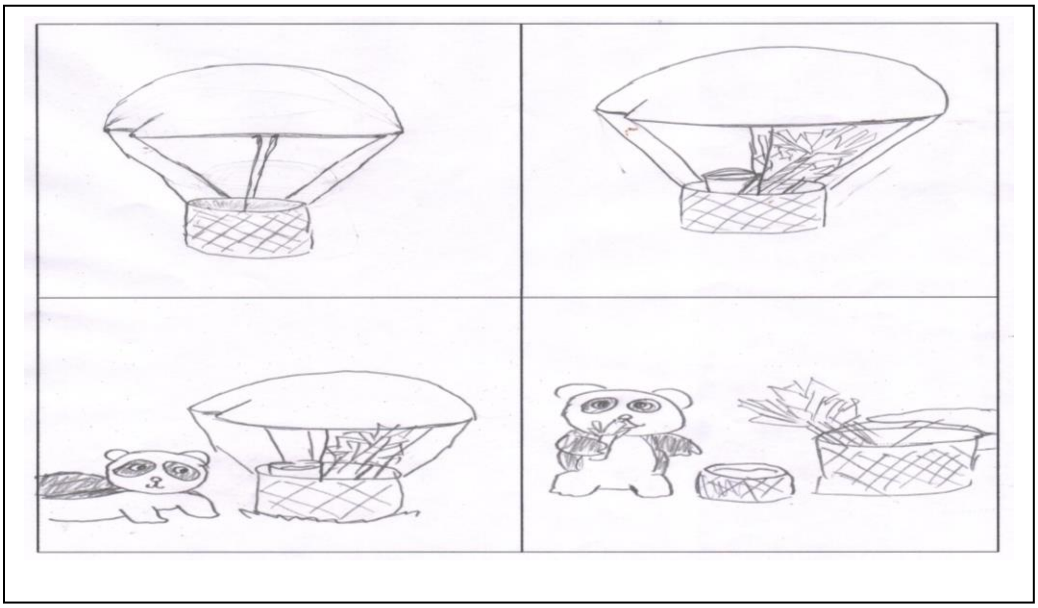


Figure 5.19: Mei Lan described the process of solving the given problem

Designing the plastic parachute activity was the maiden activity in CETM and it was prominent to observe that Mei Lan has used her creative thinking skills to explain the entire process of overcoming the given challenge through her sketches. At the same time, Mei Lan's sketches were clearly drawn and her ideas was eloquently expressed.

In order to hatch ideas, children must be given something to work with. The closer the children came to a solution on their first attempt, the more likely it was that they will succeed on the second attempt or later attempts. The process of finding the solution produced more active thoughts from the children. In fact, the children were observed to manifest their creativity in different ways during the CETM activities.

Practicing intellectual discussion.

Practicing intellectual discussion is about having intelligent conversations either among the children or between the children and the teacher. These conversations can develop into chain of valid arguments throughout the CETM activities. The collaborative atmosphere during the CETM activities encouraged the children to contruct engagements by asking questions, critizing their group members and making decisions in creating the prototypes during the activities.

For example, during the activities, children interacted with each other, especially among their group members. The classroom atmosphere for each of the activity was noisy yet sparked intellectual dialogue exchange. At the same time, it was observed that the noise that the children created was simply a collection of arguments and interactions between the group members. The following conversation is an example of how the children argued during the Activity One when the children were creating a plastic parachute using the pipe clearner and wooden bead.

Amirul: How can I cut this *(the pipe cleaner)?*
Kar Fei: Just cut it, it doesn't matter.
Wahida: Why its' long and short? It's not the same!
Amirul: That's because you did not measure. Can't simply cut. Wait.
Abu: It doesn't matter, as long as it can enter this *(wooden bead).*
Linda: Don't say like that, you must be careful *(in cutting the pipe cleaner)*
Wahida: You *(referring to Abu)* are wrong. It has to enter *(wooden bead)* like this *(showing how it has to be done).*
Kumar: Watch this *(after seeing Wahida's idea, Kumar was trying to fix pipe cleaner into the bead).* See it works!

(Verbal interaction, Activity One, Group 2, 28 October 2014)

Based on the verbal interaction in Activity One, it was perceived that this group of children were engaged in an intellectual discussion when they were creating the plastic parachute design. Amirul and Wahida who were involved in Activity Two, poised higher level questions such as how and why. Meanwhile Kar Fei, Abu and Linda elaborated on each other's opinions about the pipe cleaner and wooden bead. On the other hand, Kumar proved that the pipe cleaner measurement doesn't matter much as long as it functions as a part of the entire design.

Based on the verbal interaction, the children have constructed their knowledge independently by making engagement while creating the plastic parachute design. For instance, when Wahida asked the question referring why, Amirul reasoned using because and he further supported his argument with his actions. Similarly, Wahida critized Abu while fixing the pipe cleaner into the wooden bead. Wahida was firm and certain that Abu was not correct, when Wahida mentioned “No”. Although the conversations were mainly on the technical aspect, the children overcame the situation by focusing on their technical skills ability and cooperative efforts.

Correspondingly, Figure 5.20 displays the different gestures and body language of Amirul, Kar Fei, Linda and Wahida while they were collaborating in designing the plastic parachute. It was observed that Linda was pointing her finger towards the plastic. Linda extended her index finger pointing towards the plastic that was being adjusted by Kar Fei. To clarify, Linda was asking Kar Fei; “…How do you know that’s the correct way (correct measurement) to cut the plastic?” However, Kar Fei replied; “… I am not sure, let’s just try it”.

Figure 5.20: Collaborative effort in designing the plastic parachute

Meanwhile, Amirul was having the wooden bead in one hand and the other hand was asking suggestions from Wahida who was standing beside him. The fingers holding the part of the prototype indicated that Amirul was unsure and asking for clarification from

Wahida. Amirul was asking Wahida; "…Do we have to use all the nuts (to fix the pipe cleaner)?" After sometime, Wahida replied; "…I don't know. Let me see other group (Wahida was seen to be observing other group's work)". Wahida came back to her own group and replied to Amirul; "…I think it depends on us how many nuts to place (into the pipe cleaner)".

The children were observed to be standing and having their entire body close to table where the work can be done in creating the prototype. It displayed that children were independently designing the prototype using their own thoughts or ideas in designing the plastic parachute. According to the teacher, in their daily Science lessons, children hardly discuss with each other because they were used to ask the teacher for all their doubts. However, throughout the CETM activities, children worked collectively to design and develop their prototypes such the plastic parachute.

After a week of experiencing on how to solve a problem using the plastic parachute, children participated in Activity Four. They were encouraged to design a metal tin robot. The following conversation shows how children interacted in their group while designing the metal tin robot to overcome the challenge provided in the Activity Four.

Tan:	How nice if we can visit the moon!
Amir:	I wish that too!
Syikin:	If the oxygen level is okay (sufficient), I will build a bridge from here (Earth) to the moon.
Yuvan:	What? How is that possible?
Indrajit:	I will be the first to cross the bridge.
Azlan:	Yea and we don't have to bring (transfer) the minerals, can just live in the moon!

(Verbal interaction, Activity Four, Group 4, 5 November 2014)

Based on the verbal interaction between the children, it was noted that, Syikin pinpointed a rebuttal point in her description argument while creating the metal tin robot design. Syikin's rebuttal argument indicated her changed decision in determining on the prototype's necessity by using metaphorical thoughts. However, Yuvan disputed Syikin's rebuttal by questioning in what way the bridge could be build. Meanwhile Azlan continued Syikin's argument by giving his reasons and valid grounds in building the bridge.

Based on the children's verbal interactions, it was found that the children's ability to argue and reason can make a difference in creating a real-world prototype, particularly in the ever-evolving technology operations and concept such as metal tin robots. These verbal answers displayed that the children can have an impact in the real world especially in encouraging their imagination to visualize the possibilities of reaching beyond the practical limits. Syikin's idea of building a bridge may seem imaginative but it also reflects the possibility of achieving something beyond the practical limits.

Other groups of children were also creating the metal tin robot simulatenously in Activity Four. Figure 5.21 (a) illustrates the gestures of the teacher and children during the Activity Four. The teacher was facilitating the children by observing their metal tin robot designing process. The children were observed accepting criticism since they tend to consider other points of views. When the children accepted criticism from other group members, the process of designing prototypes was corrected.

For example, while designing the metal tin robot prototype, Kuhan and Amirul noticed that their designed prototype was only vibrating and not moving. Hence, Kuhan criticized his group member, Amirul by saying; "…This is wrong. The straw needs to be bent". As a result, when the straw was bent, the metal tin robot began to move. Subsequently, Amirul replied; "…Oh! Is it, I thought the problem was the tin can". Meanwhile Figure 5.21 (b) illustrated how the children were closely attached in designing their prototypes. Both the teacher and children had their heads and body titled to have a close look on the designing process. At the same time, other group members were concentrating in their own efforts of designing the prototype.

(a)

(b)

Figure 5.21: Practicing verbal discussion between children and teacher

Once the children have designed the metal tin robots, they began to test their prototypes. The following dialogue exchange encompassed some of the HOTS elements. HOTS elements such as making judgment, plausible reasoning, verbal reasoning and inductive reasoning was observed while the children were completing the cyclic process (using improvisation) during the Activity Four. The following dialogue exchange between the teacher and the children who evaluated the metal tin robot displayed here.

Teacher:	Okay, let's race, which one is faster?
Avantika:	Fuhyoo! *(Looking at the prototype's movement)*
Husna:	Why our prototype is (moving) slowly?
Teacher:	Okay, so alright. Everyone see. Which one is faster? The yellow (tin) or the white (tin)?
Husna:	The white one!!!
Teacher:	Okay, your observation is the white is faster than the yellow. Try to make an inference. What is the reason?
Evaraj:	Maybe the wire (from the prototype) did not reach the prototype.
Teacher:	Maybe...
Sangeetha:	The legs are too long (tentacles)
Teacher:	Yes, that's correct. The legs are too long. That's why it is turning slowly. This one is turning one at the front (first leg) and the other (second leg) at the back.
Husna:	Let's correct it, let's correct it.
Teacher:	Ha, can you see that? That's why it (prototype) was slow. That's the use of it (this activity), application.
Evaraj:	Do until it (prototype) functions! Do until it functions! (motivating children in other group as well)
Teacher:	Once completed, can race!
James:	We shall do better than before (screw (the nuts) again the entire prototype).
Avantika:	Okay, that's enough (completed the design). Who wants to race with us? Who wants to race with our prototype *(While carrying the prototype and asking the entire class)?*

(Verbal interaction, Activity Four, 5 November 2014)

As shown in dialogue exchange for Activity Four, the teacher encouraged the children to race using their designed metal tin robots. It was observed that the children were engaged in asking high level questions such as the why questions apart from being inquisitive to find the reasons for that questions. Husna, Avantika, Sangeetha and James were in the same group. Meanwhile Evaraj was from a different group but he was engaged into the dialogue exchange since his own group has accomplished to design the preferred metal tin robot. Once he was engaged into the dialogue exchange with the children from different group, he was interested to know how to improve their prototype. He too joined them to improve their metal tin robot prototype.

Based on the observation, the children tried to make their judgment based on the teacher's explanation. The teacher used terms such as 'observation', 'inference' and 'reason' which were fundamental elements of teaching and learning science. This incorporation into the CETM activities revealed the practice of interdisciplinary knowledge or skills. In fact, the children had the opportunity to determine some plausible reasons that could relate to one another in order to have the overall picture.

In the meantime, after having the right reason as to why their prototype was slow as compared to the others, the children instigated other group members to look into the prototype and overcome the limitations. The children were also encouraged to reason verbally throughout the conversation. In fact, the children were spontaneously reasoning their explanations as they were engaged into the designing process.

Once the child made the decision that the prototype had sufficient correction and ready for race, the teacher just observed and allowed them to go through the cyclic process once again. While testing the metal tin robots, different levels of questions such as which, what, why and who were poised during the conversations either between the teacher and children or between the children themselves.

Once the children have completed their prototypes, it was observed that some of the children spontaneously asked the teacher 'why' and 'how' questions. For example, during Activity Two, Azian questioned the teacher about the necessity of using all the nuts in creating the prototype, once her group members and she herself have designed the windmill. The following conversation was between Azian and the teacher while they were creating the windmill prototype in Activity Two.

Azian: Why some of the groups used all the nuts? Our group has some unused extra nuts!

Teacher: There must be a reason as to why some if it (nuts) you use and some you don't. Why are there extra nuts? Must think. Why there are extra nuts? Try to see why there are extra nuts? Is it really enough or if there's extra you just screw it (without much thought)? Check and observe carefully all the nuts (for the prototype). If it's enough, then it's okay. See carefully. Don't panic.

Azian: Let's try using all the nuts (inviting other group members as well)

(Verbal interaction, Activity Two, 30 October 2014)

As shown in Figure 5.22 (a), Azian noticed that some of the groups have used all the nuts provided to create the windmill prototype. Meanwhile although Azian's group did not use all the nuts provided, their designed windmill still worked. Hence, as shown in Figure 5.22 (b), Azian questioned the teacher about her doubt as also displayed in the verbal interaction above.

Based on the verbal interaction between Azian and the teacher as in Figure 5.22 (c), it can be said that the teacher tried not to give straight answers to Azian and her classmates. When the teacher did not give the answer to Azian, Azian asked the other group members. Azian realized that it was not necessary to use all the nuts in designing the windmill prototype. When the right nuts were used, the connection becomes strong enough to withstand the battery and motor. Azian and her group members have successfully designed their windmill prototype using a different way without them realizing that the designing process was correct and complete.

(a)

(b)

(c)

Figure 5.22: Reflecting the process of designing windmill prototype

Likewise, children also practiced intellectual discussions during the question and answer session after evaluating their prototypes during the CETM activities. Based on the children's verbal interaction, it can be pointed out that the children had applied high level questions using 'how' and 'why' during the questions and answer session.

Each of the group sent a representative to present their prototype. The presenter was free to explain what he or she would like to talk about their designed prototype. The other children listened carefully and later asked questions to the presenter. However, it was observed that the other group members also helped the presenter to answer the questions. The following conversation that took place was between the presenter and five different children during the Activity Five.

Luke:	Can this robot fly?
Syamsiah:	Yes.
Luke:	How can it fly?
Syamsiah:	There is a fan here *(pointing at the robot)*. That's how the robot can fly. The group members helped the presenter.
Luke:	Is there an engine?
Syamsiah:	Yes, at the bottom of the robot. *(The presenter and group members spontaneously answered).*
Abhiraj:	Can your robot stand?
Syamsiah:	*(The presenter puts the robot on the table and shows to the classmates that it can stand). (The classmates shouted 'Yeay' and clapped their hands for the presenter).*
Shreeta:	If your robot can change its shape, what shape can it change into?
Syamsiah:	Changing shape? *(The presenter was unsure of the answer, looking up and thinking).*

(Fourth presentation, Activity Five, Group 4, 7 November 2014)

Based on the conversation, one of the answers displayed imaginative features of the humanoid robot when words such as 'fan' and 'engine' were used. Both Syamsiah and Luke had imaged these gadgets in the prototype when they were reasoning the explanation. Meanwhile some questions were answered using only physical gestures to prove and justify that the prototype has achieved its objective. For example, when

Abhiraj asked whether the robot can stand, Syamsiah placed the robot on the table and showed it to the classmates that the robot can stand as shown in Figure 5.23.

However, when Shreeta asked about the transformation of robots, Syamsiah could not answer. However, at the same time, Syamsiah did not mind being criticised by sceptical manner of asking questions. The question was probably based on the movie Transformer and this could mean that Shreeta has related the question to the daily basis experience of watching the movie. Figure 5.32 displayed how children argued with one another during the Activity Five.

Figure 5.23: Designing humanoid robot

A designed prototype was often estimated for a bigger population by looking into a broader perspective. In contrast, it was often observed that the children looked into a narrower paradigm when they wished to know how the prototype could help themselves first before a bigger population and later an entire nation.

Subsequently, there were also some arguments observed among the other children in different groups when children were presenting their prototypes. For example, some of the children were arguing about creating bigger humanoid robots while others were presenting their prototypes. Children were learning about the strength and stability concept in the Science subject during the humanoid robot designing process. The following verbal interaction was between a group of children who were arguing about creating a bigger humanoid robot using more cardboards.

Meena:	This is wrong, it's not right!
Lim:	Is it? Then, how?
Daniel:	The cardboards not necessary same colour and size.
Shankar:	Teacher won't scold us if it's wrong; it's just up to us.
Chong:	It's huge now, why are you keep putting in the pieces, it's enough.
Meena:	As long as the base is wide, it's fine. Won't fall down.
Daniel:	I want to make one robot that can do all my work.
Meena:	Then, fix the eraser and pencil for it (prototype) to do some work.
Faizal:	Including the homework!

(Verbal interaction, Activity Five, Group 5, 7 November 2014)

This dissected argument included prompts and refutations. When dealing with the humanoid robots, Meena argued that the way Lim fixed the pieces to create the prototype was incorrect. Lim prompted Meena for clarifications by questioning the right way to do it. However, Shankar explained that there were no such thing as wrong or correct notions in designing the prototype. Chong decided that the design is already good enough but Daniel insisted to create a multi functionality robot which was also supported by Faizal. However, both Meena and Daniel discussed to improvise the prototype using a creative yet useful idea. Meena explained that as long as the base is wide, the prototype won't fall and that was a science concept which Meena employed to design the humanoid robot. The children argued with each other to create a better yet a stable prototype. In fact, the children gave some suggestions during their arguments.

Each group indicated some evidence to show progression in the children's acquired argumentation skills in designing the prototype. Whether the child disproofs or not in an argument, he or she still gets involved to practice an intellectual discussion. Parallel to that, in another example, a different group of children were noticed to be discussing about how their designed prototype can play football. The conversation between the children during Activity Five was as following:

Andy:	How this robot going to play football? It can't move like the other robot we built last week. *(referring to metal tin robot, Activity Four)*
Rosli:	I was just thinking about it.
Diane:	Yea, it would be great the robots can fly too!
Rosli:	Fly and at the same time play football. Something like in the Harry Porter *(movie)* flying using the broom and hiting the ball.

(Verbal interaction, Activity Four, Group, 5 November 2014)

Children had the ability to accept criticism when they were discussing about their prototypes in front of their group mates. For example, when Rosli asked whether the humanoid can play football, Andy from the same group as Rosli, critized him on how a static robot can move. However, Rosli accepted the criticism by sharing his imagination on how he wanted the robots to fly while playing football. In fact, Rosli related to his experience watching Harry Porter movie. The ability to think and concurrently answer imaginative questions was clearly noticed.

Children took turns to present their prototypes and experience the question and answer session during all the activities. In another example, children displayed the question and answer session during the Activity Five. Based on the conversation, it was found that the presenter, Ahmad had to reason to his classmates why certain design was made on the humanoid robot and the purpose of the design itself. Some interesting explanations such as the usage of helicopter and transporting the human was observed in the first presentation. Ahmad's answer was explained by sequencing the components with classic evidence such as helicopter in the following question and answers session.

David:	How old is your robot?
Ahmad:	We just designed it.
David:	If this robot helps the humans, why does those gadgets *(while pointing at the robot)* in the robot exist? What is the use of it?
Ahmad:	It can be used as transport. If it's big, human can be kept here *(while showing the gadgets in robot).* Here, we can design a helicopter *(while showing upper part of robot)* so that it can fly with human *(while lifting up the robot).*
Dayalan:	Is it stable?
Ahmad:	It is stable. *(The presenter puts the robot on the table and proves that the designed robot is stable. Other children in the class give a loud clap and responses by saying 'fuh').*

(First presentation, Activity Five, Group 1, 7 November 2014)

However, when Ahmad could not reason using verbal expression, Ahmad justified using physical actions such as placing the designed humanoid robot on a flat surface, either on the classroom floor or on the children's desk. These types of arguments were quite common during all the CETM activities where the children were motivated to ask questions to the presenters.

Similarly, during the presentation session in Activity Two, the presenters displayed the same gestures of justifying their reasons in the question and answer session. The presenters turned the blades of the designed windmill prototype when the presenters were asked how the windmill functioned. It was perceived that some of the children preferred to engage in providing physical actions using gestures and body language rather than verbal interaction. However, based on the findings, children used the combition of verbal expressions and body languages to support their reasoning in all of the CETM activities.

Based on the findings, children constructed engagement using argumentation and reflection throughout the CETM activities. This is because children readily wanting to ask questions either to their teacher or to their classmates. It was also observed that although children worked in groups, they often compared and contrasted their work with other group members as well. It was observed that, children reduced their mundane doubts while creating the prototypes but increased more challenging arguments among themselves.

The human brain is made to grow and learn. It can be materialized since the goal of every CETM activity is to allow the children to learn and grow intellectually. By observing the conversations or verbal interactions during the CETM activities, the possibility to achieve a HOTS environment among the children was quite feasible.

Evaluation of the Children's Engineering Teaching Module (CETM)

According to Halpern (2014), everything we know and everything everyone else knows was created by someone. Hence, each creation or design must be evaluated. The developed CETM was also evaluated by the teachers, the findings from Science Reasoning Skills Test (SRST) and the children's responses in prototype testing using close-ended questions. Children's achievement in higher order thinking skills (HOTS) was identified through the administration of SRST and the close-ended questions in the CETM activities. The following information discussed the teacher's perceptions on the developed CETM, followed by the children's achievement in HOTS.

Teacher's Perception on Children's Engineering Teaching Module (CETM)

There were two teachers involved in evaluating the CETM. These teachers were interviewed using a total of ten questions (Appendix 16). The teachers responded in both Malay and English language. However, all the responses were translated into English language to standardize the clarification from the teachers.

The first teacher Siti, was the teacher who carried out the activities in the classroom whereas the second teacher Liza, was also a primary school teacher in the same school. Siti answered all the interview questions. Meanwhile, Liza gave her feedback on selected questions since she did not carry out the activities. At the same time, other questions which Liza did not answer required the experience in implementing the CETM activities which Siti had. Liza gave her feedback on the CETM based on the language, structures of activities and the font usage (Q3). Apart from that, Liza also commented on the CETM module aim, subject content, learning outcomes, teaching and assessment strategies (Q4). Parallel to that, Liza gave some suggestions in what way and how she would improve the CETM activities (Q8 & Q9). Finally, she also commented on the ability to design her own activities in future based on the designed CETM as guidance (Q10). In general, both the teachers gave some comprehensive feedback on the designed and implemented CETM activities.

When Siti was asked how she felt after carrying out the CETM activities (Q1) and why she experienced those feelings or thoughts (Q2), Siti responded that the CETM activities were interesting and unique. She continued saying that the experience was something new to the teaching and learning in science. Siti expressed that by looking at the children's feedback and the noise they created, it was certainly an interesting atmosphere to be experienced. She said it is not easy to keep the children engaged into the teaching and learning science with the presence of technology and entertainment. Hence, she was happy to guide the children during the CETM activities.

Subsequently, Siti and Liza also gave some feedback on the language usage in the CETM, pattern or structure of activities in the CETM and the fonts display in the overall CETM (Q3). Siti revealed that the language was 'okay' and since Siti was from an English-speaking background where she was educated in a convent school, Siti did not have much challenge in handling the CETM activities. Siti added that the pattern of the activities was something unique or new. Siti did not have much comment on the fonts or spacing in the CETM as she said it was 'okay'. However, on the other hand Liza gave some contrast feedback when Liza said that the language could be simplified for better understanding. Liza also mentioned that the outline of the activities was new but could be time consuming if not given the appropriate guidance required. In regards to the fonts display or the physical display of CETM activities, Liza suggested that more colours and pictures could be added in the CETM activities to attract the interest from the teachers and children in teaching and learning science. In short, Liza said that children love to see pictures of cartoons and she suggested that pictures of metal tin robots and windmills in the form of cartoons can be placed in the CETM activities.

Likewise, when asked about the criterias in the CETM such as the module aim, subject content, learning outcomes, teaching and assessment strategies (Q4), Siti said that all of the criteria were parallel with the CETM design. Siti mentioned that the CETM has the ability to promote HOTS for children. At the same time, Siti added that any activity in CETM, if could attract the children's attention, has the ability to foster HOTS. She stressed that the children must be interested first before aiming to promote thinking skills. Conversely, Liza gave some suggestions of improvement for learning outcomes and teaching strategies. According to Liza, the learning outcomes in CETM had the elements of beyond the classroom but it can be improvised to be parallel with the current science syllabus. For example, in Activity One, the learning outcome was broad and it could be either written specifically or straightforward like the other activities in CETM. Liza also said that since the essence of questioning was crucial in CETM, there should be a list of questions that could be embedded within the CETM to guide the teachers. For example, Liza said that some example of questions that could be asked in the brainstorm session can be written for each activity to save the teacher's time in implementing the CETM. In fact, Liza said sometimes teachers go blank since they teach continuously for hours when they have back to back lessons in different classes, teaching different kind of subjects. Hence, the lists of questions to kick start the CETM activities can be added into the brainstorming session for the teacher's convenience.

In the same way, Siti gave some feedback when asked which part in the CETM was the most interesting to her as a teacher (Q5). Siti revealed that the rubric which measures the thinking skills was one of the most interesting parts in the CETM. Siti said that; "…The rubric makes our (teachers) work much easier because we can assess the type of thinking skills children have achieved at the end of each activity. We (teachers) don't have to figure out (the HOTS) ourselves." Accordingly, to Siti, there are not many rubrics in the current curriculum with the specified and itemized categories of HOTS elements such as in the CETM. She said, teachers themselves can experience and discover which HOTS element the children have achieved throughout the CETM activities.

Parallel to that, Siti also liked Activity Two where the children came up with the windmill prototype. In fact, Siti mentioned that Activity Four which comes up with the metal tin robot prototype was the best activity in the CETM. Siti said the children were very excited and the class was in chaos during the Activity Two and Activity Four. Siti mentioned that;

> …Children love these types (hands-on) of activities. Designing things (prototypes) that either can move, make noise (sound), show (produce) light and so on attract the children's interest in learning science. This (activity) make them (children) to enjoy science.

In contrast, when asked which part in the CETM was time consuming (Q6), Siti said that she noticed the children took some time in the activities, particularly while creating the prototype. Siti described that each of the group completed the prototype at different times and for each activity, there were one group which could not completed the prototype within an hour (the duration for Science lesson). Siti also mentioned that Activity Three (Soap bubbles) was not appropriate since it was time consuming and was not align with the current science syllabus. Similarly, while giving the feedback on which part or where she required help during the CETM activities (Q7), Siti said sometimes it was tough to be self-reliant since at times it was difficult to connect other subjects such as Mathematics, History and Geography into the CETM activity. For example, in Activity Two, Siti mentioned that she herself was not aware that windmills were used in certain islands in Malaysia. In fact, she was not aware where some of these islands were situated geographically. She continued that planning is important in teaching field and in order to plan, teachers need more knowledge or information especially across other subject contents.

Siti also said although the CETM had the guidance for the teachers, it could be better if the CETM does not involve sharp tools. Siti said needed extra 'eyes' to watch the children using screw drivers because there were some naughty children in the class where they might misuse the tools provided to them. In the same way, while giving response in improvising the CETM activities (Q8), Siti mentioned that Activity Three (Soap bubbles) can be omitted from the CETM. Siti pointed out that the atmosphere of the class was bizarre because she felt that there was not much learning process involved. Siti also stressed that the scenario for Activity Three was too high level for the children because terms such as 'black hole' were not easy to explain to the children and it was time consuming. Siti argued that;

> …To my understanding prototype must be a solid or a 3D (3-dimensional) thing (source). I can't see soap bubbles as a prototype for Activity Three in the module (CETM).

Meanwhile Liza pointed out that there were number of high level phrases in the CETM that could be removed. Liza mentioned:

> …I noticed there were words (phrases) such as alpha brain waves and transferable skills which in my opinion doesn'need to be included in the CETM.

However, Liza praised the guidance that CETM had in grooming the teachers to design their own activities in future. At the same time, Liza was also parallel with Siti about Activity Three since it had quite number of flaws such as in testing stage. This raised doubts in how to test a bubble since it will only burst after a few seconds. In the same way, Liza gave ways of improving the CETM activities (Q9) by giving constructive suggestions in improving the CETM. Liza suggested:

> …I am not sure about others (teachers) but I would prefer a module (CETM) that is less wordy and more (examples) on the activities. Maybe you can add more symbols, diagrams or colourful animations to make the module (CETM) more attractive.

Likewise, Liza said for each theme in the syllabus, more activities could be embedded in CETM instead of one activity for each theme. Liza praised that the present activities in CETM were interesting and helps the children to see beyond the classroom. Parallel to that, more ideas such as metal tin robot and windmill can be embeddd into the CETM. Liza also mentioned that, the photos that were captured during the implementation of CETM can be embedded into the CETM as some illustrated examples for future usage. When asked whether they can design their own activities in future, Liza portrayed some positive gestures while giving the following feedback:

> …I have not tried teaching (using the CETM) but I would like to try implementing some of the activities. I saw (observed) Siti teaching (using the CETM). Teachers act like the facilitator and I like that (concept).

Meanwhile, Siti said that she would try but preferred to have more guidance and experience before creating the activities independently. However, Siti revealed that, by using the CETM as guidance, she might design a simpler version of activities for children in learning science. When asked why, Siti said; "…when the activities were less difficult, the materials and tools will be easier to get (obtain)".

Siti said that she needed more help in finding appropriate resources and strategies to incorporate the CETM activities in the teaching and learning science. It will take time and energy to create such an activity within the science curriculum. She expressed that continuous training or guidance was needed to implement these activities in the classrooms.

This suggested that teachers need consistent amount of training. If having a practice run of the CETM activities among the children was necessary, the teachers must also experience the hands-on training and understand the children's perspectives while completing the exercises. Previous research supports the enclosure of active learning components in the hands-on activities whereby allowing the teachers to engage and experiment before implementation is an important stage while training the teachers.

The CETM activities has been improved based on the teacher's perception. The CETM activities has been improvised on several aspects and the aspects are language (grammar), pattern or structure of the activities and type of font, font size and the spacing. At the same time, some captivating images has also been added into the CETM activities.

In the nut shell, the teachers found the developed CETM as an interesting new addition in teaching and learning science. They also advised on designing more activities to embed into the CETM.

Children's Achievement in Higher Order Thinking Skill (HOTS) using Science Reasoning Skills Test (SRST)

The developed CETM was evaluated by the SRST which was administrated to the children before and after the CETM activities. The SRST was administrated on the following week once children have completed all the CETM activities. Subsequently, children's HOTS level before and after the SRST administration was analysed using paired *t-test,* descriptive analysis and significance different.

The paired *t-test* for the SRST test items (*n*=20) which was administrated to the Year 5 children indicated that the children's post-test scores (*M*=0.582, *SD*=0.148) were significantly higher than the pre-test scores (*M*=0.417, *SD*=0.149), *t* (5) =7.558, *p*=0.000 (two-tailed). The maximum score of the SRST is 20 and the minimum score is 0. Table 5.3 shows the comparison between pre-test and post-test using paired t-test to evaluate the children's HOTS level after the CETM activities.

Table 5.3: Pre-test and post-test comparison using paired t-test

Paired Differences						
Test	**Mean**	**N**	**SD**	***t***	**df**	**Sig (2-tailed)**
Pre-test	0.417	30	0.149	-7.558	19	0.000
Post-test	0.582	30	0.148			

*p < 0.05

Based on the findings, in a general perspective, these results suggested that the children have significantly improved their HOTS level after completing the CETM activities in the classroom. The mean difference between pre-test and post-test was 0.165 because the average mean has increased after the CETM activities. However, the descriptive analysis showed that not all of the HOTS elements in each test item showed the improvement. There were some HOTS elements which showed improvement among the children and some which did not show any improvement.

Parallel to that, descriptive analysis was carried out to observe the difference in achievement for each test item in SRST which represented the HOTS element. As the pre-test aimed at diagnosing children's (*n*=30) HOTS in science, most of the HOTS elements in the post-test showed improvement through mean difference after the CETM implementation. Table 5.4 shows descriptive analysis of pre-test and post-test for each of the HOTS element in the SRST.

Table 5.4: Descriptive analysis for each HOTS element

No.	HOTS elements	Test	Mean	MD	SD
Q1	Informal logical reasoning	Pre	0.367	0.066	0.490
		Post	0.433		0.504
Q2	Making judgment	Pre	0.367	0.300	0.490
		Post	0.667		0.479
Q3	Syllogism inductive reasoning	Pre	0.433	0.267	0.504
		Post	0.700		0.466
Q4	Conditional reasoning	Pre	0.400	0.033	0.498
	(imagined function)	Post	0.433		0.504
Q5	Correlational reasoning	Pre	0.233	0.300	0.430
		Post	0.533		0.507
Q6	Conditional reasoning	Pre	0.533	0.134	0.507
	(imagined extension of actual events)	Post	0.667		0.480
Q7	Plausible logical reasoning	Pre	0.433	0.300	0.504
		Post	0.733		0.450
Q8	Case-based reasoning	Pre	0.133	0.167	0.346
	(blood relations)	Post	0.300		0.466
Q9	Predicting	Pre	0.500	0.233	0.509
		Post	0.733		0.450
Q10	Formal logical reasoning	Pre	0.500	0.167	0.509
		Post	0.667		0.479
Q11	Un-cogent argumentative	Pre	0.733	0.100	0.450
		Post	0.833		0.379
Q12	Generalized inductive reasoning	Pre	0.300	0.267	0.466
		Post	0.567		0.504
Q13	Analyzing	Pre	0.433	0.000	0.504
		Post	0.433		0.504
Q14	Mechanical reasoning	Pre	0.533	0.100	0.507
		Post	0.633		0.490
Q15	Deductive reasoning	Pre	0.567	0.100	0.504
		Post	0.667		0.479
Q16	Probability reasoning	Pre	0.367	0.200	0.490
		Post	0.567		0.504
Q17	Cogent argumentative	Pre	0.300	0.033	0.466
		Post	0.333		0.479
Q18	Numerical reasoning	Pre	0.500	0.100	0.509
		Post	0.600		0.498
Q19	Case-based reasoning	Pre	0.133	0267	0.346
	(sense of directions)	Post	0.400		0.498
Q20	Practical reasoning	Pre	0.567	0.166	0.504
		Post	0.733		0.450

Almost the entire HOTS element pointed out improvement except for one HOTS element. Only HOTS element analyzing in Q13 did not show any improvement as the mean (*M*=0.433) was the same before and after the activities. Meanwhile Q2, Q5 and Q7 indicated the biggest mean difference (*MD*= 0.300). At the same time, the least improvement was in Q4 and Q17 with both showed (*MD*= 0.033).

Parallel to that, significant difference for each test item was analysed and described to show the significance of each HOTS element in both the pre-test and post-test. In order to remove the individual differences among the children, one-way ANOVA was employed to show the contrast comparisons between and within the pre-test and post-test.

As $p<0.05$, this indicated that there was a highly significant difference between both the test. In total, six HOTS elements produced significance difference in pre-test and post-test. Q2 (making judgement) showed F (1,58) =5.743; $p<0.05$, Q3 (syllogism inductive reasoning) reported F (1,58) =4.527; $p<0.05$, Q5 (correlational reasoning) indicated F (1,58) =6.101; $p<0.05$, Q7 (plausible logical reasoning) stated F (1,58) =5.917; $p<0.05$, Q12 (generalized inductive reasoning) pointed out F (1,58) =4.527; $p<0.05$ and Q19 (case-based reasoning) informed F (1,58) =5.800; $p<0.05$.

These results demonstrated that the implementation of CETM activities induced some fraction of HOTS element prior to children's learning in science. The results also showed a significant enhancement of HOTS among the children. However, the overall increment of HOTS elements in the administrated tests was one third from the total percentage. The following Table 5.5 displays the contrast comparisons for all the HOTS elements in both of the pre-test and post-test.

Table 5.5: Comparison of pre-test and post-test for each HOTS element using ANOVA

No.	HOTS elements	MS	F	Sig. (2-tailed)
Q1	Informal logical reasoning	0.067 0.247	0.270	0.605
Q2	Making judgment	1.350 0.235	5.743	0.020*
Q3	Syllogism inductive reasoning	1.067 0.236	4.527	0.038*
Q4	Conditional reasoning *(imagined function)*	0.017 0.251	0.066	0.798
Q5	Correlational reasoning	1.350 0.221	6.101	0.016*
Q6	Conditional reasoning *(imagined extensions of actual events)*	1.267 0.244	1.094	0.300
Q7	Plausible logical reasoning	1.350 0.228	5.917	0.018*
Q8	Case-based reasoning *(blood relations)*	0.417 0.168	2.474	0.121
Q9	Predicting	1.275 0.249	3.544	0.065
Q10	Formal logical reasoning	0.417 0.244	1.706	0.197
Q11	Un-cogent argument	0.150 0.173	0.867	0.356
Q12	Generalized inductive reasoning	1.067 0.236	4.527	0.038*
Q13	Analyzing	0.000 0.254	0.000	1.000
Q14	Mechanical reasoning	0.150 0.249	0.603	0.441
Q15	Deductive reasoning	1.250 0.242	4.620	0.434
Q16	Probability reasoning	0.600 0.247	2.428	0.125
Q17	Cogent argument	0.017 0.224	0.075	0.786
Q18	Numerical reasoning	0.150 0.253	0.592	0.445
Q19	Case-based reasoning *(sense of directions)*	1.067 0.184	5.800	0.019*
Q20	Practical reasoning	0.417 0.228	1.826	0.182

*$p < 0.05$.

Children's Feedback in Close-Ended Questions for Specific Items

In each of the CETM activity, children practiced the cyclic process which involved six stages. The first stage was writing the problem, second stage was brainstorming for solutions through sketches, followed by creating the solution decided and testing the solution created. After testing the solution, children evaluated and finally presented the solution. The following information will describe the descriptive analysis for children's feedback in close-ended questions for specific items**.**

Out of the 24 testing measures in all the CETM activities, nine of the total testing measures represented analysing skill in Revised Bloom Taxonomy (RBT). Hence, the following analysis is based on the nine testing measures for all the CETM activities.

Activity One was embedded with four items (b, d, e and f), Activity Two was embedded with one item (d), Activity Four was embedded with two items (d and f) and Activity Five was embedded with three items (c, d and f). Children's responses in the testing stage can be categorized into three types of responses. Most of the children have answered "Yes" or "No" whereas some of the children left it blank with answering the testing measures. Table 5.6 displayed the outcome of children's ability in answering the following items.

Table 5.6: Children's response in prototype testing for specific items

Testing measures in CETM activity	Number of children's response			Suggested answer
	Answered Yes	Answered No	Left blank	
Activity 1: Plastic Parachute				
b. Does the height of where the plastic parachute floated influences the total time the plastic parachute flies?	18	10	2	Yes
d. Can the plastic parachute fly better if bigger plastic is used?	29	1	0	Yes
e. Can the plastic parachute fly further if heavier supplies are tied to it?	10	8	12	No
f. Does the wind speed important for the plastic parachute to fly?	30	0	0	Yes
Total responses	87	19	14	
Activity 2: Windmill				
d. Does the wind speed make a difference in lighting the LED lamp?	12	9	9	Yes
Total responses	12	9	9	
Activity 4: Metal Tin Robot				
d. Does your model function better in a different metal can?	27	2	1	No
f. Does a different battery brand with the same voltage make a difference in the model?	22	5	3	No
Total responses	49	7	4	
Activity 5: Humanoid Robot				
c. Does the change of colour in the card make a difference in your model's flexibility?	13	16	1	No
d. Does the space area and height influences in designing your model?	29	1	0	Yes
Total responses	42	17	1	

In a broad spectrum, majority of the children answered correctly for all the four activities. However, for Activity Four, children did not quite achieve the ability to think and answer correctly for both the (d) and (f) items. Although children had the opportunites to manipulate the variables such as the different metal cansand different brand batteries, 82% of the children misunderstood the true demeanor that kept the metal tin robots functioning. Yet, seven of the responses for Activity Four was correct.

On the contrary, 69% of the children answered correctly for Activity One, 40% of the children responded rationally for Activity Two and 75% of the children reasoned logically for Activity Five. In total, 44% of the children answered “Yes” when the possible answer was “Yes” and 11% of the children answered “No” when the possible answer was “No”. Hence, 55% of the children responded correctly for the nine higher level items in testing stage. Children managed to reason correctly based on the manipulation of the variables and accurate observation which enhanced their experience for prototype testing.

Summary

This study generated a few ways of identifying the emergence of HOTS using CETM activities. Verbal expressions, sketches and written responses were among of the ways analysed and described. The designed CETM was evaluated based on the children’s achievement in SRST, children’s responses in prototype testing using close-ended questions and the teacher’s feedback using interview and observation. The following chapter discusses how the emerged findings in this chapter answered the research questions of this study.

CHAPTER 6: SUMMARY, CONCLUSION, DISCUSSION, IMPLICATION AND RECOMMENDATION

Introduction

Chapter Six displays a summary of the entire study. Chapter Six summarizes the conclusions and discussions of the research questions. Besides that, this chapter also discusses the implications of learning theories and design and development research using Isman Model. Parallel to that, methodological reflections and Children's Engineering Teaching Module (CETM) practicality, especially on how CETM helped the teachers and policy makers were also discussed in this chapter. Recommendations for future research were also displayed at the final section to conclude this chapter and the entire research study.

Research Summary

Malaysian science education is aiming at making science more appealing to children and indirectly inviting more children to pursue their studies in science-related areas to realize Malaysia's goal of becoming an industrialized country (Saat, 2012). Knowing that Malaysian science participant's performance in Trends International Mathematics and Science Study (TIMSS) 2011 and Program for International Student Assessment (PISA) 2009 were disappointing particularly in fostering higher order thinking skills (HOTS) and reasoning skills, the key question now will be what will the future of science education look like to inspire young children and ensure they understand the concepts, processes and role of science in the world? (Hartwell, 2010). This is because Malaysian children were detected weak in HOTS, not only in answering science questions but also in solving science problems. Though literature reviews revealed the several attempts to enhance HOTS among children, the possibility of improving HOTS still remained uncertain (Anderson & Contino, 2010; Avargil et al., 2011; Kershner et al., 2010; Madhuri et al., 2012; Mant et al., 2007; Oliveras, Marquez & Sanmarti, 2011; Preus, 2012; Skillen, 2008). Reasoning skills was also investigated in Smeding (2012)'s study because reasoning skills is one of the HOTS hallmark in Science, Technology, Engineering and Mathematics (STEM) disciplines (Pronin, Steele & Ross, 2004).

According to Rhoads (2004) the increasing flow in STEM pipeline has become a better way to motivate young minds to continue interests in science. Moreover, making science come alive for primary school children through engineering has been highlighted and emphasized in education system (Rhoads, 2004). One of the most powerful styles of reasoning which has permanently changed the modern world can be achieved through engineering design (Hacking, 2002; Daugherty & Mentzer, 2008; Zhao & Maher, 1998). Malaysia's science education requires a path of improvement especially on increasing HOTS mainly in reasoning domain (Abdullah & Osman, 2010; Meeteren & Zan, 2010; Salih, 2010).

Since the science curriculum is still undergoing transformation, which includes restructuring of scientific content and the mode of assessment (Saat, 2012), CETM could be embedded into the current science curriculum to add more possible solutions for HOTS enhancement among the children. CETM was designed and developed to foster HOTS and reasoning skills among eleven years old children. CETM underpins not only the worthwhile innovations but also emphasizes on attracting the children to enjoy learning science in classrooms. This study answered the following research questions:

1. What are the elements in teaching science that could enhance HOTS for the CETM?
2. What kind of activities embedded in the CETM in order to enhance HOTS in teaching science?
3. How does the developed CETM enhanced reasoning domain of HOTS in teaching science?
4. How do the teachers perceive the developed CETM?

This study employed design and development research to develop the CETM. Modified Delphi method was employed in this study whereby 22 shortlisted experts who participated were required to respond a total of thirteen interview questions via e-mail. The theoretical foundation of this qualitative design was based on Gagne, Piaget and Vygotsky views.

This study used online interviews to investigate the practice of fostering HOTS among eleven years old children through the CETM development. These experts were selected based on their publications in academic journals, experience in specific fields and the ability to influence the policy. The written responses received from the experts were analysed and four themes emerged from a total of 66 codes and ninteen categories. The process of achieving mutual consensus in regards to the emerged findings experienced at least five rounds of discussion.

CETM was implemented in a primary school and the findings of CETM activities was analysed and discussed. Based on the findings, it was evident that CETM provided the opportunities for children to get engaged in science lessons apart from increasing their HOTS, as this cognitive skill is crucial for the 21st century. Another prominent outcome that arose in this study was the expert's conviction on HOTS and reasoning skills in the prospect of engineering design. The research findings showed that this relationship leads children beyond obtaining higher level thinking because designing engineering activities are capable of nurturing intelligence apart from optimizing the usage of the human brain.

Conclusions and Discussion

Based on the findings, three conclusions can be drawn from this study. The conclusions are: (1) CETM enhanced HOTS and reasoning skills among children (2) CETM features has encouraged the children to improve their HOTS and reasoning skills and (3) CETM is well perceived by the teachers. The following sub-sections elaborates on each of these conclusions as mentioned above.

CETM Enhanced Higher Order Thinking Skills (HOTS) and Reasoning Skills

In line with Maier (1933, 1937), this study assessed HOTS and reasoning skills when children analyse, create and evaluate their designed prototype during CETM activities. SRST indicated some improvement in reasoning skills among children after their participation in CETM activities.

Reasoning skills such as inductive reasoning, conditional reasoning, correlational reasoning, case-based reasoning, logical reasoning, mechanical reasoning, deductive reasoning, probability reasoning and numerical reasoning showed improvement after the CETM implementation.

Apart from that, children also showed some improvement in other HOTS elements such as making judgment and argumentative. HOTS elements such as making judgment, inductive reasoning, correlational reasoning, plausible logical reasoning and case-based reasoning improved as compared to other elements.

Converging evidence showed children’s engineering does promote HOTS and reasoning skills in the application of science (Clark & Andrews, 2010; Tu, 2006).

HOTS and reasoning skills have been nurtured through children's engineering among primary school children in various countries across the globe (Jones, 2006; Jones & Compton, 2009; Hill, 2009; Lachapelle & Cunningham, 2012; Muchtar & Majid, 2009; Nwohu, 2011).

At the same time, children's reasoning in an argument was also prudent and obvious while evaluating and creating the prototypes. According to Mulnix (2012), arguments increase children's abilities to think critically, especially when they are engaged in an interesting social engagement such as CETM activities. Although children accepted criticism in an argument, children shared different viewpoints and placed own ideas of improvement. Apart from that, children made fundamental connections to justify their arguments, either in a discussion or question and answer session. Higher level thinking skills require children to involve in active argumentation and reasoning (Behar-Horenstein & Niu 2011). CETM activities stimulate children to engage among themselves or with the teacher and indirectly produce arguments and debates which requires higher level thinking skills (Freeley & Steinberg, 2013).

By providing original alternatives and using relational symbols in sketches while brainstorming, children reflected their experiences in other subjects such as Mathematics, Technology and Living Skills apart from Science subject. The idea of relating their reasoning ability using interdisciplinary fields also displayed higher level thinking skills. Reflection of image describes a state where the children are able to rely on reasoning skills and informed intuition to reach a decision (Beever & Brightman, 2015). Children reflected their mathematic knowledge and transferred the information into their sketches, representing like a weighing machine (De Smedt, Noël, Gilmore & Ansari, 2013). According to Gojak (2013), reasoning using mathematical knowledge is the internal process children go through in their minds to think about a problem that needs a solution.

In line with that, according to DeLoache (2002), children who used symbols have achieved something called dual representation. Dual representation means children were able to simulatenously display both the concrete and abstract nature of a symbol (DeLoache, 2002). Children who explains information using symbols to solve a simple target problem (Brown, 1990; Chen, 1996). In fact, children will be prepared to gain access for scientific analogies. Children will be able to solve complex problems by getting involved in designing activities (Gentner, Ratterman, Markman & Kotovsky, 1995; Goswami, 2002). Looking at the children's sketches, CETM activities stimulates the usage of relational symbols. According to DeLoache (2002), children's progressively effective practice in symbolic retrieval activities such as CETM activities is supported by analogical reasoning skills which is also a crucial element of HOTS.

Reseachers claimed that reasoning skills is strongly linked to the children's mind usage. According to the cognitive psychologists, the use of reasoning skills tries to explain how children's mental imagery and intellectual thoughts are interrelated (De Soto, London, & Handel, 1965; Kosslyn, 1994). Parallel to that, Leutner, Leopold and Sumfleth (2009) have observed children who sketched have higher possibility in not only creating a mental image but at the same time experienced higher thinking gains.

At the same time, practicing intellectual discussions supported the development of arguments during the CETM activities. Practicing intellectual ability levels can enhance higher level thinking skills (Lai & Wu, 2012; Saade, Morin & Thomas, 2012). Chain of arguments and debates helps to increase children's higher thinking capacity (Freeley & Steinbery, 2013; Mulnix, 2012). On the other hand, the notion of taking in new information, combining the new information with previous information, or reorganizing such information to find potential solutions to perplexing circumstances all connected to HOTS (Halpern, 1996; Lewis & Smith, 1993).

Evaluation is the second highest stage in the Revised Bloom Taxonomy (RBT) hierarchy. The children made judgements based on criteria and standards through checking and critiquing. For example, the children critized other children's work or even their own work but still provided recommendations while designing the prototype. According to Fisher (2005), the capability to evaluate is essential for HOTS because the process of evaluation involves developing and using criteria of judgment. CETM activities provide the opportunity for children to assess ideas, action or solutions by using the practice of open-ended enquiring.

In the present study, the children were observed holding and rotating the metal tin robot prototype while observing its structure. Frequent self-evaluation is critical for HOTS, especially in guiding children on how certain things could have been done differently while designing the prototypes (Whitney & Luparell, 2012). Meanwhile, a gesture of thumbs-up was observed (conveying teacher's gesture) when the designed prototype fulfils the criteria. Only by exercising critical judgments, children will be developed into higher level thinkers (Fisher, 2005).

Researchers across the globe have indicated that activities integrated engineering design such as in the developed CETM activities has increased the higher level thinking skills among the children (Burghardt, 1999; Duncan, 2003; Golanbari & Garlikov, 2008; Paul, Niewoehner & Elder, 2006; Schauble, Glaser, Raghavan & Reiner, 1991; Silk, et al., 2009). In fact, researchers have also revealed that engineering design activities encouraged functional reasoning skills and spatial reasoning skills among the children (Far & Elamy, 2005; Hsi, Linn & Bell, 1997; Humphreys, Lubinski & Yao, 1993; Olkun, 2003; Umeda & Tomiyama, 1997).

CETM Characteristics has improved the Higher Order Thinking Skills (HOTS) and Reasoning Skills

Some of the characterictics in the developed CETM has enhanced HOTS and reasoning skills among the children. These characteristics were the practice of cyclic process in designing a prototype, the variety of features in an activity to express children's answers, the essence of learning beyond curriculum content and the involvement of sustainable engineering design in each of the activity.

The Practice of Cyclic Process in Designing a Prototype

This study summarized that cyclic process in CETM activities has stimulated the acquisition of HOTS and reasoning skills among the children. The cyclic designing nature requires children to think critically based on the cyclical reflective process and into a hypothesis-driven phase. Cyclic designing activities are active learning course that encourages children to improve their higher level thinking skills (Plack & Santasier, 2004). Activities that involve cyclic process improve the quality of HOTS and reasoning skills (Lo¨hner, van Joolingen, Savelsbergh & van Hout-Wolters, 2005; Smith & Szymanski, 2013). These researchers added that different activities which used cyclic processes induced significantly different reasoning skills.

Meanwhile Hmelo-Silver, Nagarajan & Day (2002) revealed that children have the opportunities to distinguish the use of previous analogies or knowledge, observing, assessment, replication and scientific reasoning during a cyclic process. Children also propose ways to systematically test some of their generated reasons during the cyclic process (Apedoe, Reynolds, Ellefson & Schunn, 2008). This is parallel with the cyclic process in CETM activities, whereby children were able to differentiate the processes by understanding problem, brainstorming solutions, creating the best solutions, testing solutions, evaluating solutions and finally redesigning prototype.

Furthermore, Murray (2013) added that activities which encourages cyclical process provide teachers with practice-based experiences that help them learn about pedagogy, interdisciplinary fields and student thinking. These experiences are necessary in order to help teachers learn how to implement standards-based instruction, and ultimately higher order thinking in their classrooms (Murray, 2013).

Subsequently, Zimmerman (2000) indicated that cyclic process is a self-regulated learning where the children fix their aims, practice their plans, monitor their learning development and transform their plans when they believe the plans are ineffective. Vygotsky (1978) believed that children participated in hands-on activities independently by monitoring their own actions through communications and actions. For example, during the CETM activities, children capitalized on dialogue and group learning. Based on the findings, it was observed that children worked in teams to brainstorm, create, design and test solutions. As group members, children learnt to listen to each other, compromised and shared the responsibilities. Practicing intellectual discussions during the cyclic process increased the possibility of fostering higher level reasoning tasks such as self-regulation and problem solving among the children.

The Variety of Features in an Activity to Express Children's Answers

CETM activities consist of variety of features for children to express their answers. Children can write their answers, sketch their ideas, give their response for the close-ended questions and present their solutions once they have completed their design. Hence, during the CETM activities, children provided divergent opinions in reasoning their ideas. In a broader spectrum, children expressed their responses in all the CETM activities through written words, verbal discussions, sketches, testing prototypes, displaying gestures and body languages. The variety of features in the

CETM activities provided the platform for the children to deliver their different viewpoints.

Delivering different viewpoints during the CETM activities increased the prospect of improving HOTS among children. Children were able to write the challenge and evaluate their developed prototype in their own words. According to Gagne (1985), expressing different opinions can be observed as receiving multiple perspectives from various sources apart from making efforts in testing the created prototypes. Divergent ideas involve creative thinking especially when they can be involved in relevant activities where children can show their creative reasoning (Green, Cohen, Kim & Gray, 2012). According to Atchley, Strayer and Atchley (2012), creative reasoning enhances HOTS functions such as problem solving activities such as CETM. Generating different viewpoints between current ideas is an important form of creative thinking. This is because different viewpoints often lead to real life applications which involves children's usage of reasoning skills (Donnelly & McDaniel, 1993; Dunbar & Blanchette, 2001; Holyoak & Thagard, 1995).

There is ample evidence that creative thinking requires different viewpoints because different viewpoints encourages children to image and produce various type of answers or solutions for a given challenge (Diamond, Barnett, Thomas & Munro, 2007; Haring-Smith, 2006; Kaufman & Sternberg, 2007; Kim, 2006; Sawyer, 2006; Simonton, 2004; Vandervert, Schimpf & Liu, 2007). Dym and Little (2004) revealed that engineering design encourages creative thinking skills and different answers in children.

Children were also able to transfer their knowledge either by written words, sketches or verbal expressions. Transferring prior knowledge in an independent manner, using a child's own thinking helps to generally overcome related barriers in children's learning process (Gagne & Dick, 1983; Piaget, 1955). HOTS requires something more fundamental than basic knowledge or skills, namely, a set of process which emerge simulatenously in an activity (Newmann, 1990). However, transferring or applying knowledge in an independent learning environment helps to trigger the HOTS among the children.

This is because according to Wineburg and Schneider (2009), the goal of higher level thinking is not just about thinking but to acquire new knowledge as well. The recovery of previous knowledge to solve engineering design challenge is a crucial section of the engineering design process (Daugherty & Mentzer, 2008). The importance of integrating engineering design content and processes into the science education depends on the storage and recovery of previous knowledge within the problem-solving process (Daugherty & Mentzer, 2008; Visser, 1996). Hence, transferring knowledge helps to create a new piece of information apart from creating a solid foundation for HOTS.

During CETM activities, there were many opportunities for children to interact with each other. Constructing engagements while designing CETM prototypes is a crucial outcome that helps to improve HOTS among children. Constructing engagements embeds transfer of knowledge and produces interactive conversations during the activities. At the same time, according to Stien and Beed (2004), some of the biggest challenge of the teachers is to get children involved in an interactive dialogue or conversation. Interactive dialogues created feedback from children while they created the prototypes. For example, during the interactive group discussion, children were observed to be questioning and showing sense of urgency of the activity in an energetic motion. Children also were seen continually moving their hands and bodies while reasoning their ideas among the group members.

Verbal interactions are important in promoting higher level thinking because according to Vygotskian (1978), verbal interactions enhance children’s cognitive development and learning (King, 2002). Feedbacks are necessary for brain growth because brain operates in feedback (Harth, 1995). Interactive exchange of ideas supports the enhancement of higher level thinking skills among children (Sendag & Odabasi, 2009).

CETM activities also encouraged children to sketch their prototypes during brain storming session. Children's sketches in brainstorming the prototypes have been randomly chosen for each of the four activities. The obtained data in the form of sketches also indicated how the developed CETM had influenced thinking skills among the children. The CETM activities encouraged children to sketch their answers as one of the platform for them to express their ideas.

According to Hope (2008), generating, creating, developing and cooperating are the main elements of children's sketching during the hands-on activities. The mind is always thinking during the process of sketching because sketching develops the mental abilities of the children, especially when the activities offer higher level of challenge to the children (Bartel, 2010). Bartel added that through sketches, children's confidence is improved. This is because sketches help children to discover new encounters that allows their designs or solutions to be articulated, especially once the solution is completed. Children who were given the opportunity to sketch, can describe better than using words. This is because sketches are useful for recording, expressing their thoughts and keeping track of how they use their experiences in producing their sketches for a hands-on activity such as the children's engineering (Anim, 2012).

By the same token, Hope (2008) described sketching as a handy tool that allows children to learn and understand the ideas of others. When children do that, they effectively improve, produce, magnify and converse on their own ideas. Children's sketches can offer a window into their representational world and visual practicality because sketching ideas can improve children's reasoning skills, especially in describing their solutions for a given challenge (Cherney, Seiwert, Dickey & Flichtbeil, 2006). Subsequently, Quillin and Thomas (2015) mentioned that assigning sketches to children to help them engage in scientific activities are different pedagogical goals yet it can solve a HOTS problem.

The development of HOTS in children can prepare the children to foster thinking skills across various content areas such as the Science, Technology, Engineering and Mathematics (STEM) education (Epstein, 2003). Hence, the variety of platforms in the CETM activities has helped the children to improve their HOTS and reasoning skills in learning science.

The Essence of Learning Beyond Curriculum Content

Another distinctive feature of CETM is that the children's activities were entailed to be beyond their syllabus or science curriculum. Each CETM activity was embedded with a real situation challenge which was beyond the science curriculum. For example, eventhough renewable energy such as wind and solar were mentioned in the textbooks, the real situations involving these energies were not explained. Hence, CETM activities provided the real situations such as the how windmills were also implemented in Malaysia and where windmills were built in Malaysia. On the other hand, knowledge about the essential minerals which was found in planet Moon can be transported to Malaysia if there was a proper idea or solution. Hence, the metal tin robot was designed to transport these minerals for the benefit of mankind. Likewise, the design of humanoid robots which was beyond the science curriculum was crucial for the children's realization, since robotic world upholds the future of mankind.

Learning beyond curriculum is important because when children come across new contexts, children can use their newly learned conceptions appropriately (Georghiades, 2000). In fact, learning beyond curriculum can stimulate HOTS among children (Hopson, Simms & Knezek, 2001) because children can practice their ability to go beyond the level of sensible experience (Bialik & Kabbach, 2014).

Parallel with promoting beyond science curriculum, children who have not been involved in science or mathematics, can still evaluate a design if they are given an opportunity through activities such as children's engineering (Cunningham & Carlsen, 2014). In fact, though the children have not been exposed to science or mathematics, but if the given engineering challenge is relevant to the child, it helps the children to indirectly use their thinking skills to produce a solution or a prototype (Cunningham & Carlsen, 2014). By employing more varied assessment measures, this research invited the engagement of children to use their varied knowledge and abilities. Children don't require a teacher if ever their windmill prototype or metal tin robot doesn't work. They can use their technical skills and reason the productive failure until a solution can be made. Technical abilities in CETM activities support the HOTS enhancement because according to Heong, Othman, Yunos, Kiong, Hassan and Mohamad (2011), technical skills improve HOTS when children apply knowledge in hands-on activities.

The Involvement of Sustainable Engineering Design

Sustainable prototypes are the developing practice, especially in the new construction progress for the green development movement which has been adopted by the builders, engineers and designers (Leffers, 2010). Integration of the sustainability principles into the early engineering content needs the teacher's commitment to assist the children's intelligent development (Darwish, Agnello & Burgess, 2010).

CETM also integrated sustainable green design engineering. Different sustainable materials have been woven into several of CETM activities. Each of the activity in CETM used the recycled material as the main part of prototype. For example, plastic parachute used plastic wrapper, windmill used water bottle, metal tin robot used metal tin can and humanoid robot used cardboards. Children were exposed towards the usage of recycled materials in creating sustainable prototypes for real situation challenges. Constructing real tangible prototypes using their mental ability helps children to go beyond their projected reasoning abilities. This can be carried out by demonstrating a variety of reasoning patterns (Mioduser & Levy, 2010).

If children were trained to be problem solvers, why not present the world's problems as challenges for children to tackle? With global awareness raised, children could see the connections as between scientists and engineers which was part of the CETM solutions. In terms of the environment and renewable energy sources, children in this research become interested in learning about the science behind technological solutions (such as windmill and metal tin robots) once the application and impact were realized. The key was to connect STEM issues to the challenge provided in CETM that affects their daily life, community, country and planet. This interconnectedness is an important aspect to stress because pedagogically children think more holistically and invoke systems thinking (Chen, Vanasupa, London & Savage, 2006).

Sustainable design engineering promotes HOTS such as systems thinking (Chen, Vanasupa, London & Savage, 2006). Our ever changing and challenging world requires children to use their knowledge as they need to develop HOTS such as systems thinking, decision making and problem solving (Dillon, 2002; Miri, Ben-Chaim & Zoller, 2007; Zohar & Dori, 2003; Zoller, Dori & Lubezky, 2002).

Apart from that, Dawe, Jucker and Martin (2005) have identified that teaching sustainable design engineering supports the growth of problem solving skills, team work and interdisciplinary thinking skills. Children become aware of the challenges given as they develop their solutions by learning to think deeper especially on how to integrate their knowledge into designing the solutions or prototypes (Donald, 2002). Learning approaches using sustainable design engineering supported children's HOTS

(Donald, 2002). Problem-based learning, inquiry-based learning and cooperative or collaborative learning methods contribute to HOTS in experiencing the sustainable design engineering (Thomas, 2009). CETM activities promoted awareness and motivation for children to use their technical skills for the betterment of society and the planet. CETM activities also served to show children that individuals out in the real world were actually doing something exciting and were making a difference.

CETM is Well Perceived by the Teachers

The teachers gave comprehensive feedback on the designed and implemented CETM activities. In fact, the teachers mentioned that the CETM activities were interesting and unique. They added on by mentioning that the experience was something new to the teaching and learning process for the primary school science subject. The teachers repeatedly mentioned that the children were attracted to the lesson and they were engaged with the CETM activities.

This proved that, apart from HOTS and reasoning skills, some essence of motivation and interest during the CETM activities was also noticed by the teachers. Gestures and body movement's supports the ability of the children's brains to notice the patterns of movements during the CETM activities. Based on the teacher's observations, the body movements and gestures not only play a role during the children's speech, but at the same time, also in other intellectual activities, such as problem solving and reasoning (Alibali & DiRusso, 1999; Roy & Macchiette, 2005).

Throughout the CETM activities, the teachers observed that the children were kneeling, squatting and standing as they were excited and motivated to create the prototypes. Their body postures in all the CETM activities expressed the level of curiosity and interest of a child. Children were also observed to be leaning towards the prototypes because they wanted to be close to their prototypes all the time. The teachers also noticed that the children were joyful, excited, laughing and jumping during the CETM activities. For example, some of the children also drew happy and smiling faces when brainstorming ideas for humanoid robots. Interest and motivation also enhance deeper processing, promise better memory power and help to achieve higher achievement among the children (Ainley, Hidi & Bernforf, 2002; Hofer, 2000; Pintrich, Marx & Boyle, 1993).

Numerous studies have revealed that primary school children's interest and motivation towards science learning has deteriorated throughout their early years at school (Galton, 2009; Osborne, Simon & Collins, 2003; Vedder-Meiss & Fortus, 2013) Motivation and interest is an important factor in having children engaged with the science lesson because it increases the possibility of fostering HOTS and reasoning skills among the children. According to the teachers, CETM activities could be the alternative hands-on learning approach to improve the interest and motivation among the children in learning and experiencing science.

Research Implications

This research study reflected some implications on methodology and the CETM practicality in teaching science.

Methodological Reflections

One interesting insight in the research methodology is the usage of online interview in designing and developing CETM. Parallel to this research, online interviews were crucial to maximize rapport with the participants because online interviews were not only feasible in gathering responses from the participants but also does not require the researcher and participant to be online simultaneously (Davis, Bolding, Hart, Sheer & Elford, 2004; Enochsson, 2011; Hunt & McHale, 2007; Jowett, Peel & Shaw, 2011).

After almost a decade of research documenting issues surrounding the use of the Internet to conduct interviews, there were no consensuses on the suitability of the method. At present, online interviews were widely used to capture opinions and gather feedback from participants (Seakins & Dillon, 2013). Although the usage of online interviews was only a part of the research, yet this research has offered some ideas on how to design and develop a teaching module using online interviews.

Another interesting contribution was the involvement of 22 experts from other countries in designing and developing the CETM. These experienced researchers were not only engaged in this research but at the same time exchanged crucial viewpoints in sharing their ideas for early engineering design and STEM education. They became aware that Malaysian academicians were also interested in early engineering design and STEM education. In this study, international experts were crucial in providing their views for designing the CETM. This is because the design and development of CETM is a new research area for developing countries such as Malaysia. This study could be a maiden attempt for the local education system and in fact, other ideas for further development of CETM could be materialized in the future.

CETM Practicality in Teaching Science

As compared to existing teaching modules based on the literature reviews and experts, CETM has some unique features which are limited in the present teaching modules (Avargil, Herscovitz & Dori, 2011; Hashim, 2006; McLeod, 2003; Salih, 2010). The designed and developed CETM activities has the stimulating features that are beneficial to the teachers and children. For example, each activity in CETM which has an activity outline encompasses inter-disciplinary knowledge such as technology, astronomy, sustainable energy and ecology. These various fields help the teachers to indirectly expose children to other avenues which are related to science. In fact, through CETM activities, children experienced on how to integrate design, engineering and technology instructional resources into the current science curriculum which indirectly enhanced their accomplishment in learning science. The challenges in CETM activities intertwined science more closely with the teaching and learning of other disciplines such as Mathematics, Technology and Engineering, as compared to other existing teaching modules.

Activity challenges such as designing and creating structures, windmills, plastic parachutes and robots with movable parts allowed children to utilize their knowledge and thinking skills. Teachers also learned how to create and use activity outlines to guide children through their hands-on and real life activities. Children kept an eye on the design process, which incorporated understanding of the challenge given, brainstorming, creating, testing, evaluating and finally redesigning their solution.

In addition, the teacher realized that the practicality of CETM activity lies in the fact that designing is not just something to be done for its own sake and in isolation, but rather something that can be widely built a lot through during the science lessons in the classroom. The teacher also devoted more time in implementing the CETM activities. The teacher provided more time for CETM activities and covered science content beyond syllabus. The teacher allowed the children to go back and forth with various science concepts to enable a deeper understanding of these concepts.

The CETM activities was carried out at a slow pace with no rush as the teachers felt quite comfortable with teaching science to the children. This is because each of the CETM activity encompassed the main science content for each topic. For example, when children designed the windmill prototype, they not only learnt about the energy concept but at the same time, children could apply the concept to other situations as well. When the teacher asked them about examples of renewable energy, apart from wind energy children gave answers such as solar energy. The designing process in CETM activities helped the teacher to evaluate the children's understanding of science concepts in an overall view. Apart from that, the teacher assessed more than one particular science concept. For example, during Activity One where the children designed the plastic parachute, children learnt two different science concepts from two different chapters in the science syllabus. The teacher could assess children's thinking ability in the important of survival of the panda species (Chapter One) and the need of wind energy to fly their designed plastic parachute (Chapter Two). The cross learning from two different chapters helped the teacher to observe the children's understanding and thinking ability in two different chapters simulatenously.

In fact, the teacher allowed the children to pose questions and encouraged the intellectual arguments with one another in the class. Being able to link science with those disciplines which the teacher taught for many years also made the teacher feel more comfortable and confident in teaching science. Both children and teacher explored more resources in science, which reflects many different areas, components and parts of the world.

However, Activity Three in CETM was not successful since the teacher could not handle the classroom atmosphere during the activity. The teacher was unable to control the children's enthusiasm since they were over excited in creating rather than testing the prototypes. At the same time, according to the teacher, the soap bubbles activity did not represent the engineering elements. The teacher disagreed that the Activity Three should be included in the CETM because creating soap bubbles did not encourage the cyclic process among the children. In fact, the teacher saw other CETM activities as practical and the teachers became conscious of the children's involvement in the CETM activities. It was made sure that each CETM activity is related to the cyclic process and STEM education is a barrier that needed to be addressed.

Recommendations for Future Research

This research focused on the design and development of CETM, HOTS and reasoning skills among the children. While investigating how CETM improved HOTS and reasoning skills among the children, this study also unravelled issues that needed some follow-ups. The following recommendations are made for the future research.

Considerations for Teaching Children's Engineering

There is an inadequate amount of study that observes the requirement skills, principles, knowledge and experiences necessary for teachers to implement integrated instruction (Fykholm & Glasson, 2005). For Children's Engineering, since it is relatively new, this statement rings even more true. The importance of focusing on what teachers need to effectively teach Children's Engineering was noted by the National Science Board (NSB) in the document A National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System. They call for more consideration on attracting, preparing and retaining qualified and committed teaching candidates (NSB, 2007). However, the best way in which to attract, prepare and retain qualified teachers remains to be answered.

Implementing effective STEM education such as Children's Engineering requires devoted, systematized and knowledgeable individuals (Stohlmann, Moore & Roehrig, 2012). It is important to have teachers that are committed to being long-term teachers and not just waiting for a math, science, or other job to become available (Stohlmann, Moore & Roehrig, 2012). Teacher turnover can have negative effects for schools in terms of school cohesion, teaching effectiveness, and students' achievement

(Cochran-Smith, 2004). While teachers are developing their content knowledge of integrated STEM education, they can focus on quality strategies for teaching. A growing number of institutions are offering integrated programs that lead to licensure in both math and science, particularly at the primary school level that might serve to lessen the effect of this issue (Frykholm & Glasson, 2005). Since teachers may have different backgrounds, it is significant for schools to provide support and time for collaboration. Associating with a local university or a nearby school, attending professional development, taking advantage of training offered by curriculum companies, having common teacher planning time, and encouraging open communication can help teachers to feel that they have the support they need to be successful. Mathematics and science teachers should try to collaborate to make sure that they are maximizing student learning. Teachers can build on the recommendations for effective teaching of integrated science and mathematics (Stohlmann, Moore & Roehrig, 2012).

While this study did not investigate self-efficacy, it is an important area for further study. Research has shown that teachers' content knowledge, experience, and pedagogical content knowledge have a large impact on self-efficacy (Stohlmann, Moore & Roehrig, 2012).

Summary

In summary, three conclusions were drawn from this study. First, the developed CETM enhanced HOTS and reasoning skills among children. CETM activities managed to improve several elements of HOTS and reasoning skills among children. CETM activities enhanced HOTS and reasoning elements such as making judgment, inductive reasoning, correlational reasoning, plausible logical reasoning and case-based reasoning.

The second conclusion of this study was identifying the CETM characteristics which influenced HOTS and reasoning skills. There were four characteristics in CETM which improved the children's higher level thinking skills. These characteristics were the practice of cyclic process in designing a prototype, the variety of features in an activity to express children's answers, the essence of learning beyond curriculum content and the involvement of sustainable engineering design in each of the activity. These characteristics helped children to improve their higher-level thinking skills.

The third conclusion was the teacher's positive outlook on the CETM activities. The teacher revealed that the CETM activities has the potential to increase the children's motivation and interest in learning science. Based on the teacher's viewpoint, CETM activities were not only effective in promoting children's engagement and interest in science but at the same time its data indicated a high level of children's motivation towards the STEM education. CETM activities were observed to be joyful and interesting which made science and engineering come alive through motivation and exposure of different aspects of learning. Since HOTS also defined as the expanded use of mind to meet new challenges (Rajendran, 2008), CETM activities inevitably produce deeper investigation for unexpected solutions.

It is crucial for children in primary school to utilize HOTS for brain growth (Conklin, 2013). Petroski (2003) pointed out, children are fascinated with engineering problems such as buildings and they take things apart to see how buildings are made up. STEM education encourages manipulation and multiple representations through early engineering because it involves the design of a solution under specified constraints in response to a particular need or goal. These several promising directions may guide future research in children's engineering.

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Appendix 1

Virginia Student Assessment Consent Letter

COMMONWEALTH *of* VIRGINIA

DEPARTMENT OF EDUCATION

P. O. Box 2120

Richmond, Virginia 23218-2120

October 2, 2014

Via e-mail to drkamal_83@yahoo.com

TO: Kamal Waran

FROM: Carol Brown, Division Secretary
Division of Student Assessment and School Improvement

SUBJECT: Copyright Permission

This is written in response to your e-mail request to use materials copyrighted by the Virginia Department of Education. Specifically, you requested use of the Virginia Standards of Learning released tests located on the Department's Web site at the following URLs:

http://www.doe.virginia.gov/testing/sol/released_tests/2010/test10_science5.pdf
http://www.doe.virginia.gov/testing/sol/released_tests/2011/test11_science5.pdf
http://www.doe.virginia.gov/testing/sol/released_tests/2010/test10_science3.pdf

You stated in your request that the tests will be used as part of a research study to evaluate the children's thinking skills. You also stated that these tests will not be used for commercial purpose.

The Virginia Department of Education is willing to grant permission to use the requested copyrighted materials for the specific purpose and manner in which you have described.
The grant of permission is subject to the following terms:

- Where you use materials precisely as they appear in Virginia's copyrighted materials, you must include the following acknowledgement:

  Include [the title of the materials] © [year of copyright] by the Commonwealth of Virginia Department of Education. All rights reserved. Reproduced by permission.

  Example: *Virginia Standards of Learning Assessments – Spring 2008 Released Tests* © 2008 by the Commonwealth of Virginia Department of Education. Reproduced by permission.

Needs Analysis Interview Questions

1. How many years have you been teaching in this school?
2. What subjects are you teaching in school and which forms are they in?
3. What strategies or techniques do you use during a science lesson? May I know why do you use these strategies?
4. How do you teach thinking skills among students during science lesson?
5. Have you heard of higher order thinking skills (HOTS) or *Kemahiran Berfikir Aras Tinggi (KBAT)*? If yes, in your opinion why is it important in especially in learning science?
6. How has HOTS helped you in teaching your students?
7. Have you heard of early engineering or introducing simple and easy engineering to students?
8. In your opinion, do you think that introducing early engineering could enhance HOTS among science students?

Appendix 3

Curriculum Vitae (CV) for Delphi experts

No.	Name	Country	Academic level	Research areas	Professional services	Years of experience	Honours, awards & contributions
1.	Balder Onarheim	Copenhagen, Denmark	Associate professor	Design practice, design thinking, teaching, applied creativity, teaching & research	At Norconsult A/S as Innovation specialist, manager for Lateral Design & product developer for Quantum Precision Instruments Asia Private Ltd	15 years (since 1999 to present)	Reviewers favourite presentation award (2013) & Top 8% Wiley PhD dissertation award (2012)
2.	Barbara Ann Mott Adcock	Virginia, United States (US)	Elementary school teacher (grade 2, 3 & 4)	Science inquiry & early engineering (or children's engineering)	STEM academy teacher, Engineering Camp teacher & Lead Science Teacher Programme	27 years (since 1987 to present)	"Programmes That Work" for STEM academy (2013), State finalist for PAEMST award (2012), Teacher of the year award (2010/2011)
3.	Cathy P. Lachapelle	Massachusetts, United States (US)	Research & assessment director (Research evaluation specialist)	Engineering is elementary (EiE), brain & cognitive sciences	STEM education	22 years (since 1992 to present)	Numerous publications in established journals. Presented abundant of papers at local & international conferences.
4.	Christian Dieter Schunn	Pittsburgh, United States (US)	Professor & research scientist	STEM education, reasoning and learning, neuroscience of complex learning, engagement and learning and web-based peer interaction & instruction	Committee member of National Academy of Engineering (NAE) and International Society for Design & Development in Education	27 years (since 1987 to present)	Society fellowships (2011), conference awards (2003), research fellowships (1995) and undergraduate awards
5.	Christine Maria Cunningham	Massachusetts, United States (US)	Vice president and the founder and director of Engineering is Elementary (EiE)	Engisneering is Elementary (EiE) and science education, curriculum and instruction	Advisory committee for Partnership To Improve Student Achievement Physical Science: Integrated STEM approaches (PISA)	23 years (since 1991 to present)	Outstanding leadership award American Society of Engineering Education (ASEE) K-12 (2005) and National Association for Research in Science Teaching Award (1996)

6.	David M. Burghardt	Long Island, United States (US)	Professor & co-director of the Centre for Technological Literacy & former Chair of Engineering & Computer Science	STEM education and engineering fundamental in thermodynamics and diesel engines	Helped in designing Children's Engineering programme and was former Mayor for Village of Kensington	25 years (since 1989 to present)	Won $30 million of National Science Foundation (NSF) grants for STEM education research
7.	Eli M. Silk	Michigan, United States (US)	Research fellow & instructor	Cognitive studies in education and engineering design	Journal and conference reviewer, interviewer and maths tutor	15 years (since 1999 to present)	Numerous publications in established journals. Presented abundant of papers at local & international conferences.
8.	Fitzgerald Mike	Delaware, United States (US)	Researcher	Engineering and technology education	State Supervisor of Engineering & Technology Education and the Technology Student Association	22 years (since 1992 to present)	Numerous publications in established journals
9.	Jim Batterson	Virginia, United States (US)	Scientific programmer for LTV corporation and research engineer at NASA Langley Research Centre	Mathematics, physics and aerospace engineering	Senior advisor for the Commonwealth for STEM initiatives, grant review panels for National Science Foundation (NSF)	28 years (1980-2008) Now retired	Authored and co-authored more than 50 technical papers and presented numerous papers on K-12 STEM education for local and international audience.
10.	Jorgen Sjaastad	Oslo, Norway	Senior researcher	Educational choices, social psychology, psychometrics, stochastic analysis & Rasch analysis	Media contributions	12 years (since 2002 to present)	Numerous publications in established journals. Presented abundant of papers at local & international conferences.
11.	Khiew Poi Sim	Kuala Lumpur, Malaysia	Associate professor	Advanced nanomaterial synthesis and Nano engineering.	Fellow for higher education academy UK, scientific journal reviewer and affiliate member for Electron Microscopy Society Malaysia (EMSM) and Institute Materials Malaysia	13 years (since 2001 to present)	Gold medallist (International Invention, Innovation & Technology) (2013) and National Science Fellowship (MOSTI) (2002-2005)

12.	Lawrence E. Carlson	Colorado, United States (US)	IDEO fellow & professor	Mechanical engineering, engineering design, economic and evaluation	National Science Foundation (NSF) GK-12 for engineering & technology education) and Colorado Commission on K-16 integrated engineering outreach	43 years (since 1971 to present)	Bronze award for Lincoln Arc Welding Design Competition (1981) and Vince Kontny Award Engineering & Applied Science (1990)
13.	Lisa A. Dieker	Florida, United States (US)	Pegasus professor (highest honour given to faculty in teaching, researching and service)	Science, mathematics, special education and elementary education	Member of National Council for Mathematic teachers and member of National Science Teacher Association	29 years (since 1985 to present)	Doctoral advisee selected for order of Pegasus, highest honour given to graduate student (2013) and Innovative Technology of the year Award (2012)
14.	Matthew A. Cannady	California, United States (US)	Director of Quantitative Research and Senior Research Scientist	Educational research, measurement, evaluation, science, engineering and physics	Consultant of Educating the Next Generation of Massachusetts Teachers, Engineering is Elementary, Museum of Science and Transforming Engineering Education. (All in 2010)	14 years (since 2000 to present)	Donald White Excellence in Teaching Award. Boston College (2009) and Emerald Satellite Thermal Design 1st Place, Design Conference. Santa Clara University, (2000)
15.	Martin Reisslein	Arizona, United States (US)	Professor	Engineering, distance learning and energy engineering	Local professional committee, scientific and professional society memberships	20 years (since 1994 to present)	Graduated 22 master's theses, 12 PhD theses and 3 post-doctoral researchers apart from numerous publications in established journals and abundance presentation of papers at local & international conferences.
16.	Peter Sellings	Australia	Assistant principle	Science and mathematics	Taught secondary school students between 12-18 years	23 years (since 1991 to present)	-
17.	Sergey Fillippov	Russia	Elementary School Teacher	Robotics, computer science, methodologist, physics and mathematics	Computer science programmer for state conservatory	23 years (since 1991 to present)	Published some articles and presented a few papers locally.

18.	Sharona T. Levy	Tel-Aviv, Israel	Lecturer	Science, technology education and reasoning skills	Served at the Centre for Connected Learning and Computer-based Modelling as a post-doctoral candidate.	12 years (since 2002 to present)	Numerous publications in established journals. Presented abundant of papers at local & international conferences.
19.	Raymond Dixon	Illinois, United States (US)	Lecturer and research coordinator	Design cognition, STEM integration, workforce education and development	Head of the department and technical coordinator for the National Top & Engineering Institute	14 years (since 2000 to present)	Tomblinson Award for excellence in technical & vocational education (2008) and Helston Limited Award for excellence in industrial technology (1996)
20.	Vasantha Madhuri Goteti	Hyderabad, India	Associate professor	Inquiry learning, project-based learning and higher order thinking skills (HOTS)	Reviewer for European Journal of Engineering Education (2013) and panel judge for NCSTC department of science and technology (2012)	12 years (since 2002 to present)	National Award for Teaching Excellence for Chemistry Innovation (2013)
21.	Vincent W. Childress	North Carolina, United States (US)	Professor	Manufacturing, communication, instructional technology	Member of International Technology & Engineering Educators Association (ITEA) and Council of Technology Teacher Education.	20 years (since 1994 to present)	Wilkinson Meritorious Service Award (2012), Outstanding Researcher Award (2005) and Teacher of the year Award for Children Council (2003)
22.	William Turner. J	Rhode Island, United States (US)	High school teacher	Engineering design process and simple machines	Designed robotics and programmable logic as a curriculum controller and member of the International Technology and Engineering Educators Association (ITEA)	7 years (since 2007 to present)	Educational Testing Service (ETS), recognition of Excellence Award Principles of Learning and Teaching Grade 7-12 and Dean's list recognition scholastic achievement.

Appendix 4

Interview questions (Design & development of CETM)

1. How many years have you been teaching in this school?
2. What subjects are you teaching in school and which forms are they in?
3. What strategies or techniques do you use during a science lesson? May I know why do you use these strategies?
4. How do you teach thinking skills among students during science lesson?
5. Have you heard of higher order thinking skills (HOTS) or *Kemahiran Berfikir Aras Tinggi (KBAT)*? If yes, in your opinion why is it important in especially in learning science?
6. How has HOTS helped you in teaching your students?
7. Apart from HOTS, do you promote reasoning skills among your students? (Personal idea or effort in what they might think of reasoning skills itself)
8. Have you heard of early engineering or introducing simple and easy engineering to students?
9. What sort of engineering activities do you carry out to enhance HOTS among your students?
10. How do you carry out these activities among your science students?
11. How was the student's reaction when you carry out these activities in the classroom?
12. In your opinion, do you think that introducing early engineering could enhance HOTS among science students? (if yes, what would be the HOTS criteria involved)
13. Based on your experience and knowledge in promoting early engineering or engineering is elementary (EiE), how do you think the engineering activities can foster HOTS among the science students?

Codes embedment into the designed CETM

How do children benefit from Children's Engineering Teaching Module (CETM)?
Based on the research findings from this research, three conclusions can be made. The conclusions are:

(a)	CETM enhanced Higher Order Thinking Skills (HOTS) and reasoning skills among children.
(b)	CETM features has encouraged the children to improve their HOTS and reasoning skills. The CETM features were: i) practice of cyclic process in designing a prototype, ii) the variety of features in an activity to express children's answers, iii) the essence of learning beyond curriculum content and iv) the involvement of sustainable engineering design in the activities.
(c)	CETM enhanced children's motivation and interest in learning science.

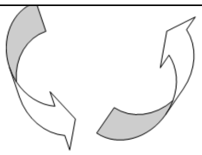
The Design Process
The design process is an organized approach to help children work through designing, building, testing, evaluating and presenting a prototype.

Comment [u1]: ***Designing process*** encourages a clear understanding of a problem and challenges children to brainstorm multiple solutions.

Code 1: Designing process

- Try to digest the challenge provided.

3. Brainstorm solutions
- Think of some ideas and draw free hand sketches.
- Be bold and sketch what could solve the problem.
- Try to answer 'how' you will solve by your sketches.



6. Evaluate your solution/prototype
- Was it best solution?
- What would you have done differently?
- Can you add to it to make it better?

5. Test your solution/prototype
- Observe the functionality.
- Look into other groups' work as well.
- Try to figure out the differences.

4. Create the solution you think is best
Make sure that you have a plan for how you will create your solution.
- What things will you need to create your solution?
- How will you start building it?
- How will you design it? Trial and error, being logical and argumentative.
- How to save time? Incorporate the ideas from group members as well.

Figure 1: Cyclic process

(Source: Adapted from Whiting & Hickey, 2009 & modified based on the Delphi findings, 2014)

Comment [u2]: All the activities designed in CETM are based on ***cyclic process*** where each prototype undergoes design; test, build and rebuild (improvise).

Code 2: Cyclic process

Children's Engineering Teaching Module (CETM)
Kamaleswaran (PHA110042) University of Malaya

Understanding the cyclic process

When introducing the design process, the cyclic process by using a graphic with the children. Be sure the students see the connection between the design process and the cyclic process. The following step involves exploring the design process in the activity.

Comment [u3]: Every step in the procedure aids in ***connecting ideas*** to in the design process. These linkage guides the children to come up with the prototype.

Teacher students brainstorming session

Teacher can kick off the lesson by carrying out a brainstorming session by asking some questions of 'how' and 'why' about the design challenge given. Meanwhile students can start thinking about the given challenge.

➢ Teacher must try to ensure this session ends by 5 minutes.

Code 3: Connecting ideas

Brainstorm solutions

Brainstorming solutions involves accepting all ideas. Students record the ideas they generate by making sketches. Sketching ideas is especially helpful as students are often able to visualize how parts of different sketches or ideas can be combined, resulting in a better design. Brainstorming can be difficult because it can be risky. There is always the possibility of having peers reject one's ideas.

- Brainstorming can be done in 4 minutes, but be prepared for the children to revisit this step as they think of more ideas.

Comment [u4]: Being ***argumentative*** among children comes in handy when their different explanations are emerged before, during and after the prototype designing process.

Creating the solution you think is the best

As students are building, problems can occur that cause the group to revisit the cyclic process and alter their plan. When it is time for the students to share and test their designs, they will often refer to notes about the problems that caused them to alter their original plan.

- Building the solution can take around 40 minutes depending on the challenge. Teachers may want to limit the amount of time for creating the solution or children will

Comment [u5]: ***Deductive reasoning*** helps the children in deriving the conclusions from the given evidence to form the best solution in designing the prototype.

Code 4 & 5: Argumentative & Deductive reasoning

Test solution

Groups may have already performed informal tests along the way they worked through the design process. This testing takes place as way to determine if designs need to be altered.

- Testing solutions can usually be completed in one session depending on the difficulty of the problem and the number of groups that need to share. This session can take 3 minutes.

Comment [u6]: Testing the prototypes does involve ***measuring intelligence*** because the sequence of inspecting the HOTS allied cognitive loads is related with the children's brain process.

Evaluate your solution

Having the children evaluate their solution provides them the opportunity to think back over the project and discuss what they would change, what they would keep the

3

Comment [u7]: Having the children in ***assessing*** their prototype provides them the space to think back over the activity. Children can discuss what they would change, what they would keep the same and if there is something they might add if they were to build it again.

Code 6 & 7: Measuring intelligence & Assessing

Introduction to writing activity outlines

What is an activity outline?

An activity outline is a clear report of a problem. It is an explanation of what the student is going to design. In CETM, the activity outline has two parts:

1. A description of the kind of thing needed. For example, a way to get the minerals from the moon or a transportation to send food and supplies for war zone nation.
2. A list of what the teachers need to know to solve the problem.

Hints for choosing topics for CETM activities:

- Build the activity around topics the students are currently studying.
- Activities can be built around topics that your students need to review.
- Ask yourself, how does this challenge support the curriculum? Think about all curriculum areas in the particular subject, not just the targeted area.
- It's okay to start an activity out as a scientific research assignment on a general topic and then ask students to apply mathematic concepts or technological concepts in their building plans.

Code 8: Activity outline

The elements of higher order thinking skills (HOTS) and reasoning skills embedded in the CETM for the teacher to evaluate

No.	Checklist for CETM rubrics (Based on early engineering articles, Engineering is Elementary (EiE) program, Children's Engineering journals, HOTS rubrics (Allen, 2006) & Delphi findings 2014)	Elements of HOTS based on Delphi findings (based on emerged themes), literature reviews & HOTS rubrics (Allen, 2006)
A.	**Teacher students brainstorming session**	
1.	Argues with teacher or with classmates or little or nothing to do the discussion.	a) Argumentative
2.	Offers some ideas to the group but the ideas are not original, are not presented in sufficient detail, or are only vaguely related to the problem	a) Argumentative b) Transforming ideas into practical situations

Comment [u9]: ***Building aesthetically and technically*** for each prototype help to provide various type of assessment for the children. Authentic assessment asks children to demonstrate skills and concepts they have learned.

Code 9: Building aesthetically & technically

C. Children's Engineering Teaching Module (CETM) Activities

This teaching module consists of 4 activities. Each activity is explained in-detail for teachers as an example on how to design and implement an activity for Year 5 students.

Activity 1: Plastic Parachute

Making Connection either through the teacher's own knowledge or from the textbook
Factual reading makes a great beginning for most lessons. However, teachers are welcomed to get the connection from the science textbook itself. For example, the importance of survival is emphasized in the textbook at page 20. Teachers can get the idea from this lesson.

Comment [u10]: ***Designing goals*** are mentioned in the objective of designing a prototype in an activity apart from being a platform for developing ownership for essential knowledge.

Prior Knowledge

Teacher: The teacher should review the design brief and rubrics to become familiar with the design challenge, criteria, materials and tools needed to complete the activity.

Code 10: Designing goals

Introduce the ***Activity*** and the ***Cyclic process***.

a. *Independent or small group work*

Using their own words, students work together to answer. **"What is the problem?"** This is recorded in the activity. Students meet with the teacher to discuss their understanding of the problem before they begin planning their solution.

Comment [u11]: An autonomous situation is achieved when children use their ***independent thinking*** in solving the given challenge.

Students begin to **"Brainstorm solutions".** Students use their engineering thinking skills to generate many, varied and usual ideas. Students record their ideas in the activity with either sketches or words. Sketching helps student to optimize their alpha brain waves because students' transferable skills from the drawings are incorporated into learning outcomes of the activities.

Students also use decision-making skills to come to a consensus on which idea is the best solution. Students frequently combine ideas from their activity to create the final solution.

Comment [u12]: ***Making decision*** at the end of the conversation lead towards children's higher mental processing in each activity.

Code 11 & 12: Independent thinking & Making decision

Upon completion of the parachute, the whole class meets **"Test your solution".** When testing the solution, remember that if the activity meets the criteria of the challenge it was successful. This is recorded in the activity

c. *Small Group*

Children return to their small groups to **"Evaluate your solution".** Evaluation of the design should be entered in the activity.

d. *Representative from small groups*

Children will present their design in the class while standing on the own position in their groups. Children will explain freely about their design and how it can be improvised better in future.

Comment [u13]: Each time the children test while presenting their designed prototype, the ***encouragement*** of getting involved further into the design or future design activities will be boosted.

Code 13: Encouragement

Design challenge (One of the design ways)

Design and build a parachute that can fly at least for 10 seconds from place it is floated. Supplies such as food and water must be tied to the parachute without falling to the ground.

Criteria:

Your parachute must:

- Consists of the plastic.
- Be able to fly without floating from left to right or otherwise.
- Be able to fly with the supplies even with the increase of the wind speed.

Materials: *(What can you use?)*
(Your teacher might give you the materials you can use in a paper bag to help you track of them)

• Pipe cleaner	• Wooden bead
• Polystyrenes	• Small nuts with equal size

Tools: *(You many use these things to help you build. They may not become part of your prototype)*

• Scissors	• Adhesive tape
• Plastic bag	• Thread ball

Comment [u14]: In ***engineering design***, there are multiple ways to solve a problem. Different solutions fit different societal needs at different times. Hence, these different solutions can be represented through design sketch or drawings by the children.

Code 14: Engineering design

Curriculum Learning Outcomes:

At the end of this unit, students learn the importance of survival of the species. Students are encouraged to think critically on how to design a parachute using the given materials and tools in order to rescue the panda species which face extinction due to deforestation and dry season.

Comment [u15]: All design objectives must be ***correlating the curriculum*** so that when the children are completing the challenges they are reinforcing skills taught and striving for HOTS.

Group members:

1.		**4.**	
2.		**5.**	
3.		**6.**	

14

Code 15: Correlating the curriculum

Activity 2: Windmill

Making Connection either through the teacher's own knowledge or from the textbook
Genuine reading makes a great beginning for most lessons. At the same time, teachers are welcomed to get the connection from the science textbook itself. For example, the importance of energy is emphasized in the textbook at page 34. Teachers can get the idea from this lesson.

Prior Knowledge

Teacher: The teacher should review the design brief and rubrics to become familiar with the design challenge, criteria, materials and tools needed to complete the activity.

Children: Children should have prior exposure to the concept of energy to do work. Children should know the type of energy involved when a machine functions.

Comment [u16]: ***Mechanical reasoning*** involves on how the prototype machines work which are fundamental to the real-world tasks

Code 16: Mechanical reasoning

Manage the materials

Use paper bags to control materials. Prepare one paper bag of materials for each group. Place all of the materials the group may use to complete the challenge in the bag. Each bag should hold a variety of materials, but all bags don't have to contain exactly the same materials. Make sure to provide enough materials for the children to experiment. They will only be allowed to use what you initially provide them.

What materials are needed for testing the windmill?

- Different size of mineral bottles.
- Different level of speed in a stand fan.

The children must fill up the mineral bottles with water to ensure that the windmill stands firm and functions without the help of them.

Comment [u17]: ***Inductive reasoning*** encompasses on trial and error since a perfect solution is not possible in a convincing design prototype.

Safety Issues

- All materials should be clean before children handle them.
- Discuss proper use of stand fan.

Code 17: Inductive reasoning

- Introduce example of renewable energy such as solar energy and its use. Ask students what other type of renewable energy exist. Inform them that the wind speed in certain province of Malaysia is high. Give example of places where this situation occurs in Malaysia. Then, ask students how to generate electricity from the wind.
- Teacher can read out the design brief or ask the students to read it aloud. This is a good chance to practice shared reading skills.
- Children may work within their small group to help each other read the design brief. (Try to make sure to set your cooperative groups up with children having a wide range of different mode thinking skills so that they can help each other).

Comment [u18]: It's important to realize that ***divergent mode thinking*** is exactly what can design a prototype when a wide variety of minds working together. This usually equates to more detail and a better design or end result.

Differentiate Instruction through the Challenge
Be sure to differentiate instruction as needed. Ways to differentiate instruction include:

- Simplify the criteria
- Add to the criteria to make it more challenging
- Present the design brief to the class as a whole
- Assign the design brief as an independent reading lesson
- Rewrite the design challenge to incorporate the criteria and remove the separate checklist of criteria.

Code 18: Divergent mode thinking

problem?" This is recorded in the activity. Students meet with the teacher to discuss their understanding of the problem before they begin planning their solution.

Students begin to **"Brainstorm solutions".** Students use their engineering thinking skills to generate many, varied and usual ideas. Students record their ideas in the activity with either sketches or words. Sketching helps student to optimize their alpha brain waves because students' transferable skills from the drawings are incorporated into learning outcomes of the activities.

Students also use decision-making skills to come to a consensus on which idea is the best solution. Students frequently combine ideas from their activity to create the final solution.

Each team uses the approved materials to **"Create the solution you think is best".** In this case it will be a windmill. There is room in the activity for students to record problems as they occur and how they solved the problems.

Comment [u19]: ***Transferable skills*** help to incorporate children's drawing into learning outcomes of the activities.

Comment [u20]: Designing each prototype is an ***opportunity*** for empowering mind boggling thinking among children.

Code 19 & 20: Transferable skills & Opportunity

Upon completion of the windmill, the whole class meets **"Test your solution".** When testing the solution, remember that if the activity meets the criteria of the challenge it was successful. This is recorded in the activity.

c. *Small Group*

Children return to their small groups to **"Evaluate your solution".** Evaluation of the design should be entered in the activity.

d. *Representative from small groups*

Children will present their design in the class while standing on the own position in their groups. Children will explain freely about their design and how it can be improvised better in future.

Comment [u21]: Children present their solution by ***expressing own words*** in an oral presentation.

Code 21: Expressing own words

Unit 4: Energy
Lesson 3: Renewable Energy

- At the end of this unit, students learn the various sources of energy and how utilize renewable energy to produce electricity. Students are stimulated to transform windmill prototypes into the real world situation.

Unit 5: Electricity
Lesson 1: Sources of Electricity

- At the end of this unit, students learn the source of electricity. Students are motivated to be curious in using the dry cells apart from the fact that they don't experience these materials to design a windmill in a classroom.

Unit 6: Light
Lesson 1: How Does Light Travel

- At the end of this unit, students learn how light travels. Though the windmill design focuses more in energy concept, it is still crucial to help students develop a flexible mind in learning variety of concepts using the windmill.

Comment [u22]: Children can act like engineers by ***transforming ideas into practical situations*** by coming up with specific designs.

Comment [u23]: Every designed activity has the possibility in ***fostering curiosity*** among children with the provided materials and tools. Children will be inquisitive in holding, meddling and using the provided things because they don't see often these things in their classroom.

Comment [u24]: Every activity in CETM requires the children to develop their ***flexible thinking*** to keep an open mind in facing the new truth about the world.

Code 22, 23 & 24: Transforming ideas into practical situations, Fostering curiosity & Flexible thinking

Activity 3: Metal Tin Robot

1. Making Connection either through the teacher's own knowledge or from the textbook

Factual reading makes a great beginning for most lessons. Benefits of minerals which can be found in Moon can be discussed on the surface. For example, silica is important in microchip industry to produce electronic devices. Aluminum is used to make airplanes whereas calcium oxide is used to produce cement. At the same time, teachers are welcomed to get the connection from the science textbook itself. The Earth's natural satellite is the Moon and it's emphasized in the textbook at page 103. Teachers can get the idea from this lesson.

Comment [u25]: ***Systemic thinking*** can be infused during the designing process where it can be can either be taught from simple/straightforward concept to complicated/sophisticated understanding or vice-versa. For example:

a) Example to idea concept
b)Idea concept to example

Prior Knowledge

Teacher: The teacher should review the design brief and rubrics to become familiar with the design challenge, criteria, materials and tools needed to complete the activity.

Children: Children should have prior exposure to the concept of energy and force such as kinetic energy, electric energy and sound energy. Children should also recall the

Code 25: Systemic thinking

- Check the design brief for materials before you begin the lesson. You may add or delete materials from the list on the design before copying it for the children. Children may not alter the materials list. Children do not have to use all of the materials provided.
- All students should have access to general supplies such as markers, glue, pencils, scissors, rulers and other supplies.

Comment [u26]: Based on the criteria, children must use their ***logical thinking*** in adapting the given scenario or circumstance.

Suggested materials for activity 4 *(Metal Tin Robot)*:

• 1 body plate	• 2 plastic legs	• 2 gripper hands
• 4 body rings	• 2 metal wires	• 15 small screws
• 4 bolt and nuts	• 2 moving eyes	• 2 straw attachments
• 2 terminal caps	• 1 axle with gear	• 2 eye base plates
• 1 toy motor with gear	• 1 motor/axle cover	

Suggested tools for activity 4 *(Metal Tin Robot)*:

• 1 metal tin can drink (325 ml)	• 2 long straws (20 cm)

Comment [u27]: Children who have the interest in saving the world will be interested in ***sustainable engineering***. However, in order to achieve this, children must be aware that they must design a prototype with a restricted environment by using recycling methods to achieve earth friendly prototypes.

Manage the materials

Use paper bags to control materials. Prepare one paper bag of materials for each

Code 26 & 27: Logical thinking & Sustainable engineering

Classroom Management

- Children should work in small groups.
- Prepare one paper bag with allowed materials for each group.

1. Approaching the Activity

Choose an appropriate way to introduce the activity to the class

Possible approaches:

- Inform students that minerals are important to mankind. Give example of minerals that are slowly finishing due to heavy consumption by human being. Explain how these minerals help human. Tell students that other planets have these minerals and rovers are needed to dig there minerals in other planets. Ask them how they can design these robotic rovers to help get the minerals from other planets in space.
- Teacher can read out the design brief or ask the students to read it aloud. This is a good chance to practice shared reading skills.
- Children may work within their small group to help each other read the design brief. (Make sure to set your cooperative groups up with children having a wide range of divergent mode thinking skills so that they can help each other).

Comment [u28]: ***Nurturing thought provoking atmosphere*** is the role of the teacher as a facilitator because it leaves options open for children to explore and learn through doing. Facilitator listens carefully and tries to share their comments in the form of questions.

Code 28: Nurturing thought provoking

problem?" This is recorded in the activity. Students meet with the teacher to discuss their understanding of the problem before they begin planning their solution.

Students begin to **"Brainstorm solutions".** Students use their engineering thinking skills to generate many, varied and usual ideas. Students record their ideas in the activity with either sketches or words. Sketching helps student to optimize their alpha brain waves because students' transferable skills from the drawings are incorporated into learning outcomes of the activities.

Students also use decision-making skills to come to a consensus on which idea is the best solution. Students frequently combine ideas from their activity to create the final solution.

Each team uses the approved materials to **"Create the solution you think is best".** In this case it will be a metal tin robot. There is room in the activity for students to record problems as they occur and how they solved the problems.

b. *Whole Class*

Comment [u29]: ***Emphasizing team work*** is integral to the success of the entire group members in designing the prototypes during the activity. Each child brings different strengths to the team, without which the team can't function as efficiently.

Code 29: Emphasizing team work

Children return to their small groups to **"Evaluate your solution".** Evaluation of the design should be entered in the activity.

d. *Representative from small groups*

Children will present their design in the class while standing on the own position in their groups. Children will explain freely about their design and how it can be improvised better in future.

Comment [u30]: ***Critical thinking skills*** are also enhanced when children organize the ideas in presenting their prototype because students will try to answer questions of 'how' and 'why' from either the teacher or other group members.

32

Code 30: Critical thinking skills

Activity 3: Metal Tin Robot

Mineral such silica, aluminum and calcium oxide getting reduced on Earth. All these mineral are vital for mankind. Astronomers at National Space Centre has identified moon is rich with silica, aluminum and calcium oxide. However, we cannot dig these minerals in moon because the oxygen level is not enough for us to breathe.

Imagine yourself as an astronomer. How you will dig these minerals in moon? How you can help in getting silica, aluminum and calcium oxide for human use on Earth?

Source: (Moon. (2014, October 3). Wikiversity)

- Teacher helps to create brainstorm session to gather student's responses. Teacher should leave the answers open by not restricting students suggestions. *(5 minute*

Design challenge:

Design and create a metal tin robot. Your metal tin robot has to be moving freely without your help.

Comment [u31]: As facilitators, teachers do not solve or answer children's questions, but instead give ***open-ended problem*** or ask questions to promote ***problem solving skills***.

Code 31: Open-ended problem & problem solving skills

• 4 bolt and nuts	• 2 moving eyes
• 2 terminal caps	• 1 axle with gear
• 2 gripper hands	• 2 eye base plates
• 15 small screws	• 1 motor/axle cover
• 2 straw attachments	• 1 toy motor with gear
• 1 short leg and 1 long leg	• 1 battery casing with cover and wires (black and red)

Tools: *(You many use these things to help you build. They may not become part of your prototype)*

• 1 1.5 V battery	• 2 long straws (20 cm)
• 1 small screw driver	• 1 metal tin can drink (325 ml)

Be sure to be careful when using the screw driver.

❖ You do not need to use all of the materials and tools.

Curriculum Learning Outcomes:

- At the end of this unit:

Students learn to design a model that can function in the Moon.

Comment [u32]: Inter-disciplinary fields in STEM education develop ***leaps of knowledge*** in all the CETM activities.

Code 32: Leaps of knowledge

Manage the materials

Use paper bags to control materials. Prepare one paper bag of materials for each group. Place all of the materials the group may use to complete the challenge in the bag. Each bag should hold a variety of materials, but all bags don't have to contain exactly the same materials. Make sure to provide enough materials for the children to experiment. They will only be allowed to use what you initially provide them.

What materials are needed for testing the humanoid robot?

- Different card boards are used to design the humanoid robot.
- Classroom desk is used to test whether the humanoid robots can stand independently.

The children should design in such way that the humanoid robot stands firm and functions without the help of them.

Comment [u33]: ***Strategic thinking*** assists children in adapting the existing challenge in each activity to ensure the most effective use of provided resources.

Code 33: Strategic thinking

Students begin to **"Brainstorm solutions".** Students use their engineering thinking skills to generate many, varied and usual ideas. Students record their ideas in the activity with either sketches or words. Sketching helps student to optimize their alpha brain waves because students' transferable skills from the drawings are incorporated into learning outcomes of the activities.

Students also use decision-making skills to come to a consensus on which idea is the best solution. Students frequently combine ideas from their activity to create the final solution.

Each team uses the approved materials to **"Create the solution you think is best".** In this case it will be a humanoid robot. There is room in the activity for students to record problems as they occur and how they solved the problems.

b. *Whole Class*

Upon completion of the humanoid robot, the whole class meets **"Test your solution".** When testing the solution, remember that if the activity meets the criteria of the challenge it was successful. This is recorded in the activity.

Comment [u34]: ***Optimizing alpha brain waves*** in a child's brain is evident because sketching ideas helps children to visualize how different sketches parts or ideas are combined, resulting in a better design. Every activity here inspires the children to make sketches.

Comment [u35]: Structured ***cooperative learning*** exists in a ***collaboration learning*** environment in which the children work together toward a common or shared objective by also receiving some help from other group members directly or indirectly.

Code 34 & 35: Optimizing alpha brain waves & Cooperative learning & Collaboration learning

Curriculum Standards Targeted

Science

Theme E: Investigating Technology

Unit 12: Strength and Stability
Lesson 1: I see shapes

- At the end of this unit, students learn to design a model that is strong and stable. Students try and fix using the card boards until they have discovered the factors that affect the flexibility of humanoid robots. Students will discover that there are endless possibilities to design and no design is perfect as all of them are open for restructure.

Comment [u36]: Challenging children with a restricted or given situation helps in ***motivating discoveries*** because discoveries can be inspired by combining everyday things in unusual combination and to add new ones too.

Code 36: Motivating discoveries

being. These robots will help Malaysia in robotic industry, domestic or home, medicine, service, army, entertainment, space and competitions. How can you help Malaysia in designing the humanoid robots?

(Source: Amin, 2013)

- Teacher helps to create brainstorm session to gather student's responses. Teacher should leave the answers open by not restricting students suggestions. *(5 minutes)*

Design challenge:
Design and create a flexible humanoid robot. The flexibility of the humanoid robot must be good because they must stand without your support.

Criteria:
The humanoid robots must:

- Consists of all the given parts.
- Have head, arm and legs as a human being.
- Have different appearances as compared to each other.
- Be able to be renovated and designed by using your imagination.

Materials: *(What can you use?)*
(Your teacher might give you the materials you can use in a paper bag to help you track of them)

Comment [u37]: Some of the most amazing inventions on the market today can exist because ***exploring future technologies*** are crucial be initiated at an earlier stage of learning.

Code 37: Exploring future technologies

Appendix 6

CETM Holistic Rubric

No.	<u>Checklist for CETM rubrics</u> **(Based on early engineering articles, Engineering is Elementary (EiE) program, Children's Engineering journals, HOTS rubrics (Allen, 2006) & Delphi findings 2014)**	**Elements of HOTS based on Delphi findings (based on emerged themes), literature reviews & HOTS rubrics (Allen, 2006)**
A.	**Teacher students brainstorming session**	
1.	Argues with teacher or with classmates or little or nothing to do the discussion.	a) Argumentative
2.	Offers some ideas to the group but the ideas are not original, are not presented in sufficient detail, or are only vaguely related to the problem being considered. Generally, respects other are ideas.	a) Argumentative b) Transforming ideas into practical situations
3.	Offers reasonable ideas based on everyday experience and respect the ideas offered by others.	a) Argumentative b) Transforming ideas into practical situations c) Motivating discoveries
4.	Offers unexpected, creative or unique ideas relevant to the task and respects the ideas offered by others.	a) Argumentative b) Transforming ideas into practical situations c) Motivating discoveries d) Exploring future technologies
B.	**Stating the problem**	
5.	Restates the problem by trying to use own words.	a) Independent thinking
6.	Uses own words and show a clear understanding of the problem.	a) Independent thinking b) Designing process
7.	Uses own words with clear understanding by including previous knowledge they learnt.	a) Independent thinking b) Designing process c) Bridging the gap
8.	Answers lead to a decision for creating a solution by using own words, showing clear understanding and examples of previous knowledge usage.	a) Independent thinking b) Designing process c) Bridging the gap d) Deductive reasoning
C.	**Brainstorming solutions**	
9.	Sketches choosing what he/she wishes to include.	a) Opportunity
10.	Freely sketches different parts of a prototype.	a) Opportunity b) Optimizing alpha-brain waves
11.	Freely sketches different parts or all the parts of a prototype.	a) Opportunity b) Optimizing alpha-brain waves
12.	Freely sketches (parts or all) prototype using free hand.	a) Opportunity b) Optimizing alpha-brain waves c) Flexible thinking
13.	Freely sketches (parts or all) prototype using ruler.	a) Opportunity b) Optimizing alpha-brain waves c) Transferable skills
14.	All the sketches differ from size, measurement and pattern whether its free hand or ruler or both.	a) Opportunity b) Optimizing alpha-brain waves c) Transferable skills d) Flexible thinking

15.	All the sketches differ from size, measurement and pattern whether its free hand or ruler or both. Adds some additional notes related to the design process.	a) Opportunity b) Optimizing alpha-brain waves c) Transferable skills d) Flexible thinking e) Designing process
16.	All the 4 sketches differ from size, measurement and pattern whether its free hand or ruler or both. Adds some additional notes by giving some insightful ideas to smoothen the design process.	a) Opportunity b) Optimizing alpha-brain waves c) Transferable skills d) Flexible thinking e) Designing process f) Systemic thinking
D. Creating the best solution		
(I) Designing the prototype using hands on participation		
17.	Fixes the gadget by trial and error.	a) Inductive reasoning
18.	Uses the provided resources effectively through organization by trying out various means.	a) Inductive reasoning b) Strategic thinking
19.	Uses resources in the most effective manner using trial and error method and not afraid to be different from other group members.	a) Inductive reasoning b) Strategic thinking c) Engineering thinking
20.	Incorporates various information based on previous lesson, experience and observation beyond classroom in trying out various means in a structured mode. Unafraid to be different from others.	a) Inductive reasoning b) Strategic thinking c) Engineering thinking d) Divergent mode thinking
(II) Designing the prototype by showing an interest to fulfill certain target collectively		
21.	Urges group members not to waste time in completing the prototype.	a) Emphasizes team work
22.	Wants to complete the task on time and eager to have a completed prototype.	a) Emphasizes team work b) Problem solving skills
23.	Encourages group members to produce a prototype that fulfills the design challenge and its criteria in given time frame.	a) Emphasizes team work b) Problem solving skills c) Encouragement
24.	Argues with group members stressing that his/her is the correct step in fulfilling the design challenge of the prototype. Gives explanation either verbally or non-verbally (gestures & facial expression)	a) Emphasizes team work b) Problem solving skills c) Encouragement d) Engineering thinking
(III) Designing the prototype using observation & verbal interaction		
25.	Observes other group members and follows how a prototype is designed.	a) Structured cooperation in collaboration learning
26.	Observes other group members but does not follow how a prototype is designed.	a) Structured cooperation in collaboration learning b) Independent thinking
27.	Observes other group members, does not follow but shares his/her view on how the prototype should be designed.	a) Structured cooperation in collaboration learning b) Independent thinking c) Evaluating
28.	Accepts criticism from other group members when his/her ideas are shared voluntarily.	a) Structured cooperation in collaboration learning b) Independent thinking c) Evaluating d) Engineering thinking

E. Testing the prototype		
29.	Observes the designed prototype.	a) Opportunity
30.	Observes touches and checks the completed prototype.	a) Opportunity b) Fostering curiosity
31.	Observes, handles the prototype and asks group members' opinion.	a) Opportunity b) Fostering curiosity c) Making decision
32.	Argues with group members the necessity of making adjustments or amendments on the designed prototype.	a) Opportunity b) Fostering curiosity c) Making decision d) Measuring intelligence
F. Evaluating the prototype		
33.	Wants to bring home the prototype.	a) Encouragement
34.	Explains why he/she want to bring home the prototype.	a) Encouragement b) Inductive reasoning
35.	Reasons why the prototype need amendments and gives logical suggestions.	a) Encouragement b) Inductive reasoning c) Building aesthetically and technically
36.	Argues how the suggestions will be carried out or how the suggestions will help to improve the prototype.	a) Encouragement b) Inductive reasoning c) Building aesthetically and technically d) Mechanical reasoning
G. Presenting the prototype		
37.	Presents by using own words and speaks at an understanding rate.	a) Expressing own words
38.	Describes how they designed the prototype by trying to relate to the prototype.	a) Expressing own words b) Idea connections
39.	Answers the questions from other group members by providing reasons or explanation.	a) Expressing own words b) Idea connections c) Nurturing thought provoking atmosphere
40.	Tries to answer questions such as 'how' and 'why' about their designed prototype.	a) Expressing own words b) Idea connections c) Nurturing thought provoking atmosphere d) Critical thinking skills

Curriculum Vitae (CV) for rubrics and scales experts

No.	Name	Country	Academic level	Research areas	Professional services	Years of experience	Honours, awards & contributions
1.	Mary J. Allen	California, United States (US)	Professor emeritus	Statistics (assessment & measurement) & psychology	Former director of the California State University Institute for Teaching & learning. Served as department chair and founded the faculty development center & assessment center at California State University-Bakersfield, & supported faculty development & assessment efforts for the California State University System.	25 years (since 1990 to present)	Offered assessment workshops to more than 150 education institutions. Led theses workshops at variety of conferences, including American Association for Higher Education, the Association of American colleges and Universities, and the Western Association of Schools and Colleges.
2.	Craig A. Mertler	Los Angeles, California, United States (US)	Lecturer and consultant	Action research, educational assessment and measurement	Owns and operates Mertler Educational Consulting, LLC.Can be reached at craig.mertler@gmail.com for consulting, professional development, and speaking engagements.	30 years (since 1985 to present)	Served as research methodology expert on more than 100 doctoral and Masters dissertations. Author of 18 books, four invited book chapters, and 17 refereed journal articles. Has presented more than 35 research papers at professional meetings. Consulted numerous educational instituitons on classroom-based action research and on the broad topic of classroom assessment.

Curriculum Vitae (CV) for CETM validation experts

No.	Name	Country	Academic level	Research areas	Professional services	Years of experience	Honours, awards & contributions
1.	Cathy P. Lachapelle	Massachusetts, United States (US)	Research & assessment director (Research evaluation specialist)	Engineering is elementary (EiE), brain & cognitive sciences	STEM education	22 years (since 1992 to present)	Numerous publications in established journals. Presented abundant of papers at local & international conferences.
2.	Christian Dieter Schunn	Pittsburgh, United States (US)	Professor & research scientist	STEM education, reasoning and learning, neuroscience of complex learning, engagement and learning and web-based peer interaction & instruction	Committee member of National Academy of Engineering (NAE) and International Society for Design & Development in Education	27 years (since 1987 to present)	Society fellowships (2011), conference awards (2003), research fellowships (1995) and undergraduate awards
3.	John E. Woods	Clevenland, United States (US)	Master Instructor in Oceanography, Meteorology & Coordinator of the USNA Polar Science Program & Military Instructor	STEM Curriculum using field activity and effectively linked them for the classroom environment.	Science Officer at the National Ice Center	7 years (since 2008 to present)	Coordinator of the US Interagency Arctic Buoy Program, handpicked to lead 70 personnel as Acting Executive Officer and managing a $13 million budget and managed the US Naval Academy Oceanography Departmental Budget of over $275,000.
4.	Denis Lajium Andrew	Sabah, Malaysia	Senior Lecturer	Chemistry education & science education	-	15 years (since 2000 to present)	Numerous publications in established journals. Presented abundant of papers at local & international conferences.

Ministry of Education (MOE) consent letter

BAHAGIAN PERANCANGAN DAN PENYELIDIKAN DASAR PENDIDIKAN
KEMENTERIAN PENDIDIKAN MALAYSIA
ARAS 1-4, BLOK E-8
KOMPLEKS KERAJAAN PARCEL E
PUSAT PENTADBIRAN KERAJAAN PERSEKUTUAN
62604 PUTRAJAYA.

Telefon : 03-88846591
Faks : 03-88846579

Ruj. Kami : KP(BPPDP)603/5/JLD. 14(81)
Tarikh : 19 Julai 2013

Kamaleswaran A/l Jayarajah
No 6082, Batu Satu, Jalan Slim
35900 Tanjung Malim
Perak

Tuan/Puan,

Kelulusan Khas Untuk Menjalankan Kajian Di Sekolah, Institut Perguruan, Jabatan Pelajaran Negeri Dan Bahagian-bahagian Di Bawah Kementerian Pendidikan Malaysia

Adalah saya dengan hormatnya diarah memaklumkan bahawa permohonan tuan/puan untuk menjalankan kajian bertajuk :

"Developing Children's Engineering Teaching Module For Year 5 Elementary School Children" diluluskan.

2. Kelulusan ini adalah berdasarkan kepada cadangan penyelidikan dan instrumen kajian yang tuan/puan kemukakan ke Bahagian ini. **Kebenaran bagi menggunakan sampel kajian perlu dipohon dari Ketua Bahagian/Pengarah Pendidikan Negeri yang berkenaan.**

3. Sila tuan/puan kemukakan ke Bahagian ini senaskhah laporan akhir kajian/laporan dalam bentuk elektronik berformat Pdf di dalam CD bersama naskhah *hardcopy* setelah selesai kelak. Tuan/Puan juga diingatkan supaya mendapat kebenaran terlebih dahulu daripada Bahagian ini sekiranya sebahagian atau sepenuhnya dapatan kajian tersebut hendak dibentangkan di mana-mana forum atau seminar atau diumumkan kepada media massa.

Sekian untuk makluman dan tindakan tuan/puan selanjutnya. Terima kasih.

"BERKHIDMAT UNTUK NEGARA"

Saya yang menurut perintah,

(DR HJ ZABANI BIN DARUS)
Ketua Sektor
Sektor Penyelidikan dan Penilaian
b.p. Pengarah
Bahagian Perancangan dan Penyelidikan Dasar Pendidikan
Kementerian Pendidikan Malaysia

Appendix 10

State Education (Perak) consent letter

JABATAN PENDIDIKAN PERAK
JALAN TUN ABDUL RAZAK,
30640 IPOH, PERAK DARUL RIDZUAN.

Telefon : 05-501 5000 Faks : 05-527 7273

"1MALAYSIA : RAKYAT DIDAHULUKAN PENCAPAIAN DIUTAMAKAN"

Ruj. Tuan :
Ruj. Kami : J. Pel. Pk (AM)5114/4Jld.15(3)
Tarikh : 10 Mac 2014

KAMALESWARAN A/L JAYARAJAH,
No. 608, Batu Satu Jalan Salim,
35900 Tanjung Malim,
Perak Darul Ridzuan.

Tuan,

KELULUSAN UNTUK MENJALANKAN KAJIAN DI SEKOLAH - SEKOLAH DI NEGERI PERAK DI BAWAH JABATAN PENDIDIKAN NEGERI PERAK

Sukacitanya perkara di atas di rujuk dan surat tuan bertarikh 28 Februari 2014 dan surat dari Bahagaian Perancangan Dan Penyelidikan Dasar Pendidikan, Kementerian Pendidikan Malaysia, Rujukan :KP(BPPDP)603/5/Jld.14(81), bertarikh 19 Julai 2013 adalah berkaitan.

2. Sehubungan dengan itu, dimaklumkan bahawa Jabatan Pendidikan Perak **tiada halangan** untuk membenarkan pihak tuan menjalankan kajian **"Developing Children's Engineering Modul For Year 5 Elementary School Children"** seperti dinyatakan dalam surat tuan dengan syarat-syarat berikut :-

2.1 Pihak tuan perlu mendapatkan kebenaran terlebih dahulu daripada Pegawai Pendidikan Daerah dan Pengetua sekolah untuk menggunakan sampel kajian;

2.2 Kajian yang dijalankan hendaklah tidak mengganggu proses pengajaran dan pembelajaran yang telah ditetapkan oleh pihak sekolah;

2.3 Pihak tuan bertanggungjawab menjaga keselamatan dan kebajikan guru-guru yang terlibat dalam kajian ini;

2.4 Pihak tuan hendaklah bertanggungjawab menanggung semua kos kajian;

2.5 Guru-guru/ murid tidak boleh dipaksa terlibat dengan kajian ini;

2.6 Pihak tuan dipohon agar mengemukan **satu (1) salinan laporan kajian dalam tempoh 30 hari** ke jabatan ini selepas kajian tersebut dilaksanakan; dan

"CINTAILAH BAHASA KITA"
(Sila catatkan rujukan pejabat ini apabila berhubung)

QUALITY SYSTEM SIRIM
CERTIFIED TO ISO 9001:2008
CERT. NO.: AR 4166

QUALITY SYSTEM SIRIM IQNet
CERTIFIED TO ISO 9001:2008
CERT. NO.: AR 4166

2.7 Tiada sebarang implikasi kewangan terhadap Jabatan Pendidikan Negeri Perak, Pejabat Pendidikan Daerah dan pihak sekolah.

3. Sukacita juga dingatkan sekiranya sebahagian atau sepenuhnya dapatan kajian tersebut hendak dibentangkan di mana-mana forum atau seminar atau diumumkan kepada media massa, pihak tuan perlulah **mendapatkan kebenaran terlebih dahulu** daripada Bahagian Perancangan dan Penyelidikan Dasar Pendidikan Kementerian Pendidikan Malaysia dan satu salinan kepada Jabatan Pendidikan Negeri Perak.

4. Kebenaran permohonan ini adalah untuk tujuan yang dipohon dan melibatkan sekolah dalam daerah yang dinyatakan sahaja.

Sekian terima kasih.

"BERKHIDMAT UNTUK NEGARA"

Saya yang menurut perintah,

(HAJI MOHD IDRIS BIN HAJI RAMLI, PMP., AMP.)
Timbalan Pengarah Pendidikan Negeri Perak,
b.p Pengarah Pendidikan Negeri Perak

s.k 1. Pengarah Pendidikan Negeri Perak
2. Semua Pegawai Pendidikan Daerah

nmy/upp/050314

Appendix 11

School consent letter

سکوله کبڠساءن ميتوديس ت

SEKOLAH KEBANGSAAN METHODIST

JALAN SLIM, 35900 TANJONG MALIM, PERAK.

Kod Sekolah : ABB 0049 * Tel & Faks : 05-4596332 * Web : http://skm.ppdbp.k-info.my/portal/ * Email : skmtgmalim@yahoo.com

'PERAK SENTIASA DI PUNCAK KECEMERLANGAN'

Ruj Kami : SKM/TM/01/16/018 ( )
Tarikh : 26 OGOS 2014

Prof. Madya Dr. Rohaida Binti Mohd Saat,
Dr. Rose Amnah Binti Abdul Rauf,
Fakulti Pendidikan,
Universiti Malaya,
Kuala Lumpur

Tuan,

MENJALANKAN PENYELIDIKAN
KAMALESWARAN A/L JAYARAJAH (830919-14-5479)
PENDIDIKAN DENGAN SAINS

Dengan hormatnya merujuk kepada perkara di atas.

2. Adalah dengan ini saya mengesahkan bahawa penama di atas telah menjalankan kajian PHD pada Ogos 2014.

Sekian, terima kasih.

"BERKHIDMAT UNTUK NEGARA "

Saya yang menurut perintah,

....
(HAJI MOHD MAZLI BIN MOHD ARIF)
GURU BESAR

s.k.
- Fail Sekolah

Example of CETM activity

Activity 2: Windmill

Since the number of people in Malaysia is increasing, the pollution cases are also increasing. A new alternative energy is needed to produce electric. Wind energy is clean because wind energy does not produce any air or water pollution. This is because no fuel is burnt to produce electric.

Hence, the purpose of this activity is to observe how wind energy can be used in Malaysia as an alternative energy in the future. The wind speed is quite high in places such as Mersing, Kota Baharu, Kuala Terengganu, Pulau Perhentian, Pulau Terumbu Layang-Layang, Labuan and Sabah.

(Source: Sopian, Othman & Wirsat, 1995; Muzathik, Ibrahim, Samo, Zailan & Nik, 2011)

- Teacher helps to create brainstorm session to gather student's responses. Teacher should leave the answers open by not restricting student's suggestions.

(5 minutes)

Design challenge:

Design and create a windmill that produces light. The windmill should be standing straight and firm without your support.

Criteria:

Your windmill must:

- Have rotor blades that capture the wind.
- Be tightly fixed without any loose connections.

Materials: *(What can you use?)*
(Your teacher might give you the materials you can use in a paper bag to help you track of them)

- Tail rotor
- Generator
- Motor cover
- Small screws
- Back-housing
- Front-housing
- 6 blades rotor
- LED unit lamp
- Half screw caps

Tools: *(You many use these things to help you build. They may not become part of your prototype)*

- Screw driver
- Battery
- Mineral bottles
- Stand fan

Be sure to be careful when using the screw driver while fixing the nuts.

- You do not need to use all of the materials and tools.

Curriculum Learning Outcomes:

- At the end of this unit:
  a) Students learn the various sources of energy and how utilize renewable energy to produce electricity.
  b) Students learn the source of electricity.

1. What is the problem? *(2 minutes)*

State the problem in <u>your own words.</u>

....

....

....

2. Brainstorm solutions. *(4 minutes)*

Sketch some possible solutions.

3. Create the prototype you think is best. *(40 minutes)*

4. Test your prototype. *(3 minutes)*

Circle your answer.

a.	Does your windmill have blades that spin freely in the wind?	YES	NO
b.	Does your windmill remain standing strong when the strong wind blows?	YES	NO
c.	Did you use only the tools and materials listed on the activity outline?	YES	NO
d.	Does the wind speed make a difference in lighting the LED lamp?	YES	NO

5. **Evaluate your prototype.** *(2 minutes)*

a. Was it the best solution? Would one of your other ideas have been better? Why or why not?

....

....

b. How can you make your windmill design better? What will you do?

....

....

6. Present your prototype. *(4 minutes)*

Well done!

University of Malaya

Kuala Lumpur

Parental/Guardian's Consent for Child to Participate in Research Project:

My name is Kamaleswaran s/o Jayarajah. I'm a graduate student (PHA110042) at the University of Malaya (UM), in the Department of Science Education. One of the major requirements for earning my Doctorate's degree (PhD) is to do a full thesis (research project) based research. The purpose of my research project is to design and develop a teaching module called Children's Engineering. This teaching module intends to enhance the higher order thinking skills among the participants in science lesson. I am asking your permission for your child to participate in this project. I will also ask your child if she/he agrees to participate in this project.

Project Description - Activities and Time Commitment: If your child participates he/she will be doing hands-on activities in a small group of students during the science lesson in the classroom. All the hands-on materials will be provided to your child. I will place a voice recorder in each group of students to analyze the conversation during the activities. I am recording the conversations so that I can later type a transcript – a written record of what we spoke about during the interview - and analyze the information from the interview. If your child participates, she/he will be one of a total of 35 5th-graders that will be participating in groups. I will also place a video camera to record the atmosphere of teaching and learning during the activities. Apart from that I will snap a few photos to analyze the children's manner and attitude towards the hands-on activities. If you would like to see a copy of all the 5 activities that I intend to implement for a duration of 3 weeks, please contact me via the phone number or email address listed near the end of this consent form.

Benefits and Risks: I believe there are direct benefits to your child for participating in my research project. In fact, the results of this project might help me, other teachers, and researchers to learn more about primary school students' higher order thinking skills (HOTS) by using the Children's Engineering teaching module (CETM). I believe there is little or no risk to your child in participating in this project. In fact, their own science teacher is the one who will be implementing these activities in their classroom, as I will be the silent observer. If, however, your child becomes uncomfortable or stressed by answering any of the interview questions, we will skip the question, or take a break, or stop the interview, or withdraw from the project altogether.

Confidentiality and Privacy: During this research project, I assure to keep all the data from the interviews in a secure location. Only my University of Malaya advisor and I will have access to the data, although legally authorized agencies, including the University of Malaya's Studies Program, have the right to review research records. After I transcribe the interviews, I will erase the audio-recordings. When I report the results of my research project and in my typed transcript, I will not use your child's name or any other personal identified information. Instead, I will use a pseudonym (fake name) for your child. If you would like a copy of my final report, please contact me at the number listed near the end of this consent form.

Voluntary Participation: Participation in this research project is voluntary. Your child (and you) can choose freely to participate or not to participate. In addition, at any point during this project, you can withdraw your permission, and your child can stop participating without any penalty of loss of benefits. I recognize that I am the researcher in this project and, at the same time, your child's teacher. Thus, I will ensure that your child's participation or non-participation in my research project does not impact his/her grades, or our teacher-to-student relationship at this primary school: ………………….

Questions: If you have any questions about this project, please contact me, Kamaleswaran, via phone ……………..or e-mail…………….You can also contact my advisor at the University of Malaya, Prof. Madya. Dr. Rohaida, at ……………….or via e-mail at………………..If you have any questions about your rights, or the rights of your child as a research participant, you can contact the University of Malaya's Human Studies Program, by phone at………………..or by e-mail at ……………………..
Please keep the prior portion of this consent form for your records.
If you consent for your child to participate in this project, please sign the following signature portion of this consent form and return it to ***.

Tear or cut here

Signature(s) for Consent:

I give permission for my child to participate in the research project entitled, *"The Development Of A Year Five Children's Engineering Teaching Module For HOTS"*. I understand that, in order to participate in this project, my child must also agree to participate. I understand that my child and/or I can change our minds about participation, at any time, by notifying the researcher of our decision to end participation in this project.

Name of Child (Print):____
Name of Parent/Guardian (Print): ____

Parent/Guardian's Signature: ____

Date: ______________________________

Example of parents/guardian consent

Please keep the prior portion of this consent form for your records.
If you consent for your child to participate in this project, please sign the following signature portion of this consent form and return it to ***.

Tear or cut here

Signature(s) for Consent:

I give permission for my child to participate in the research project entitled, *"Developing Children's Engineering Teaching Module for Year 5 Primary School Children"*. I understand that, in order to participate in this project, my child must also agree to participate. I understand that my child and/or I can change our minds about participation, at any time, by notifying the researcher of our decision to end participation in this project.

Name of Child (Print): Nursalmiah binti Ahmad Husni

Name of Parent/Guardian (Print): Ahmad Husni bin Mazlan

Parent/Guardian's Signature: ______________

Date: 27.08.2014

Appendix 15

Parents consent for the use of photographs in the final write-up

The final write-up of the thesis titled as: “The Development Of A Year Five Children’s Engineering Teaching Module For HOTS” recognises the need to ensure the welfare and safety of all children taking part in all the five activities associated with this study. In accordance with your child’s protection, this study will not permit photographs, video or other images of children to be taken without the consent of the parents. As your child will be taking part in the CETM activities, we would like to ask for your consent to use the photographs/videos of the activities that may contain images of your child in the final write-up of the thesis.

This thesis will take all steps to ensure these images are used solely for the purposes they are intended. If you become aware that these images are being used inappropriately you should inform University of Malaya (UM) immediately.

I………………………………………allow/ do not allow my child’s photographs and video to be used in the final write-up for the thesis titled as: “The Development Of A Year Five Children’s Engineering Teaching Module For HOTS”.

Date: …………………

Interview Questions (Evaluation of CETM)

1. How did you feel after carrying out the activities in the CETM?
2. Why did you feel so? (either positive or negative feedback)
3. Can you give some feedback on the CETM based on its:
    a) Language usage (eg: grammar)
    b) Pattern or structure of activities
    c) Type of font, font size and spacing
4. After looking at the module, what can you tell about these criteria in the CETM?
    a) Module aim
    b) Subject content
    c) Learning outcomes
    d) Teaching strategies
    e) Assessment strategies
5. What part of the CETM was the most interesting? Why?
6. What part of the CETM was the most time consuming? Why?
7. What part of the CETM required you to seek other's help? Why?
8. What would you like to add or remove from the CETM? Why?
9. Can you suggest some ways to improve the CETM?
10. By using the CETM as guidance, will you be able to design your own activities in future?

Observation Instrument

This observation instrument has been designed after a major refinement from Quality Learning Instrument (QLI) (Walsh, 2000; Walsh & Gardner, 2005). The observation instrument was refined and adapted according to the needs and prerequisites of perceiving the process of fostering HOTS while carrying out the activities designed and developed in the Children's Engineering Teaching Module (CETM). This observation instrument included 15 elements of perceived actions displayed by the children during the activities. There are two components in this instrument where the field notes are jotted down during the implementation of the CETM. Meanwhile the expanded field notes are written after analyzing the field notes written by the teacher and researcher.

No.	Elements of perceived actions displayed by the children during the implementation of CETM in classroom.	Field Notes	Expanded Field Notes
1.	Displayed self-confidence		
2.	Showed persistence in what he/she did		
3.	Used thinking language such as: a) reflection b) remembering c) paying attention and d) listening		
4.	Used gestures to explain or reason out something.		
5.	Engaged in planning for creating the prototype.		
6.	Completed the tasks competently.		
7.	Categorized and sequenced successfully.		
8.	Made comment or criticized other children's work.		
9.	Evaluated own work.		
10.	Explained why the children have done things in a certain way.		
11.	Was open to suggestions from others.		
12.	Showed signs of creativity in what the children were doing.		
13.	Sensitive to the group members' needs: Tune in easily to when and when not to intervene.		
14.	Encouragement and praises within group members.		
15.	Made suggestions about what to do next.		

Collective observation for CETM activities

Elements perceived in observation instrument	**Perceived actions displaced by children during the CETM activities**		**CETM**
	Teacher	**Researcher**	
E1.	Raised the voice at one another in order to stress a point.	Repeated the same reasons to their group member for doing such action. Constantly said *"Because the string was too short."*	Activity 1
	Carried out the presentation without any notes.	Presented the prototype using firm and clear voice.	Activity 2
	Took charge as a group leader.	Answered most of the questions raised by the classmates during the presentation.	Activity 4
	Influenced the group members to work fast.	Made attempt to solve any small challenge by themselves. Repeatedly said *"Let's do it."*	Activity 5
E2.	Carried a chair and stood on it to test the prototype.	Kept trying to improvise the prototype until it could fly.	Activity 1
	Continuously said *"Faster! Faster!*" while looking at the wall clock in the classroom.	Tried to blow the blades of the windmill to observe the red light.	Activity 2
	Sat on the classroom floor to test the prototype.	Turned back on the group that completed the design and rushed towards his/her group to repair the prototype.	Activity 4
	-	Incessantly added the cardboard pieces so that the prototype stood firmly.	Activity 5
E3.	Seldom paid attention to the teacher because too excited handling the prototype.	Used fingers to signify the items (threads) they were counting.	Activity 1
	Kept asking the teacher to give permission on continuing to design the first activity because they were not satisfied with the prototype.	Children expressed *"We did this (sketching) last activity."*	Activity 2

	Listened more to the group members than the teacher.	Children voiced: *"Listen! Listen! You do that, I will do this."* (delegating the task)	Activity 4
	Paid attention when the teacher said *"There will be no more activity if you're not going to listen to me now".*	Listened to the teacher attentively when the teacher mentioned during the early stage of the activity: *"This is your last activity. No more activities after this."*	Activity 5
E4.	Ran towards the teacher to ask for more plastic when the prototype could not fly.	Raised the arm that was holding the prototype before letting it to fly.	Activity 1
	Smiles and laughter's were often heard.	Rotating the blades using index finger.	Activity 2
	Jumped with joy when the prototype moved and made noise.	Moved the arm with open curved palm to show the cylinder shaped tin.	Activity 4
	Used a pencil and drew faces on the cardboard pieces.	Moved both arms to express the reasons on how the prototype should move.	Activity 5
E5.	-	Children quickly started the activity without wasting time.	Activity 1
	Children used most of the time creating the prototype but eventually manage to present within the time frame allocated.	Planning was carried out naturally as no instruction came from the teacher.	Activity 2
	Children tested and evaluated the prototype without the teacher's instructions.	Children were constantly looking at the clock as they did not want to waste time.	Activity 4
	-	Some girls were noticed to have delegated the work among their group members.	Activity 5
E6.	Leaned the body towards the prototype and continued to stand on feet.	Ran across the classroom to get some support for the group.	Activity 1
	Stood and screwed the nuts to design the prototype.	Observed the teacher's act in guiding other groups.	Activity 2
	Squatted on the classroom floor to design the prototype.	Children yelled *"Yeay! Yeay!"* when the prototype worked.	Activity 4
E7.	-	Drew the sketches step by step in the four columns.	Activity 1

	-	Lined up at the table's table to get the materials and tools.	Activity 2
	Observed the time as the children were eager to complete within the time.	Kept away all the textbooks from the table to start the activity.	Activity 4
E8.	Children repaired their prototypes when the teacher gave some feedback on it.	Showed a thumb to a group member when the teacher praised him/her.	Activity 1
	-	Used questions such as "why' and 'how'.	Activity 2
	The noise level was high.	Lots of verbal exchange took place.	Activity 4
	Shook the head when the group member explained.	Facial expressions were observed. Some were happy whereas some were frowning.	Activity 5
E9.	-	Showed body language such as nodding to show the agreement.	Activity 1
	Wrote the evaluations on the activity instrument.	Rotated the prototype from one group member to another.	Activity 2
	Invited other groups to race using the prototype to observe which was faster.	Tilted the prototype to give close observation.	Activity 4
	Continuously adjusted the prototype.	Observed the prototype and wrote the assessment.	Activity 5
E10.	Wrote the reasons on the activity instrument.	Exchanged verbal reasoning with their group members.	Activity 1
	There were questions such as "Why" and "How" asked by classmates after the presentation.	Argued with the group members when certain processes were not same with the other groups.	Activity 2
	When the teacher probed, the children were seen trying to explain to the teacher.	Made blank facial expressions while using the index finger to scratch the lips when asked some uncertainties by group members or teacher.	Activity 4
	Some presenters placed the prototype on the table to answer the question on its flexibility.	Answered some high level questions during the presentation by using 'because' as a start of answer.	Activity 5
E11.	Did not listen much to teacher.	Listened to the group members for ideas.	Activity 1
	Constantly trying to figure out using own effort.	Exchanged views when a challenge emerged.	Activity 2

	The atmosphere was noisy; all the children were talking.	Used questions such as "Then, how?"	Activity 4
	Children were seen moving from one group to another, observing each other's prototype.	Scratched the head using the index finger trying to garner attention while hoping for some idea from other group members.	Activity 5
E12.	Asked the teacher for more plastics to make a bigger parachute.	Tried to tie more strings to design a firm prototype.	Activity 1
	Added more water in the bottle to make sure the prototype was heavy and stood firmly.	Raised the prototype higher towards the ceiling fan hoping the blades would turn faster.	Activity 2
	Used a rubber band (not provided) to tie the eyes of the prototype.	Took off the watch and tied it to the prototype. The prototype moved with the time on it.	Activity 4
	Combined with other group's prototype to create a larger prototype.	Used the water bottle (not given) as a support for the prototype.	Activity 5
E13.	No physical argument seen.	Helped each other by holding and supporting the prototype.	Activity 1
	No bad usage of words observed.	Gestures of tolerance seen when the children gave in to one and another. Children were seen to pass the tool or the prototype itself without much hesitance.	Activity 2
	No disturbing behaviour witnessed.	Observed other group's work but did not intervene with their work.	Activity 4
E14.	-	Crowded the child who stood on the chair to test the prototype.	Activity 1
	Clapped the hands for each group presentation.	There were whispers such as *"We have to do better than them (other group)"*	Activity 2
	-	Used words such as *'fuhyo'* and *'wah'.*	Activity 4
	Clapped the hands for each group presentation.	Children uttered: *"Ours (prototype) is taller than yours! Hahaha."*	Activity 5
E15.	Constantly asked the teacher about the next activity and gave ideas on what could be	Touched each other's shoulder to seek attention, to give some	Activity 1

	designed.	feedback.	
	Observed at other group's prototype to improve the design.	Asked the teacher whether can bring home the prototype for further improvement.	Activity 2
	-	Whispers and mutters were heard and seen in the final stages of the activity.	Activity 4

Appendix 19

Conversations between teacher and children

Malay Language	English Language
<u>Activity 1: Payung Terjun Plastik</u> Cikgu: Eh jangan jatuhkan! Its flimsy! Murid: Apa tu? Cikgu: Maksudnyer mudah pecah. Murid: Tak fragile? Cikgu: Fragile pun boleh, lebih kurang maksudnyer. Murid: Hehehe! Kan aku pandai! Cikgu: Bagus, ok teruskan! Sikit lagi!	**<u>Activity 1: Plastic Parachute</u>** Teacher: Eh don't drop it! Its flimsy! Children: What is that? Teacher: Means, it breaks easily. Children: Not fragile? Teacher: Fragile also can be used; the meaning is more or less the same. Children: Hehehe! I am smart! Teacher: Good, okay continue! A bit more to go!
<u>Activiti 2: Kincir Angin</u> Murid: Cikgu, kenapa ada kumpulan dah abis pakai semua nut? Group kita ada nuts yang lebih! Cikgu: Dia mesti ada sebab kenapa ada yang kamu guna, ada yang kamu tak guna. Kenapa ada lebih? Mesti pikir. Why ada extra nuts? Cuba tengok kenapa ada extra nuts? Adakah betul2 cukup ataupun kalau ada lebih kamu sumbat saja? Check and tengok betul2, dia punya nut dia. Klu dah cukup, ok. Tengok betul2. Jangan kelam kabut. Murid: Jom cuba guna semua nut (sambil ajak ahli kumpulan yang lain).	**<u>Activity 2: Windmill</u>** Child: Why some of the groups used all the nuts? Our group has some balanced nuts! Teacher: There must be a reason as to why some if it (nuts) you use and some you don't. Why are there extra nuts? Must think. Why there are extra nuts? Try to see why there are extra nuts? Is it really enough or if there's extra you just screw it (without much thought)? Check and observe carefully all the nuts (for the prototype). If it's enough, then it's okay. See carefully. Don't panic. Child: Let's try using all the nuts (inviting other group members as well).

Malay Language	English Language
<u>Activiti 4: Robot Tin Logam</u>	**<u>Activity 4: Metal Tin Robot</u>**
Cikgu: Ok, lumba-lumba, yang mana lebih laju?	Teacher: Okay, let’s race, which one is faster?
Murid 1: Fuhyoo! *(melihatkan pergerakan model)*	Child 1: Fuhyoo! *(Looking at the prototype’s movement)*
Murid 2: Mengapa kita punya (model) slow?	Child 2: Why our prototype is (moving) slow?
Cikgu: Ok, so alright. Tengok ya semua. Yang mana lebih laju? Yang kuning ke putih?	Teacher: Okay, so alright. Everyone see. Which one is faster? The yellow (tin) or the white (tin)?
Murid: Yang putih!!!	Children: The white one!!!
Cikgu: Ok, pemerhatian kamu yang putih lebih laju daripada yang kuning. Cuba buat inferens. Apa sebab dia?	Teacher: Okay, your observation is the white is faster than the yellow. Try to make an inference. What is the reason?
Murid 3: Mungkin sebab wayar dia tak sampai kat model.	Child 3: Maybe the wire (from the prototype) did not reach the prototype.
Cikgu: Mungkin..	Teacher: Maybe..
Murid 4: Kaki dia panjang sangat (sesungut)	Child 4: The legs are too long (tentacles)
Cikgu: Ha, betul. Kaki dia panjang sangat. Sebab itu dia pusing lambat. Yang ni dia pusing, satu depan, satu belakang.	Teacher Yes, that’s correct. The legs are too long. That’s why it is turning slowly. This one is turning one at the front (first leg) and the other (second leg) at the back.
Murid: Betulkan balik, betulkan balik.	Children: Let’s correct it, let’s correct it.
Guru: Ha, Nampak tak? Sebab itu dia (model) lambat. Itu la guna dia, pengaplikasian.	Teacher: Ha, can you see that? That’s why it (prototype) was slow. That’s the use of it (this activity), application.
Murid 5: Buat sampai jadi, buat sampai jadi (memotivasikan murid-murid yang lain dalam kumpulan)	Child 5: Do until it (prototype) functions! Do until it functions! (motivating children in other group as well)

Guru:	Kalau dah siap, boleh lumba!	Teacher:	Once completed, can race!
Murid 6:	Nanti kita buat elok-elok (sampai skru semula model).	Child 6:	We shall do better than before (screw (the nuts) again the entire prototype).
Murid 7:	Dah dah cukup. Siapa nak lawan dengan kita? Siapa nak lawan dengan kami punya model *(mengangkat model sambil bertanya kepada seluruh kelas)*	Child 7:	Okay, that's enough (completed the design). Who wants to race with us? Who wants to race with our prototype *(While carrying the prototype and asking the entire class)*

Conversations between children in groups

Malay Language	English Language
<u>Activiti 1: Payung Terjun Plastik</u>	**<u>Activity 1: Plastic Parachute</u>**
Amirul: Macam mane nak potong ni?	Amirul: How can I cut this *(the pipe cleaner)?*
Kar Fei: Potong jer la, tak pe.	Kar Fei: Just cut it, it doesn't matter.
Wahida: Nape ada panjang dan pendek? Tak sama la.	Wahida: Why its' long and short? It's not the same!
Amirul: Tu sebab ko tak ukur. Ko potong je. Jap jap..	Amirul: That's because you did not measure. Can't simply cut. Wait.
Abu: Lantak la, janji masuk dalam ni.	Abu: It doesn't matter, as long as it can enter this *(wooden bead).*
Linda: Jangan cakap macam tu, kenapa hati-hati la.	Linda: Don't say like that, you must be careful *(in cutting the pipe cleaner)*
Wahida: Ko salah. Tu patut masuk sana macam ni ar.	Wahida: You *(referring to Abu)* are wrong. It has to enter *(wooden bead)* like this *(showing how it has to be done).*
Kumar: Tengok ni, kan dah boleh!	Kumar: Watch this *(trying to fix the pipe cleaner into the bead).* See it works!
<u>Activiti 4: Robot Tin Logam</u>	**<u>Activity 4: Metal Tin Robot</u>**
Tan: Bestnya kalau boleh gi bulan!	Tan: How nice if we can visit the moon!
Amir: Tu la, saya fikir macam tu!	Amir: I wish that too!
Syikin: Kalau oksigennyer ok, saye bina jambatan dari sini ke bulan.	Syikin: If the oxygen level is okay (sufficient), I will build a bridge from here (Earth) to the moon.
Yuvan: Apa? Macam mane?	Yuvan: What? How is that possible?
Indrajit: Saye yang akan cross dulu!	Indrajit: I will be the first to cross the bridge.
Azlan: Yea, kalau macam tu, tak payah la bawa mineral dia, leh duk kat bulan jer.	Azlan: Yea and we don't have to bring (transfer) the minerals, can just live in the moon!

Activiti 5: Robot Humanoid	Activity 5: Humanoid Robot
Meena: Ni salah la, tak betul!	Meena: This is wrong, it’s not right!
Lim: Ye ke? Abis, cam ne?	Lim: Is it? Then, how?
Daniel: Kad itu tak semestinya kaler (warna) dan saiz yang sama.	Daniel: The cardboards not necessary same colour and size.
Shankar: Cikgu tak marah la kalau salah, kita punya robot.	Shankar: Teacher won’t scold us if it’s wrong; it’s just up to us.
Chong: Dah besar dah, nape ko asyik sambung dia, dah la.	Chong: It’s huge now, why you’re keeping putting in the pieces, it’s enough.
Meena: Janji permukaan dia luas, ok la itu. Tak akan jatuh.	Meena: As long as the base is wide, it’s fine. Won’t fall down.
Daniel: Saye nak buat satu robot yang leh buat semua kerja saya.	Daniel: I want to make one robot that can do all my work.
Meena: Pas tu, letak pemadam dan pencil kat sini ar supaya robot kite dapat buat kerja.	Meena: Then, fix the eraser and pencil for it (prototype) to do some work.
Faizal: Termasuk kerja rumah!	Faizal: Including the homework!

Appendix 21

Curriculum vitae (CV) for sketch experts

No.	Name	Country	Academic level	Research areas	Professional services	Years of experience	Honours, awards & contributions
1.	Esther Burkitt	Chichester, West Sussex, United Kingdom (UK)	Reader in Developmental Psychology, Lecturer, Chartered Psychologist & Chartered Scientist.	Educational Psychology, Social Psychology, Critical Thinking and Research Methodology. Currently module co-ordinator for the Level 1 modules Everyday Experience and Psychology	Previously holding lecturing posts at The Open University, UK, Victoria University, New Zealand, the University of Portsmouth, UK, and the University of Sussex, UK. Member of the Research Committee and is Admissions Tutor for the Psychology BSc.	18 years (since 1997 to present)	Was awarded PhD examining expressive aspects of children's drawings from the University of Surrey in 2000. Esther's publications focus on children's drawings, factors which facilitate children's memory and learning.
2.	Derek Bland	Queensland, Australia	Senior Lecturer	Education Systems, Specialist Studies in Education. Currently working on visual research project, invited Year 5 and 6 students from a range of Queensland schools to imagine, draw, and write about their ideal learning environment.	Member of the Children and Youth Research Centre (CYRC), QUT, Australian Association for Research in Education (AARE) & Queensland College of Teachers Certificate of Teacher (QCoT) Registration.	24 years (since 1991 to present)	Established the Q-Step Program, a special entry and student support initiative of the university to assist people from socio-economically disadvantaged backgrounds.
3.	Robert Watts	Roehampton, London, United Kingdom (UK)	Senior Lecturer	Using artists' work in primary education, drawing in primary education & children's notions of visual beauty.	Member of NSEAD (National Society for Education in Art and Design)	24 years (since 1991 to present)	Published over 150 creative projects and articles on primary education for teachers and parents in Child Education, Junior Education, Nursery Education, Teach Primary and Right Start magazines.

Children's written problem

Malay Language	English Language
<u>Activiti 1: Payung Terjun Plastik</u>	**<u>Activity 1: Plastic Parachute</u>**
Murid 1: Negara X telah menghadapi kemarau, jadi saya ingin menghantar air dan buluh untuk panda. Murid 2: Masalah yang dihadapi oleh mereka ialah keadaan cuaca yang kurang baik. Murid 3: *(Telah menulis dalam English)*	Child 1: Country X is facing drought, so I wish to send water and bamboo for the pandas. Child 2: The problem faced by them is the poor weather condition. Child 3: We must help the panda to send food.
<u>Activity 2: Kincir Angin</u> Murid 1: *(Telah menulis dalam English)* Murid 2: Kekurangan kincir angin di Malaysia, sebab itu manusia menggunakan petroleum dan membuatkan pencemaran alam.	**<u>Activity 2: Windmill</u>** Child 1: There is no electric if there is no wind. Child 2: There are few windmills in Malaysia, that's why humans use petroleum and produce pollution.
<u>Activiti 4: Robot Tin Logam</u> Murid 1: Manusia memerlukan mineral. Mineral hanya ada di bulan. Ahli astronomi tidak boleh mengambil kerana kekurangan udara. Ia memerlukan robot untuk mengambil. Murid 2: Di bumi tiga jenis garam mineral sudah berkurangan. Kita perlu mengambilnya di bulan. Kita perlu gunakan robot kerana robot tidak menggunakan oksigen. Murid 3: *(Telah menulis dalam English)* Murid 4: Terlalu berat kerana terlalu banyak benda. Murid 5: Kekurangan garam mineral dekat bumi jadi mikrocip, barangan elektrik, kapal dan simen tidak akan wujud lagi.	**<u>Activity 4: Metal Tin Robot</u>** Child 1: Humans need mineral. Mineral only can be found on moon. Astronomers can't take because less air. We need robot to take. Child 2: Three types of minerals are decreasing on Earth. We need to take from Moon. We need to use robots because robots don't need oxygen. Child 3: We cannot send human to moon because there is not enough oxygen. Child 4: Too heavy because too many things. Child 5: Lack of minerals in Earth, hence microchips, electrical devices, ships and cement will not exist.

Activiti 5: Robot Humanoid	**Activity 5: Humanoid Robot**
Murid 1: Manusia memerlukan robot untuk memajukan Malaysia.	Child 1: Humans need robot to advance Malaysia.
Murid 2: *(Telah menulis dalam English)*	Child 2: Malaysia needed humanoid robots for robot's industry, domestic or home.
Murid 3: Malaysia juga mencipta robot tetapi ada serba kekurangan. Malaysia hendak mencipta lebih baik dan canggih.	Child 3: Malaysia also creates robot but there are some limitations. Malaysia wishes to create better and sophisticated robots.
Murid 4: *(Telah menulis dalam English)*	Child 4: The limitation of movement for a robot is one of the problems and so is functionality.

Children's written evaluation

Malay Language	English Language
<u>Activiti 1: Payung Terjun Plastik</u> Murid 1: a) Tidak, kita boleh meminta bantuan orang ramai dan menggunakan kapal terbang. b) Hias dengan baik dan betul. Murid 2: a) Tidak kerana ia adalah sesuatu idea yang berbahaya jika tali terputus. b) Kita boleh mengecat. Murid 3: a) Tak, ia akan bergerak lancar jika gunakan hovercraft. b) Membuat dengan teliti dan hias dengan kasih saying.	**<u>Activity 1: Plastic Parachute</u>** Child 1: a) No, we can ask help from people and use the aeroplane. b) Decorate it well and correctly. Child 2: a) No, because it's a dangerous idea especially if the string gets snapped. b) We can paint it. Child 3: a) No, it will move smoothly if we used hovercraft. b) Do attentively and decorate it with love and passion.
<u>Activiti 1: Payung Terjun Plastik</u> Murid 1: a) Ya, ia tidak mengunakan battery dan tidak mencemarkan udara. Murid 2: a) Tidak. Saya nak guna bahan yang bagus untuk menjadikannya lebih bagus. b) *(Telah menulis dalam English)* Murid 3: a) Tidak. Kita boleh buat kenderaan yang tidak menggunakan bahan asli seperti petroleum. Murid 4: a) Tidak, lebih baik kita buat kereta tanpa petroleum. Murid 5: a) Tidak, kita boleh menggunakan basikal. Murid 6: a) Tidak, kita boleh menggunakan air sebagai tenaga. b) Menghiasnya dan menambah warna.	**<u>Activity 2: Windmill</u>** Child 1: a) Yes, it does not use battery and doesn't pollute the air. Child 2: a) No. I wish to use better substance to make it better. b) Do some decoration. Child 3: a) No. We can do vehicles that do not use minerals such as petroleum. Child 4: a) No, it is better we do cars without petroleum. Child 5: a) No, we can use bicycle. Child 6: a) No, we can use water as an energy source. b) Decorate it and add colour.

Murid 7: a) *(Telah menulis dalam English)* b) *(Telah menulis dalam English)* Murid 8: a) *(Telah menulis dalam English)* b) Tidak sebab saya fikir untuk menggunakan kuasa solar.	Child 7: a) No, but we can use water instead of wind. b) Change the water bottle cover. Child 8: a) No. Solar is better. b) No, because I am thinking of using the solar power.
Activiti 4: Robot Tin Logam	**Activity 4: Metal Tin Robot**
Murid 1: a) *(Telah menulis dalam English)* b) *(Telah menulis dalam English)*	Child 1: a) Yes because it does not need oxygen like human. b) We can add 2 more tyres on the robot.
Murid 2: a) *(Telah menulis dalam English)* b) *(Telah menulis dalam English)*	Child 2: a) The robot can help us and the robot doesn't need oxygen at the moon. b) I want to put more tyres and engine to make the robot more useful.
Murid 3: a) *(Telah menulis dalam English)* b) *(Telah menulis dalam English)*	Child 3: a) Yes, because it can move without any support and it did not need oxygen at moon. b) Add more batteries.
Murid 4: a) Ya, ia bergerak dan tidak bernafas. b) Bakul boleh meletakkan logam dan lain-lain.	Child 4: a) Yes, it moves and does not breathe. b) Basket can keep metals and other materials.
Murid 5: a) *(Telah menulis dalam English)* b) *(Telah menulis dalam English)*	Child 5: a) No. It would be broken easily. It would add too much weight and will not move. b) A better design.
Murid 6: a) Ya, kerana ia boleh bergerak dengan laju. b) Ya, kalau kita tambah hiasan, ia akan menjadi berat.	Child 6: a) Yes, because it can move fast. b) Yes, if we add decorations, it will become heavy.

Activiti 5: Robot Humanoid			**Activity 5: Humanoid Robot**		
Murid 1:	a)	Ya, kerana robot ini sungguh menarik dan seimbang.	Child 1:	a)	Yes, because this robot is very interesting and balanced.
	b)	Boleh, kami akan menambah kaki, tangan dan lain-lain.		b)	Sure, we will add legs, hands and other things.
Murid 2:	a)	Ya, kerana robot humanoid menarik minat kepada manusia dari dalam luar Negara.	Child 2:	a)	Yes, because humanoid robot can attract interest from people within and outside the country.
	b)	Bateri, wayar, motor, dawai, kaki besi dan gear untuk menjadikannya bergerak.		b)	Battery, wire, motor, metal stand and gear to make it moveable.
Murid 3:	a)	*(Telah menulis dalam English)*	Child 3:	a)	Yes, because it help civilian in Malaysia a lot.
	b)	*(Telah menulis dalam English)*		b)	We can create more legs to the humanoid robot so it can stand independently.
Murid 4:	a)	Ya, kerana ia akan lebih menyenangkan kita dalam kehidupan harian.	Child 4:	a)	Yes, because it will be easier in our daily lives.
	b)	Mesin mengubah diri seperti kita mengubah diri mengikut kemahuan kita.		b)	Machines that can change itself like us changing ourselves, following our needs.
Murid 5:	a)	Ya, kerana ianya boleh membantu manusia melakukan apa saja pekerjaan.	Child 5:	a)	Yes, because it can help humans to do any work.
	b)	Tambah bateri dan saiz badan.		b)	Add more batteries and body size.

24 testing measures in all the CETM activities

No.	Activity One: Plastic Parachute		
1.	Does your plastic parachute fly freely when there is wind?	YES	NO
2.	**Does the height of where the plastic parachute floated influences the total time the plastic parachute flies?**	**YES**	**NO**
3.	Does all the supplies such as food and water flies without falling to the ground?	YES	NO
4.	**Can the plastic parachute fly better if bigger plastic is used?**	**YES**	**NO**
5.	**Can the plastic parachute fly further if heavier supplies are tied to it?**	**YES**	**NO**
6.	**Does the wind speed important for the plastic parachute to fly?**	**YES**	**NO**
7.	Does every supply which you tie to the plastic parachute take the same time?	YES	NO
8.	Are you confident your plastic parachute will reach country X with all the supplies?	YES	NO
	Activity Two: Windmill		
9.	Does your windmill have blades that spin freely in the wind?	YES	NO
10.	Does your windmill remain standing strong when the strong wind blows?	YES	NO
11.	Did you use only the tools and materials listed on the activity outline?	YES	NO
12.	**Does the wind speed make a difference in lighting the LED lamp?**	**YES**	**NO**
	Activity Three: Metal Tin Robot		
13.	Does your model move once the design is complete?	YES	NO
14.	Does your model produce sound when it moves?	YES	NO
15.	Does your model move in a specific circle?	YES	NO
16.	**Does your model function better in a different metal can?**	**YES**	**NO**
17.	Did you use only the tools and materials listed on the activity outline?	YES	NO
18.	**Does a different battery brand with the same voltage make a difference in the model?**	**YES**	**NO**
	Activity Four: Humanoid Robot		
19.	Does your designed model stand independently?	YES	NO
20.	Does your model represent a human?	YES	NO
21.	**Does the change of color in the card make a difference in your model's flexibility?**	**YES**	**NO**
22.	**Does the space area and height influences in designing your model?**	**YES**	**NO**
23.	Did you use only the tools and materials listed on the activity outline?	YES	NO
24.	Does your model could be used in designing a real robot to help human being?	YES	NO

- The bolded testing measures the analyzing skills in Revised Bloom Taxonomy (RBT)

Science Reasoning Skills Test (SRST)

Instructions: ***Circle*** your answers using a pen. Answer ***all*** the following questions. Time given is ***20 minutes*** for ***20 multiple choice*** questions.

1. Arrange the situation accordingly:

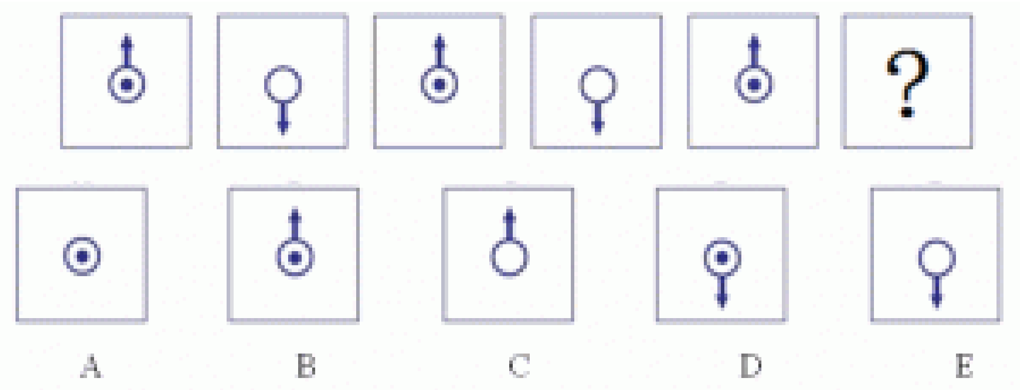
   1. Mother 2. Child 3. Milk 4. Cry 5. Smile

   A. 2,4,1,3,5
   B. 3,2,1,5,4
   C. 1,5,2,4,3
   D. 2,4,3,1,5

2. The school principal has received complaints from parents about bullying in the school yard during recess. He wants to investigate and end this situation as soon as possible, so he has asked the recess aides to watch closely. Which situation should the recess aides report to the principal?

   A. Girl is sitting glumly on a bench reading a book and not interacting with her peers.
   B. Four girls are surrounding another girl and seem to have possession of her backpack.
   C. Two boys are playing a one-on-one game of basketball and are arguing over the last basket scored.
   D. Three boys are huddled over a handheld video game, which isn't supposed to be on school grounds.

3. What should be in the final box?



4. Suppose you know that There are black cats only if there are pink cats. There are black cats Then would this be true? There are pink cats.

   A. Yes
   B. No
   C. Maybe
   D. I don't know

5. Farmer Brown was observing the mice that live in his field. He discovered that all of them were either fat or thin. Also, all of them had either black tails or white tails. This made him wonder if there might be a link between the size of the mice and the color of their tails. So he captured all of the mice in one part of his field and observed them. The picture shows the mice that he captured.

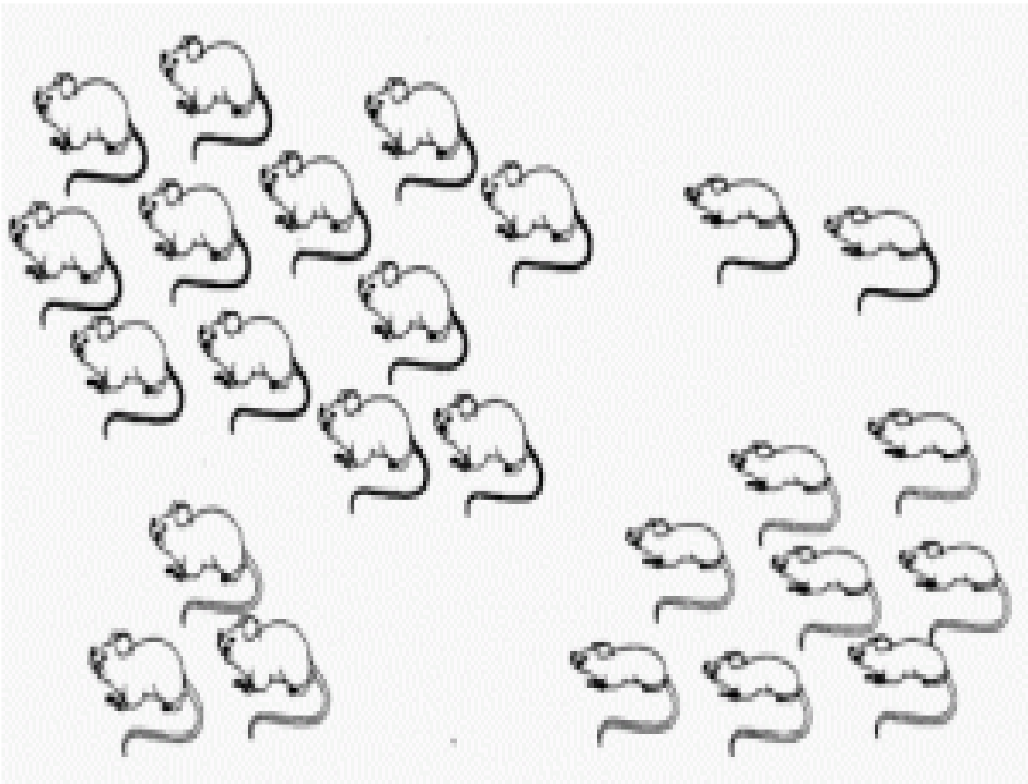


Diagram 1

Based on the captured mice, do you think there is a link between the size of the mice and the color of their tails?

A. appears to be a link
B. appears not to be a link
C. appears to have a link and no link.
D. cannot make a reasonable guess.

6. Suppose you know that if the bicycle in the garage is Bob's, then it is red. The bicycle in the garage is not red. Then would this be true? The bicycle in the garage is not Bob's.

A. Yes
B. No
C. Maybe
D. I don’t know

7.

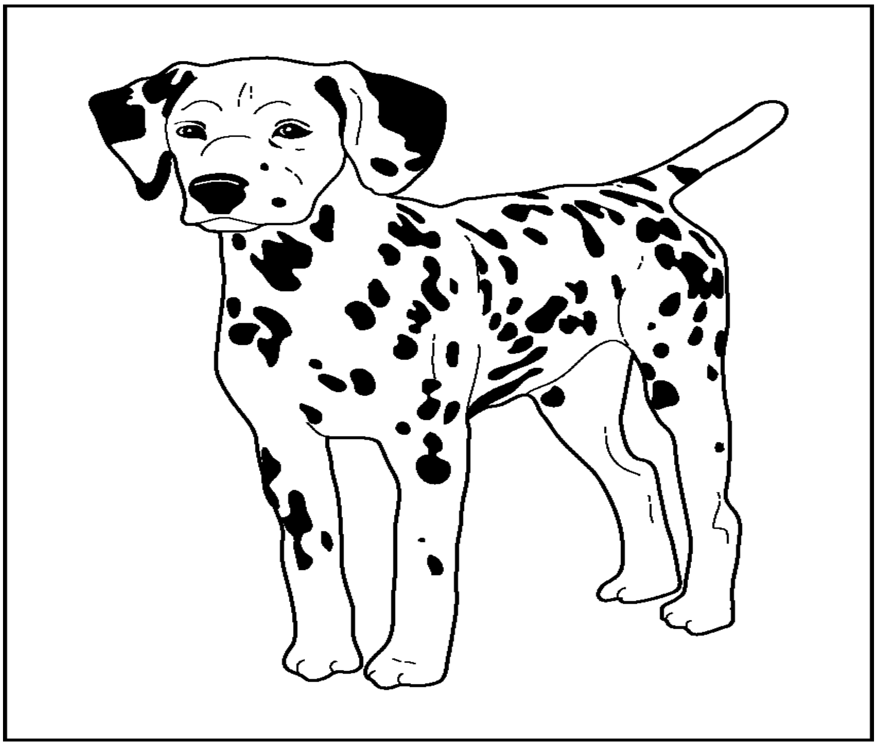


Diagram 2

Based on the picture in Diagram 2, an observation can be made that this animal (dog)

A runs fast
B barks loudly
C jumps high
D has spots

8. Pointing towards a person, a man said to a woman, “His mother is the only daughter of your father.” How is the woman related to that person?

A. Sister
B. Daughter
C. Mother
D. Wife

9. Pat set up four different jars with a burning candle in each jar. He put the lids on jars 1, 2, and 3, as shown in the Diagram 3 below.

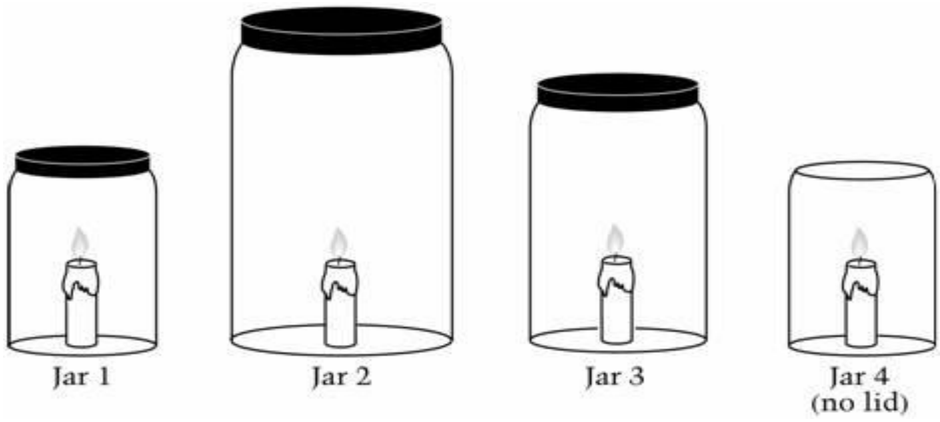


Diagram 3

The candle in jar 1 burned for 2 minutes after the lid was put on. The candle in jar 2 burned for 8 minutes. About how long the candle in jar 3 burn did after the lid was put on?

A. 1 minute
B. 4 minutes
C. 8 minutes
D. 10 minutes

10. Arrange the situation accordingly:

Patients 2. Diagnosis 3. Bill 4. Doctor 5. Treatment

A. 1,4,3,2,5
B. 1,4,2,5,3
C. 1,4,2,3,5
D. 1,2,3,4,5

11.

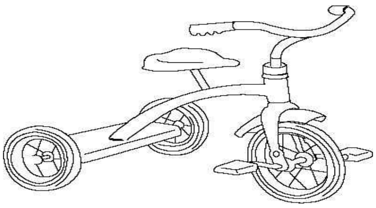
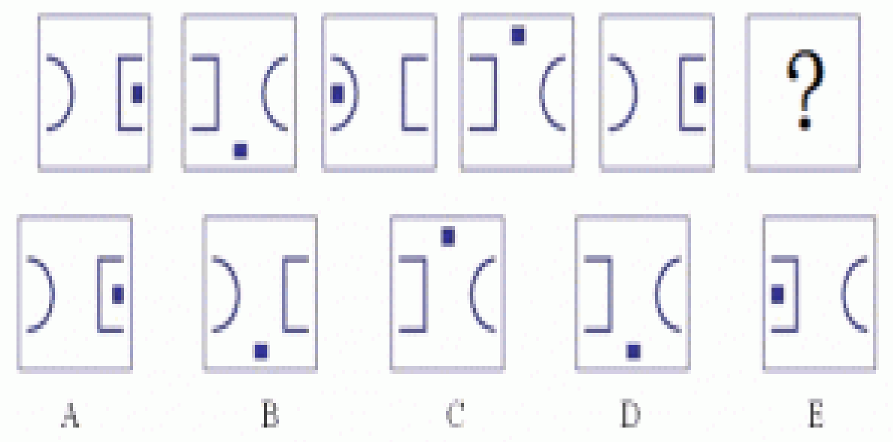


Diagram 4

The objects shown in Diagram 4 above can be described as

A. having moving parts
B. having the same size
C. needing a magnifying glass to be seen
D. being made from more than one material

12. What should be in the final box?



13. Choose the word which is least like the others word in a group?

A. Lion
B. Cheetah
C. Bear
D. Tiger

14. Which handle requires less force to lift?

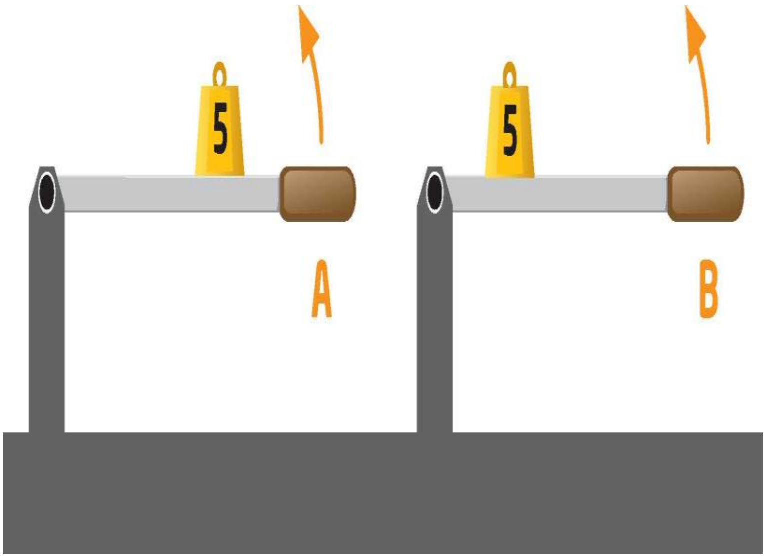


Diagram 5

A. Handle A
B. Handle B
C. Both handles require equal force.
D. I don't know the answer.

15. There is a small cabin in a forest. Inside are two dead men. The trees around the cabin are burning, although the cabin is not. The men had not been fighting and possessed no weapons. How did they die?

A. They attacked each other.
B. They were burned to death.
C. They couldn't breathe due to the smoke.
D. A tiger had entered the cabin and killed them.

16. You and your friends bought some apples from the store. The apples are either small or large and are either dark red or light yellow (see the Diagram 6 below). Imagine that all the apples were put into a bag so that you cannot see the color or size of the apple from outside.

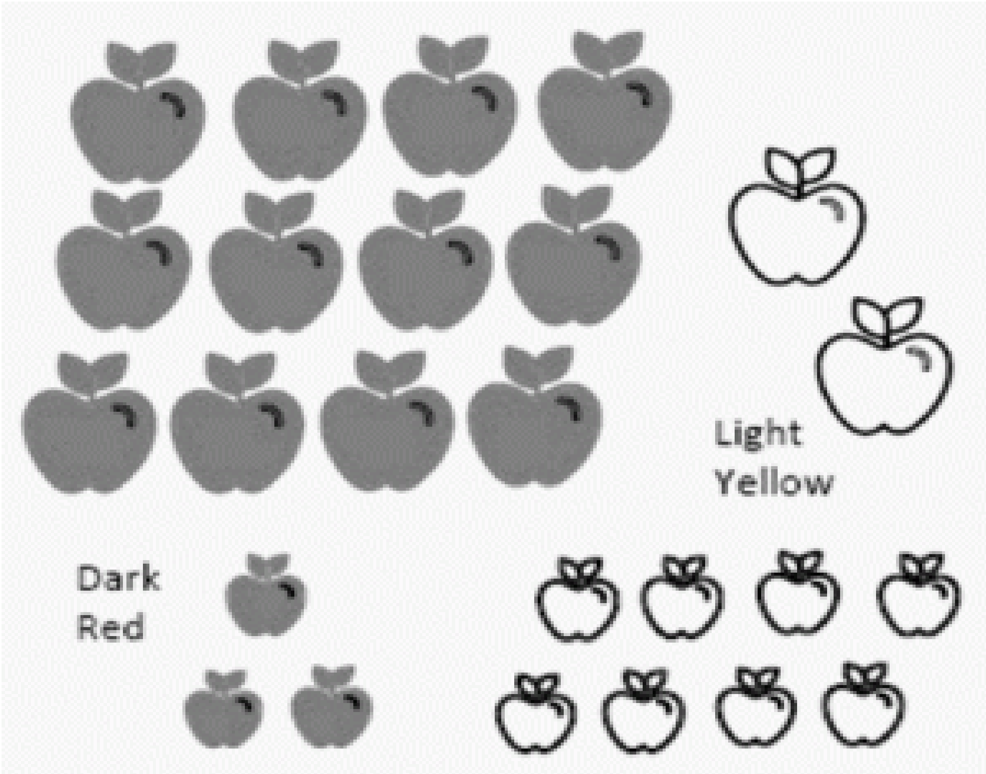


Diagram 6

Suppose you close your eyes and reach into the bag to pull out an apple. You feel that it is a really big apple. What color do you think it will most likely be?

A. red
B. yellow
C. equally possible for it to be yellow or red
D. cannot be determined

17.

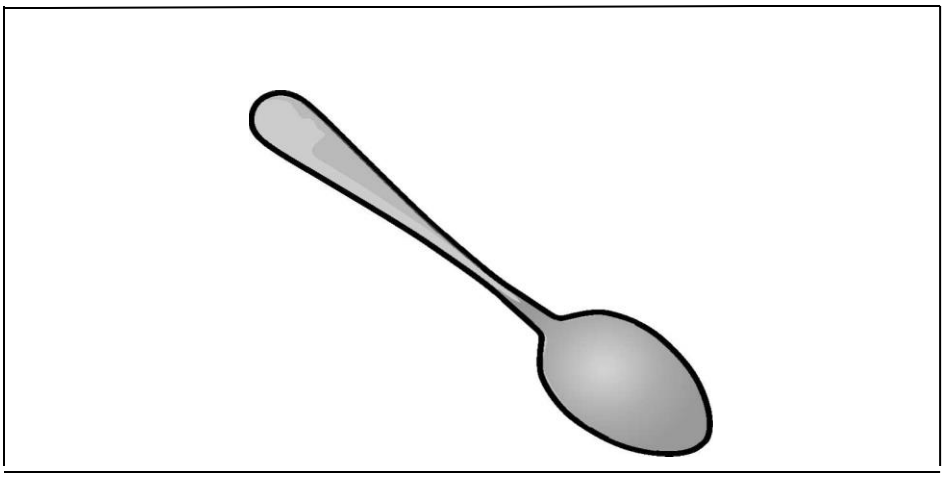


Diagram 7

Which of these BEST describes the texture of the metal spoon?

A. Small
B. Smooth
C. Flexible
D. Shinny

18. A container was filled with ice cubes. The container was left outside until the ice cubes melted. Based on the picture, how much water came from the melted ice cubes?

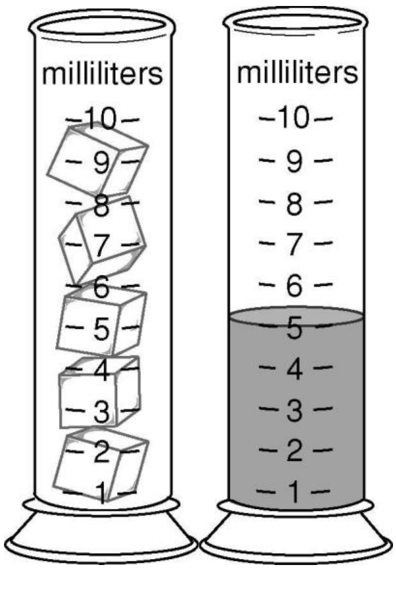


Diagram 8

A. 3 milliliters
B. 5 milliliters
C. 7 milliliters
D. 10 milliliters

19. The diagram 9 below shows the top of a toy car as it travels on a curved track. Four students, Matt, Samantha, Josh, and Ashley stand in the positions shown and watch the toy car move.

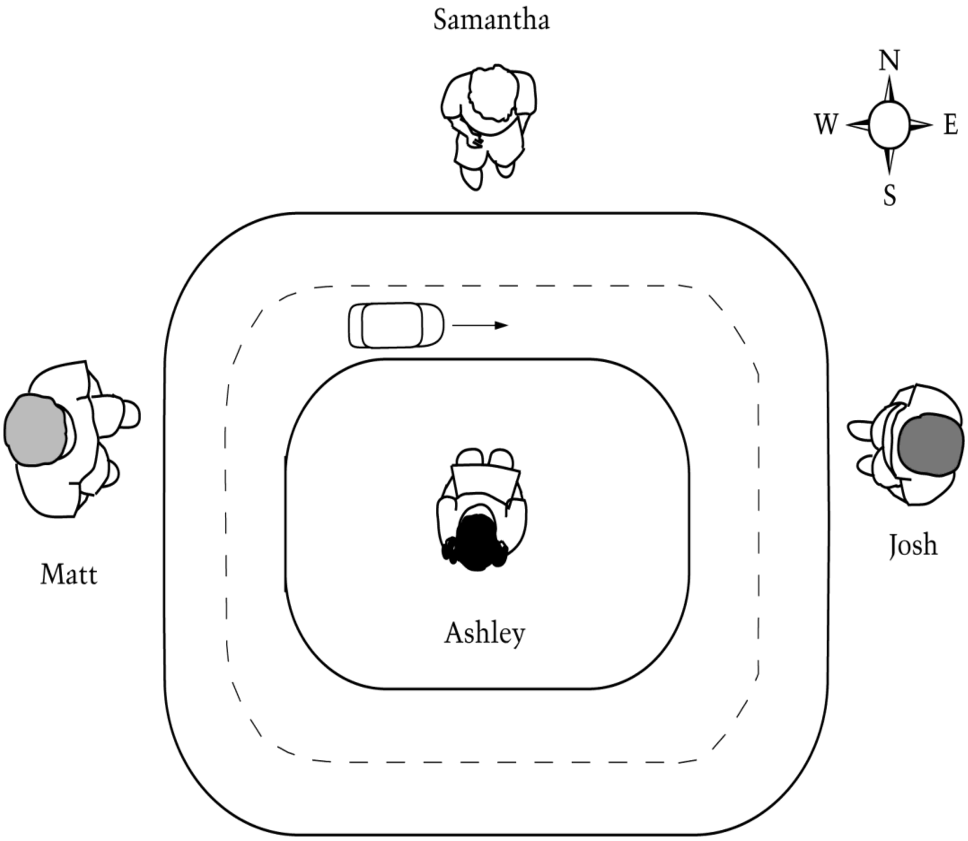


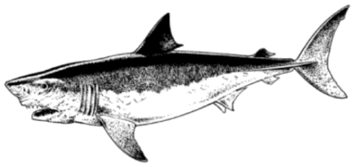
Diagram 9

When the toy car is in the position shown in the Diagram 9, what can all four students correctly conclude about the direction in which the car is moving?

A. The car is moving left to right.
B. The car is moving right to left.
C. The car is moving east to west.
D. The car is moving west to east.

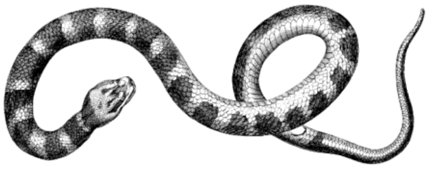
20. Which animal lives in water when very young and then lives on land as an adult?

A.



Shark

B.



Snake

C.

Frog

D.

Penguin

Kemahiran Berfikir Aras Tinggi (KBAT) (Kemahiran 'Reasoning') Untuk Murid Tahun 5

Arahan: ***Bulatkan*** jawapan anda dengan menggunakan pen. Sila jawab ***semua*** soalan yang berikut. Masa yang diberi adalah ***20 minit*** untuk ***20 soalan*** aneka pilihan.

1. Susun situasi di bawah secara teratur:

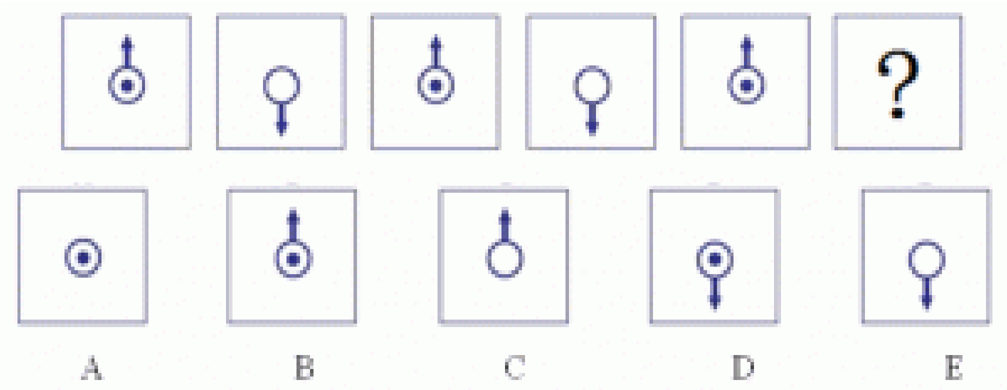
   1. Emak 2. Bayi 3. Susu 4. Menangis 5. Senyum

   A. 2,4,1,3,5
   B. 3,2,1,5,4
   C. 1,5,2,4,3
   D. 2,4,3,1,5

2. Seorang guru besar telah menerima laporan daripada ibubapa mengenai masalah buli di sekolah sewaktu masa rehat. Guru besar tersebut ingin mencari punca masalah tersebut dan ingin menyelesaikannya secara segera. Jadi guru besar tersebut telah mengarahkan pengawas yang bertugas sewaktu rehat untuk memerhatikan situasi pada masa rehat. Apakah situasi yang sepatutnya dilaporkan oleh pengawas kepada guru besar?

   A. Seorang murid perempuan sedang duduk atas bangku sambil membaca tanpa bercakap dengan rakan-rakannya.
   B. Empat pelajar perempuan sedang mengelilingi seorang lagi pelajar perempuan untuk mendapatkan beg sekolahnya.
   C. Dua pelajar lelaki yang sedang bermain bola keranjang sedang bertengkar tentang skor perlawanan itu.
   D. Tiga orang pelajar lelaki sedang berlumba untuk bermain alat video game yang tidak sepatutnya berada di perkarangan sekolah.

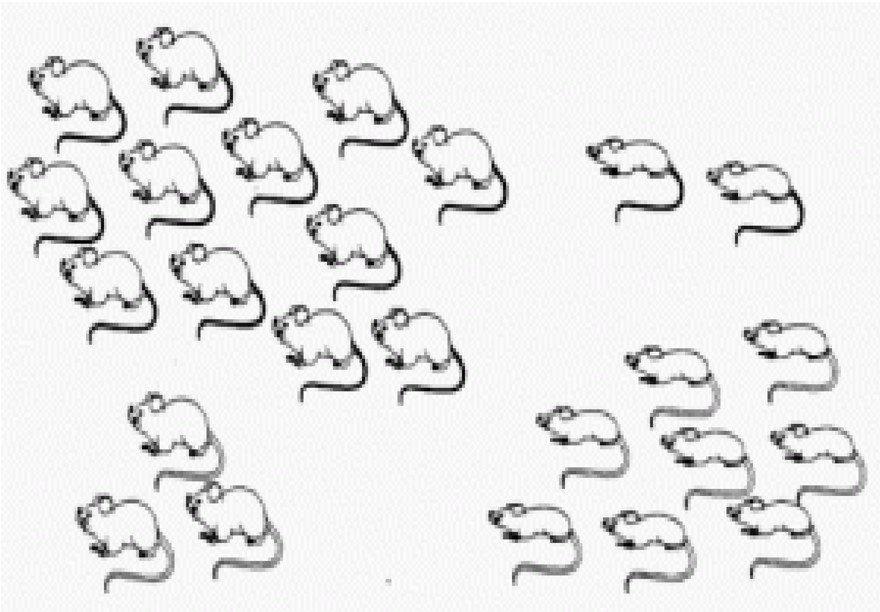
3. Apakah yang sepatutnya ada dalam kotak yang terakhir?



4. Kucing berwarna hitam hanya ada apabila ada kucing berwarna putih. Didapati bahawa ada kucing yang berwarna hitam. Oleh itu, kucing berwarna putih turut ada. Adakah situasi ini benar?

   A. Ya
   B. Tidak
   C. Mungkin
   D. Saya tidak tahu jawapannya

5. Seorang petani yang dikenali sebagai Pak Ali telah memerhatikan tikus-tikus yang hidup di sawah padinya. Dari jauh, Pak Ali dapati bahawa kesemua tikus berkenaan mempunyai saiz yang sederhana. Pada masa yang sama, kesemua tikus berkenaan juga mempunyai sama ada ekor berwarna hitam atau ekor berwarna putih. Keadaan ini membuatkan Pak Ali berfikir jika saiz tikus dan warna ekor tikus mempunyai perkaitan. Oleh itu, Pak Ali telah menangkap kesemua tikus di sawah padinya dan memerhatikan tikus-tikus tersebut secara dekat. Rajah 1 di bawah ini menunjukkan tikus-tikus yang Pak Ali telah tangkap.



Rajah 1

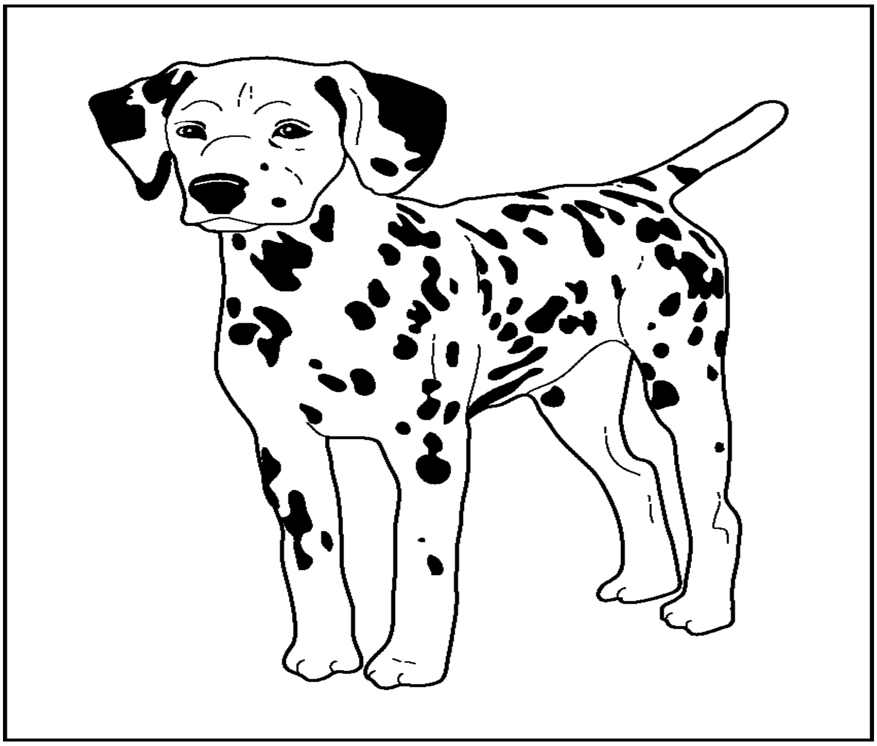
Pada pendapat anda, berdasarkan Rajah 1, adakah saiz tikus dan warna ekor tikus berhubung kait?

A. Ada hubung kait
B. Tidak ada hubung kait
C. Ada hubung kait dan tiada hubung kait
D. Tidak dapat membuat keputusan tentang hubung kait

6. Jika basikal dalam bengkel itu milik Chong, basikal tersebut berwarna merah. Didapati basikal dalam bengkel itu bukan berwarna merah. Maka adakah ayat berikutnya adalah benar? Basikal dalam bengkel itu bukan milik Chong.

A. Ya
B. Tidak
C. Mungkin
D. Saya tidak tahu jawapannya

7.



Rajah 2

Berdasarkan Rajah 2, suatu pemerhatian yang boleh dibuat mengenai haiwan (anjing) tersebut adalah:

A berlari dengan pantas
B menyalak secara kuat
C melompat dengan tinggi
D mempunyai tompok hitam

8. Sambil menunjuk kepada seseorang, seorang lelaki berkata kepada seorang perempuan, “Ibu dia adalah satu-satunya anak perempuan ayah kamu.” Apakah pertalian antara perempuan itu dengan seseorang itu?

A. Kakak
B. Anak perempuan
C. Ibu
D. Isteri

9. Jagbeer telah menyediakan empat balang dengan lilin yang menyala dalam setiap balang tersebut. Jagbeer telah meletakkan penutup hitam di atas tiga balang yang pertama seperti yang ditunjukkan dalam Rajah 3. Balang keempat tiada penutup hitam.

Rajah 3

Lilin dalam balang pertama telah menyala selama 2 minit selepas penutup telah diletakkan. Lilin dalam balang kedua pula telah menyala selama 8 minit selepas penutup diletakkan. Ramalkan masa yang diambil oleh lilin dalam balang ketiga untuk menyala selepas penutup diletakkan?

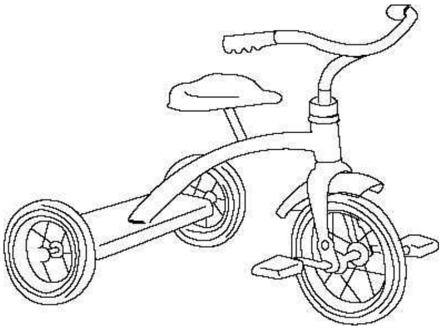
A. 1 minit
B. 4 minit
C. 8 minit
D. 10 minit

10. Susun situasi di bawah secara teratur:

1. Pesakit 2. Keputusan tahap kesihatan 3. Bil pembayaran 4. Doktor 5. Rawatan

A. 1,4,3,2,5
B. 1,4,2,5,3
C. 1,4,2,3,5
D. 1,2,3,4,5

11

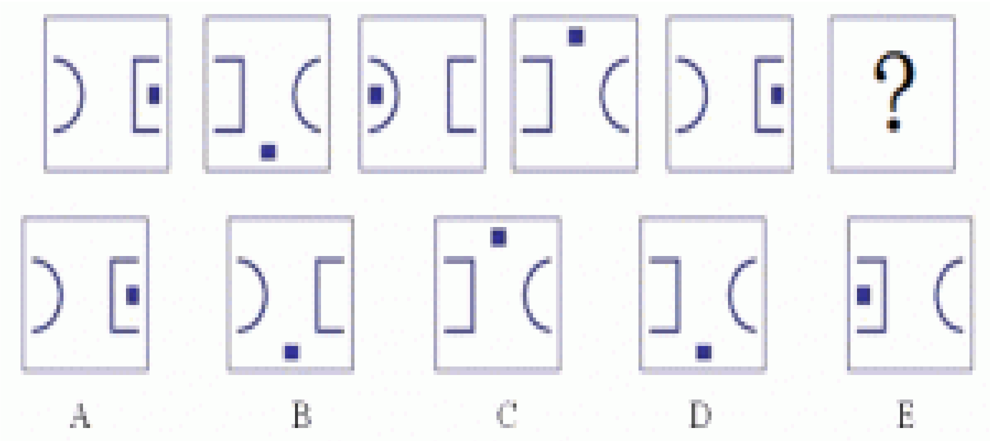


Rajah 4

Objek-objek dalam Rajah 4 boleh dikategorikan sebagai

A. mempunyai bahagian yang boleh bergerak
B. mempunyai saiz yang sama
C. memerlukan kanta pembesar untuk dilihat
D. diperbuat daripada satu bahan sahaja

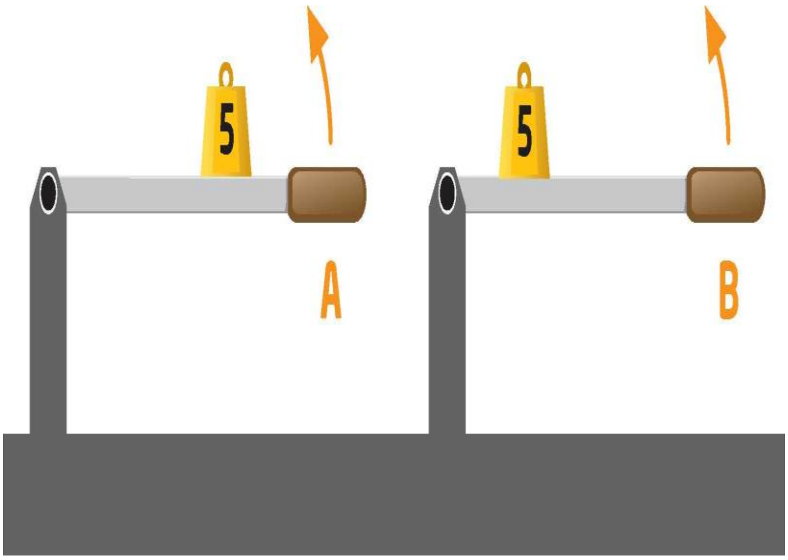
12. Apakah yang sepatutnya ada dalam kotak yang terakhir?



13. Pilih perkataan yang paling berbeza dalam kumpulan yang berikut.

A. Singa
B. Cheetah
C. Beruang
D. Harimau

14. Antara pemegang A dan B, yang mana lebih mudah untuk diangkat di mana kedua-duanya mempunyai berat sebanyak 5kg?



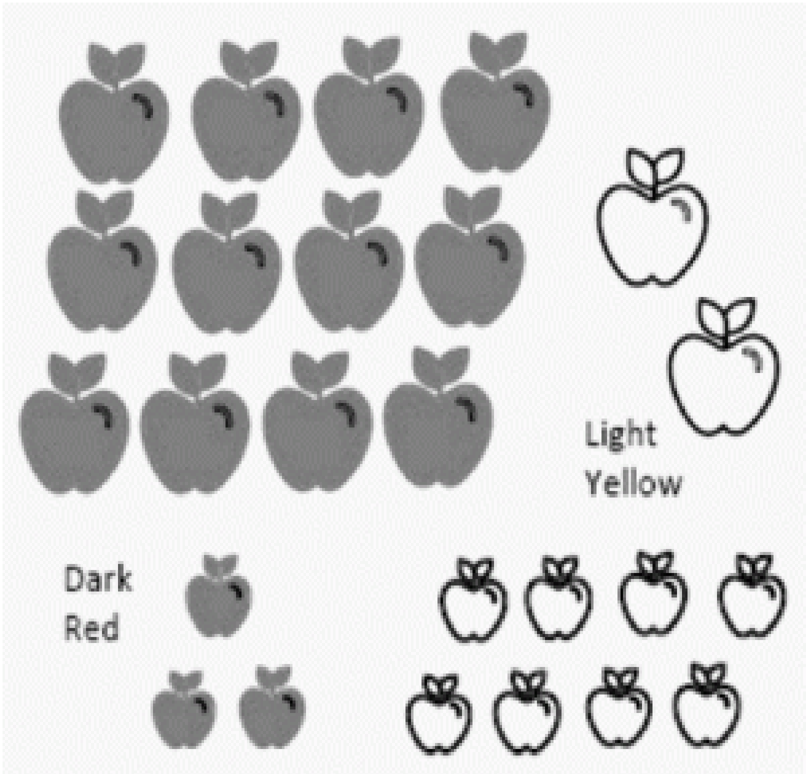
Rajah 5

A. Pemegang A
B. Pemegang B
C. Kedua-dua pemegang A dan B pun mudah diangkat.
D. Saya tidak tahu akan jawapannya.

15. Terdapat sebuah kabin yang kecil dalam sebuah hutan. Di dalam kabin tersebut ada dua mayat lelaki. Pokok-pokok sekeliling kabin tersebut sedang terbakar. Namun kabin tersebut tidak dijilat api. Kedua-dua lelaki itu menyerang antara satu sama lain dan tidak memiliki apa-apa senjata. Bagaimana mereka meninggal dunia?

A. Mereka telah bergaduh antara satu sama lain.
B. Mereka mati disebabkan kebakaran.
C. Mereka tidak dapat bernafas dan mati.
D. Mereka mati sebab tertembak antara satu sama lain.

16. Anda dan kawan-kawan anda telah membeli beberapa epal dari pasar. Epal-epal itu sama ada kecil atau besar dan merah gelap (*dark red*) atau kuning terang (*light yellow*). (lihat Rajah 6). Bayangkan kesemua epal tersebut telah dimasukkan ke dalam sebuah bag yang anda tidak dapat lihat warna atau saiz epal dari luar.

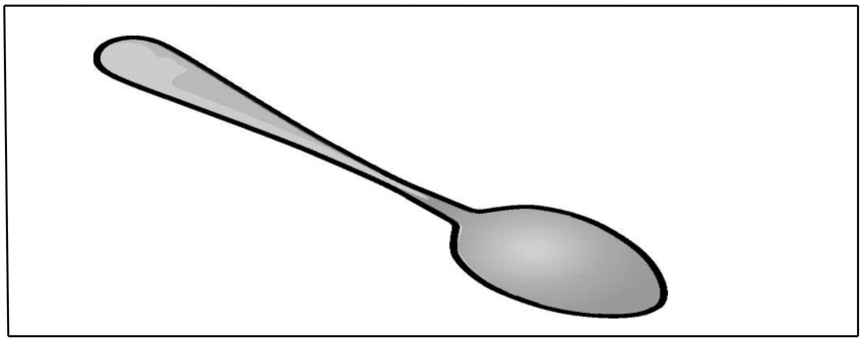


Rajah 6

Jika anda menutup mata dan masukkan tangan ke dalam beg berkenaan untuk memilih sebiji epal. Anda dapat merasakan epal tersebut adalah besar. Apakah kemungkinan warna epal tersebut?

A. merah gelap
B. kuning terang
C. peluang yang sama untuk epal merah dan kuning
D. tidak boleh dikenalpasti

17.

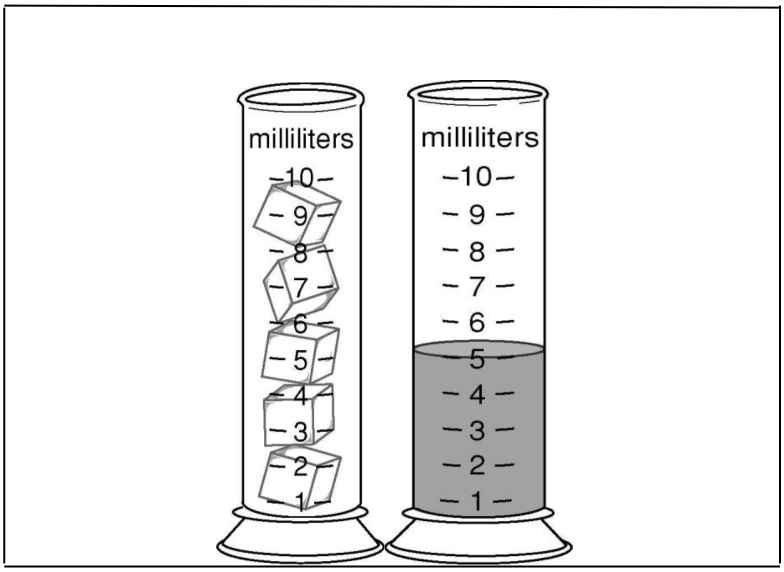


Rajah 7

Yang manakah ciri yang **paling sesuai** untuk menjelaskan permukaan sudu logam itu?

A. Kecil
B. Licin
C. Fleksibel
D. Berkilat

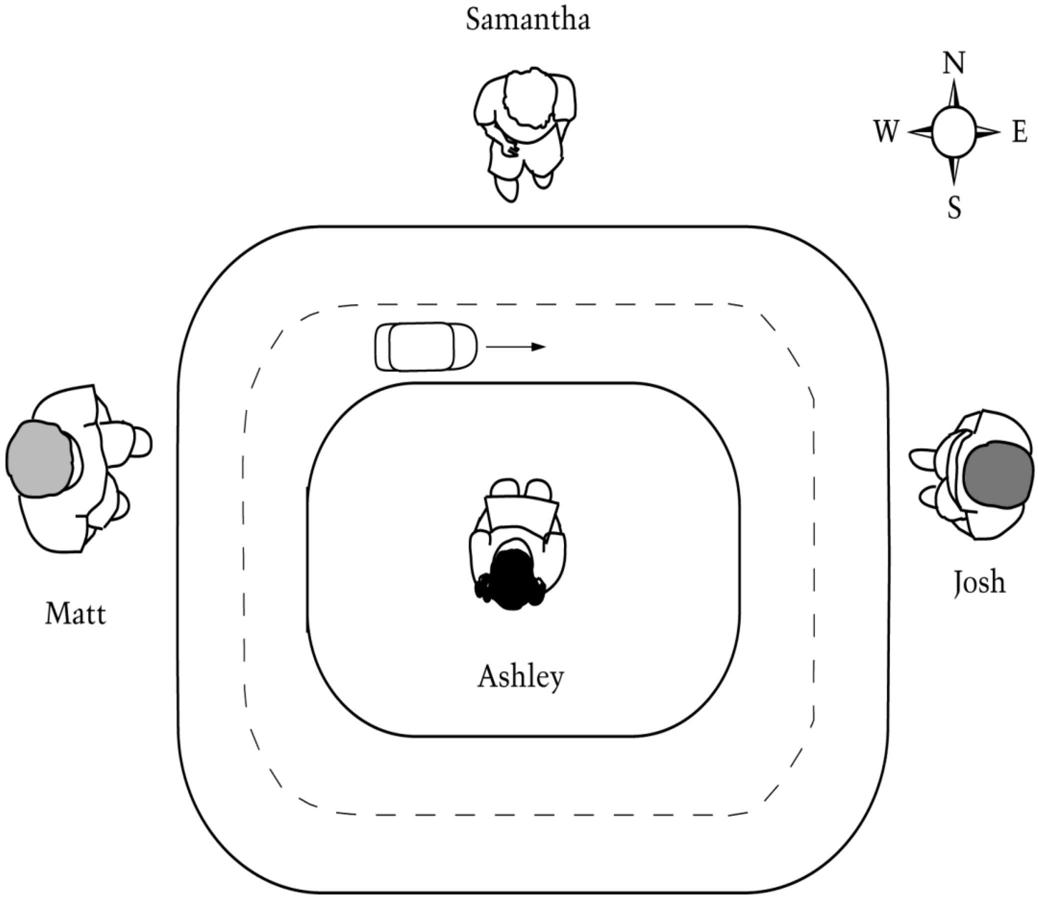
18. Sebuah bekas diisikan dengan ketulan ais. Bekas tersebut dibiarkan di luar sehingga kesemua ketulan ais itu cair. Berdasarkan Rajah 8, berapa banyak air yang terkandung dalam ketulan ais itu?



Rajah 8

A. 3 milliliter
B. 5 milliliter
C. 7 milliliter
D. 10 milliliter

19. Rajah 9 menunjukkan pandangan atas sebuah kereta mainan yang sedang bergerak dalam trek litar yang melengkung. Empat murid yang bernama, Matt, Samantha, Josh, dan Ashley sedang berdiri dalam kedudukan yang ditunjukkan dalam Rajah 9 yang sedang memerhatikan pergerakan kereta mainan tersebut.

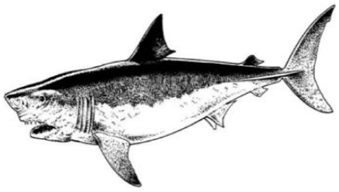


Rajah 9

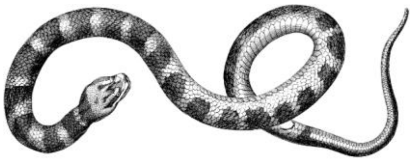
Apakah kesimpulan yang boleh dibuat oleh murid-murid itu mengenai pergerakan kereta itu jika simbol N adalah Utara, S adalah Selatan, E adalah Timur dan W adalah Barat?

A. Kereta itu bergerak ke kanan.
B. Kereta itu bergerak ke kiri.
C. Kereta itu bergerak dari Timur ke Barat.
D. Kereta itu bergerak dari Barat ke Timur.

20. Haiwan manakah yang hidup di dalam air sewaktu kecil dan hidup atas darat apabila dewasa?

A. 

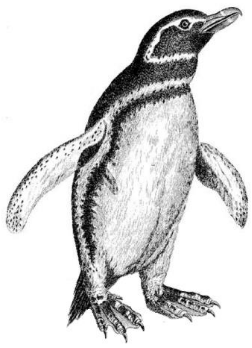
Jerung

B. 

Ular

C. 

Katak

D. 

Penguin

Children's presentation

Malay Language	English Language
<u>Activiti 2: Kincir Angin</u> Kumpulan 1 Apabila kita guna kincir angin, bumi kita ni sihat. Tidak ada pencemaran. *Nampak (sambil memutar bilah kincir angin menunjukkan kepada seluruh kelas) Gelak tawa seluruh kelas dengan aksi murid yang bentang.* Kincir angin ni berfungsi dengan menggunakan motor (sambil menunjukkan motor) dan bila dia (bilah) pusing, cahaya merah di bawah ini menyala. Ahli kumpulannya menjerit: Itu tanda kejayaan! Murid terus memusingkan bilah supaya lampu merah terus menyala. Murid-murid dalam kumpulan lain bertepuk tangan. Ahli kumpulan lain pula: Cikgu, dah siap! Cikgu dah siap! Nak bentangkan model mereka juga. Kumpulan 2 Kincir angin ini dapat dihasilkan dengan bekerjasama, semangat kawan-kawan saya. Kami menggunakan botol mineral dan sebagainya untuk menghasilkan lampu tanpa menggunakan petroleum, gas asli dan sebagainya. Murid menggunakan jari dan memutar bilah, lalu lampu merah menyala. Bertepuk tangan! Cikgu, kami dah siap! (Tak sabar nak bentang) Kumpulan 3 Kincir angin ini menghasilkan lampu tanpa menggunakan petroleum, bateri dan sebagainya. *(Sambil putar, lampu merah menyala).* Kami buat ini dengan penuh semangat.	**<u>Activity 2: Windmill</u>** Group 1 When we use the windmill, our Earth is healthy. No pollution. Look (*the child turned the blades of windmill and showed to the class*). *There were burst of amusement looking at the way the child presented.* This windmill functions by using a motor *(the child pin pointed the motor)* and when the blades turn, a red light lights up below. *Group members' shouts:* That's the sign of success! *The child continues to turn the blades to allow the red light continue to be seen. Other group members clapped their hands.* Other group members: Teacher, we have completed! Teacher we have completed! (They wanted to present their prototype as well) Group 2 This windmill was produced with cooperation, (and) my friends' willpower. We used mineral bottle and other (things) to produce light without using petroleum, natural gas and others. *(The child used the finger and turned the blades, the red light was seen) Hand claps were heard!* Teacher, we have completed! (Children were impatient to present) Group 3 This windmill produced light without the usage of petroleum, battery and others. *(While turning the blades, the red light was seen).* We did it with lots of passion.

Kumpulan 4 Kincir angin ini membekalkan kita tenaga elektrik. Arr..Tanpa menggunakan petroleum, ia boleh menghasilkan tenaga elektrik. Arr, hm..Kita belajar cara bekerjasama untuk membuat kincir angin ini dan cara untuk berkongsi. *(Sambil putar, lampu merah menyala).* Kumpulan 5 Walaupun kincir angin berfungsi, tiada wakil murid untuk bentang sebab segan untuk bentang.	Group 4 This windmill supplies us electric energy. Arr..Without using petroleum, it can produce the electric energy. Arr..hm..We studied the way of cooperating to design this windmill and the way to share. *(While turning the blades, the red light was seen).* Group 5 Though the windmill functioned, there were no representatives to present because the children were shy.
<u>Activiti 5: Robot Humanoid</u> Kumpulan 1 Ini adalah robot humanoid (*sambil melihat dan memegang robot).* Ia banyak membantu manusia dalam pekerjaan seharian ataupun pekerjaan2 manusia yang perlu dibantu. Robot ini dicipta bersama-sama dengan ahli-ahli kami. Robot ini mempunyai system yang sangat hebat. Ada apa-apa soalan? Kumpulan 2 Ini ar..Robot. Kumpulan saya cipta 3 jenis robot, pastu combine jadi satu. Pastu dah jadi tinggi macam ini (sambil tunjuk model, menggaru kepala mcm berfikir). Dia ada pelbagai jenis robot, dia ada robot warna-warni arr..ar…,pastu kami buat ini kerjasama antara satu sama lain. Kumpulan 3 Kemunculan robot ini sangat penting. Robot ini boleh digunakan dalam pertanian, boleh bermain, kanak-kanak boleh gunakan robot ini dan bermain. Nama robot ini adalah robot Doremon *(kelas gelak tawa).* Dia membantu membuat kerja-kerja bantu manusia. Dia	**<u>Activity 5: Humanoid Robot</u>** Group 1 This is humanoid robot *(while observing and holding robot).* It helps human a lot in daily work or other work that needs to be helped. This robot is designed together with our mates. This robot has sophisticated system. Any questions? Group 2 This ar..Robot. My group created 3 different robots, then combined them into one (robot). After that, it became tall like this *(while showing off the prototype, the child scratching the head indicating of thinking gesture).* It has many types of robot, it has colorful robots (parts of robot) arr..ar…,then we design this (the robot) by cooperating with one another. Group 3 The emergence of this robot is very important. This robot can be used in agriculture, for playing, children can use this robot and play. The name of this robot is Doremon *(the entire classroom laughs).* It can stand, yea, won't fall. Stable *(while placing the robot on the table).* The class

juga boleh stand yea, tak jatuh. Stabil (sambil letak atas meja) Kelas tepuk tangan. Kumpulan 4 Ini adalah robot humanoid. Kegunaannya adalah untuk membantu manusia memajukan err…errr…Nama robot ini Robot Tornedo. Saya rasa robot ini kegunaan…dah itu saja..Tanpa ditanya, murid ingin bertanya sangat (mengangkat tangan) Kumpulan 5 Ia juga, robot ini juga boleh membantu kami ataupun membantu manusia dalam pekerjaan seharian ataupun keluaran ataupun ekonomi. Cara-cara mencipta robot ini, kami menggunakan kad board ataupun robot *(sambil belek2).* Kami ada melukis sedikit kat bahagian sini dan sini (*sambil tunjuk).* Nama robot ini adalah IronRod. Kami menggunakan robot ini sebagai perhiasan kerana robot ini bukanla robot humanoid yang lebih hebat ataupun yang sebenar ataupun lebih berkuasa ataupun berteknologi.	applauds. Group 4 This is humanoid robot. The use is to help human in developing err…errr…The name of this robot is Tornedo. I think this robot has its uses…ok, that all.. Though the presenter did not open to the floor for questions, other classmates were eager to ask questions to the presenter as they were raising their arms. Group 5 This robot also helps us or helps human in daily work or production or economy. The ways of designing this robot is, we used card boards or robot *(observing the prototype simultaneously)*. We have sketched a little here and there *(while showing to the classmates).* The name of this robot is Iron Rod. We used this robot as decoration purpose because this is not the more sophisticated or the real one or more powerful or with technology.

Appendix 27

Question and answer after presentation

Malay Language	English Language
<u>Activiti 5: Robot Humanoid</u>	**<u>Activity 5: Humanoid Robot</u>**
Soal Jawab Kumpulan 1	Question & Answer Group 1
Murid 1: Berapa umur robot tu?	Child 1: How old is your robot?
Respon: Kami baru siap buat.	Answer: We just designed it.
Murid 2: Kalau robot ni tolong manusia, nape ada benda-benda tu *(sambil tunjuk robot)* ada kat robot? Apa guna benda tu?	Child 2: If this robot helps the humans, why does those gadgets *(while pointing at the robot)* in the robot exist? What is the use of it?
Respon Ianya boleh digunakan sebagai pengangkutan. Kalau besar la, dia boleh masukkan manusia di sini *(sambil tunjuk benda itu).* Kat sini, kita boleh buat helicopter *(sambil tunjuk atas robot)* supaya dia boleh terbang dengan manusia *(sambil angkat robot itu).*	Answer: It can be used as transport. If it's big, human can be kept here *(while showing the gadgets in robot).* Here, we can design a helicopter *(while showing upper part of robot)* so that it can fly with human *(while lifting up the robot).*
Murid 3: Adakah robot ni stabil?	Child 3: Is it stable?
Respon: Dia stabil. (*Murid letak robot atas meja dan buktikan robot yang dibina itu stabil. Murid lain dalam kelas beri tepukan gemuruh sambil kata 'fuh').*	Answer: It is stable. *(The presenter puts the robot on the table and proves that the designed robot is stable. Other children in the class give a loud clap and responses by saying 'fuh').*
Soal Jawab Kumpulan 2	Second presentation, Group 2
Murid 1: Apa guna robot ni?	Child 1: What is the use of this robot?
Respon: Robot ni bantu manusia dalam semua benda.	Answer: This robot help the humans all fields.
Murid 2: Apa nama robot awak?	Child 2: What is the name of your robot?
Respon Name robot ini adalah robot Bazuka. Kalau ada angin, robot ni boleh terbang.	Answer: The name is Robot Bazuka. If there is wind, this robot could fly.
Murid 3: Kalau robot ni boleh main bola sepak, apa position dia leh main?	Child 3: If this robot can play soccer, what position it can play?
Respon: Kalau dia leh main bola sepak, dia jadi goal keeper.	Answer: If it plays soccer, it becomes the goal keeper.

Soal Jawab Kumpulan 3 Murid1: Leh robot ni buat kerja rumah? Respon: Boleh. Murid2: Leh buat sekarang? Respon Sekarang dia takde bateri, jadi dia tak dapat buat. *(Murid bertepuk tangan dengan spontan, tanda pujian untuk jawapan murid).*	Third presentation, Group 3 Child 1: Can this robot do school homework? Answer: Yes. Child 2: Can it do now? Answer: Now it doesn't have battery, so it can't do. (*Children clap their hands applauding the presenter's answer)*
Soal Jawab Kumpulan 4 Murid1: Leh robot awak terbang? Respon: Boleh. Murid2: Macam mane dia terbang? Respon Ade kipas sini *(sambil tunjuk robot).* Ada ahli kumpulan lain bantu pembentang. Murid3: Ada enjin ke? Respon: Ada, kat bawah ni ha. (Murid dan ahli kumpulan jawab dengan spontan). Murid4: Boleh robot awak berdiri? Respon: *(Murid letak robot atas meja dan tunjuk macam mana robot boleh berdiri). (Rakan sekelas menjerit "Yeay" and bertepuk tangan untuk murid yang bentang).* Murid5: Kalau robot tu boleh tukar bentuk, bentuk apa dia boleh tukar? Respon: Tukar bentuk? (Murid tak pasti dengan jawapan, tengok atas sambil berfikir).	Fourth presentation, Group 4 Child 1: Can this robot fly? Answer: Yes. Child 2: How can it fly? Answer: There is a fan here *(pointing at the robot)*. The group members help the presenter. Child 3: Is there an engine? Answer: Yes, at the bottom of the robot. *(The presenter and group members spontaneously answered).* Child 4: Can your robot stand? Answer: *(The presenter puts the robot on the table and shows to the classmates that it can stand). (The classmates shouted 'Yeay' and clapped their hands for the presenter).* Child 5: If your robot can change its shape, what shape can it change into? Answer: Changing shape? *(The presenter was unsure of the answer, looking up and thinking).*
Soal Jawab Kumpulan 5 (Tiada sesi soal jawab sebab pembentang gelisah dan segan untuk menjawab).	Fifth presentation, Group 5 (There was no question answer session since the presenter was nervous and shy to answer questions).

Appendix 28

Curriculum Vitae (CV) for thematic analysis experts

No.	Name	Country	Academic level	Research areas	Professional services	Years of experience	Honours, awards & contributions
1.	Christian Dieter Schunn	Pittsburgh, United States (US)	Professor & research scientist	STEM education, reasoning and learning, neuroscience of complex learning, engagement and learning and web-based peer interaction	Committee member of National Academy of Engineering (NAE) and International Society for Design & Development in Education	27 years (since 1987 to present)	Society fellowships (2011), conference awards (2003), research fellowships (1995) and undergraduate awards
2.	Kumaraguru Mahadevan	Sdyney, Australia	Management consultant & researcher (engineering)	Fleet management operation at Uniting Care Australia	-	7 years (since 2009 to present)	Publications in established journals. Presented papers at local, international conferences.
3.	Rebecca Petersen	Iowa, United States (US)	Teacher & researcher	STEM academic manager, STEM specialist & STEM coordinator especially for 3-D engineering projects.	-	15 years (since 2001 to present)	Worked closely with schools in Thailand for elementary school children on STEM education. Specialist for direct hands-on participation in designing 3D models
4.	Jessie Grace U. Rubrico	KL, Malaysia	Senior Lecturer	Language, literacy, linguistics & pedagogy	Visiting senior lecturer, examiner & featured researcher for innovations educational research	7 years (since 2009 to present)	Publications in established journals. Presented papers at local & international conferences
5.	Denis Lajium Andrew	Sabah, Malaysia	Senior Lecturer	Chemistry education & science education	-	15 years (since 2000 to present)	Publications in established journals. Presented papers at local, international conferences.
6.	Richard Clint Penny	Bath, United Kingdom	Senior Lecturer & Researcher	Photonics, physics & engineering	-	12 years (since 2004 to present)	Publications in established journals. Presented papers at local, international conferences.
7.	Siti Aishah	Perak, Malaysia	Teacher	Elementary science	-	18 years (since 1998 to present)	District chief for science education

Examples of experts' responses during the thematic analysis

Experts	Examples of experts' responses
One	…Good work! Your coding – sorting process is fine: first cycle coding method (theming data); post-coding (code mapping); second cycle coding (pattern coding). However, I miss the synthesis of all data presented which triggers theorizing. You have systematically presented your findings. …I now will sleep on it as a read-through is needed to conclude if your coding, categories and themes are supporting your HOTS connection. My first inclination is to say 'yes' but I believe more direct connection is needed to why/how these all support/are related to HOTS. Your audience will not necessarily all be academics who understand "behind the scene assumptions.
Two	…I've looked at the information you gave me in the attachment and email multiple times over several weeks. All I can say so far as the work seems appropriate and interesting, but I feel is a necessary to provide appropriate foundation knowledge to gain greater perceptiveness. …Interactive thinking is conceptualized as a mundane way a child has of handled information in CETM activities. Interactive thinking is characterized by a particular sequence or pattern of thoughts. Different types of responses display different type of thinking.
Three	…Wow-very impressive, detailed thinking on how to code your data. A very good start indeed. I did a few run through as follows: Grammar/written word consistency. I highlighted wording issues in yellow. In short, be consistent in your verb tense in each section. …The children have identified own strengths, limitations and ways to improve. For instance, children kept trying to improvise the prototype until it could fly (Activity 1: Plastic Parachute). Some of them also carried a chair and stood on it to test the prototype without asking them to do so. Children also kept asking the teacher to give permission on continuing to design because they were not satisfied with the prototype. Hence, for this section, I am in line with the code placing children's ideas of improvement.
Four	…Some of the sketches (Activity 2: Windmill) yield unanticipated answer. For instance, most of the windmill sketches included the essential components of windmill which are the tower, axle and vanes, and their assembly. These components of windmills were unexpected because windmill prototypes are rarely exposed among children. …Cohesion. Be consistent in generalizing your idea first, then supporting it with actual examples. You bounce back and forth between idealism and actual.

Five	…I see that children have classified their own limitations. They have used personal standard for evaluating success and effectiveness of own actions. For instance, children tested and evaluated the prototype (Activity 4: Metal Tin Robot) without the teacher's instructions while producing their own benchmark by taking things into their hands. Children also seldom paid attention to the teacher because too excited handling the prototype by themselves. I do agree that children use their own limitation to place their own thoughts in improving the prototype. …Had another look at the work. No problem there except you need to link to the work of other researchers. Made some suggestions on the categories. Let's talk about this on Skype.
Six	…Cross-referencing. Your tables are good at triangulating your data. But it's easy for the reader to get "lost" as you have so much of it. It would be helpful to increase your numbering/leveling. Either use numbers 1 to .... for all items or use 1a, 1b, 1c etc if you want to keep your subgroups (I think this would be best).
Seven	…This category denies the limited scope in studying reasoning skills since it represents interactive thinking and instructive mind construal. Through observation and listening, a child could engage in a reasoning process. Both observation and listening focuses on two ways thinking which not necessarily involve a two people because it could also involve the classroom atmosphere (teacher & children) and the CETM activity itself. In short, the frame minds analysis which observed through sketches and shared thoughts the children to engage in the reasoning process. …Now, map out an Operational Model Diagram to show the relationships among codes, categories themes. This will also show your theoretical framework and will afford your readers a full picture of your work in just one diagram. This will also clarify your theorizing and enhances your understanding and appreciation of your contribution to pedagogy. Synthesis also gives you a perspective on how the findings answer your research question/s. I hope this helps as I wish you all the best on this significant contribution to pedagogy.

Definition of codes and subcategories for Research Question Three

No.	Sub-categories	Codes	Source of the findings
1.	**Justifications:** Throughout CETM activities children have justified their responses through sketches while brainstorming for ideas and written answers. Children's ideas were based on evidence and inference. Their answers were expressive and open. For example, in Activity 4 children justified that machines such as metal tin robots need to be flexible and transformative. A child wrote that, *"Machines that can change itself like us changing ourselves, following our needs."* At the same time, children's sketches had written notes indicating the purpose of each robot. For instance, the sketches in Activity 5 exhibited the duty of a robot as *"I am a cleaner"* and *"I am a teacher".* The body position of each sketch was raised up indicating that the robots were ready to function. Apart from that, children also showed the difference between a teacher and a cleaner. The child used the broom which showed that the child differentiated the relationship between a cleaner and a teacher. Other sketches were well organized and evident with short notes such as food, water and 'buka' which means open. For instance, the parachute design was illustrated as strong and stable to withstand the	***Explaining using key features:*** Children's sketches were scrutinized and varied based on several key features such as shapes, pattern, symbols, numbers and its expressiveness. a) <u>Shapes</u> Several different types of shapes were sketched in the brainstorming section. Shapes such as triangles, squares, rectangles, spheres, ovals and others were sketched during the CETM activities. b) <u>Pattern</u> Some of the drawings were colored and decorated with lines, circles, shades and hearts. c) <u>Symbols</u> Several other drawings had measurement symbols such as kilograms (kg) and meters (m). There were also symbols such as block arrows, bent arrow and circular arrow. d) <u>Numbers</u> Mathematical figures were also infused into the drawings. Numerical digits such as one, seven and ten were incorporated in explaining the sketches. e) <u>Expressive</u> There were also animated drawings. For example, the humanoid robots were expressed using the cartoon figures such as ninja, doremon and transformers. The sketches were vibrant and lively with these	a) Sketches

	weight of food and water for the pandas. Each design brainstormed the fusion between the creativity and technical ability, especially from the existing ideas to the improvised sketches. These assertions are categorized into explaining using key features and adapting logical examples.	expressions. In another instance, most of the windmill sketches included the essential components of windmill which are the tower, axle and vanes, and their assembly. These components of windmills were surprising justifications among the children because windmill prototypes were rarely exposed among children. The various sketches displayed the ways of solving problem in each activity. The heights of ingenuity for the sketches are wide-ranged from being imaginative, displaying relationships, showed improvement on existing ideas and finally justified the solutions.	
		Adapting logical examples: Children used logical examples to justify their answers. Some of the answers had definite and specific examples. For example, in Activity 1 where the children designed a plastic parachute, a child gave 'hovercraft' as an alternative example. The child mentioned that: *"No, it will move smoothly if we used hovercraft."* In another situation, during Activity 5, a child mentioned that humanoid robots are crucial to attract interest from people. The child wrote: *"The humanoid robot can attract interest from people within and outside the country."* The answers had a collective logical meaning that was common or open to all of us when referring to the importance of humanoid robots. Moving forward in another example during	a) Children's written answers

		Activity 2, children logically justified the limitations of a windmill prototype. The children mentioned that: *"There is no electric if there is no wind".* In a similar situation for Activity 2, children's written answers were sensibly written depending on their observations and previous knowledge. For example, a child wrote that: *"There are few windmills in Malaysia, that's why humans use petroleum and produce pollution."* In general, the written answers were justified with acceptable examples. The answers were rational and uniformly arranged.	
2.	**Evaluation:** During the CETM activities, children used evaluation skills to make sufficient claims and build their arguments. Children placed own ideas of improvements and they experienced accepting criticism throughout all the activities. For instance, children assessed the ideas of other group members to give their independent feedback. Some of the children's answers were complex and it does not represent direct understanding. For example, while writing the evaluation for metal tin robots, children criticized its functionality by saying: *"The limitation of movement for a robot is one of the problems and so is functionality."* These responses from the children displayed the effort in trying to reason out their opinions in trying to design a better prototype. In a different	***Placing own ideas of improvement:*** Children placed their own ideas of improvement through the sketched, written answer, verbal expression, testing prototypes and other interactions which refers to classroom observations. In numerous situations children gave their own ideas to improve their prototypes. In some situations, they reconsidered own ideas in light of input of others. For instance, in Activity 1, while designing plastic parachute, a child raised the voice and said: *"Listen! Listen! You do that, I will do this."* (Delegating the task by leading the group using their own ideas). Soon after that, they evaluated the plastic parachute which used strings and plastics. The plastic parachute was not flying as it supposed to fly and simultaneously, another child mentioned that: *"Because the string was too short."* Meanwhile, other group	a) Sketches b) Children's written answers c) Verbal expression & testing prototypes d) Children's various interaction in the classroom

	example, while designing windmill prototype, it was observed that a child criticized her group member by saying: *"This is wrong, la, it's the other screw, not this one".* The other team mate listened to the criticism and used the screw proposed by her group member to design the windmill.	members shook their heads agreeing, when their group member explained. Consequently, children identified the prototype's strength, limitations and ways to improve the designed prototype. For instance, children kept trying to improvise the prototypes until the prototypes can function. Children were observed to constantly evaluating and improvising the plastic parachute in Activity 1 until it could float properly in the air. Some of them also carried a chair and stood on it to test the plastic parachute without asking them to do so. Children also kept asking the teacher to give permission on continuing to design because they were not satisfied with the prototype. These were some examples of how the children placed their own idea to improve their prototypes.	
		Accepting criticism: Open-mindedness reflects the flexibility in a discussion. The ability to accept criticism or suggestions while placing own ideas and different points of views displays the elasticity in conversations. Answers resembled judgment followed by the critic. For example, when the children wrote their evaluations on how to improve the metal tin robots for Activity 4, a child responded that: *"If we add decorations, it will become heavy."* When asked upon the child as why he mentioned that since most of the children agreed that decoration is one of the way to improve the prototype, he criticized them by saying *"It is more important for it (metal in*	a) Verbal expression & testing prototypes

		robot) to move than coloring it (decorating it)." The recipe of saying "Yes", followed by narrating the idea of decorations and finally criticizing the idea showed the synthesis of engaging in reasoning progression.	
3.	**Different viewpoints:** Throughout the activities, children expressed different viewpoints especially in written answers, verbal expressions and while testing the prototypes. Children brought together their different ideas into a unified whole concept. For instance, there were questions such as "Why" and "How" asked by the classmates after the presenting the prototype as the final cyclic process. These questions tie the entire explanation of how and why the prototype was designed. As a result, children were often observed to shift into an alternative gear when a solution or method is not working. For instance, children from different groups tried to tie different strings with different lengths to design a firm plastic parachute during Activity One. The children concluded that it was not necessary for the string be with one particular standard length. This is because, different length produced plastic parachute with different types of flying ability. Children used different viewpoints through showing unexpected solutions and the ability to manipulating variables during the activities.	***Unexpected solutions:*** Some of the written answers and verbal expressions yielded unanticipated answer. Children's answers showed sufficient detail for the thinking behind the narrated idea. For example, when some of the children continued tied the box contained food and water to the plastic parachute in Activity 3, a child mentioned that it was a dangerous way to send water and food for the dying pandas. The child responded that "*It's a dangerous idea especially if the string gets snapped."* The elaboration was matured and deeply figured out. Instead the child proposed to collaborate with another group and discussed with them to send water and food in two different plastic parachutes instead of one. This was an unexpected solution because each group were only encouraged to design one plastic parachute but this particular child has used two different plastic parachutes to send water and food, separately. In an another situation, a child mentioned that instead of worrying for the decreasing petroleum and natural gas, it was more appropriate to design cars and lorries that doesn't use petroleum and natural gas. The child revealed that: *"We can do vehicles that do not use minerals such as petroleum."*	a) Children's written answers b) Verbal expression & testing prototypes

		Manipulating variables: Children manipulated variables (tools and materials) that were not provided. The children thought out of the box and reasoned with different set of ideas while evaluating the prototype. For example, while evaluating the metal tin robot for Activity 4, several children provided different ways in manipulating the variables and creating a better prototype. A child mentioned that: *"I want to put more tires and engine to make the robot more useful."* Other child said: *"Basket can keep metals and other materials."* Variables such as tires, basket, engine and other materials were manipulated in the argument, unconsciously yielding a synthesized thinking process.	a) Verbal expression & testing prototypes b) Children's various interaction in the classroom
4.	**Construct engagement:** Throughout the process of designing the prototypes, children argued and reflected on what they were working on. Children were observed to be not only working in groups but eventually cooperating with other members from other groups and also the teacher. For example, in Activity 4, children invited other groups to race using their designed prototype to observe which was faster. Children constantly asked the teacher about the next activity and gave ideas on what could be designed. Children also helped each other by holding and supporting the prototype. They showed a thumb to a group member when the teacher praised him/her. At the same time, they clapped their hands for	***Argumentation:*** Argument depends on the final judgment, claim, decision and belief of a child. An argument synthesizes different points of view or strands of evidence. However, the structure and the quality of an argument during the CETM activities differs from initial codes such as clear, relevant, adequate and significant. Some of the responses indicated disagreements with combination of detailed reasoning. For example, when children designed humanoid robots in Activity 5, they were discussing with each other. It was observed that when most of the children in a group agreed that more cardboards must be added to design a huge humanoid robot, one particular child disagreed. The child argued that: *"No. It would be broken easily. It would add too*	a) Children's written answers b) Verbal expression & testing prototypes c) Children's various interaction in the classroom

	each group presentation. These types of engagements involved constant arguments and reflections from the children. Children were seeing arguing and reflecting with one another to design a better prototype.	*much weight and will not move (stand-still)."* These responses were synthesized using evidence and concrete explanations. It was observed that children were engaged in a complex but appropriate verbal argumentation throughout the CETM activities. For instance, the children and the teacher were also continuously exchanging questions and answers while designing a prototype. The conversations are occupied with questions and remarks of *'maybe it could be'* or *'I think'*.	
		Reflection: Reflection indicates the maturity to consider own strength and limitations besides evaluating other's work and pinpoints on how to improve the prototype. This consideration represents the possibility of having a decent educational in a discussion. It was observed that children reflected their mathematical knowledge when they used their fingers to signify the items (threads) they were counting in Activity 1. Another child turned back on the group that completed the design and rushed towards his/her group to repair the prototype. The child touched each other's shoulder to seek attention, to give some feedback in regards to the other successful groups. Children constructed their knowledge by reflecting on what was done by other groups' members. They reflected on their previous knowledge, observation and experience while designing the prototypes in the CETM activities. On a different note, child was observed to be	a) Verbal expression & testing prototypes

		listening more to the group members than the teacher. Gestures of tolerance seen when the children gave in to one and another. Children were seen to pass the tool or the prototype itself without much hesitance. These types of considerations were observed throughout the activities.	