UPTAKE OF SKILLFULL THINKING INFUSION AMONG SELECTED YEAR FOUR SCIENCE TEACHERS THROUGH STEPS

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ABSTRACT

This study explored selected teachers infusion of skillful thinking (ST) into Year Four Science subject matter. ST consists of three elements: teaching of various thinking skills, development of learners' habits of mind and cultivation of metacognitive thinking among learners which should be taught simultaneously with subject matter. Though each element has many sub-elements, for the purpose of this study only one sub-element from each element was chosen. They were analysing information and ideas, habit of questioning and problem posing, and awareness in metacognitive thinking. The study was divided into two phases. Phase 1 consisted of gaining insight into teachers' current ST practices and used these insights to prepare an educative material, Skillful Thinking Educative Pedagogical Support (STEPS) to support teacher learning in infusing ST for the topic 'Properties of Materials'. Phase 2, the dominating phase for this study, was the implementation of STEPS that described changes in teachers' practices of ST infusion and how STEPS had influenced the infusion of ST. In Phase 1, nine purposively selected Year 4 science teachers from schools in Negeri Sembilan participated. Qualitative data collection techniques such as semi-structured interviews with teachers, classroom observations and focused group interviews with students were employed. Using constant comparative method, three themes emerged about the selected teachers' ST practices. The themes were lack knowledge on ST, lack pedagogical skills of ST and poor classroom management. Based on these findings, STEPS was designed. STEPS was conceptualized as design heuristics that consisted of educative features that delivered recommendations and rationales on how the teachers might infuse ST into lessons. Three teachers from Phase 1 participated in Phase 2. Qualitative data collection techniques were employed as

in Phase 1. Using constant comparative method three themes 'teachers teach students to analyse information and ideas about properties of materials', 'developing students' habit of asking questions and posing problems' and 'promoting students to be aware of their thinking and learning' were identified. Within each of them, categories that showed unsatisfactory and satisfactory practices of ST were described. For example, for the first theme, at the unsatisfactory stage, the teachers spent more time in probing students' content knowledge but at satisfactory stage, teachers began teaching students to gather information and ideas about properties of materials, modelling specific thinking strategies to analyse the information and teach to transfer learnt thinking strategies into new contexts. Findings of Phase 2 revealed that all three teachers, eventually were able to independently enact ST infused lessons by adapting recommendations provided in the STEPS. They enacted enhanced lessons that show solid infusion of all three elements of ST. To ensure that these enhancements were actually from the STEPS, this study also described how the educative features helped teachers in enhancing their practices of ST. The study does indicate that in designing support for teacher learning to infuse ST, focus should be on pedagogical areas in which teachers are found to be lacking. Implications of this study and recommendations for future research were discussed.

PENERAPAN PEMIKIRAN MAHIR KE DALAM SAINS TAHUN EMPAT DALAM KALANGAN GURU TERPILIH

ABSTRAK

Kajian ini telah menerokai penerapan pemikiran mahir (PM) dalam kandungan subjek Sains Tahun Empat dalam kalangan guru-guru terpilih. PM terdiri daripada tiga elemen; pengajaran pelbagai strategi pemikiran, pembangunan tabiat berfikir murid dan pemupukan pemikiran metakognitif murid yang perlu diterapkan secara serentak dalam pengajaran kandungan subjek. Walaupun setiap elemen ini terdiri daripada beberapa sub-elemen lain, hanya satu sub-elemen untuk setiap elemen dipilih dalam kajian ini. Sub-elemen tersebut ialah menganalisis maklumat dan idea, tabiat menyoal dan mengutarakan masalah serta kesedaran pemikiran metakognitif murid. Kajian ini terbahagi kepada dua fasa. Fasa 1 menerokai pemahaman tentang amalan semasa pengajaran PM guru, justeru itu, dengan menggunakan pemahaman ini suatu bahan pembelajaran guru yang disebut Bahan Sokongan Pedagogi Pemikiran Mahir (STEPS) telah disediakan untuk menyokong pembelajaran guru dalam penerapan PM ke dalam topik 'Sifat Bahan'. Fasa 2, sebagai fasa utama dalam kajian ini, melibatkan pelaksanaan STEPS menerangkan perubahan amalan penerapan PM guru dan bagaimana STEPS mempengaruhi penerapan PM tersebut. Dalam Fasa 1, seramai sembilan guru Sains Tahun 4 yang dipilih secara persampelan bertujuan dari sekolah di Negeri Sembilan, telah mengambil bahagian. Kaedah pengumpulan data kualitatif seperti temu bual separa struktur bersama guru-guru, pemerhatian kelas dan temu bual kumpulan berfokus murid telah digunakan. Dengan menggunakan kaedah perbandingan berterusan, muncul tiga tema tentang amalan PM dalam kalangan guru-guru terpilih. Tema-tema tersebut ialah kekurangan pengetahuan

PM, kekurangan kemahiran pedagogi PM dan pengurusan kelas yang kurang memuaskan. Berdasarkan dapatan ini, STEPS telah direkabentuk. STEPS dikonsepsikan sebagai reka bentuk heuristik yang terdiri daripada ciri-ciri pembelajaran untuk menyampaikan cadangan serta rasional bagaimana guru-guru boleh menerapkan PM ke dalam pembelajaran. Seramai tiga guru dari Fasa 1 terlibat dalam Fasa 2. Kaedah pengumpulan data secara kualitatif telah digunakan seperti mana dalam Fasa 1. Dengan menggunakan kaedah perbandingan berterusan, tiga tema telah dikenal pasti iaitu ‘guru mengajar murid menganalisis maklumat dan idea tentang sifat bahan’, ‘membangun tabiat menyoal dan mengutarakan masalah’ dan ‘mempromosi kesedaran tentang pemikiran dan pembelajaran murid’. Untuk setiap tema tersebut, kategori yang menunjukkan amalan PM yang memuaskan dan tidak memuaskan telah diterangkan. Sebagai contoh, untuk tema pertama, pada tahap tidak memuaskan, guru-guru menghabiskan banyak masa dengan hanya mencungkil pengetahuan murid, tetapi pada tahap memuaskan pula, guru-guru mula mengajar murid mengumpul maklumat dan idea tentang sifat bahan, menunjukcara bagaimana untuk menganalisis maklumat dan idea tersebut menggunakan strategi pemikiran spesifik serta mengajar untuk memindahkan strategi pemikiran yang dipelajari ke dalam konteks baru. Dapatan kajian Fasa 2 menunjukkan bahawa ketiga-tiga guru, secara berperingkat mampu mengamalkan penerapan PM ke dalam pengajaran mereka dengan mengadaptasikan cadangan-cadangan dalam STEPS. Mereka memperlihatkan peningkatan amalan pengajaran PM dengan menunjukkan penerapan berkesan untuk ketiga-tiga elemen PM. Bagi memastikan peningkatan amalan ini adalah berkait dengan penggunaan STEPS, kajian ini juga menerangkan bagaimana ciri-ciri pembelajaran membantu guru mempertingkatkan amalan penerapan PM. Kajian ini menunjukkan bahawa dalam membangun bahan sokongan untuk pembelajaran guru dalam penerapan

PM, fokus perlu diberikan kepada bidang pedagogi yang dikenal pasti mempunyai kelemahan. Implikasi kajian and cadangan untuk kajian masa depan telah dibincangkan.

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CHAPTER 1

INTRODUCTION

Introduction

A vast body of research is related to teaching thinking skills to learners, particularly in teaching them to think skilfully (Beyer, 2008b). Thinking skills, such as critical, analytical or creative thinking skills would require different kinds of thinking with specific thinking strategies (Swartz et al., 2008). Specific thinking strategies include procedural mental steps namely, comparing and contrasting, predicting, classifying, cause and effect, generating ideas, reasoning or making conclusions (Beyer, 1995; Walsh, Murphy, & Dunbar, 2007). For example comparing the phenomenon of the Moon and Sun eclipses, looking at how the eclipse of the Sun differs from the eclipse of the Moon or looking for similarities between the two. The use of such thinking strategies enables learners to analyse information they have gathered, thus facilitating subject matter understanding. These thinking strategies should be explicitly taught and put into practice (Beyer, 1987, 2008). As such, teaching thinking requires teachers to teach and develop specific strategies among learners to be skilful in thinking (Snyder & Snyder, 2008).

However, teaching thinking is not merely about teaching the aforementioned thinking strategies. Learners often become frustrated in challenging thinking tasks, therefore, the affective domain of thinking should also be developed as part of teaching thinking (Costa, 1999). The term affective domain in thinking refers to the driving force that learners should possess to be persistent in thinking (Costa, 1999). This persistence in thinking can be cultivated by encouraging students to be open to ideas from others, become good listeners or being comfortable in asking questions and posing problems

(Costa & Kallick, 2000). Costa and Kallick (2000) referred to this affective domain of thinking as habits of mind because it displays certain mental habits, which traditionally are often associated with learners' thinking dispositions or thinking behaviours (Tishman, Jay, & Perkins, 1993). Here, teachers need to create opportunities for learners to mindfully engage with their thinking operations. This is important to keep the momentum in performing thinking operations with persistence, curiosity, open mindedness and flexibility, to name a few (Costa, 1999; Jensen & Greenfield, 2012). Developing learners' affective domain of thinking or habits of mind should also be accompanied by making them reflect upon their thinking performance or widely known as metacognitive thinking. Therefore, the process of teaching thinking strategies has to be extended to guide learners' assessment on their own thinking operation by making metacognitive reflections (Bensley & Spero, 2014). Thinking at a metacognitive level would require learners to reflect upon their thinking on what, when, why and how they had performed the specific thinking strategies in any given thinking task (Beyer, 1998; Fisher, 2007). This is important to make thinking visible so that learners would be able to verbalise their thoughts by describing what and how they think, thus be able to take charge of their thinking (Beyer, 2008b; Fisher, 1998; Metcalfe & Finn, 2013).

The simultaneous integration of the teaching of specific thinking strategies, habits of mind and metacognition is called skillful thinking (Swartz, Costa, Beyer, Reagen, & Kallick, 2008). The term skillful thinking (ST) was introduced by Swartz, Perkins, and Parks as an infusion methodology in teaching thinking skills (McGuinness, 1999). Swartz et al., (2008) repackaged the teaching of thinking skills with two other elements; habits of mind and metacognitive thinking, thus coined it as ST. ST can be integrated into content lessons by the infusion approach. As an infusion, ST caters for developing learners' higher cognitive abilities for thinking simultaneously with subject matter knowledge acquisition. The infusion of ST, particularly among young children would aid the development of their higher order thinking skills or HOTS (Kaplan, 1997; Reagan, 2008). Cultivating ST among young children would facilitate their ability to perform these facets of thinking skills during lessons (Murphy, Bianchi, McCullagh, & Kerr, 2013). Further, learners not only learn to perform cognitive abilities like higher levels of thinking strategies and metacognitive thinking ability, but also acquire the motivation to sustain their performance in thinking tasks.

Hence, teachers play a vital role in implementing curriculum changes, especially in developing students' thinking skills (Ben-David & Orion, 2013; Beyer, 2008a; Thompson, Bell, Andreae, & Robins, 2011). Teachers need to be equipped with the knowledge of ST and the pedagogical knowledge in teaching ST to young children (Swartz, 2008; Zohar & Schwartzer, 2005). Knowledge of ST is about knowing what ST is, for example knowing that ST comprises of three elements – teaching students specific thinking strategies, developing their habits of mind and promoting metacognitive thinking. Next is having the knowledge of practices, which is knowing how to infuse the three elements of ST into their content lessons. This includes knowing how to plan and enact ST rich science lessons and organise small group discussions in classrooms to promote thought sharing about science concepts among students.

One of the ways teachers may acquire the pedagogical knowledge in ST infusion is through using educative curriculum materials (Beyer & Davis, 2009a; Davis & Krajcik, 2005; Davis et al., 2014). Most science teachers would conduct scientific investigations as part of their teaching approach; however, teaching young learners to analyse and generalise their observations can be challenging (Miri, David, & Uri, 2007; Spektor-Levy, Baruch & Mevarech, 2013). For example, once students have completed an investigation, they would need to make a conclusion from their findings about the science concept being investigated. However, teachers need to teach students to use specific thinking strategies, such as to compare and contrast information and ideas (observations). They also need to encourage students to ask questions about their observations and pose problems for further investigation. In addition, promoting students to think about how they had performed thinking strategies to analyse their observations is equally crucial (Kawalkar & Vijapurkar, 2013; King, Goodson, & Rohani, 2012). This would allow teachers to evaluate if their students have developed skills in performing the different kinds of thinking strategies, habits of mind and metacognition (Costa & Kallick, 2000; Swartz et al., 2008). Thus, the challenge for teachers is to explicitly infuse these three elements of ST simultaneously into science content lessons. It is this part of teachers' pedagogical knowledge in infusing ST that needs upgrading. One of the ways to enhance this knowledge or skill is through the usage of educative curriculum materials (Beyer & Davis, 2009; Lin et al., 2012; Arias, Smith, Davis, Marino & Palincsar, 2017).

Educative curriculum materials scaffold teacher-learning on new teaching approaches across various disciplines and thus promote teachers' professional development (Davis & Krajcik, 2005; Davis et al., 2014; Grossman & Thompson, 2008). Such material should be able to provide the rationale and support for teachers with a set of design heuristics to promote teacher learning (Grossman & Thompson, 2008; Mckenny, Voogt, Bustraan, & Smits, 2009; Lin et al., 2012). Design heuristics are a set of rules in designing materials with features that would educate teachers and enhance teacher-learning to adopt new teaching approaches such as teaching ST. Thus, educative curriculum materials with easy access for teacher use could accelerate the development of in-service teachers' pedagogical knowledge in infusing ST in primary science classrooms (Arias, Bismack, Davis, & Palincsar, 2015).

The present study describes the infusion of ST among selected Year Four science teachers, upon using a support for teachers called the STEPS (Skilful Thinking Educative Pedagogical Support). This study consisted of two phases. The first phase was on the preparation of the STEPS, with features to educate the selected teachers in infusing ST in the topic 'Properties of Materials'. The second phase, being the dominant phase of this study, described the infusion of ST, among the selected teachers, upon using the STEPS.

Background of the Study

Science learning is often widely associated with inquiry-based learning, as it involves understanding of various scientific concepts based on scientific investigations This requires teachers to teach students the skills of questioning and seeking scientific explanations (DiBiase & McDonald, 2015). In structured inquiry, students conduct scientific investigations prescribed by the teacher, investigating scientific concepts known in advance to confirm them first-hand. It is important to shift structured inquiry to an open inquiry approach, so that students would learn to propose questions and scientific problems to investigate on their own with less teacher guidance (Zion & Mendelovici, 2012). Furthermore, primary science emphasises the teaching of science process skills, which are also thinking skills, such as observing, classifying, making inferences, drawing conclusions and controlling variables. Within these thinking skills, there are specific thinking strategies that science teachers need to teach students (Beyer, 2008b). For example, to classify, teachers ought to teach students how to attribute, compare and contrast observations and relate observations to make generalisations. Another example would be, in teaching students about properties of materials, teachers need to teach how to compare and contrast properties of different materials, so that they would be able to classify materials according to a common property, such as rubber, plastic and metal objects do not absorb water.

In Malaysia, science is taught in Year 1 (7-year-old children). Year 1 to Year 3 science comprise the learning about the world around them using their five senses. At this level, they learn how to develop science process skills such as observing and making inferences. As they progress to Year 4 to Year 6, primary students learn more complex thinking such as the integrated thinking skills. These thinking skills are embedded in the acquisition of science process skills. Table 1.1 shows a few examples of science process skills with their respective thinking strategies, from the Malaysian Year 4 science curriculum specification document. This includes higher order thinking skills, for instance analysing, evaluating and generalising (CDC, 2006).

Table 1.1

Example of Thinking Skills related to Acquisition of Science Process Skills (CDC 2006, p. 6)

Science Process Skills	**Thinking Skills/ Strategies**
Observing	Attributing, Comparing and Contrasting, Relating
Making Inferences	Relating, Comparing and Contrasting, Analysing, making inferences
Interpreting Data	Comparing and Contrasting, Analysing, Detecting Bias, Making Conclusions, Generalising, Evaluating

The acquisition of these science process skills is seen as a challenge for primary science teachers, whereby students were found to encounter difficulties in performing these thinking strategies in learning science (Faridah Darus & Rohaida Mohd Saat, 2014; Rose Amnah Abd Rauf, Mohammad Sattar Rasul, Azlin Norhaini Mansor, Zarina Othman, & Lyndon, 2013).

Reforms in the Malaysian science curriculum, have given emphasis to approaches in developing learners' thinking skills. Among the efforts taken by the Malaysian Education Ministry was the I-THINK programme launched in 2011. This programme was launched to help teachers to use thinking maps in developing students' higher order thinking skills. In the context of primary science, the I-THINK thinking maps were introduced to science teachers to aid students' thinking skills. Graphic organisers and thinking maps, such as the I-THINK maps, are recommended tools to help students retrieve and organise information; the stimulants in the form of questions or instructions to scaffold student thinking should, however, come from the teachers themselves (Beyer, 2008a; Swartz et al., 2008).

The Malaysian Year Four primary science curriculum also encourages teachers to provide opportunities for students to be "aware of their thinking skills and thinking strategies that they use in their learning" (CDC, 2006, p. 8). Here, teachers should scaffold students' metacognitive thinking so that students would start taking charge of their own thinking. Therefore, the teaching of thinking skills becomes the focus of attention in Year Four science education, which requires teachers to be well equipped with the pedagogical knowledge in teaching students how to think about science concepts. The topic focused in this study is 'Properties of Materials', where teachers need to teach students to analyse knowledge about the properties of materials. Students share and carry out scientific investigations to understand specific properties of materials and classify them into different groups relative to their observed properties. For example, students classify list of objects based on the objects' ability to conduct electricity. Then they would need to analyse the objects to gain knowledge about the objects. Based on their analysis, whereby looking for similarities and differences among the materials of the objects, the students make generalisations about the materials. As an example, students test several objects for ability to conduct electricity using an electric toolkit. Then they would be able to observe objects that lit up the bulb in the circuit and have the ability to conduct electricity, such as keys, metal ruler, iron nail and paper clips. Next, they would need to further analyse to identify common properties between the materials that make up these objects. Since these objects were made of mostly metals, the students should be able to conclude that objects made from metals have the ability to conduct electricity. To arrive at this generalisation, teachers need to explicitly teach students to use specific strategies such as comparing and contrasting, predicting and making inference in helping them analyse information and ideas they have gained from conducting investigations. At the end of this topic, students need to design an object to solve a problem and justify their selection for their choice of materials used to build the designed object.

Therefore, teachers must equip themselves with practices to teach students to perform different thinking strategies to analyse information and ideas, pose questions about properties of materials and think about the way they had performed the learnt thinking strategies to analyse properties of materials (CDC, 2012). Nevertheless, local scholars have argued that a thinking culture is still far away despite the breakthroughs in the curriculum over the years (Abdullah Mohd Noor, 2009; Norshima Zainal Shah, 2011; Rahil Mahyuddin, Zaidatol Akmaliah Lope Pihie, Habibah Elias, & Konting, 2004;

Rajendran, 2001). These scholars claim that the major challenge for teachers is to redesign their actual classroom practices to suit the new curriculum demand, which is to make the teaching of thinking skills explicit. To achieve this, teachers need to upgrade their knowledge in thinking skills and pedagogical knowledge in teaching thinking skills explicitly (Abdullah Mohd Noor, 2009; Rajendran, 2008).

In line with this, other studies have suggested that if teachers teach students to think skilfully, the acquisition of thinking skills and subject matter knowledge could be enhanced (Aubrey, Ghent, & Kanira, 2012; Murphy et al., 2013; Walsh et al., 2007). Infusing ST into primary science lessons would encourage students to think about science concepts and promote better subject matter understanding (McGuiness, 1999; Oliver & Venville, 2017; Swartz et al., 2008).

Problem Statement

ST has three main elements, which are the teaching of specific thinking strategies, development of students' habits of mind and the promotion of metacognitive thinking among students. ST can be infused into content lessons simultaneously (Swartz et al., 2008). This means that teaching of ST elements could be integrated while students learn science subject content knowledge. Nevertheless, developing thinking skills among young children in the classroom setting had always been a challenge for primary science teachers (Jones, 2008; Salmon & Lucas, 2011).

Teachers move from knowing about teaching (theoretical knowledge) to knowing how to teach (practical knowledge) during the first few years of their service, since they put theory into practice (Choy, Chong, Wong, & Wong, 2010). Enacting lessons for diverse students, effectively managing classrooms and time management were among the areas found most challenging (Choy et al., 2010). These challenges have arisen because science teachers, in general, even struggle in choosing effective instructional strategies in teaching the science as inquiry approach (Kind, 2009; Zohar, 2013). When teaching thinking skills was found difficult, what more teaching ST which consists of additional elements such as developing students' habits of mind and metacognitive thinking. Thus, science teachers were found to be less motivated in teaching students to think skilfully, especially when it comes to teaching mixed ability students (Nair & Ngang, 2012; Yen & Siti Hajar, 2015; Zohar, 2013). This causes them to revert to the traditional method of teaching science which is teaching to the test (Jensen, McDaniel, Woodard, & Kummer, 2014). On the contrary, generally in-service science teachers practice teaching science by employing the inquiry discovery method or by carrying out hands-on activities (Kirschner, Sweller, & Clark, 2006; Oliveira, Boz, Broadwell, & Sadler, 2014). Here, they would allow students to conduct scientific investigations to learn and discover new knowledge. The students formulate investigation questions, collect data and make conclusions. For example, in investigating materials that can absorb water, students would normally carry out simple experiment to find out which material absorbs water. They would record their observations in a given table, mostly provided by teachers. They gather information and ideas about materials using their senses. However, when teachers do not teach the more important aspects of scientific investigation such as, to analyse observations, students are unable to make generalisations about water absorbent materials (Kirschner et al., 2006; Oliveira et al., 2014). Students are simply recording data, rather than to break down observations, compare which materials do or do not absorb, group them into categories and share ideas as to why only certain groups of materials are water absorbent.

If teachers do not teach students how to think about scientific observations and ideas, students are unable to recognise what to do with the information (observations) they have gathered through investigations (Kramer, Nessler, & Schluter, 2015). This is where ST among students is seen lacking, because teachers do not explicitly teach students to think about what and how they learn from their scientific investigations. This hinders students from learning meaningfully and gaining deep understanding of a given topic. This happens because most elementary science teachers perceive teaching thinking skills as only about developing students' cognitive ability to think at higher levels. They seem to isolate the two other elements of thinking - developing students' habits of mind or promoting metacognitive thinking to sustain their thinking ability (Costa & Kallick, 2000; Swartz et al., 2008; Shu, Goh, & Kamaruzaman Jusoff, 2013). When teachers do not develop students' habit of being actively engaged in their thinking tasks, students seem to lose motivation to succeed in completing assigned tasks. Zohar (2013) has asserted that one of reasons science teachers could not teach thinking is their lack of knowledge regarding ST. Science teachers were found having inadequate knowledge about ST and its three elements (Zohar, 2013).

With limited time to teach in real classroom situations, teachers were found perplexed on how to teach subject matter and simultaneously develop students' thinking abilities. This refers to the lack of knowledge on how to devise lessons that cater for ST infusion. Thus, primary science teachers need scaffolding on how to teach students to perform different thinking strategies, develop students' habits of mind and promote students to think at metacognitive levels. This is the ST infusion that science teachers must acquire, which is still found lacking (Hugerat, Najami, Abbasi, & Dkeidek, 2014; Zohar

& Barzilai, 2013). It shows that science teachers need support in learning to infuse ST while simultaneously teaching science content lessons (Swartz et al., 2008; Zohar, 2013).

One way to scaffold teachers' learning to teach new approaches in science education is by using educative curriculum material aimed at educating teachers on how they can adopt the new approach into their practices (Davis & Krajcik, 2005; Schneider, 2006). Educative curriculum materials designed to meet teachers' learning needs have been found to enhance science teachers' pedagogical knowledge in learning to teach thinking skills in science education (Arias, Bismack, Davis, & Palincsar, 2015; Beyer, Delgado, Davis, & Krajcik, 2009; Davis et al., 2014). This include learning a new approach such as the infusion of ST, because it is embedded in the teaching of thinking skills. In-service science teachers, in particular, need continuous support in learning how to develop skillful thinkers for better science knowledge acquisition among students. Lack of support in terms of educative curriculum materials for science teachers hinders them from successfully implementing ST in their classrooms (Grossman, Hammerness, & McDonald, 2009; Grossman & Thompson, 2008; Schneider, 2013). However, little is known about how science teachers who teach young children can develop the pedagogical knowledge (knowing how) to infuse ST into lessons, upon using such materials (Schneider, 2013; Schwarz et al., 2008). Without the support from educative curriculum materials, these teachers may be unable to plan and enact lessons rich in ST practices (Shu et al., 2013; Topcu & Yilmaz-Tuzun, 2009; Zohar & Schwartzer, 2005). Hence, by using educative curriculum materials, teachers' practices that indicate develop in their pedagogical knowledge in ST infusion can be explored.

Even in Malaysia, both the infusion of ST and the use of educative curriculum materials for teachers need to be addressed. This is because local academics have highlighted that the current classroom practices across various disciplines call for a re-design that focuses on developing thinking skills as an integral part (Abdullah Mohd Noor, 2009; Nair & Ngang, 2012). Although science teachers are given guidebooks and modules in teaching thinking skills, they were prescriptive and generic in nature (Azlili Murad & Norazilawati Abdullah, 2016). Such materials appeared to be recipe-like books without explicitly providing the rationale behind the steps suggested. This impedes teachers, particularly elementary science teachers, from being creative and manoeuvring their lessons to actively engage students in ST (Davis et al., 2014). If teachers understood the rationale of infusing ST into their current lessons, they would be motivated to devise ST rich lessons, thus taking ownership of their practices to develop students' thinking skills (Schneider, 2013). Furthermore, existing materials were prepared based on the top down system, whereby policy makers prepare teaching modules and conduct professional development training for teaching a designated new approach. Information about how to implement the new approach would be passed on from top level to target groups at lower levels; normally it would be the teachers. Such training seemed to employ the cascade model, since the information gets diluted by the time it reaches the targeted teachers (Dichaba & Mokhele, 2012).

Hence, teachers could not grasp the rationale of ST infusion as a holistic approach in fostering thinking skills among students. This requires teacher-materials that aim at facilitating teacher-learning by providing suggestions and the rationales behind the suggestions on how they can adopt ST infusion into their current lessons (Davis, Palincsar, Smith, Arias, Kamedian, 2017). This must include teachers learning how to engage students in thinking skills, develop students' habits of mind and promote students' metacognitive thinking. Indeed, this is an issue to be addressed, if ST were to take shape in primary science classrooms.

Since the concept of ST with its three elements is wide, for the purpose of this study, the researcher had identified one sub element representing each element of ST (thinking skills, habits of mind and metacognition). ‘Analysing information and ideas’, ‘questioning and problem posing’ and ‘being aware of metacognitive thinking’ are the sub elements for the three main elements of ST which are, thinking skill, habits of mind and metacognition respectively. The process of how the researcher identified these three sub elements is described in detail in chapter 4 (Methodology).

Objectives of the Study

The objectives of this study were:

Research Objective 1: To gain information on Year Four science teachers’ current knowledge and practices of ST infusion in science lesson.

Research Objective 2: To prepare the STEPS (Skilful Thinking Educative Pedagogical Support), with design heuristics for the selected Year Four science teachers to infuse ST for the topic ‘Properties of Materials’.

Research Objective 3: To describe the selected Year Four science teachers’ ST infusion practices, upon using the STEPS for the topic ‘Properties of Materials’.

Initially, there were only three research objectives. However, as the data emerged, the researcher realised there were positive gains in terms of ST practices. Thus, the researcher was intrigued and interested to discover the selected teachers’ uptake of ideas in the educative features in the STEPS. Hence the fourth research objective was:

Research Objective 4: To describe the selected teachers' uptake of ideas in the educative features in the STEPS for the topic 'Properties of Materials'.

Research Questions

Based upon the abovementioned objectives, the following research questions were formulated.

Research Question 1: What are Year Four teachers' current knowledge and practices of ST infusion in their science lessons?

Research Question 2: What are the design heuristics for the STEPS (Skillful Thinking Educative Pedagogical Support) for the selected Year Four science teachers to infuse ST for the topic 'Properties of Materials'?

Research Question 3: How did the selected teachers' ST practices change upon using the STEPS for the topic 'Properties of Materials'?

Based on the fourth research objective, this study also planned to answer the following research question:

Research Question 4: How did the selected teachers' uptake of ideas in the educative features in the STEPS support the teachers' ST infusion practices for the topic 'Properties of Materials'?

Rationale of Study

The researcher has been teaching science in primary schools for more than ten years. Initially, the researcher as a primary science teacher familiarized with the teaching of primary science by imitating the way senior teachers teach science. However, the researcher found that the teaching ‘culture’ which her senior teachers cultivate seem to be ‘not evolving’ despite the rapid changes in the curriculum. The culture of ‘teach to the test’ remains up to this day (Jensen, McDaniel, Woodard, & Kummer, 2014). The ideal practice of teaching primary science as envisioned by the policy makers and primary science curriculum developers include catering for development of students’ thinking skills during science lessons (Malaysian Education Blueprint, 2013-2025). However, there is a mismatch between the actual practices in teaching primary science compared to the ideal practices. Science teachers were found to encounter challenges to teach thinking skills simultaneously with content matter knowledge (Abdullah Mohd Noor, 2009; Faridah Darus & Rohaida Mohd Saat, 2014).

As a teacher, the researcher often finds herself perplexed with certain aspects to focus during teaching and learning of science as in the curriculum. Reasoning ability, critical thinking and creative thinking (CCTS), entrepreneurship and information and communications technology (ICT) are elements to be integrated during teaching and learning. According to the science specifications by the CDC (Curriculum Development Centre), mastering CCTS would be profound if pupils are able to reason inductively and deductively (Curriculum Development Centre MOE, 2012). Therefore reasoning and CCTS are classified under the same umbrella called general thinking skills. As a result, the researcher found herself struggling to incorporate these elements holistically into the teaching of thinking skills and subject matter.

The elements of reasoning, critical and creative thinking skills, science knowledge acquisition, scientific skills, scientific attitudes and noble values are often seen as compartmentalised entities (Aktamış & Yenice, 2010; Faridah Darus & Rohaida Mohd Saat, 2014; Özgelen, 2012; Zimmerman, 2000). This would require in-service teachers to upgrade their pedagogical knowledge in teaching thinking concurrently with the above facets of science education. As such, the researcher encountered difficulties in developing the required pedagogical knowledge to integrate the above mentioned facets of science education.

In attempting to upgrade teachers' pedagogical knowledge in teaching thinking skills, the researcher believes that instructional materials should cater for both subject matter and thinking skills along with other components elements. Instructional materials should be congruent with curriculum requirements (Edwards & Briers, 2000). While preparing for upcoming science sessions within the limited time, the researcher often left without choice. Further, currently, teachers including the researcher, teach more than one subject in the same academic year. Thus, we need to equip themselves with pedagogical knowledge on how to infuse the teaching of thinking skills into content lessons within the given time. Science teachers need to know how to manage time to focus on teaching students to think skilfully and make sense of experiments and hands-on activities that students carry out (Jones, 2009; Nair & Ngang, 2012).

Existing teacher materials such as teacher guides and modules for science teachers help them to teach thinking skills. Many teaching materials for teachers aim at prescribing them the teaching steps (lesson plans) to teach thinking. These materials tell teachers what to do, without providing the rationale of doing so (Beyer & Davis, 2009). It is important to create space for in-service teacher learning through educative curriculum materials that provide the rationale of suggested ideas, support that teachers need and enough scaffolding for them to teach thinking skills (Davis & Krajcik, 2005; Schneider, 2012). Prescriptive teacher materials tend to tell teachers what to do without giving contextual reference on why and how they might teach thinking skills. (Davis et al., 2014; Grossman

& Thompson, 2008). Thus, an educative pedagogical material for teaching primary school science with preferences given to teaching thinking skilfully is indeed required.

Significance of the Study

The findings of this study add insight to the body of knowledge on ST in teaching thinking skills among young children. This would lead primary science teachers to experience the infusion of ST by taking account on the three elements of ST (thinking strategies, habits of mind and metacognition). The use of educative materials had given the selected teachers new experience in infusing all three elements simultaneously teach subject matter knowledge. This has provided the flexibility and ability to take baby steps for the selected teachers in ST infusion.

The adapted design heuristics (Davis & Krajcik, 2005; Davis et al., 2014) and educative features (Arias et al., 2016; Lin et al., 2012) in the Skilful Thinking Educative Pedagogical Support (STEPS), would aid teacher-learning on how to infuse ST. This would also provide the support and scaffolding for teachers on implementing ST in primary science classrooms. The design heuristics in the present study was determined from literature readings and insights gained from current practices of ST infusion. Hence the STEPS prepared in this study is flexible in nature, whereby the teachers can use it at their own pace. The teachers were given freedom to choose the recommendations in the STEPS, adopt and modify them to suit their needs. This was because the STEPS was prepared to stimulate teachers' thinking about how to infuse ST for teaching properties of materials. It was not prepared to be prescriptive but rather educative. Therefore, this would add light to curriculum developers to design curriculum materials that are educative for teachers and address their learning needs.

The STEPS also provided implementation guidance and support for the selected teachers on how to implement ST in their science classrooms. This is important for teachers to understand the process of change in teaching practices that would lead them in becoming practitioners of ST. With this knowledge, teachers would be able to successfully implement ST in their classrooms. This would include teachers having pedagogical knowledge to plan and enact lessons that cater for developing students' habits of mind and metacognitive performances besides selecting the appropriate instructional strategy to develop students' thinking skills (Beyer, 2008b; Reagan, 2008; Swartz et al, 2008).

Apart from providing support strategies in infusing ST, the STEPS also had provided opportunity for teachers to catalyse students' group discussions to initiate thought sharing among students. Hence, teachers' role changes from being the 'informer' of knowledge to an initiating agent of students' thinking (Zohar & Schwartzer, 2005). By learning to infuse ST, teachers not only get to know about ST, but they develop the pedagogical knowledge in ST infusion.

Conceptual Definitions

The following are the conceptual definitions of terms as they are used in this study.

Skillful Thinking (ST). ST embraces three elements; thinking skills, habits of mind and metacognition (Swartz et al., 2008). These three elements of ST are wide, for example, there are various kinds of thinking strategies, sixteen habits of mind and several levels of metacognitive thinking. In the present study, however, ST denotes the ability to perform specific thinking strategies to analyse information and ideas (thinking skills), manifest the habit of questioning and problem posing (habits of mind) and being aware of ones' own thinking (metacognition).

Analysing information and ideas. Analysing information and ideas in this study refers to the thinking strategies performed by the participating students such as skillful decision making, open compare and contrast, focused compare and contrast, skillful causal explanation, skillful prediction and skillful evaluation. These thinking strategies were performed to analyse information and ideas about properties of materials. The focus of this study was on how the selected teachers teach students to perform thinking strategies in analysing information and ideas about properties of materials.

Questioning and problem posing. The term habits of mind in this study represent students' habits of mind manifested during classroom science lessons (Colcott, Russell, & Skouteris, 2009; Costa & Kallick, 1996; Goodell, 2005). There are sixteen habits of mind, one of which is students' ability in questioning and problem posing (Costa & Kallick, 1996). The present study focuses on one of the sixteen habits of mind; questioning and problem posing. The central attention was on the selected teachers' practices in developing students' habit of questioning and problem posing about properties of materials.

Being aware of metacognitive thinking. In this study, the term metacognition refers to students' awareness of their metacognitive thinking. Being aware of the kind of thinking the student is engaged with would mean able to name, describe and identify difficulties in thinking (Swartz et al., 2008). The focus of the present study was on how the selected teachers promote metacognitive awareness among their students during lessons on properties of materials.

ST infusion. The term ST infusion in the context of this study refers to integrating the aforementioned elements of ST which is embedded in the content matter for the topic 'Properties of Materials'. It reflects the explicit teaching of analysing information and ideas, developing students' habit of questioning and problem posing and promoting awareness of metacognitive thinking among students.

Teachers' practices of ST infusion. This term refers to the selected teachers' classroom lesson enactments to engage students in ST simultaneously teach the topic Properties of Materials, upon using the STEPS. Teachers' practices of ST could reflect their pedagogical knowledge as knowing how to infuse ST into science lessons (Zohar, 2013). Practices of ST infusion also denote the strategies employed by the selected teachers for ST infusion.

Skillful Thinking Educative Pedagogical Support (STEPS). The STEPS prepared in this study was a supplementary material aimed at educating the selected teachers to infuse ST for the topic 'Properties of Materials'. It was intended to inform them with recommendations and suggestions on how ST elements can be infused into the teaching of properties of materials, so that the teachers can adopt the recommendations into their science lessons. The STEPS was prepared based on ideas adopted from several prominent studies in the use of educative curriculum materials for teachers.

Design heuristics. Design heuristics are guidelines or rules for designing educative curriculum materials for teacher-learning (Davis et al., 2017; Lin et al., 2012). Design heuristics provide the support and implementation guidance for teachers to plan and enact lessons (Beyer & Davis, 2009; Davis et al., 2014). In the present study, the three design heuristics (DH) were used. They were support for the support for teachers' knowledge of ST (DH 1), support for teachers' ST practices (DH 2) and support for teachers' classroom management (DH 3). The STEPS was prepared based on these three design heuristics.

Scope of Study

This study focused on the selected science teachers' process in infusing ST elements upon using the STEPS. However the scope of the ST elements has been narrowed down. For example, for the first element in ST, which is the different kinds of thinking skills, the researcher had limited the scope to one kind of thinking skill, which was analysing information and ideas. This was because for the topic 'Properties of Materials', students need to learn how to analyse knowledge about properties of materials. Therefore the scope for the first ST element was on analysing information and ideas. Similarly, there are sixteen habits of mind in ST (Costa & Kallick, 2000). However, the scope of this study was only one habit of mind; that was questioning and problem posing. This was also because Malaysian science teachers need to encourage students to pose questions and problems to enhance the learning of science through inquiry (CDC, 2012). As for the metacognitive thinking, the third element of ST, the scope was on promoting awareness of metacognitive thinking among students. This was because, since the selected teachers were unfamiliar with the wide concept of metacognitive thinking, the researcher had to limit the scope to the fundamental level of metacognitive thinking, which is being aware of one's own thinking (Zohar, 2013).

Another scope of the present study was the participating teachers. This study focused on selected science teachers, with less than five years of experiences in teaching Year Four science. This was because researchers have found that beginning / less experienced teachers tend to respond positively in using educative materials more than experienced teachers (Ball & Cohen, 1996; Grossman & Thompson, 2008; Hanuscin, Lee, & Akerson, 2011; Schwarz et al., 2008). Their findings suggest that beginning / less experienced teachers seek more guidance and support compared to their senior counterparts. According to Gatbonton (2008), beginning / less experienced in-service science teachers refer to teachers who have been teaching for less than two to five years. However, in the context of this study, selected teachers refers to teachers who have less than two years of experience in teaching Year Four science. They are considered less experienced in the sense that they have very little experience with the Year Four content matter.

Limitations of the Study

The present study was aimed at describing selected teachers' ST practices for the topic of 'Properties of Materials' in Year Four science. An educative material called the STEPS was prepared for the teachers' use in infusing ST. The participants in this study have provided information about their knowledge and practices of ST in science lessons. In regard to teachers' knowledge and practices in this study, it was rather difficult for the researcher to verify information about their knowledge, which was considered as a limitation. However, this limitation was reduced by collecting data on teachers' actual practices to verify claims about their knowledge. For example, when the participating teachers talked about what they know of metacognition, it was perhaps due to theoretical knowledge or information recalled from their past experience. Thus, by looking at their actual classroom practices, the researcher was able to see if the teachers really practiced what they know about metacognition.

Summary

This chapter sets the stage for the present study. Skilful thinking (ST) is embedded in the teaching of higher order thinking skills. The concept of ST in the present study revolved around three elements; ‘teaching analysing information and ideas’, developing students’ habit of ‘questioning and problem posing’ and ‘promoting awareness in metacognitive thinking’. Since less is known about how these three elements of ST can be integrated and infused simultaneously with the teaching of primary science (ten year old children), the researcher had set to explore it. Therefore, this study attempted to explore and describe how selected teachers infuse these three elements of ST into Year Four science lessons. To support teachers in learning to infuse ST, an educative material called the STEPS was prepared for the selected teachers to provide insights on how they could infuse ST concurrently in teaching the topic ‘Properties of Materials’. The next chapter will discuss the review on related literature.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Introduction

This chapter will review the areas of studies related to Skillful Thinking (ST). Firstly, the review would focus on an introductory segment on the ST approach. In this segment, the researcher explains the three elements of ST: teaching thinking skills, habits of mind and metacognitive thinking. Secondly, the review covers literature on situating ST in the primary science education by examining how other facets on thinking skills, such as critical & creative thinking skills, scientific reasoning, scientific thinking and habits of mind are related to ST. Thirdly it will discuss the curriculum supporting infusion of ST followed by the fourth segment – the infusion of ST, involving science teachers' pedagogical knowledge in the context of ST infusion, current practices and how ST is practiced in Malaysia.

Subsequent segments covers the review of the use of educative curriculum materials for teachers. Here, the researcher discusses the three design heuristics for the preparation of the *Skillful Thinking Educative Pedagogical Support* (STEPS). In the fifth segment, educative features associated to each of the design heuristics are discussed to review how such features aid teacher-learning. The sixth segment is about the tools for teaching ST such as graphic organisers and concept cartoons. Next, the researcher briefly discussed on several qualitative and quantitative data collection techniques in studies related to ST. Finally, a literature map is presented to consolidate the review, thus identifying gaps in the related literature. Figure 2.1 shows the content sequence of this chapter.

1. Introduction to skillful thinking (ST)	• General over view of ST elements • Teaching thinking strategies (First element) • Developing habits of mind (Second element) • Promoting metacognitive thinking (Third element)
2. Situating ST in the primary science education	• Critical & creative thinking • Scientific reasoning • Scientific thinking • Habits of mind in science education
3. Curriculum in teaching ST	• Curriculum for the infusion of ST - a brief comparison
4. The infusion of ST	• Teachers' pedagogical knowledge in teaching ST • Current practices of ST • ST in the Malaysian context
5. Educative curriculum Materials	• Role of educative materials in enhancing teachers' pedagogical content knowledge in science education • Educative curriculum materials in the Malaysian context.
6. Design heuristics and educative features	• Types of Design Heuristics • Determining design heuristics for the STEPS
7. Tools for ST infusion	• Assessing students's ST • The use of Graphic organizers and thinking tools • The use of concept cartoons in science education
8.Past Methodologies	• Qualitative and quantitative studies about ST
9. Literature Map	• Literature Gap

Figure 2.1. Areas of literature covered in this chapter.

Skillful Thinking (ST)

The word 'thinking' is an event that occurs on daily basis. We make choices and decisions every day. It is an innate process that happens spontaneously in any familiar situation, yet takes time and effort for the unfamiliar ones. Although innate, thinking can be a teachable, developed and mastered skill (Lan & Hwa, 2002; Murphy, Bianchi, McCullagh, & Kerr, 2013).

In education, thinking is given much consideration to a level of becoming the central of learning in most education systems and curricula, such as thinking schools (Dewey & Bento, 2009; Koh, 2013; McGuinness, 1999). With regard to primary science, children come to school with considerable prior knowledge of the world around them. Primary science teachers play a crucial role in children's science learning process. Teaching children how to think about the world around them to make meaning of their observations is indeed essential.

Teaching primary science is associated with teaching thinking skills such as lower and higher order levels, often referred to as basic science process skills and integrated science process skills (Germann, Aram, & Burke, 1996; Hogan, 1999; Mutlu & Temiz, 2013). This include observing, making inference, classifying and predicting, formulating hypothesis, controlling variables and making generalisations. These science process skills are the essential skills in learning science, which are very much related to teaching children how to think and further explore the world around them. And teachers need to keep themselves well equipped with approaches that would stimulate children's thinking abilities. Thus teachers need adequate instructional approaches to teach children to think and build their proficiency in primary science (Duschl, Schweingruber, & Shouse, 2007).

A vast number of studies exist on the approaches in teaching thinking, which reform curriculums to cater for the development of thinking skills among young children (Burke & Williams, 2009; Dewey & Bento, 2009; Murphy et al., 2013). Studies abound, especially for the teaching of higher order thinking skills (HOTS), across various disciplines (Brookhart, 2010; Murphy et al., 2013).

Three main approaches are found in teaching thinking skills (McGuiness, 1999). The first approach is the subject specific approach, such as science related thinking skills. An example would be is the CASE (Cognitive Acceleration through Science Education), drawn from Piaget's and Vygotsky's learning theories. It is an innovative way of teaching whereby the teaching of science was found to accelerate thinking skills among students aged 11 to 14 (Adey, 1999; Oliver & Venville, 2017). Such approach is highly structured within the content of the subject and mainly aims at achieving subject understanding (McGuiness, 1999; Oliver & Venville, 2017). Another way of teaching students to think better is by teaching them various kinds of thinking operations, such as de Bono's thinking hats and CoRT thinking skills (Cognitive Research Trust) (Zohar & Dori, 2003). The various kinds of thinking operations include the fostering of higher order thinking strategies and applying them in any given topic. For example, a study carried out to investigate how thinking skills can be integrated into the teaching of the unit flood among kindergarten children found that the incorporation of thinking skills enhanced information processing about flood (Rule, 2012). The children were able to share ideas for solving flood issues through creative games derived from the CoRT thinking skills. This approach is general as it can be applied in any subject matter. Despite this, scholars have agreed on a third approach which is called the infusion methodology, often referred to as ST (Beyer, 2008b; Galvin, 2008; Swartz et al., 2008; Tishman et al., 1993). The third approach is by teaching various thinking strategies concurrently with the teaching of subject matter. This approach is called the infusion approach and often referred as ‘skillful thinking’ (ST) as shown in Figure 2.2.

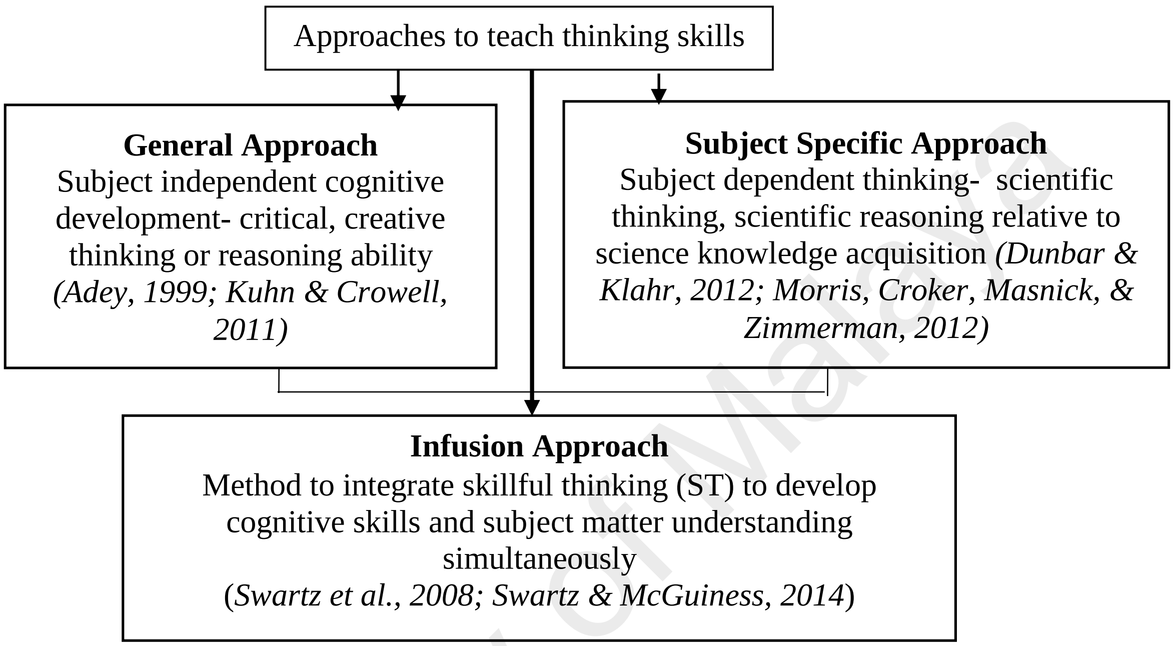


Figure 2.2. The different approaches in teaching thinking skills described by McGuiness (1999).

The infusion approach differs from the other two approaches because it focuses on thinking across context. Dewey and Bento (2009) claimed that the general approach treats thinking as information processing, whereby learners are taught how to use general thinking skills such as reasoning skills. This approach focuses on learners’ cognitive development regardless of context. On the contrary, subject specific thinking approaches focus on cognitive development by creating cognitive conflict in learners (Adey, Robertson, & Venville, 2002); for example, engaging learners in higher order thinking through cognitive conflict about a science concept and thus building knowledge through teacher-learner social interaction (Adey et al., 2002). When a learner is confronted by a science idea that contradicts with prior knowledge about the science concept, discussions among teacher and learner would aid the learner in constructing new knowledge (Adey et al., 2002). The CASE intervention on young learners suggested that learners' thinking can be accelerated through science learning (Adey et al., 2002; Venville, Adey, Larkin, Robertson, & Fulham, 2003). The infusion approach, on the other hand, suggests that thinking can be accelerated simultaneously with subject matter knowledge by teaching learners to think skilfully. The notion to think skilfully denotes ST in which the three elements (specific thinking strategies, habits of mind and metacognition) are taught concurrently with subject matter (Dewey & Bento, 2009; McGuiness, 1999; Swartz et al., 2008).

Robert Swartz, David Perkins, and Sandra Parks repackaged the teaching of HOTS with two other elements – the development of students' habits of mind and the promotion of metacognitive thinking and rebranded it as Skillful Thinking (Swartz et al., 2008). ST is a holistic way of teaching students to think at higher levels and sustain the thinking in challenging situations. McGuiness (1999) and Swartz et al., (2008) have asserted that the elements of ST can be taught by infusing each element simultaneously into content lessons. This means that teachers ought to explicitly teach various thinking strategies, develop learners' habits of mind, promote metacognitive thinking and at the same time teach subject matter content.

Infusion of ST can be structurally carried out since it involves providing explicit instructions for students on how to perform specific thinking strategies. Such instructions for thinking would gradually dissipate until students are able to perform the learnt thinking strategies autonomously. Comparing this to immersive approaches in thinking such as de Bono's CORT or Needham's Top Ten Thinking Tactics, that target developing cognitive abilities, the infusion approach can be employed to an extent whereby students are able to perform general thinking skills independently or with least teacher guidance. Teachers who adhere to immersive approaches may employ infusion approach until the teaching of general cognitive skills become immersive in lessons (Swartz et al., 2008). For instance, teachers could use infusion approach to teach general cognitive abilities concurrently with subject matter and gradually move to fine tuning the development of more general cognitive abilities in any discipline.

On the contrary, embedded approaches can be employed in sections of lessons that integrate specific method to enhance thinking. For example, employing thinking tools to promote metacognitive at the end or in the beginning of a lesson. These methods or tools can be embedded in lessons on thinking about science phenomenon or reasoning about scientific evidences, data and information, are widely employed in scientific inquiries (Swartz et al., 2008). In teaching scientific thinking, teachers could infuse the habits of mind and metacognitive elements for meaningful and deeper thinking. This would promote students to think about their habit of questioning and problem posing and how it evolves over time. Teachers could also encourage students to think about the significance of developing such habit to acquire higher levels of scientific thinking. Therefore, this would provide the privilege for teachers to decide when, where and how to employ infusion method as an embedded approach in teaching domain- specific thinking skills.

It can be implied that the infusion approach has the potential to weave in with both immersive and general approaches in teaching thinking. The uniqueness of the infusion approach lies in how teachers view the teaching of thinking skills simultaneously with content lessons. Their understanding about how the infusion approach can work in combinatory forms with other approaches would reap benefits for their students' development of thinking skills.

The infusion of ST

The infusion approach can be said the middle approach (McGuiness, 1999), between the general approach and the subject specific approach. The focus of infusion is to teach ST (Swartz et al., 2008) simultaneously with the teaching of subject matter. Moreover, to teach ST would mean to teach thinking skills along with two other elements- habits of mind and metacognition explicitly. It can be said that ST is an innovative approach for developing learners' thinking skills because it not only focuses on learning the different types of thinking strategies but also on developing habits of mind and metacognitive skills. To explicitly teach various thinking strategies means to directly guide learners on how to perform specific and appropriate mental procedures. Various thinking strategies include comparing, contrasting, looking into parts-whole relationships, reasoning and predicting. Such strategies are mainly used as the basic skill for more complex thinking, namely, problem solving or decision making.

Developing learners' habits of mind denotes the sustainability in using the learnt mental procedures. This would manifest learners' mental behaviours. Costa and Kallick (1996) have listed sixteen habits of mind, all related to learners' change in behaviour when engaged in thinking tasks. For example, encouraging learners to be persistent in a given thinking task or listening with empathy to what others have to say, are among the sixteen habits of mind by Costa and Kallick (1996). These sixteen habits of mind were later extended to more subject specific habits of mind, such as mathematical habits of mind

(Gordon, 2011), academic habits of mind (Murray, 2016) and English Language habits of mind (Shu et al., 2013).

The third element is the thinkers' own assessment. According to Swartz et al., (2008), metacognitive thinking involves naming, describing, evaluating and planning a learnt thinking strategy. Learners should be taught to think about their thinking by recalling the type of thinking they had performed, describing in detail how they had performed it and evaluating if they had performed it well and plan to correct it if they found any weakness in their thinking. This allows learners to take charge of their thinking (Beyer, 2008; Fisher, 2005; Swartz et al., 2008). ST is embedded in the teaching of HOTS, however at superficial level and needs attention to be carried out explicitly in classroom (Zohar & Schwartzer, 2005). Teachers were found to lack the pedagogical knowledge to engage students in active higher order thinking tasks, such as metacognitive thinking (Zohar & Barzilai, 2013). The next section will present an overview on the practices of infusion for each ST element. Figure 2.3 shows a graphical representation of ST elements.

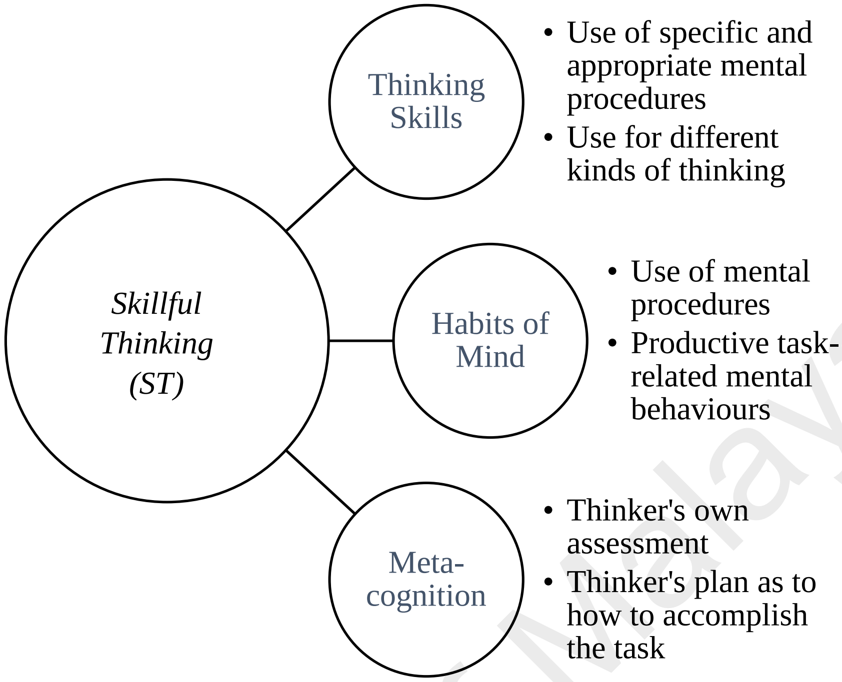


Figure 2.3. Graphical representation of the elements in ST as defined in Thinking-based Learning (Swartz et al., 2008, p. 2).

Element 1- Teaching thinking strategies. In this information loaded era, developing skillful thinkers would be a challenge to overcome, particularly among young children (Nair & Ngang, 2012; Zohar, 2013). Teachers need to teach children to manage information by performing different types of thinking (Swartz et al., 2008). There are two main important types of thinking. Firstly is the processing and extending information and secondly is critically assessing information. Processing and extending information involves generating ideas, synthesizing ideas, clarifying ideas and arguing ideas. On the other hand, critically assessing information means to check for reliability of basic information, judging in terms of relevancy, accuracy, making inference, looking at cause and effect explanations, predicting, and making generalisations. Figure 2.4 shows the two main thinking strategies required to perform complex thinking task.

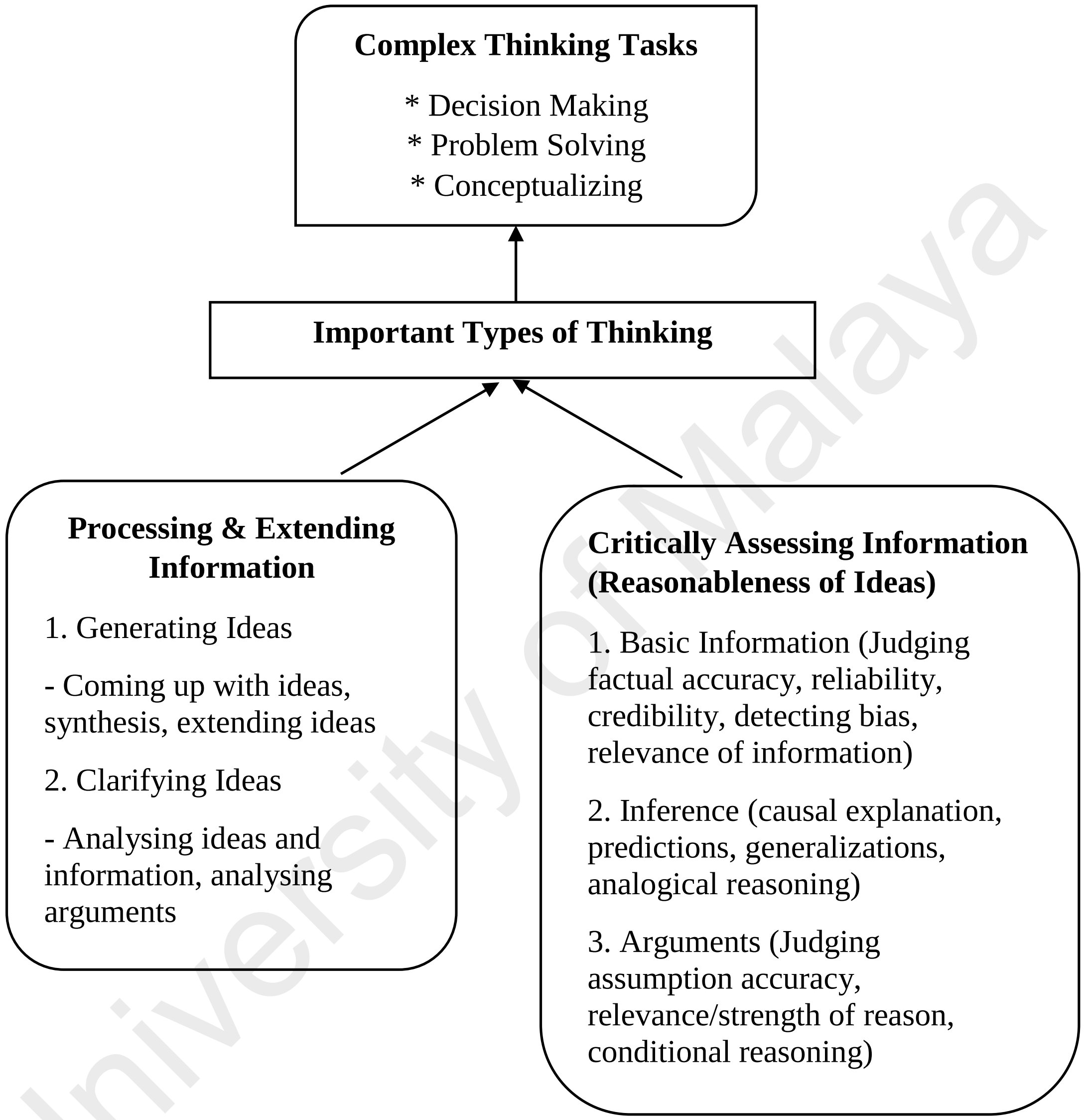


Figure 2.4. Different kinds of thinking strategies for performing complex thinking task by Swartz et al., (2008).

This conditions the learners to argue information and ideas about a topic and seek meaning of the topic under discussion. These two types of thinking are important for students to perform complex thinking tasks such as decision making, problem solving and conceptualizing (Swartz et al., 2008). Decision making involves looking at possibilities and reflecting on the decisions made. For example, a student might have chosen a strategy to solve a mathematical problem. The student then needs to examine if the strategy chosen was a good decision in solving the mathematical problem. This consist carefully and skillfully analysing the options of strategies to solve the problem. Problem solving involves students thinking of solutions to a given problem, in which they need to analyse the cause and effect the solution, predict and make decision to solve the given problem. These two important thinking tasks lead to students conceptualizing the learnt concept, for example, how learners understand and make generalization about a topic.

The two main types of thinking (as shown in Figure 2.4), according to Swartz and McGuiness (2014) can be carried out *skilfully* by performing specific thinking strategies. Thinking strategies refer to the specific procedural mental steps to carry out different kinds of thinking to perform complex tasks (Dewey & Bento, 2009; McGuiness, 1999; Swartz & McGuinness, 2014). The term is stated as 'using specific and appropriate mental procedures for the kind of thinking engaged in by the thinker' (Swartz et al., 2008, p.1). This include skillful decision making, open compare and contrast, focused compare and contrast, skillful causal explanation, skillful prediction and skillful evaluation are among the proposed thinking strategies (Swartz et al., 2008). It is focused on teaching the procedural steps required for each kind of thinking. These specific thinking strategies are important for developing critical, creative and reasoning abilities (Aktamış & Yenice, 2010; Jones, 2008; Tan & Chong, 2002). By learning the different mental procedures involved while performing the different kinds of thinking strategies, young learners would be able to process, extend and critically assess information (Beyer, 2008; Swartz et al., 2008).

Furthermore, ST emphasizes the knowledge of when, where and why use a certain kind of thinking strategy which is important for children to take charge of their thinking. With some basic ideas about the term 'teaching thinking strategies', it is essential to move on to explore how the teaching of thinking strategies can be infused into content lessons. Most curricula are designed based on the original Bloom's Taxonomy or the revised version (Lee, Kim, & Yoon, 2015; Yen & Siti Hajar, 2015). Both versions of the Bloom's Taxonomy show lower and higher thinking levels. Lower level of thinking include knowledge, understanding and application Higher level thinking starts with analysing, synthesizing and evaluating or creating (in the revised version) (Yen & Siti Hajar, 2015). At primary level, the analysing skill, forms the foundation for higher levels because it is the first level of higher order thinking skills (HOTS). According to the infusion methodology, students should be taught how to analyse information and ideas about a topic under discussion by performing specific thinking strategies. This include open compare and contrast, focused compare and contrast, skillful causal explanation, skillful prediction skillful decision making and skillful evaluation (Swartz, 2008). He asserted that students must be taught to compare and contrast ideas and information, provide reasons for the arguments and evaluate arguments based on their comparison, before making generalizations. For example, in a science lesson, students compare two scientific phenomenon and make sense of the information gathered about the phenomenon. Graphic organizers which are prepared for students to perform different thinking strategies such as compare, look for similarities or differences, making decisions, evaluating arguments are effective tools to help students analyse topic under discussion.

Beyer (2008) in his research on how to teach thinking skills by infusion of ST, strongly recommended that teachers should firstly introduce a thinking strategy. This includes getting students to name the thinking strategy, for example, predicting skillfully. Next, students need to understand how skillful prediction can be performed such as how they predict an event or a phenomenon, by looking and making sense of observed patterns of data. Secondly, teachers should make it clear for students to identify in which situations they can practice how to predict, which the learnt thinking strategy was. It is to help students practice predicting skillfully using tools like graphic organizers or thinking maps, until the use of such tool gradually diminishes. This is when predicting becomes autonomous, whereby students would know what predicting means, how and why perform it. Thirdly, is to promote students to think about how they had performed predicting to see if they had predicted skillfully. And fourth, teaching students to transfer the skill into new context. These four tactics are the pathways for ST infusion in any content lessons (Beyer, 2008b; Swartz, Costa, Beyer, Reagen, et al., 2008). It is about what students do with the information or ideas that they are exposed to. With regard to primary science education, children are constantly exposed to either past knowledge or new information as they conduct science hands –on activities and investigations. They need to make sense of what they observe to understand the science concept being learned. For that, teacher need to explicitly teach students to analyse information and ideas by performing different thinking strategies (Swartz & McGuinness, 2014).

Element 2 - Developing habits of mind. Teaching science to children is not only about the acquisition of thinking skills such as analysing information and ideas. The art of students asking questions, sharing thoughts with peers and collaboratively analysing science concepts that demands a sustained interest in thinking. This can be achieved by developing the habits of mind in thinking – the second element of ST.

There are many types of Habits of Mind as to types of thinking. Habits of Mind (HoM) denotes a state whereby one values particular pattern of thinking over another and making choice of the appropriate one to solve a problem (Costa & Kallick, 1996). It requires behaviours and skilfulness to use a kind of thinking effectively. In past studies, HoM was much referred to Thinking Disposition (Burns, 2009; Ros-Voseles & Fowler-Haughey, 2007). According to Ros-Voseles and Fowler-Haughey (2007), 'disposition is a frequent and voluntary habits of thinking and doing'. They categorised dispositions in classroom settings as the act of being independent, creative, self- motivated and resilient (Ros-Voseles & Fowler-Haughey, 2007).

Costa and Kallick (1996), identified sixteen habits of mind namely; persisting, managing impulsivity, listening with understanding and empathy, thinking flexibly, thinking about thinking, striving for accuracy, questioning and posing problems, applying past knowledge to new situations, thinking and communicating with clarity and precision, gathering data through all senses, creating, imagining, innovating, responding with wonderment and awe, taking responsible risks, finding humour, thinking interdependently and remaining open to continuous learning (Costa & Kallick, 1996; Swartz et al., 2008).

The concept of Habits of Mind is stated in Mezirow's Transformative Learning theory (1997). Transformative Learning theory helps to develop autonomous thinking.

> Habits of mind are broad, abstract, orienting, habitual ways of thinking, feeling, and acting influenced by assumptions that constitute a set of codes. These codes may be cultural, social, educational, economic, political, or psychological. Habits of mind become articulated in a specific point of view—the constellation of belief, value judgment, attitude, and feeling that shapes a particular interpretation. (Mezirow, 1997, p. 5)

According to the theory, autonomous thinking refers to understanding, skills and dispositions required to become critical thinkers, being able to make reflection and thinking about one's own thinking to validate their perceptions as well as others point of view during discourse (Mezirow, 1997). Kitchenham (2008) in a review on Mezirow's Transformative Learning theory, has stated that making meanings of a subject becomes apparent, when the learner goes through critical discourse with others, which is in line with several other paradigms, such as Kuhn's (1962) and Vygotsky's (1978) social constructivist theories (Kitchenham, 2008). In Mezirow's revised Transformative Learning Theory (2000), 'perspective transformation consists of meaning perspective, which is a frame of reference', which comprises Habits of Mind. Although Mezirow's Transformative Learning theory (1997) has provided great implications to adults learning, Costa and Kallick (1996) argued that HoM is one of the main ingredients in skillful thinking among young learners as well.

With brief overview on the definitions of habits of mind, it is important to know which of those sixteen habits of mind (Costa & Kallick, 1996) is closely related to inquiry learning in science education. Inquiry learning is found to be one of the best approaches in teaching science; however, there are two ways of looking into it. The first one is related to how teachers ask questions or inquire as cues to stimulate students' thinking (Ireland, Watters, Brownlee, & Lupton, 2011; Zion & Mendelovici, 2012) and the second one, is to encourage students to ask questions as part of inquiry learning (Kawalkar & Vijapurkar, 2013; Peters, 2009).

Ireland, Watters, Brownlee, and Lupton (2011) suggested that teachers need to provide space for students to seek answers for scientific explanations by themselves. Through their study with 20 elementary science teachers, three conceptions of inquiry learning were derived. They were experience centred, problem centred and question centred conceptions. The third conception – questions centred particularly, consisted of students' generated questions, whereby teachers help students to ask questions and answer their own questions. Zion and Mendelovici (2012) argued that science teachers still face challenges as they do not seem to understand the different types of inquiry –structured, guided and open inquiry. They found that one way to change structured inquiry to open inquiry science lessons is to create a database in which teachers learn to come up with various activities and worksheets to support open inquiry (Zion & Mendelovici, 2012). However, for open inquiry to take place in primary science classrooms, teachers must first explicitly develop students' habit of asking questions and posing problems for further science investigations. One way to develop this habit among young learners is by dialogic questioning sessions (Van Booven, 2015).

Dialogic questions encourage students to actively engage in critical thinking during group discussions as the questions are more open to different ideas. Van Booven (2015) has found that a balance between authoritative questions and dialogic questions create more meaningful inquiry among learners. Put differently, scaffolding students' science talk can create the balance between authoritative questions and dialogic questions (Kawalkar & Vijapurkar, 2013). They have asserted that questions used to promote discussion lead to deeper exploration of the topic under discussion. By this, science inquiry would reach the level of open inquiry whereby students generate questions, seek explanations and acquire broader ideas about science concepts (Van Booven, 2015; Zion & Mendelovici, 2012). Therefore, inquiry learning plays a pivotal role as students need to ask questions, such as what, why and how to seek explanations for scientific events (Harris & Rooks, 2010; Zion & Mendelovici, 2012). Both Harris et al., (2010) and Zion et al.,

(2012) argued that teacher-led inquiry must transform into child-led inquiry science. Children should be given the space to ask questions more than the teachers would. Besides that, children need to be able to express themselves fluently by sharing their ideas about a given science concept during classroom discourse. This way children would make their thinking visible to others (Ritchhart & Perkins, 2008). Thus, it can be said that, among the sixteen habits of mind, questioning and problem posing is the fundamental habit that needs developed among children for effective inquiry learning in science lessons.

When children acquire the habits of mind in thinking, it would help them to reason and apply information in new context (Shu et al., 2013). This is because students would learn to appreciate the value of analysing information in solving problems. By sharing their doubts with others, they tend to perform thoughtful consideration of the information they receive; particularly in mathematics problem solving, in which students need to be persistent to solve a difficult sum by critically analysing possible solutions (Gordon, 2011). Similarly in science education, students embark on scientific investigations, they would also need to carefully analyse the variables involved. Here, the motivation to sustain in such complex thinking tasks calls for strongly built habits of mind.

Even children with challenging behaviours could perform better when they learn to develop these habits. Burgess (2012) conducted an interesting study on challenging children's habits of mind. Children with social and emotional difficulties who are aged 7 to 12 years, were found to be able to manifest eight types of habits of such as being persistent, listening with empathy, and thinking flexibly (Burgess, 2012). The students were able to verbalise that they now think more about what they wanted to say due to the activities and strategies proposed to teachers on how to develop students' habit in thinking. This promotes the ability to be aware of how they think and gain confidence in participating in classroom discussions (Gordon, 2011). While some scholars have studied how to assess students' habits of mind (Duckor et al., 2014; Costa & Kallick, 1996; Goodell, 2014), some others have shared their recommendations developing students' habits of mind. Costa and Kallick (1996) have described how teachers can built habit forming instructions in classrooms; among which is to model habits of mind. For example, preparing an activity in which students reflect on their habit of mind based on cues provided by teachers. This include cues that ask students if they had perseverance in solving long mathematical problems or formulating the possible hypothesis for science investigations. The teachers may also encourage the students to listen to what their peers had to share during discussions and if the new information shared had added value to their understanding of the topic discussed. These cues may not only be the strategies to build students' habits of mind but also be indicators for teachers to assess them.

Jensen (2012) and Fletcher (2013) have embarked on studying how teachers can help to develop such habits. They asserted that teachers need to help students with their narrative and reasoning skills. Asking for reasons and justifications for their ideas will indirectly help students to formulate questions on their own. This means that teachers should plan and enact appropriate instructional strategies to facilitate the development of habits of mind among students, as part of the teaching goals. Figure 2.5 shows a graphical representation of the importance of developing students' habits of mind, based on selected studies.

Habits of Mind (HoM)(Costa & Kallick, 1996**)**
The ability to behave intellectually when confronted with problems

16 Important habits of mind in skillful thinking (Costa & Kallick, 1996; Swartz et al., 2008)

Why is it important to develop HoM?

- To help students to reason & apply information (Shu et al., 2013)
- Overcome challenging behaviours among students (Burgess, 2012)
- Promote students' thoughtful considerations (Gordon, 2011)
- Gain confidence in participating constructively (Gordon, 2011)
- Improve metacognitive strategies, reflective process & mindful learning (Jensen, 2012)
- Essential to develop critical thinking (Fletcher, 2013)

How teachers could help students' develop HoM?

- Explicitly teach HoM (Fletcher, 2013)
- Practice the habit until it is established (Costa & Kallick, 1996)
- Create or use instructional strategies to facilitate HoM (Jensen, 2012)
- Identify problems and ways to overcome them when developing students' HoM (Goodell, 2014)

Figure 2.5. Graphical representation of selected studies in habits of mind, discussed in the literature review.

The selected studies on habits of mind may suggest that by developing these habits, students will have higher sustainability levels in complex thinking tasks. However, less is known about developing young learners' habits of mind in science classrooms, especially on developing students' habit in questioning and posing problems in primary science lessons. Teachers need to be equipped with the pedagogical knowledge and skills to develop and assess mental habits, thinking dispositions and behaviours that indicate their students' habits of mind (Fletcher, 2013). Therefore, as part of teaching students to think skilfully, they need to encourage students to ask questions and pose problems related to scientific ideas. This is the kind of inquiry anticipated in ST (Swartz et al., 2008).

As mentioned earlier, the habit of questioning and problem posing among students built the platform for self –reflection. When students ask questions to themselves, such as "Did I make the right decision?' or 'How can I improve my questioning skills?'. It opens opportunities to think about their thinking. This would eventually culminate in the promotion of metacognitive thinking among students – the third element of ST.

Element 3 – Promoting metacognitive thinking. The third element of ST is the promotion of metacognitive thinking or often known as thinking about thinking (Flavell, 2004). It is a broad concept and has been and is still being studied extensively mainly among young children (Misailidi, 2010). Metacognition can be divided into two strands – metacognitive knowledge and metacognitive processes. Metacognitive knowledge involves being aware of ones' own thinking, whereas metacognitive process refers to the ability to control, evaluate and plan to correct one's thinking, habitually called self-regulation (Flavell, 2004; Misailidi, 2010; Sperling, Howard, Miller, & Murphy, 2002). In ST, Swartz et al., (2008) conceptualised metacognitive thinking in four stages, called the 'ladder of metacognition', which consists being aware of the kind of thinking, knowing the strategy on how to perform the thinking, evaluating the effectiveness of thinking and finally planning on how to perform the same thinking in future application. It can be said that the ladder of metacognition actually was derived from the metacognitive knowledge and metacognitive process, as defined by Flavell (2004). Beyer (2008) and Swartz et al.,

(2008) have both defined metacognition as learner's own assessment on their thinking task, guided by their plan on how to accomplish the task. It is a self-assessment on one's own thinking by being aware, planning and monitoring as well as reflecting. This is parallel with the theory of self-regulation advanced by earlier studies, such as Vygotsky's self-regulation theory, whereby learners are aware and able to regulate their thinking process and take necessary action to correct it (Braten, 1991; Fisher, 1998; Vygotsky, 1978b).

Teaching children to acquire cognitive abilities in a diverse classroom setting is found to be challenging for teachers; teaching meta-cognitive abilities can be even more challenging (Zohar, 2013; Zohar & Barzilai, 2013). However research on how teachers could infuse metacognitive thinking in classrooms have been growing rapidly (Ben-David & Orion, 2013; Chatzipanteli, Grammatikopoulos, & Gregoriadis, 2014; Whitebread et al., 2008; Zohar & Barzilai, 2013). These studies, particularly, have put forth practical strategies for teachers to adapt the teaching of metacognition among students. Chatzipanteli et al., (2014) have presented a collection of strategies based on their review on metacognitive practices, among which are, modelling metacognitive skills during lessons, asking students to recall how they had performed given thinking task, self-questioning, think-aloud and metacognitive prompting. These techniques require sound and rich teacher-student interaction because they involve students sharing their thoughts about how they think, either verbally, written or visually. Providing opportunities for self-regulation activities, wait time, direct instruction to map students' metacognitive strategies, and providing explicit feedback for corrective actions are among other techniques for implementing metacognition in classrooms (Borkowski, Weaver, Smith, & Akai, 2004).

While teaching children how to think about their thinking, assessing this skill is a distinct practice for teachers. To address this problem, Whitebread et al., (2008) have developed observational tools for teachers to assess students' metacognition and self-regulation activities. The tools were used to videotape young children (aged 3-5) and with the help of a coding framework, teachers could assess how students carry out self-regulatory and metacognitive processes based on their verbal conversations. For example, when children say 'I want to draw a line' or 'I can count this', it means they are regulating their cognitive skill in a given task. Conversely, verbalising their thoughts during activities does not come naturally among children. Therefore, teachers need to ensure that instructions are made for children to talk about their thinking when they work in small groups by constantly communicating with others. It is important for teachers to ensure instructions for metacognitive thinking because there is a gap between teachers' effort to enhance learners' metacognitive thinking and what actually happens in the child's mind. Children need to make their thinking about thinking visible to others. To bridge this gap, Visible Thinking technique was found to be effective (Salmon & Lucas, 2011). Visible thinking means to share thoughts and ideas about a given topic to make thinking transparent to others. And again, teachers' role in implementing Visible Thinking is vital to develop children's metacognitive skills. Thus teachers need to organise learning sessions in order to cater to metacognition activities (Ritchhart & Perkins, 2008). The strategies such as visual representation, verbal responses and written works can be used to improve and to assess children's metacognitive thinking.

Zohar and her acquaintances have done widespread studies on metacognitive thinking both involving teachers and students. In their recent review on metacognitive thinking among young children, Zohar and Barzilai (2013) have asserted that although the promotion of metacognitive thinking is growing, it needs an upgrade. They have clearly argued that teachers' knowledge of metacognition and practices of metacognition in classrooms were areas deserving upgrade. Even more than a decade ago, Zohar (1999, 2004) had already reported that science teachers do not possess the specific knowledge about metacognition – what is metacognitive thinking, how to teach children to think at metacognitive level in classrooms and how to assess their metacognitive thinking. The exact issue was again addressed in recent studies, whereby science teachers were found lacking in the knowledge of what it means to teach students to think about thinking (Ben-David & Orion, 2013; Wilson & Bai, 2010; Zohar & Barzilai, 2013). In fact, they redefined teachers' knowledge and practice in promoting metacognition as teachers' pedagogical knowledge in the context of teaching metacognitive thinking. Teachers were found lacking in pedagogical knowledge in fostering metacognitive thinking among learners; thus this lack should be addressed.

Metacognition being the third element of ST supports the fact that teachers need to upgrade their pedagogical knowledge on how to promote metacognitive thinking in classrooms (Swartz et al., 2008). Recent related studies on thinking skills, habits of mind, metacognition, making thinking skills and mental habits explicit, thinking practice and language of thinking show an increasing interest in the infusion methodology approach such as ST (Ader, 2013; Calik et al., 2013; Caryn, 2007; Chatzipanteli et al., 2014; Duckor & Perlstein, 2014; Fenderson, 2010; Zohar & Schwartzer, 2005; Zohar, 1999). Having discussed the infusion of the three elements of ST, it is important to know how much emphasis has been given to the infusion of ST across different curricula.

Curricula for the infusion of ST- A brief comparison

As discussed in earlier sections, various teaching approaches are available for teaching thinking skills to children. In a much earlier review, McGuiness (1999) has reviewed the evaluation of approaches in developing thinking skills, found three distinctive approaches; general approaches, subject specific approaches and infusion methodology. These approaches are implicitly and explicitly covered in the teaching and learning sessions. Such approaches are weaved in most typical yet effective sessions in science education like the discovery learning, inquiry discovery, project based learning, problem solving, design based learning, collaborative learning, experimentations and many more. However, one common attribute that becomes the foundation for all the above mentioned approaches, is the promotion thinking process itself. School curricula undergo transformations in order to cater for the development of thinking skills.

There are many curricula that provide useful resources and teaching materials to develop learners thinking skills, available online or published (Adey, 1999; McGuiness, 2000; Northern Ireland Curriculum, 2007; Welsh Asssembly Government, 2010). Some however, work as a team to develop and support such resources for their educator/teachers within the organization itself, such as Welsh Assembly Government, National Science Teachers Associations and Centre for Excellence in Teaching and Learning. Bowers (2006) has reviewed discipline-specific instructional resources for developing critical thinking that are under-utilised, and found that designing teaching approaches for teachers to teach thinking skills (critical thinking) should not confounded with available resources.

The Welsh Assembly Government in the UK has conducted a programme funded by the Department for Children, Education, Lifelong learning and Skills (DCELLS) for five terms between 2005 and 2008. Under this programme, more than one hundred teachers were coached in pedagogy on developing thinking and assessment for learning in classrooms. The participants (teachers) were well coached and mentored throughout the pilot study. The pilot study has indicated some ground breaking findings on the impact of learners and classroom practices. Learners were found to be motivated to learn, actively engaged in discussion and questioning sessions which generated positive engagement with learning.

Apart from the abovementioned affective aspect, learner performance has also shown positive impact on the quality of learning. Quality of learners' speaking and listening as well as their behaviour has improved considerably. Although this programme emphasised student driven learning environment as widely found in the literature, what distinguishes this programme from other thinking skills programmes is the encouragement given to learners to reflect upon their thinking process, on what they have learnt and how they got to learn what they have learnt. In psychological terms, this process of reflecting and thinking upon one's thinking is the much studied cognitive aspect called meta-cognition. The two goals of the Welsh programme implies the need for both the development of thinking skills for learning in local context.

The Welsh Developing Thinking and Assessment for Learning programme puts metacognition as a central element, since it is crucial for both developing thinking skills and assessment for learning pedagogy. The Welsh programme has experimented and verified many thinking tools (approaches) to facilitate thinking process for learners. Among them are: allowing time for learners to act on their thinking during learning wherever possible, usage of concept cartoons, concept maps, exam question analysis, exploring wrong answers, fishbone diagram, ground rules for talk, mind mapping, review of summative test, success book, Venn diagrams and writing journals, to name a few.

There seem to be in variation in activities for learners in planning, developing and reflecting their own thinking during the learning process (Welsh Asssembly Government, 2010).

Northern Ireland (NI) Curriculum integrates various kinds of thinking skills and learning dispositions with collaborative learning as well as independent learning (Northern Ireland Curriculum, 2007). The NI Curriculum defines the term "developing thinking skills" as the process of designing learning that caters for students to think more skilfully. Hence, according to the NI Curriculum developers, thinking skills are *tools* to understand and apply ideas, create novel possibilities and make decisions. The element of metacognition or ability to plan, monitor and evaluate one's learning progress, is a part of the curriculum objectives as well. Progress in student learning is measured based on a few facets; managing information, thinking, problem solving, being creative, working with others and self-management (Northern Ireland Curriculum, 2007). Both the Welsh and Northern Ireland Curriculum make provision for thinking skills, habits of mind and metacognition. The effectiveness of such implementation has been found positive in developing thinking skills particularly in primary education (Murphy et al., 2013).

Similar curricula are adopted into school systems. Singapore has embarked on creating 'thinking schools' a decade ago (Tan, 2006). This was meant to overcome the drawbacks of a general culture whereby teachers focus more on preparing students for examinations. Efforts have been taken to shift from the conventional culture to thinking schools, in which thinking skills such as analysing, creating and critical reasoning are taught explicitly. To aid this shift, teachers are well versed with the use of worksheets and tools to guide students' learning and thinking processes. Among the approaches were project-based learning that promotes thinking including skills such as planning, processing, presenting, reflecting and evaluating (Chiam, Hong, Ning, & Tay, 2014; Wei et al., 2007). Similarities found in ST and other selected curricula in teaching thinking skills as integral part of classroom practices based on selected literature is shown in Figure 2.6.

Selected curricula in teaching thinking

(Adey, 1999; McGuiness, 2000; Murphy et.al, 2013; Northern Ireland Curriculum, 2007; Welsh Asssembly Government, 2010; Swartz et al., 2008)

↓

How are they alike in terms of teaching thinking as integral part of classrooms practice?

↓

- Focus on developing thinking skills, habits of mind, metacognition
- Encourage learners to reflect upon their thinking
- Employ 'language of thinking' in classroom to make thinking integral activity
- Manage group discussion (ground rules for effective talk)
- Provide thinking tools (concept cartoons, fishbone diagram, journal writing)
- Formative assessment tools to assess thinking / Learners assess their own thinking

Figure 2.6. Similarities found in ST and other selected curricula in teaching thinking.

These curricula support the infusion of ST. However, it all comes down to how teachers infuse ST into content lessons. Thus, teachers need to be well equipped with the knowledge and tools to teach students to think skilfully. In the context of this study, to know about ST and how to infuse ST into lessons refers to teachers' pedagogical knowledge in teaching ST.

Teachers' Pedagogical Knowledge in Teaching ST

Knowing what to do is imperative, yet knowing how to do it right to meet expectations is far more important. This section discusses a few teaching approaches widely studied in the literature. In cultivating higher order thinking skills, an advanced level of thinking from the current state has to occur. For example, teachers may ask pupils to list and classify attributes related to a certain subject of interest. Merely comparing, contrasting, classifying and presenting their knowledge will cater for lower order thinking skills by recalling, retrieving, understanding and applying into a pre-determined thinking maps (Edwards & Briers, 2000). Procedural knowledge as such is often mistaken for higher order thinking skills. Nevertheless, the thinking process should not end there; instead, it has to be progressed to analysing the knowledge, seeing patterns and making generalisations. It is a process of making sense of the learning, advancing to a further level where learners think upon their learning (Rajendran, 2001, 2008; Swartz et al., 2008).

The challenge lies in how teachers teach thinking as an integral part in content lessons. Teachers need to understand reasoning, critical, creative thinking skills and how these thinking skills lead to the acquisition of science process skills and content knowledge in science education. Ineffective science pedagogical knowledge among primary school teachers is reflected as the children land themselves in secondary or higher education (Abdullah Mohd Noor, 2009; Rajendran, 2001; Robiah Sidin, Juriah Long, Khalid Abdullah, & Puteh Mohamed, 2001; Zabidi & Rahman, 2012). The studies done by Rajendran (2001), Abdullah Mohd Noor (2009) and Nair and Ngang (2012) are underlined in an attempt to gain insight into teachers' science pedagogical knowledge in teaching thinking skills over a decade. Rajendran (2001) found that teachers lack instructional strategies for teaching higher order thinking skills, whereas in 2009, Abdullah revealed an alarming fact regarding the issue. According to Abdullah, redesigning of pedagogy or instructional methods and orienting current assessment are essential in thinking based assessment. In addition, Nair and Ngang (2012) reported in their study that teachers are occupied with a heavy workload and have difficulties infusing thinking skills in their pedagogy. It is evident that the aspiration has not been met yet despite the major transformation made to the curriculum. Although countless approaches are reported in literature on teaching thinking skills to children, the following section will discuss some of distinctive ones.

Many scholars have argued that teachers need to gain more knowledge in teaching ST, which includes acquiring theoretical knowledge of ST as well as pedagogical knowledge of how to teach ST (Coffman, 2013; DiBiase & McDonald, 2015; Wilson & Bai, 2010; Zohar, 2004; Zohar & Schwartzer, 2005). The concept of teachers' knowledge in these studies was mostly defined based on Shulman's categorisation of teachers' main knowledge: content knowledge (CK), general pedagogical knowledge (GPK), and pedagogical content knowledge (PCK) (Shulman, 1986, 1987). A wide range of issues pertaining to Shulman's categorisation of teacher knowledge has already been explored; however, there is still room for further investigations on teachers' knowledge about ST and the practices employed to infuse it. Shulman (1986, 1987) refers to pedagogical knowledge as knowledge of strategies and classroom management organisation that best conveys subject matter. In the context of ST, pedagogical knowledge denotes knowledge of the elements of ST and, subsequently, knowledge of practices of ST infusion (Beyer, 2008b; Swartz et al., 2008).

Previous research, however, has shown that teachers do not possess the pedagogical knowledge in the context of teaching ST in primary science. Science teachers were found lack knowledge of different thinking strategies, or how to teach them during lessons, how to develop students' habits of mind and to teach students to perform metacognitive thinking (Barak & Shakhman, 2008a; Zohar, 2004b; Zohar & Schwartzer, 2005). It is crucial that more research be conducted to understand exactly what current teachers do or do not know about the infusion of ST in primary science.

In terms of envisioning future teaching strategies, however, most studies claimed that teachers must possess higher pedagogical knowledge in teaching ST (Abdullah Mohd Noor, 2009; Ben-David & Orion, 2013; Yen & Siti, 2015). Swartz et al. (2008) and Beyer (2008a) argued that teachers' pedagogical knowledge in teaching ST should include the knowledge of practices in teaching all three aforementioned elements as an integrated model of teaching HOTS. Other scholars raised similar arguments, affirming that teachers should clearly understand the concept of ST as well as how, why, and when to integrate all ST elements simultaneously into science content lessons (Barak & Shakhman, 2008a, 2008b; Costa & Kallick, 1996; Miri, David, & Uri, 2007; Murphy, Bianchi, McCullagh, & Kerr, 2013).

Figure 2.7 shows the elements of teachers' knowledge in teaching ST which was derived from the literature. This framework was based on the original Shulman's (1987) pedagogical knowledge components. The framework suggests that teachers' knowledge in teaching ST consist of two components. The first component is on what the teachers know about ST and the three ST elements (the "know what is ST"). This include being aware of the different kinds of thinking strategies, the sixteen habits of mind and the concept of metacognition.

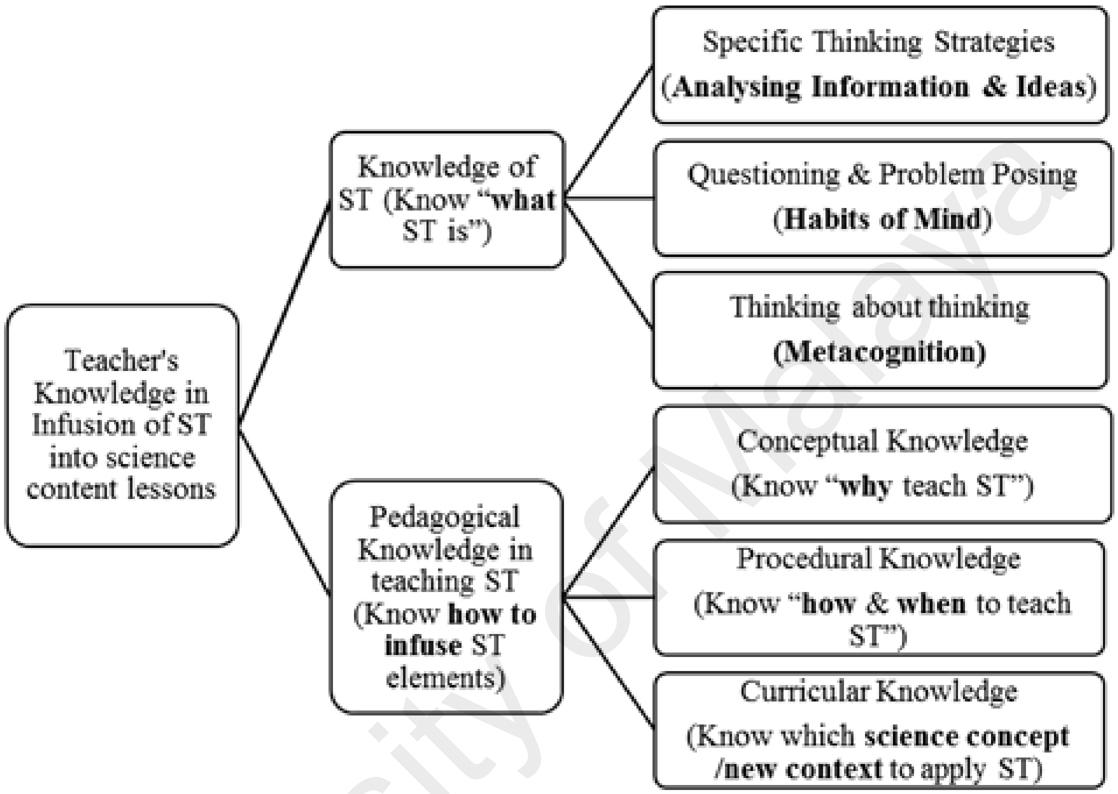


Figure 2.7. Graphic interpretation of categorization of teachers' pedagogical knowledge in teaching ST based on selected literature readings.

Knowledge of practices in teaching ST, on the other hand, represents teachers' implementation of ST in science education – the why, how, when, and what of teaching ST. Conceptual knowledge refers to the teachers' conceptualisation of teaching ST in primary science education. Procedural knowledge represents knowledge about how and when to teach ST within science content lessons. Conceptual and procedural knowledge represent the teachers' ability to explain the rationale for the procedures they employ in teaching a specific thinking skill, such as analysing (Steenbrugge, Lesage, Valcke, &

Desoete, 2014). Curricular knowledge can be related to the concepts of declarative and conditional knowledge (Chouvat, 2008). For example, knowing what kind of thinking strategies to teach under what condition, within the designated curriculum (Justi & van Driel, 2006).

Tools for ST infusion. Teaching thinking is perhaps the most important aspect as much as on how best a subject can be taught. Children with enhanced thinking skills will be able to learn subject matter regardless of the employed learning approach (Swartz et al., 2008). Whether the approach is project based learning, problem solving, scientific investigation, or design based learning, it surely demands children to think at both lower and higher levels. In this regard, numerous efforts are taken to support a thinking culture in education. Mostly, on developing effective resources and tools for teachers and learners to develop thinking skills across disciplines (Baumfield, 2006; Colcott, Russell, & Skouteris, 2009; Hyerle, 2009; Kawalkar & Vijapurkar, 2013). The researcher found that based on literature readings on tools for teaching thinking, there are three widely used tools – auditory cues, thinking maps or graphic organisers, and concept cartoons.

Auditory Cues. Auditory cues are words, phrases or verbal expressions that prompts one to think. There are two types of auditory cues: teachers' questions as prompts and students' questions during group discussions (Dresner, De Rivera, Fuccillo, & Chang, 2014). Teachers' questions as prompts for thinking has been broadly studied. In recent studies, teachers' cues are also called 'thinking language', which refers to words such as infer, state, compare, similarities, differentiate, classify and justify(Tzuriel, Isman, Klung, & Haywood, 2017; Zohar & Barzilai, 2013). For example, when teachers utter the word 'infer', they are instructing students to give inference or reasons to explain something. Rather than using common words such as 'why' or 'give reasons', teachers could use the word ‘infer’ like ‘what can you infer from this?’ or ‘give inference for your observation’ instead. This was because students would then be able to recognise such words and promptly carry out related thinking processes, such as thinking why a phenomenon occurs. Yet, prior to the use of thinking language, teachers must first start using common and familiar terms (for students), redefine them and slowly assist the transition from common words to jargon terms as the thinking language, until students are comfortable and familiar with those terms. Another reason would be for easy retrieval of thinking processes during written work. Students will be able to understand written questions that carry words such as ‘Give an inference for your observation’ or ‘Predict the temperature of water at 12th minute’. These terms are called thinking language that need to be used in daily classroom conversations, between teacher-students and among students (Costa & Marzano, 1987; Tzuriel et al., 2017; Zohar & Barzilai, 2013).

Thinking maps / Graphic organisers. Thinking maps or graphic organisers are visual tools that students could use to explicitly model their thinking (Hyerle, 2009). These tools can be prepared ahead to aid students’ thinking process. For example, when they need to classify objects into categories, they could use graphical representation to reason out their justifications as to how they group together objects based on certain way. Some graphic organisers are usually prepared with written cues, so that students would know what kind of thinking strategy they need to perform (Hyerle, 2009; Swartz et al., 2008).

Cues such as ‘*how are these two different*’ or ‘*why did you say that*’ trigger students’ thinking to compare or to make inference. Hyerle (2009) has developed eight types of thinking maps for basic cognitive skills. There are thinking maps for analogies, parts-whole, compare and contrast, describing qualities, context reference, cause and effect, sequencing and classification. These eight thinking maps are widely used across different disciplines in schools. In Malaysia, these eight thinking maps are strongly recommended for teachers to use in daily lessons, under the 'I-THINK' programme launched recently (MOE, 2013).

According to Hyerle (2009), students can use thinking maps to identify specific thinking strategies initially and by practice, should be able to self-assess their learning. Swartz et al., (2008) used the term graphic organiser to aid students' thinking process, which is generally similar to Hyerle's basic eight thinking maps. However, the graphic organizers have cues to trigger students to use specific strategies. For instance, the parts-whole thinking map as in Hyerle's eight thinking maps, is a visual representation for students to analyse parts of an event and to look at them in terms of how they function as a whole concept. On the contrary, Beyer (2008a), Reagen (2008) and Swartz et al. (2008) re-designed the thinking maps into graphic organizers with cues to help each step of the parts-whole thinking process. This is to clearly model students on how the parts-whole thinking process should be performed. At each level, there are cues like 'what happens if this part does not exist'. For example, '*what happens to photosynthesis process, if green plants do not have leaves?*' Such cue would trigger students to think of the function of tree leaves in making own food (photosynthesis), and predict the implication to the whole food chain if plants failed to make food. Thus, these cues are added to the graphic organiser to organise students' specific thinking process.

Another kind of visual tool is the concept map. Concepts are found to be equally effective to map out students' thinking (Ritchhart, Turner, & Hadar, 2009), particularly in eliciting students' thinking about thinking. The study done by Ritchhart et al. (2009) on 239 students proved that students tend to draw what they think about the way they think. By students drawing and visualising thinking, teachers would be able to diagnose students' thinking processes as well as their understanding of subject matter. Therefore, visual tools such as thinking maps, graphic organisers and concept maps are possible means to aid students' thinking processes.

Concept Cartoon. Apart from auditory cues, thinking maps or graphic organisers and concept maps, concept cartoons are gaining popularity in primary education. The significant study on concept cartoons by Keogh and Naylor (1999) has provided room for teachers to integrate concept cartoons in classroom learning, especially in science education (Keogh & Naylor, 1999). Following their study, many studies have been done to further verify the findings by Keogh and Naylor on the use of concept cartoons and how they can be a tool for stimulating thinking (Kabapinar, 2005, 2009; Kruit et al., 2012; Liston, 2011; Bahrani & Soltani, 2011). These days, concept cartoons are being used widely to sustain children's enthusiasm in learning as students are allowed to share their ideas and prior knowledge during scientific argumentations. Besides serving as a thinking tool for children in classrooms, concept cartoons also engage attention and interest during lessons. Figure 2.8 shows an example of a concept cartoons designed by Keogh and Naylor (1999), which was used to instigate scientific arguments among children in an interesting way. The three cartoon characters have different ideas or concepts about the effect of putting a coat on the snowman. This concept cartoon was used as a tool to stimulate students to think about how the coat might affect the snowman. This creates a cognitive conflict – a situation in which learners find new ideas that contradict their own idea or beliefs.

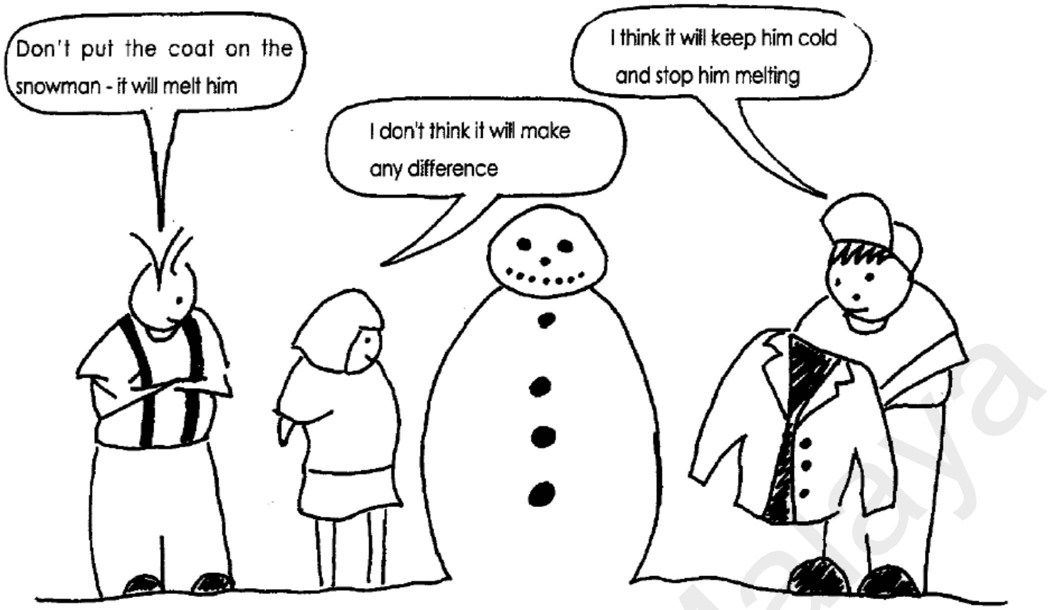


Figure 2.8. Concept Cartoon as in Keogh & Naylor (1999) p. 433

This enables teachers to get to know students' ideas or their thoughts about a science concept, when the students share their ideas. Students can either agree or disagree with the concepts (in speech bubbles) or come up with their own explanations, different from the concept cartoons. Teachers then could ask students to give their reasons and justifications for their choice of idea. With this tool, teachers could engage students in scientific argumentation (Teou & Chin, 2009). The use of concept cartoons has been noted as one of the best strategies teachers can employ particularly in addressing scientific misconceptions (Hodgson, 2010; Hodgson & Pyle, 2010). Concept cartoons are very effective as an early assessment of learners' prior knowledge and at the end of a lesson. Concept cartoons are accepted as one of the most effective diagnostic strategies teachers can use (Chin, 2001) and improvements are making concept cartoons more effective for practitioners (Kabapinar, 2009).

The use of concept cartoons as triggers for cognitive conflicts among children during inquiry or scientific investigation is most effective (Evrekli, Inel, & Balim, 2011; Keogh & Naylor, 1999). Kruit et al. (2012) have investigated the role of concept cartoons in developing children's reasoning skills. Twenty-nine children aged between 10-11 years with no experience in inquiry nor in carrying out experiments participated in the study. The researchers found that concept cartoons function as a platform for children to design and plan scientific investigations on their own. Such atmosphere creates excellent stimulus to promote argumentation and scientific investigation (Hodgson & Pyle, 2010; Sepeng, 2013). Nevertheless, the process of making sense of the claims (ideas), evidence and reasons throughout the scientific investigation needs teacher intervention. Teachers scaffold students' analytical skills so that they make sense of the information or ideas they receive, thus make generalisations of the science concept under discussion. Indeed, concept cartoon is an effective tool to stimulate thinking skills, especially among young children.

The purpose of using concept cartoons can be to promote discussion for practical work among students or for teachers to elicit students' misconceptions in science concepts (Kabapinar, 2005). An investigation was carried out to investigate on learners' reasoning behind misconceptions and on how they may remedying them (Kabapinar, 2005; Wei et al., 2007). It was discovered that using concept cartoons for discovering the reasoning behind learners' misconceptions and on remedying them is more effective with teachers' intervention during classroom inquiry sessions (Kabapinar, 2005; Wei et al., 2007).

Thus, tools such as auditory cues, thinking maps and concept cartoons are found among the most effective to stimulate and aid children's thinking processes. A graphical representation on how tools can be used in teaching thinking skills is shown in Figure 2.9.

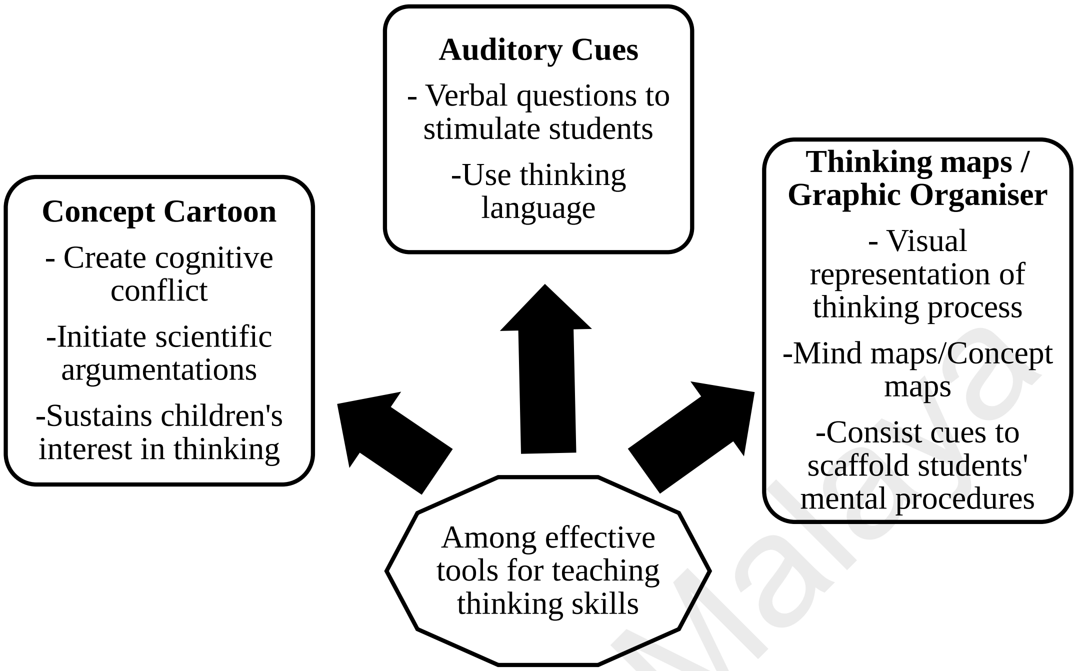


Figure 2.9. Graphical Representation to show the three main tools for teaching thinking skills.

With some general understanding about ST, the infusion of the three elements in ST, curriculafor ST and science teachers' pedagogical knowledge in ST infusion, it is essential to narrow down the scope to understand ST in the local context.

ST in the Malaysian context. The Malaysian science education system has undergone vast changes over two decades. In the 1980s, Man and Nature (*Alam & Manusia*) was introduced in the primary education starting Year Four as one of the elective subjects. It comprised a collection of Science, History and Geography topics made simple for primary children. Later, science was taught as a subject on its own, replacing the former subject, in the Integrated Curriculum for Primary School, KBSR (*Kurikulum Baru Sekolah Rendah & Kurikulum Bersepadu Sekolah Rendah*). In 2003, PPSMI or ETeMS (English in Teaching Mathematics & Science) was implemented to enhance the mastery level of the English Language through the learning of Science and Mathematics. During the ETeMS era, Science was taught as early as Level 1 (Year 1, 2 and 3) where children discover their surroundings through basic scientific skills. After much controversy over the effectiveness of ETeMS which was debated as a national agenda, ETeMS is now replaced by MBMMBI (*Memartabatkan Bahasa Malaysia*, *Memperkukuhkan Bahasa Inggeris*) or translated as *Uphold Bahasa Malaysia*, *Strengthen the English Language* (English translation). Starting 2011, MBMMBI was brought into practice in the latest curriculum, the KSSR (*Kurikulum Standard Sekolah Rendah*) and KSSM (*Kurikulum Standard Sekolah Menengah*). However, the paradigm of teaching and learning of science is still unsatisfactory based on pupils' performance (Malaysia Education Blueprint, 2013). This was mainly due to teachers' poor understanding of the thinking language and students' inability to understand the questions or cues and also to provide scientific explanations.

Following recent alarming scores of Malaysian pupils' performance in Mathematics and Science in PISA (2012) and TIMSS (2011), the newly implemented KSSR curriculum is anticipated to incorporate thinking skills, creativity and entrepreneurship skills among pupils. It is vital to question where we are now, where we are supposed to be, and more importantly, how to get there. Thoughtful learning demands a combination of learners' ability to grasp basic and higher order thinking skills (HOTS) in order to acquire scientific thinking and pedagogy that caters for such thinking to take place. Previous research has shown that young children can be taught how to think (Bao et al., 2009; Fencl, 2010; Swartz et al., 2008). Although preference is given on developing thinking skills in science classrooms, the pedagogy aspect deserves equal attention. Questions on how thinking skills are taught during science lessons, how pupils' thinking skills are being assessed and whether Malaysian teachers assess content knowledge, scientific skills or thinking skills of their pupils are on the rise.

One of the objectives of the Malaysian current (KSSR) primary science curriculum is to inculcate thinking skills in pupils that can be achieved through thoughtful learning whereby pupils are actively engaged in the learning process (Primary Science Curriculum Specifications, 2006). Preferences are given for pupil driven learning, in which pupils take charge of their learning facilitated by their teacher.

> 'This is an area where the system has historically required more improvement, resulting in pupils being less able than they should be in applying knowledge and thinking critically outside of familiar academic contexts. Consequently, it is more important than ever for the education system to help every student to acquire these thinking skills'. (Malaysia Education Blueprint, 2013 - 2025, p. E-10)

Currently, the Malaysian Curriculum Development Centre (CDC) has developed a well-designed curriculum that emphasises thinking skills. The current curriculum is the consequence of the alarming scores in the recent international PISA (2012) and TIMSS (2011), an assessment on mathematics, science and language performances among students. It was found that the unsatisfactory results reflect the lack of reasoning ability in Malaysian pupils (International Study Center, 2011). Since reasoning skills are the foundation for other integrated thinking skills, it is vital to teach pupils to reason well to become good at giving reasons for observed scientific events with enhanced thinking skills. Critical, creative thinking and reasoning ability are among the thinking strategies proposed by the new curriculum (Ministry of Education, 2013).

Thinking skills at present are anticipated to be implicitly taught during science lessons in Malaysian classrooms, whereby they are integrated during acquisition of science process skills or content knowledge (CDC, 2012). The largest threat is science teachers lacking in knowledge on the levels of thinking skills, the LOTS (lower order thinking skills) and HOTS (higher order thinking skills) (Nair & Ngang, 2012). Being unaware of the fundamentals of reasoning, critical and creative thinking skills in the curriculum, is an impediment to a thoughtful teaching and learning experience (Abdullah Mohd Noor, 2009; Nair & Ngang, 2012; Rajendran, 2001).

Despite the ongoing efforts taken by the Ministry, the essence of thoughtful learning seem lacking in science lessons nowadays. Shifting from rote learning or "chalk & talk" kind of teaching to student centred learning means adopting the culture of "hands-on activities" during science lessons, particularly in primary science education (Fencl, 2010). Hands-on activities denotes the action of pupils actually 'doing science' through science experiments or scientific projects. Yet, the argument is whether the action of thinking is active during the act of doing (Fencl, 2010). Pupils conduct scientific activities as prescribed by their teachers or practical books. The availability of recent practical and workbooks by local publishers means that scientific activities have become more of a 'cooking class based on given recipe', with little space for HOTS (Yen & Siti Hajar, 2015). Indeed, science practical in laboratories and educational field trips are fun and motivating. In the midst of joy in doing science practical, though, some pupils miss the essence of ST for thoughtful learning to occur. Such practice of teaching and learning creates inconsistency between the aspired classroom practices by the curriculum and the real practices (Hashimah Mohd Yunus, Zurida Ismail, & Raper, 2004).

Studies in Malaysia on critical thinking show consensus on teachers' perceptions on the importance of thinking skills in education across disciplines (Rajendran, 2008; Rosnani Hashim & Suhailah Hussein, 2003). Such studies have indicated that while teachers and educators realise the substance of teaching thinking skills, many are less skilful in teaching along with diagnosing students' thinking skill. The 'I-THINK' has been introduced in Malaysian schools starting in 2014 to facilitate teachers in teaching thinking skills among pupils across the country. It is a collaborative programme by the Malaysian Education Ministry (MOE) and Malaysian Innovation Agency (AIM) that provides training for teachers in conducting I-THINK strategies in classrooms across disciplines. It is aimed at creating and developing a thinking culture that helps pupils to become better critical, creative and innovative thinkers (Curiculum Development Centre, 2012). The programme comprises of eight thinking maps; circle map, bubble map, double bubble map, tree map, brace map, flow map, multi-flow map and bridge map. Each thinking map serves a different purpose of the thinking process. It includes defining in context, describing qualities, comparing & contrasting, classifying, part-whole relationships, sequencing, cause-and-effect and seeing analogies. There are still, however, issues on teachers' use of these thinking maps in teaching students to think (Abdullah Mohd Noor, 2009; Yen & Siti Hajar, 2015). Teachers were found to underutilise these thinking maps.

Researchers in Malaysia studying the aspects of thinking skills in the Malaysian context have contributed to changes in classroom practices, curriculum implementation, pedagogy content knowledge and assessment on thinking skills (Abdullah Mohd Noor, 2009; Rahil Mahyuddin et al., 2004; Maria Salih, 2010). One such example is a study by Abdullah Mohd Noor that has thrown some implications on the pedagogical shift that promotes thinking skills in classroom practices. Students require transferable skills that lead to better problem solving and decision making in any new context (Abdullah Mohd Noor, 2009). Even a decade ago, teachers were found generally incapable of teaching thinking skills and needing improvements in their teaching practices (Rahil Mahyuddin et al., 2004). Years later, Salih (2010) found that a conceptual framework called the Thinking

Skill Thinking Strategy (TSTS) by the Malaysian Curriculum Development Centre, which had potential for accelerating thinking skills among students, was underutilised by teachers. Recent studies in Malaysia which studied teachers' practices in teaching thinking skills, found that current practices to be at unsatisfactory level across different subjects such as science education (Mohd Zaidir Zainal Abidin & Kamisah Osman, 2017; Punnithann Subramaniam & Tajularipin Sulaiman, 2017) and language (Beremas Anak Inggit & Effandi Zakaria;, 2016).

From the review of related literature, it was found that the teaching of thinking skills, particularly by the infusion of ST is lacking in primary science education. This was due to lack in teachers' pedagogical knowledge in the context of ST infusion. Based on literature readings related on strategies for enhancing teachers' knowledge and practices, the researcher found that educative curriculum materials play important role.

Educative Curriculum Materials

Davis and Krajcik (2005) claimed that teacher's pedagogical knowledge and pedagogical content knowledge are important in implementing any new approach into classroom practice. The concept of pedagogical knowledge and pedagogical content knowledge originally was brought up by Shulman in the 1980s, highlighting the components of content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK) (Shulman, 1987, 1986). Thus, the use of educative curriculum materials for teachers, as part of the curriculum that supports and upgrades teachers' PCK (Schneider & Krajcik, 2002).

According to Schneider and Krajcik (2002), the role of educative curriculum material supports teachers' learning on new instructional practices, hence designing curriculum materials to be educative for teachers is crucial. Figure 2.10 shows the criteria of educative curriculum materials derived from the works by experts in the field of educative curriculum materials design and development. Based on Figure 2.10, an educative material should provide guide for teacher thinking & independently make decisions on how to incorporate new/recommended strategy.

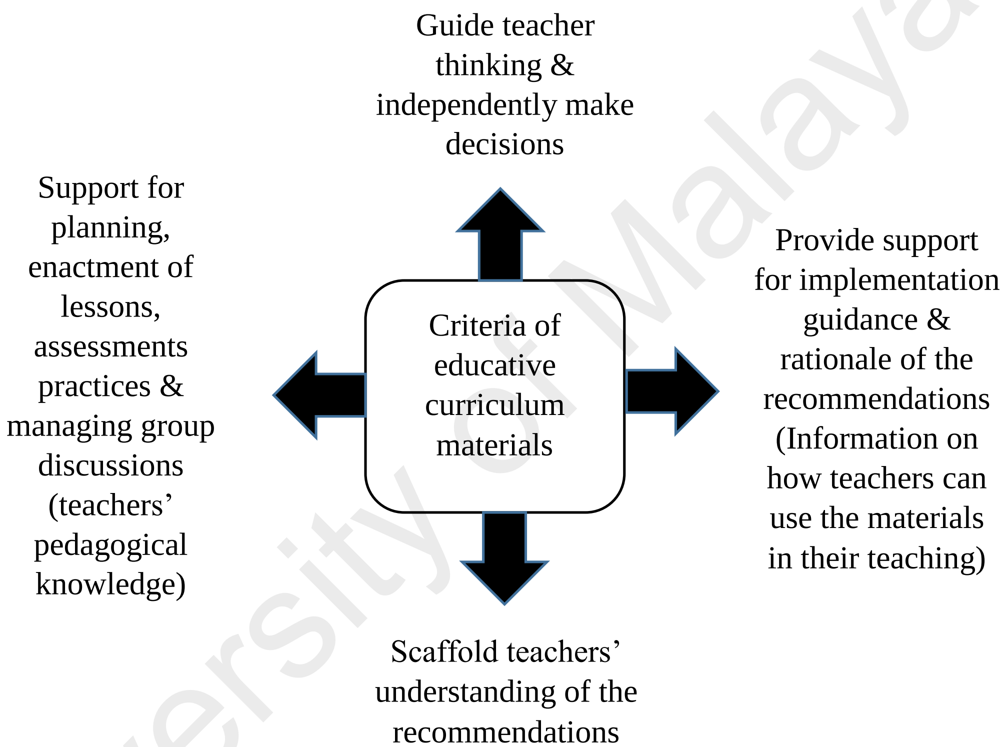


Figure 2.10. Criteria for educative curriculum materials for teacher-learning derived from studies by Davis & Krajcik, 2005; Grossman & Thompson, 2008; Schneider, 2012; Krajcik & Delen, 2017).

It also should guide and enhance teachers' pedagogical knowledge in terms of lesson planning, enactment of lessons, assessments and managing group discussions. This shows that educative curriculum materials should facilitate teacher-learning of an idea or new approach in teaching. In addition, designing educative materials as such not only supports teacher learning but students as well (Schneider & Krajcik, 2002). However, some researchers argued that the constructs of subject content knowledge, pedagogical knowledge or pedagogical content knowledge are inappropriate and unfit in the concept of teaching thinking, as focus is given on instruction for HOTS rather than subject matter (Zohar & Schwartzer, 2005). They suggested the use of term 'teachers' pedagogical knowledge in the context of teaching higher order thinking skills' to refer teachers' knowledge and practices in promoting students to think at higher levels.

Despite the disputes between the two ideas of how teachers' pedagogical content knowledge is connected to the teaching of science, current researchers found that effective educative curriculum materials for in-service teacher learning are able to enhance teaching of science, thus accelerating teachers' professional development (Davis, Nelson, & Beyer, 2008b; Shu, Lieu, Chen, Huang, & Chang, 2012). The main idea here is that if science teachers are provided with the support (guidance) in form of educative curriculum materials, then they (teachers) would be able to rationalise why an approach is significant in their students' learning process, thus employing the approach effectively.

These are the heuristics required to design educative materials that would be sufficient to 'educate' teachers on the approach, taking into account teachers' content knowledge, pedagogical knowledge and pedagogical content knowledge (Davis & Krajcik, 2004). Nevertheless, to make teachers understand and apply the approach, design features that can 'transmit' the designers' message are crucial (Davis & Krajcik, 2005; Schneider, 2013; Schneider & Krajcik, 2002). These researchers have outlined significant findings that would shape design heuristics and features of educative curriculum materials. Recent studies on educative materials have proven how such design heuristics and features support teacher learning and facilitate enactment of a concept or strategy such as inquiry method and nature of science (Krajcik & Delen, 2017; Lin et al., 2012). Davis et al. (2014) have drawn design heuristics and features for designers and developers to explore more on educative curriculum materials for science teachers, which consists of five forms; "content support features, support for scientific practices, narratives, support for literacy practices and support for assessment practices" (Davis et al., 2014, p. 36). Whatever channel and purpose educative materials are used for, the ground function is to 'educate' both students and teachers. In line with this, the benefits and limitations educative curriculum materials have been studied by Krajcik and Delen (2017), whereby they have discussed that the use of such materials do support teacher-learning of new strategies; however it can be very challenging to write educative curriculum materials. This may perhaps be due to diverse students in classrooms, in which the use of educative curriculum materials may work well to certain groups of students only.

Educative curriculum materials in the Malaysian context. Educative pedagogical materials that integrate all three elements of ST and assessment on students' thinking skills are lacking. Furthermore there exists lack of correspondence between the goals of teaching thinking and the content of subjects the being taught (Rajendran, 2001; Rosnani Hashim, 2003). The existing teaching modules for Malaysian teachers are insufficient for teaching ST in primary science classrooms. Various teaching materials available for in-service teachers to teach primary science in Malaysia; among them are Year Four Science Teaching Module, Creativity and Innovation Teaching Module, Reasoning Ability Teaching Module, Science Process Skills Teaching Module and Year Four Science Textbook / Practical books.

A common attribute to all the mentioned teaching modules is the element of thinking. In the Malaysian science primary education, reasoning, critical and creative thinking skills are acknowledged as thinking skills in general. Teaching modules such as the creativity and innovation and reasoning ability teaching modules are designed in general to tell teachers how to develop creativity, critical and reasoning abilities across various disciplines. These teaching modules tell teachers what to do without providing the rationale of why they should do so. Teachers need modules that are educative for them to learn how to teach thinking.

Educative curriculum materials should provide the support and rationale for the decisions made on the instructional strategies suggested in the material (Beyer, Davis, & Krajcik, 2007). This includes providing the implementation guidance on new ideas of an approach in order for teachers to learn and use their potential to plan and enact lessons. For example, in teaching ST, curriculum materials for teachers, should be educative on how to infuse ST by recommending strategies to explicitly teach children thinking strategies, habits of mind and metacognition. It should also provide the rationale behind each recommendation so that teachers would be able to understand how the recommended strategies help students to enhance their thinking skills. Existing teaching modules in the local context, however, mainly provide generic sample of lesson plans for teaching thinking skills. These materials are also lacking in other domains of ST such as how to develop students' habits of mind and metacognitive thinking.

It can be inferred that lack of educative curriculum materials for in-service teachers to infuse and assess ST can be a major factor for the passive development of thinking skills among students in Malaysia (Abdullah Mohd Noor, 2009; Rahil Mahyuddin et al., 2004; Rosnani Hashim, 2003). Consequently, in-service teachers need educative curriculum material that promote teacher-learning of ST to upgrade their pedagogical knowledge in teaching thinking skills among young children in science classrooms.

Design Heuristics and Educative Features

Design heuristics denote the kind of support for teacher-learning learning (Davis & Krajcik, 2004, 2005; Davis et al., 2014). They comprise areas in which teachers need an upgrade, teachers' knowledge, pedagogical knowledge and pedagogical content knowledge. This include guidelines to engage teachers in planning and teaching, responding to students' ideas and thinking, assessing students' learning, conducting conducive sessions for students' active engagement (Bismack et al., 2014). Three main heuristics are found to be widely taken into consideration when designing educative curriculum materials; support for developing teachers' knowledge, scaffolding teachers' practices and managing students' small group discussions (Davis & Krajcik, 2005; Grossman & Thompson, 2008; Neuman, Pinkham, & Kaefer, 2015).

Developing teachers' knowledge. Before looking into teachers' conceptualisation, introducing the term 'conceptual change' would provide the ground to build on understanding how teachers' conceptualisation is equally important According to Babbie (1999), concepts are made from 'the process of coming to an agreement which is called conceptualization' (Babbie, 1999, p. 99). On the other hand, conceptual change refers to as to how concepts change during the learning process. This means when teachers learn new approaches in teaching thinking skills, and are able to enact the approaches in their lessons, they would change their initial idea about the concept of teaching thinking skills, which was found difficult in the beginning.

Brilhart (2010) claimed that it is fairly important to explore teachers' conceptualisation of a subject because teachers conceptualise through their own personal experiences. It represents 'how teachers think about their work '(Brilhart, 2010, p. 169). Through observations and interviews with several teachers, Brilhart (2010) found that teachers' conceptualisation of teaching consists of teacher-student interaction. His findings suggested that preparation for teacher professional development programs should include teachers' knowledge of classroom relationships. Lin et al. (2012) argued that teacher-learning materials should provide support for teachers' understanding of teaching methods recommended. They suggested design heuristics for supporting teachers' knowledge and practices to employ an approach.

Both studies suggested that developing teachers' knowledge of student-teacher relationship is important. Therefore, it is essential to support conceptual changes in teachers in teaching thinking in order for successful implementation of any intended approach for developing students' thinking skills. One way to support conceptual changes in teachers is by providing the rationale as to why they need to adopt new approaches in teaching thinking skills. Such change in teachers' conceptual understanding of teaching thinking would be beneficial in promoting their new knowledge construction to teach thinking as an integral part (Tillema, 1997). According to Tillema (1997), new information that are presented (a newly introduced teaching approach, for example) should provide clear explanation that could be easily understood, offer effective solutions that are congruent over time and more importantly, should be useful in ways that would cater for new opportunities. Hence, to introduce a new teaching approach to teachers, support in terms of conceptual change in teaching should be emphasised. This would include new information educative and effective for teacher-learning to be presented in an understandable way.

Supporting teachers' ST practices in classroom. Teachers need to know how to teach various thinking strategies, develop students' habits of mind and promote metacognitive thinking among students. To teach by directly explaining students the name of thinking (namely compare, contrast, inference, justify and reasoning), how to perform them and how to think about how the they had performed them calls for direct instruction. Direct Instruction (DI) has developed over 25 years that has certain algorithm of teaching procedures, that supports academic achievements, problem solving abilities and confidence in young children (Binder & Watkins, 1990). DI being among the instructional strategies teachers could use, is found to be appropriate for teaching ST (Swartz et al., 2008; Reagen, 2008; Magliaro, Lockee, & Burton, 2005). Earlier perceptions on DI was negative and claimed that DI is ineffective in teaching and learning, mainly because it delivers precise scripts for teachers and restricts learners' freedom to explore more than what had been 'instructed' (Binder & Watkins, 1990; Education Consumers Foundation, 2011; Schweinhart, Weikart, & Larner, 1986). Peterson (1979) argued that the choice of teaching method should depend on the intended educational goals and that should a teacher attempts to teach inquiry skills, DI is not advisable (Peterson, 1979).

According to Magliaro et al. (2005), direct instruction (DI) is not a lecture approach which dictates dialogues between teachers and students. Direct instruction does not mean directly teach content knowledge like rote learning, but it means to directly and explicitly explain to students how to perform thinking processes. For example, teachers need to directly model students on how to classify concepts step by step until they are able to do so correctly without teacher guidance. Rosenshine (2008) highlighted that confusion in the effectiveness of DI in education originated from lack of information on the type and form as well as how DI was used to claim to be effective. Further, this situation has created controversies over the use of DI in education among educators and researchers (Education Consumers Foundation, 2011; Rosenshine, 2008).

On the contrary, recent studies have found DI to have strong positive effect on students' learning process and achievements (Adams & Engelmann, 1996; Binder & Watkins, 1990; Westerhof, 1992). Most studies on direct instructions are in the field of language education especially in reading (Byas, 2007; Carlson & Francis, 2003), Mathematics (Westerhof, 1992), special education (Kamps et al., 2008) and academic achievements and thinking skills (Bessick, 2008). DI is gaining credentials in science education, nevertheless needs more research (Ingvard, 2013; Kowalczyk, 2003). This is because teachers need to directly teach students how to perform thinking strategies by modelling for them how to do it.

As mentioned earlier, the use of DI while teaching thinking skills in science education is less explored. A growing number of studies, however, provide insights to educators to use DI in science classrooms. A study reported by Kowalczyk (2003) claims that students' ability levels, learning styles and time/class schedule were the identified issues influencing science teachers' instructional choice. The study was conducted to investigate eighty-two K-5 elementary science teachers' beliefs on the use of different instructional methods such as direct instruction, guided discovery, unguided discovery and inquiry methods. Guided discovery method was reported as the most frequently used method by the teachers. They also found that a blend of discovery method with certain degree of direct instruction is perceived as the most effective instructional method to teach elementary science (Kowalczyk, 2003). This finding is in line with some of the academics who claim that these approaches do not work because teachers provide minimal guidance to students (Kirschner et al., 2006).

Wirkala and Kuhn (2011) studied problem-based learning (PBL) in K-12 Education and its effectiveness and how it achieves such effects. They found that activation of students' prior knowledge has profound contribution to PBL effectiveness, because they (students) access information that would lead them to solving the given problem (Wirkala & Kuhn, 2011). They also found that activation of existing knowledge among students worked individually in PBL is as well as the students worked in groups. The researchers also claim that students' new ideas can be prearranged into activated prior knowledge structures. Also, they re-confirmed the statement that through PBL, students are able to consciously reflect on their thinking. Their findings shed light on teachers' role in scaffolding learning through PBL. However, the kind of instruction is claimed to be highly dependable on teachers' skill in implementing it.

Hence, regardless of the teaching methods used, integrated approaches with direct instruction play a vital role in determining the effectives of DI (Kirschner et al., 2006). This is also supported by findings of a few studies claiming that appropriate "dosage" of DI is sufficient without overpowering the intended teaching approach (Nock, 1998; Wei et al., 2007). A single session on DI in developing thinking skills is indeed inadequate to develop thinking skills explicitly. According to Beyer (2008b), novices who learn new skills require five or more learning experience in thinking skills. Beyer (2008) supported Kaplan's (1997) claim that DI in teaching thinking denotes the utilisation of instructional strategies to promote precision and reflection as well to guide learners in developing patterns in ST. Teachers, on the other hand, are unfamiliar with appropriate pedagogical approaches to teach thinking skills, especially critical thinking skills. Difficulties occur when teachers translate generic approaches to suit subject content, which is time consuming. Therefore teachers resort to readily prepared resources (Bowers, 2006).

Predominantly, studies showed that thinking skills are best taught within a domain of knowledge or specific content (Beyer, 2008b; Bowers, 2006). It is the platform in which learners work on their thinking. This is found in line with studies by Higgins, Hall, Baumfield, and Moseley (2005), whereby they found that DI among vocabulary, mastery learning and accelerative instructions, is an effective intervention (Higgins et al., 2005). While the discovery method is among the best methods to learn elementary science, adequate direct instruction is required. Teachers need to directly teach students how to think about what they discover, so that it would be a meaningful discovery learning experience (Ireland et al., 2011).

Another aspect of pedagogical knowledge in teaching thinking is knowing how to manage small group discussions when students are assigned with thinking tasks. Science teachers encounter challenges when it comes to managing classroom discussions, because they may not know how to manage the class when the students are engaged with thinking tasks (Harris & Rooks, 2010). They asserted that in science classrooms, managing classroom discussion is not merely about controlling students' behaviour, but should emphasise how teachers could generate situations for students to actively engage in thinking tasks.

Managing classroom discussion. This segment describes how science teachers manage classroom discussions, particularly in terms of managing students for exploratory talk during activities on developing thinking skills. Therefore the focus is on how teachers could organise their class to provide conducive environment to sustain students' engagement in thinking activities. Having fun activities may excite children for a while, but the essence of learning depends on the thinking activity, whereby teacher-students discuss the experiences from the 'fun activities" they encounter (Howes, 2008). Research has shown that class size has great impact on overall students' academic achievements, whereby smaller manageable class students perform better, getting full attention from teachers (Shin & Chung, 2009) and explains the need for instructional strategies to overcome barriers in larger classes (Milesi & Gamoran, 2006). Managing classroom discussions among children in large classes is indeed a threat for conducting activities on developing thinking skills.

Exploratory talks among children in science classrooms have proven to be effective in developing reasoning skills, critical and creative thinking as well as general thinking skills including problem solving (Mercer, Dawes, Wegerif, & Sams, 2004; Mercer, Wegerif, & Dawes, 1999; Webb & Treagust, 2006). This is apparent in some school curriculums that gives focal attention to developing thinking skills (Northern Ireland Curriculum, 2007; Welsh Asssembly Government, 2010a). Among the benefits of having exploratory talk among young children is the conceptual change, which occurs under particular social interactions and cognitive states (Dunbar, 1995).

Teaching thinking skills requires effective interaction between teacher and students. This does confirm Vygotsky's theory on social interaction and its effect on student learning process. Perhaps the main question is how primary science teachers can structure group discussions for effective teacher-student interactions (Gayle, Preiss, & Allen, 2006). Teachers require pedagogical skills to extend students' thinking during whole-group discussion (Cengiz, 2007). In addition, small group and full-class discussions were also found to be effective as *different kinds of scaffolding* seemed helpful (Haglund, Jeppsson, & Andersson, 2012) in developing analogical reasoning among first graders aged 7 to 8 years old.

Among other effective methods to conduct conducive classroom discussion to elevate scaffolding with less 'disruptions', is by setting ground rules. Gibson (2009) has claimed that by setting ground rules for classroom discussions, participants (students) are able to interact safely, gain confidence in expressing their ideas and thoughts and hold shared responsibility for the discussion outcomes. This claim is closely related to thinking disposition and habits of mind for ST, whereby students eventually reap the habit of applying appropriate thinking skills and exhibit thinking behaviours (Costa, 1999; Gibson, 2009; Walsh et al., 2007).

As to how exploratory talk and ground rules help improve thinking skills, particularly reasoning skills, researches have also found that ground rules assisted children in solving reasoning tasks through exploratory talks (Higgins et al., 2005; Mercer et al., 2004). Among them are to allow 'only one person to speak', become 'good listeners', 'to think' before sharing thoughts and ideas, 'show respect' for others' views but no necessarily accept them blindly and most 'importantly is to give reasons' for what has been said or suggested or disagreed (Costa & Kallick, 1996; Fisher, 2007; Welsh Asssembly Government, 2010b). Apart from helping with thinking skills, metacognitive skills and habits of mind, students' moral character building can be achieved from practicing exploratory talks and by setting ground rules (Bringzen & Sanchis, 2007). The common ground rules found in the literature revolves around several behaviours in discussions (Mercer et al., 2004; Walsh et al., 2007). Setting ground rules allows students to discuss in a harmonious way. For example, when a member is sharing ideas in a group, other members should pay attention, wait until the person has finished his/her argument, then put forth their arguments.

Recent studies also have highlighted the importance of exploratory talks with ground rules; among them are giving joint reasoning, relevant information shared with all members, taking shared responsibility of any decision made, overcome challenges, consider alternatives before making decisions, thus enhancing classroom discourse among children (Hackling, Smith, & Murcia, 2011; Kruit et al., 2012; Fung, 2014). For instance, Fung (2014) has studies the development of ground rules among Chinese students and the promotion of critical thinking by adopting ground rules during group discussions. This include ground rules such no one should interrupt when someone is talking during discussion and group members should not talk too loudly. Since group discussions are generally consist small number of members, ground rules are often obeyed. Fung (2014) found that combination of teachers' explicit instructions for thinking and adoption of ground rules provide the space for active engagement among students. Figure 2.11 shows the design heuristics that the researcher proposed in the design of the educative curriculum material in the present study.

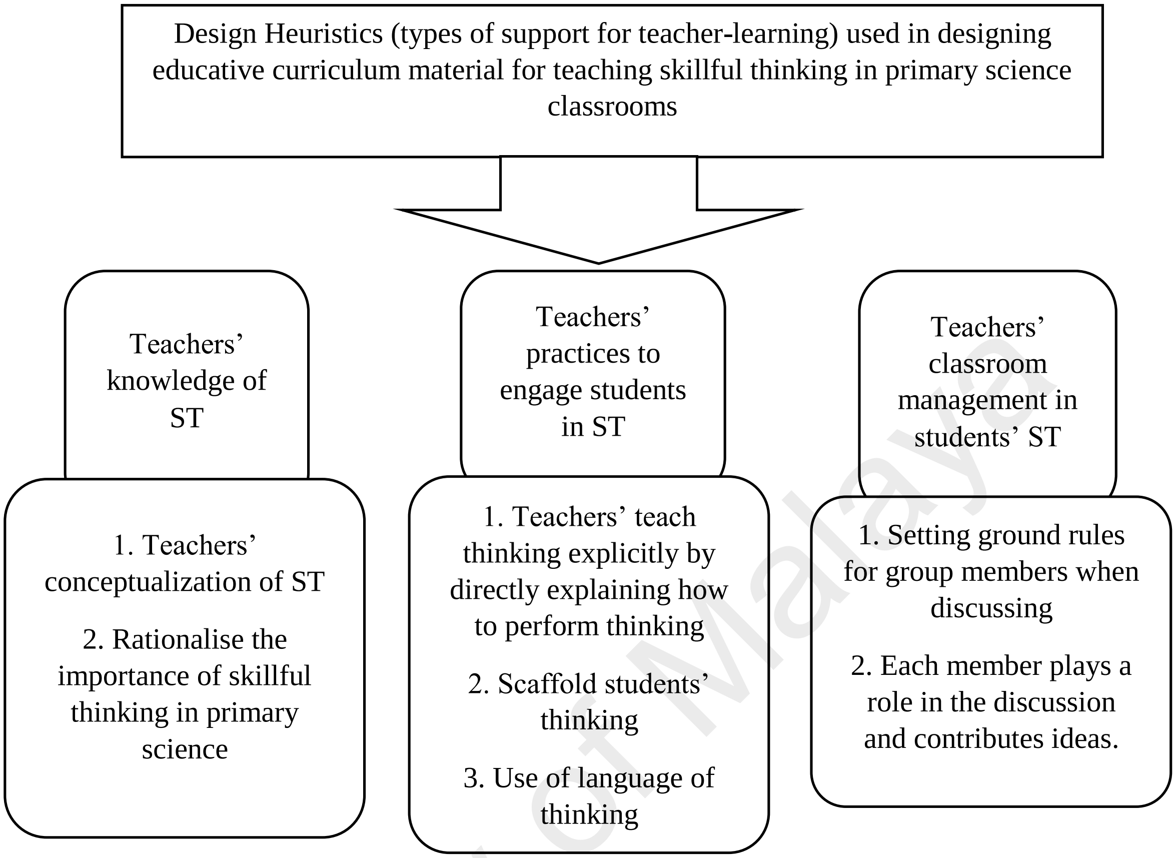


Figure 2.11. Design heuristics proposed in the present study for the design and development of the STEPS derived from Davis et al., (2014); Lin et al., (2012) and Schneider (2006).

In previous section, the researcher discussed the three design heuristics (support) for the design of educative material for teacher-learning of ST. In order for the material to be educative, design features to aid teacher-learning are equally important (Davis et al., 2014; Arias et al., 2017).

Past Methodologies in Related Studies

Various qualitative and quantitative data collection and data analysis techniques have been used in exploring teachers' practices. Quantitative researches studied what teachers know about teaching thinking in science education. Several selected studies related to teachers' pedagogical knowledge used surveys to collect data about teachers' knowledge in teaching thinking (Haciemİnoğlu, 2014; Harris & Rooks, 2010; Jones, 2008). Haciemİnoğlu (2014) studied in-service teachers' views about the integration and practices of history of science (HOS) and nature of science (NOS). Surveys on both HOS and NOS adapted to suit the study were used as source of data paired with teacher interviews. Similarly, Jones (2008) and Harris and Rooks (2010) investigated the impact of training in teaching thinking skills among science teachers. They employed questionnaires with 22 questions regarding teachers' perceptions on teaching thinking. However, these studies explained teachers' views and practices based on pre-determined criterias as in the questionnaires. Other studies related to teaching thinking skills mostly employed quantitative method to measure change in students' achievements in thinking abilities (Magno, 2010; Topcu & Yilmaz-Tuzun, 2009). The common feature between these studies was that they all have employed qualitative methods such as observation tools, interviews with participants, audiotaped lessons, journal writings, documents and field notes to support findings from quantitative method. Therefore, qualitative methods were employed to gain deep insights about how participants (both teachers and students) perceive their thinking (students) or teaching practices (teachers).

Beyer et al. (2007) analysed related documents such as teachers' guides and other curriculum materials provided for teachers, and categorized the contents based on the design heuristics. Two major components of educative features analysed were the "rationales and implementation guidance". Beyer et al. (2007) described 'implementation guidance as a form of educative support that focuses on helping teachers to know how to use instructional approaches and activities in productive ways' (Beyer et al., 2007, p. 6). And rationale are 'justifications made explicit' for infusing a certain approach in the related unit of curriculum, thus explain as to 'why doing so is pedagogically appropriate' (Beyer et al., 2007, p. 6). Based on these operational definitions, the researchers categorized the documents into nine design heuristics. Further, these categorizes were then collapsed down into three 'domains namely, teacher content knowledge, PCK for science topics and PCK for scientific inquiry' (Beyer et al., 2007, p. 7). Such document analysis strategy have outlined explicitly with using peer review and without presence of rubrics to evaluate the quality of support the documents offered.

The reliability and validity of the evaluation findings were considerately high due to the reviews made several times using different sets of materials. Using the design heuristics and evaluation criteria proposed by Beyer et al. (2009), Japanese researchers analysed textbooks provided for science teachers in Japan (Yamaguchi & Kanamori, 2009). However, they separated the category 'teachers' subject matter knowledge' apart from the support category (implementation guidance & rationale) believing that the acquisition of teachers' subject matter knowledge supports ones' own learning.

In recent study by Davis et al. (2014), 'designing educative features were carried out by analysing curriculum units for characterization of learning opportunities and characterization of student learning outcome' (Davis et al., 2014, p. 32). This is the process of looking deep into how curriculum units (learning opportunities and student learning outcomes) can be designed to provide space for teacher learning, facilitated by educative features. The researchers have used lesson observation protocols, structured field notes protocol and video tapings as data collection procedures. These techniques were then used to characterize teachers' adaptability of each curriculum unit. Schneider et al. (2000) also videotaped science lessons and described teacher practice in teaching elementary science based on recommended educative curriculum features. Interviews with teachers were carried out before and after lessons, focused on plans for instructional strategies, adaptations and reasons (Schneider et al., 2000). Questions were on helpful educative features in the materials and on how did the teachers use them. The researchers looked for emerging patterns to investigate how the educative features were perceived and employed as well as how the lessons were executed. This was to provide relevant evidence to indicate teacher conceptualization and learning through the educative features.

In another study, on using educative assessments to support teacher learning, focus group interviews with teachers were conducted to gain insight on how teachers interpreted students' responses on the designed assessments (Buxton et al., 2012). Buxton et al., (2012) employed interviews, observations, teachers' written reflections, researchers' and respondents' notes during classroom observations. In similar pattern, Berry and Davis (2009) analysed lesson plans and related educative support, by interviewing teachers on how they adapt their materials and *rationales* behind their decisions. Also, in terms of understanding teachers' conceptualisation, Beyer and Davis (2009) have conducted interviews asking 'teachers to describe their understanding of what it means to identify, interpret, and work with students' science ideas and explain why they think these practices are important to science teaching' (pp. 523-524). Thus, these studies emphasise data collection techniques that are able to probe teachers' understanding on a concept and enactments in classroom teaching. These studies have shown how interview protocols, classroom observations, relevant document analysis and field notes can be employed as data collection methods to measure teachers' conceptualisation, enactments and classroom assessment practices in favour of teacher- learning concepts (Buxton et al., 2012; Davis et al., 2014; Lin et al., 2012; Schneider & Krajcik, 2002).

Literature Map

The literature map (see Figure 2.12) shows graphical organisation of studies related to the teaching of ST in the present study. The researcher found that ST is among the approaches that teachers could use to develop their students' thinking skills. Unlike other approaches that focus on developing thinking skills per se, ST takes into account the development of habits of mind and metacognition apart from teaching thinking strategies.

Following further readings on reasoning abilities, scientific skills and critical & creative thinking skills, the researcher could conceptualise the importance of teaching ST in primary science classrooms. This provides understanding as to how teachers could teach the different kinds of thinking strategies and develop students' habits of mind and metacognitive skills. Studies on teachers' pedagogical knowledge in teaching thinking skills have contributed in understanding teachers' challenges in teaching ST. This includes teachers' conceptualisation of teaching thinking and engagement of students in thinking tasks.

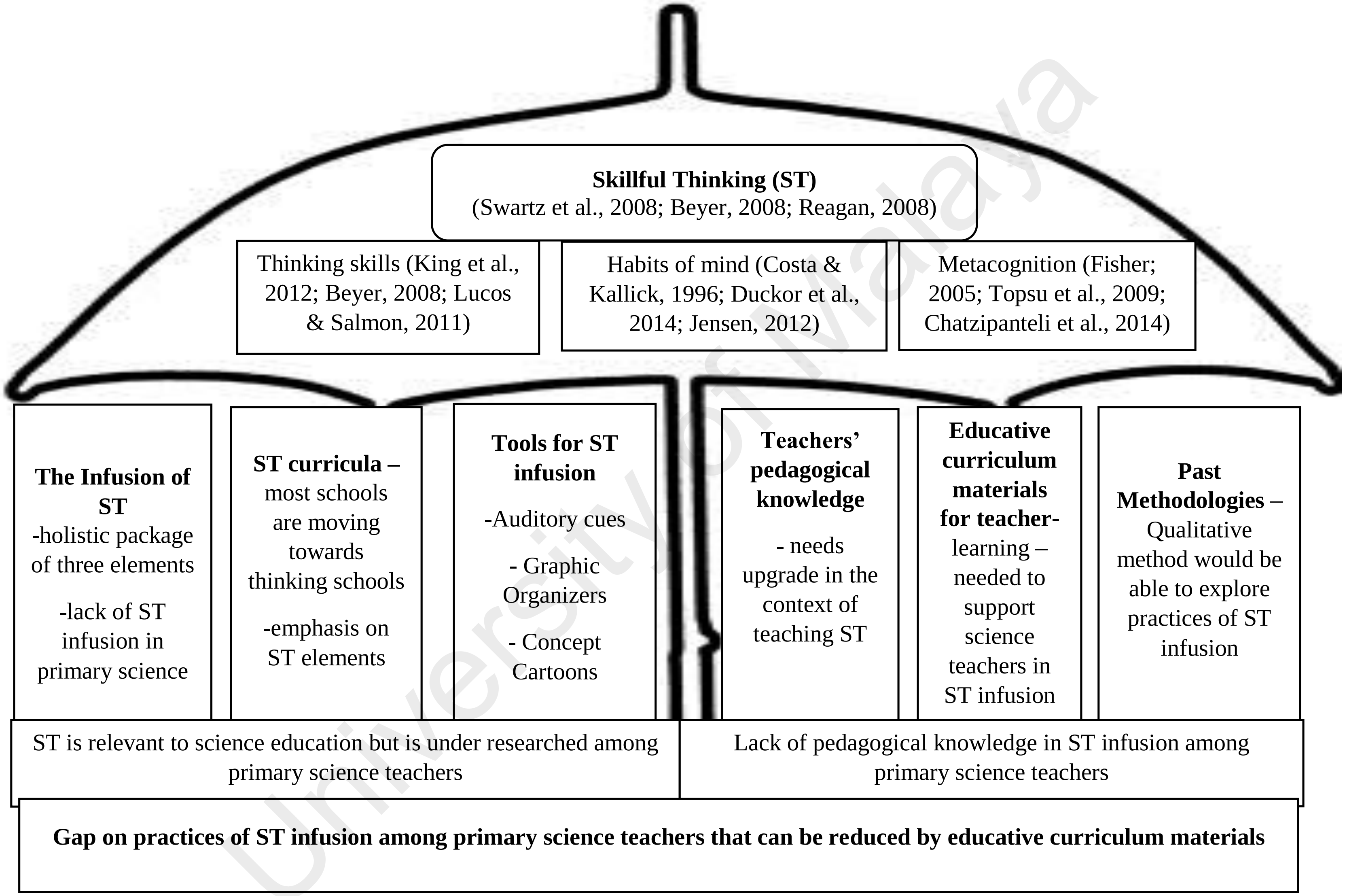


Figure 2.12. Literature map for the present study.

Summary

In this chapter, the researcher has discussed on related literature. The researcher has also identified the gap in the existing literature of teaching skillful thinking to young children. The gap can be reduced by supporting teacher-learning on how to infuse ST into science lessons. The succeeding chapter will discuss the conceptual and theoretical frameworks of this study, based on readings and related literature review.

CHAPTER 3

CONCEPTUAL AND THEORETICAL FRAMEWORKS

In this chapter, the researcher will describe the underlying concepts and theories behind the present study. The first section covers the main concepts in understanding the problem described in this study, focusing on the gaps found in the related literature review. Next, the theories related to the context of this study will be discussed.

The concepts and theories were mainly derived from the seminal works by Zohar (2004), Zohar and Schwartzer (2005), and Grossman and Thompson (2008). These studies have outlined the specific areas of teachers' pedagogical knowledge in fostering higher order thinking skills among students. Zohar (2005) and Grossman and Thompson (2008) argued the need for science teachers to possess knowledge in teaching higher order thinking skills. For example, teachers need knowledge on the different kinds of thinking strategies, knowledge of thinking dispositions, knowledge about metacognition and knowledge of ST practices required to teach higher order thinking. This would require teachers to attain constant support in upgrading their knowledge and practices to be in parallel with new reforms in the education system (Grossman & Thompson, 2008).

Conceptual Framework of This Study

The conceptual framework of this study compares teachers' current knowledge and practices with the ideal knowledge and practices of ST infusion. Thus a framework was developed to outline the gaps between these two practices and how these gaps can be reduced.

The ideal practices of ST. Studies on learners' thinking skills often emphasise teachers' practices in developing their students' thinking skills (Beyer, 2008; Kuhn, 2010). This include teachers' instructional strategies, teachers' engagement of students in thinking, managing group discussions and assessment practices on students' thinking skills. These practices reflect teachers' knowledge on thinking skills and their pedagogical knowledge to teach thinking (Zohar, 2013; Zohar & Barzilai, 2013). And it seems to be a challenge for teachers in developing learners' thinking skills.

One way to teach thinking as an integral part of content lessons in primary science classrooms, is by employing the ST approach. ST is an infusion methodology, where teachers teach thinking skills and content matter explicitly (McGuinness, 1999). Scholars seem to be in agreement on these ideal teaching practices as crucial elements in developing students' higher order thinking skills (Beyer 2008; Swartz et al., 2008; Zohar, 1999). The basic level of the higher order thinking skills based on Blooms' Taxonomy is the analysis level. Analysis requires breaking down information and coming up with generalizations to make sense of the information. This include the use of specific thinking strategies such as comparing, contrasting, giving reasons or inference, looking at parts-whole relationships and predicting. To sustain the interest in performing thinking strategies, learners should also need to acquire habits of mind, namely being persistent and posing problems. Learners also need to be aware the kind of thinking strategies they were engaged in, so that they would be able to describe and evaluate as to how they think. This is called metacognitive thinking, and it is among the goals of ST infusion.

Therefore, teachers should be able to teach the specific thinking strategies, develop students' habits of mind and promote metacognition among students. Teaching thinking strategies includes teaching students how perform specific mental steps such as to compare and contrast, analyse parts and whole relationships and to make skillful prediction. This would need students to assess, process and extend pieces of information using critical, creative thinking and reasoning abilities to form deep understanding and thus, facilitate in complex thinking tasks such as conceptualizing, problem solving and decision making (Beyer, 2008; Swartz et al., 2008).

Conventional methods of teaching thinking would focus on rote learning with minimal emphasis on developing students' thinking skills (Abdullah Mohd Noor, 2009). Swartz et al. (2008) argued that the process of teaching thinking should be made explicit and extended to developing students' thinking as a habit (habits of mind), and concurrently guide students to think about their thinking (metacognition). This would mean that by developing students' habits of mind, they would be intrinsically motivated to perform thinking tasks (Costa & Kallick, 2000). This can be done by making students understand why they need to develop habits of mind when it comes to learning. If students could understand the benefits of being persistent or asking and posing questions, they would attain the satisfaction of completing a thinking task. They would be able to value the habits of mind that they are trying to develop with the help of their teacher. When teachers see that students have completed a given thinking task, they ought to promote students' metacognitive thinking. They could start by providing cues to promote them to think about the way they think. For example, by asking them to name, describe and evaluate how they had compared and contrasted two ideas or by asking students to identify any weakness in the way they think which needs improvements (Fisher, 1998).

Metacognition involves students taking charge of their own thinking by being able to assess and take appropriate actions to improve their thinking abilities (Fisher, 1998). Studies have shown that developing students' habits of mind and metacognitive skills not only improves thinking abilities (Caryn, 2007; Costa & Kallick, 2000), but also their academic achievement (Burgess, 2012; Shu et al., 2013). This is because students would be able to take charge of their own learning, identify their weakness in thinking and improve on it. Eventually, they tend to improve in their understanding in subject matter. The challenge for teachers would be in making students' thinking explicit (Ritchhart & Perkins, 2008). This can be done by encouraging them to verbalise what they think about an idea or share thoughts and prior knowledge among peers. Teachers could also encourage students to write down what they think or how they had performed a certain thinking strategy. Similar to the teaching of thinking skills, teachers need to provide cues for students to think about their thinking and thinking behaviours (Miri et al., 2007). Engaging students in activities that require them to reflect on how they think and how their thinking behaviours (habits of mind) influence their learning experience would be helpful.

Therefore, developing students' habits of mind and metacognition should be given equal importance to the teaching of specific thinking strategies when it comes to teaching students to think. In short, it can be said that ST is an innovative approach to teach thinking to young learners. In order to engage students in ST, teachers must use appropriate instructional strategies to teach thinking explicitly and to develop students' habits of mind and metacognition (Beyer 2005, 2008). This includes presenting students the procedural steps in performing a specific kind of thinking strategy and on how to use it for more complex thinking tasks such as conceptualising, decision making and problem solving (Beyer, 2008). Teachers should also guide students to think about their thinking as suggested in the ST approach.

Another vital practice in implementing ST is using the language of thinking. Language of thinking represents the use of terminologies that refer to thinking tasks (Swartz & Reagan, 1998; Zohar & Schwartzer, 2005). This would allow students to analyse the kind of thinking tasks they need to engage in (Tishman & Perkins, 1997). For example, when teachers ask students to 'infer' about a rusty iron nail, the students would know that 'to infer' requires them think of possible reasons that might explain why the iron nail got rusty. Teachers also need to guide students to apply learnt thinking strategies, habits of mind and metacognitive thinking skills in new contexts. For instance, when analysing biodegradable and non-biodegradable waste materials, teachers could ask students to compare and contrast (thinking strategy) those materials based on their environmental effects and question (habits of mind) the use of such materials. They also could ask students to reflect the way they had compared (metacognition) biodegradable and non-biodegradable waste materials and how it had helped them in understanding the topic better. This is called teach to transfer skill (Reagan, 2008). Learnt thinking strategies, developed habits of mind and metacognitive thinking can be ingrained into students' thinking on a daily basis, if teachers create the opportunities for students to apply these skills (Swartz et al., 2008).

To achieve the ideal practices of ST infusion, teachers would need to have acquired knowledge of ST and pedagogical knowledge to implement ST. Knowledge of ST refers to the state of knowing what ST is and how it is related to developing thinking in primary science classrooms. Conversely, to have pedagogical knowledge in the context of ST infusion would mean knowing how to acquaint students in both thinking and subject matter understanding. This means that if teachers are able to identify students' weakness in thinking, they could help students to think about how they know what they know and how they can know better about a certain topic.

The ideal practices of ST infusion demand teachers to be well equipped with pedagogical knowledge on how to infuse ST into content lessons. When teachers are not equipped with this knowledge, the actual practices will not align with the ideal practices of ST infusion.

The current practices of ST. Currently, teaching thinking skills in primary science education can be said to be at superficial (Aubrey et al., 2012; Zohar, 2013). It was found that teachers would focus more on the acquisition of science matter knowledge by rote learning or by structured discovery learning method (Kirschner et al., 2006; Zhai, Jocz, & Tan, 2014). For example, teachers would teach by explaining a science concept whereby students get theoretical understanding of the concept before they carry out scientific investigations to explore it. Minimal focus is given on teaching students how to think skilfully that includes the infusion of the three elements of ST. The current practices in developing learners' thinking skills show lack of teachers' knowledge of the different kinds of thinking strategies (Abdullah Mohd Noor, 2009; Beyer, 2008).

Studies have also found that teachers' pedagogical knowledge to teach these thinking strategies explicitly need to be developed (Barak & Shakhman, 2008; Beyer, 2008; Zohar & Schwartzer, 2005). Teachers' pedagogical knowledge corresponds to their teaching practices (Shulman, 1986, 1987). Therefore, lack of pedagogical knowledge has led to ill-structured teaching practices in teaching thinking. Current practices in teaching thinking skills as exhibited by primary science teachers do not cater for developing students' thinking abilities (Abdullah Mohd Noor, 2009; Jones, 2008). This shows that teachers seem to have superficial pedagogical knowledge in teaching thinking explicitly in primary science content lessons. On the other hand they tend to teach to the test (Kirkpatrick & Zang, 2011). This is because teachers were found to directly teach subject content matter, with goals to achieve good grades. It is due to lack of teachers' knowledge on the appropriate instructional strategies to teach thinking as an integral part of primary science lessons (Zohar & Schwartzer, 2005). For example, knowing how to explicitly teach students to analyse using specific thinking strategies, namely making compare and contrast between concepts in science to further understand the topic.

The abovementioned instructional strategies include instructions for developing students' habits of mind and metacognitive skills (Ben-David & Orion, 2013). Most teachers do not emphasise these two elements of thinking, particularly for two reasons (Yeung, 2015; Zohar, 2004, 2013). Firstly, teachers are unaware that developing students' habits of mind and metacognitive thinking skills could actually enhance their HOTS. Secondly, they do not possess the knowledge on how to inculcate these two elements simultaneously into their effort in fostering the teaching of thinking skills among students.

Further, having little knowledge on how to assess students' thinking skills is another major contribution to the current ill-structured teaching practice. Because, if more teachers are at a loss to assess students' thinking, they focus more on subject matter acquisition, thus reverting to the traditional teach-to-the-test approach (Kaplan, 1997; Osborne, 2013; Sen, 2013). They lack ability to ask the right questions to elicit students' thinking; this hinders them from getting to know how their students actually think.

Teachers' perception on students' thinking abilities also affects their pedagogical decisions. When teachers hold on to the perception that only high achieving students can think at higher order, they tend to modify their lessons to suit the students (Coffman, 2013; Zion & Mendelovici, 2012); hence low achieving students miss the opportunity to take part in complex thinking tasks. With such perception about students' thinking abilities and the lack of 'know how' knowledge to infuse ST, teachers could not achieve the ideal practices of ST (Ben-David & Orion, 2013; Ireland et al., 2014). Gaps are found in the transformation of the current practice to the much anticipated ideal practice. The three prominent gaps argued much in the literature were teachers' lack of knowledge about the concept of ST, lack of knowledge on how to infuse ST and lack of support for ST infusion.

Bridging the gap. Although related literature on teaching thinking skills has shown the importance of ST infusion as another approach in developing students' higher order thinking, less has been studied with regard to primary science classrooms. For example, how the three elements of ST can be infused simultaneously into primary science lessons. A few studies have shown that the amalgam of the three elements, teaching thinking skills, developing habits of mind and promoting metacognitive thinking among students have enhanced their level of HOTS (Beyer, 2008; Costa & Kallick, 1996;

Reagan, 2008; Swartz et al., 2008). Even so, these studies were not specifically related to primary science education but were related to other subjects such as social studies and history education.

Other studies, however, researched on ST elements in various disciplines, but in isolation. For instance, studies on how to foster thinking skills among students by teaching various types of thinking strategies (Chowning et al., 2012; Fisher, 1999; King et al., 2012; Kuhn & Crowell, 2011; Lucos et al., 2011). Studies on habits of mind focused on how developing students' habits of mind can help them think better (Duckor et al., 2014; Fletcher, 2013; Goodell, 2014; Shu et al., 2013) or how teachers, in promoting metacognitive thinking, could improve students' awareness in learning and thinking (Fisher, 2005; Topsu et al., 2009; Zohar, 2013).

Fewer studies have explored how combining the three elements of ST by the infusion approach can be implemented in primary science education. For example, how one type of named thinking skill, say, creative thinking skills, can be fostered simultaneously developing students' habit of responding with wonderment and awe. Or how these two elements (creative thinking and the habit of responding with wonderment and awe) can be enhanced by encouraging students to reflect the way they think creatively, which is the third element of ST –metacognition. Past studies have shown that primary science teachers lack the knowledge about the three elements of ST (Swartz et al., 2008; Nair & Ngang, 2012; Zohar & Barzilai, 2013). One of the main reasons was that teachers do not know these elements can be infused simultaneously into content lessons. When teachers are unaware that all three ST elements should be infused holistically into their lessons, their current practices are lacking in ST infusion. The lack of this knowledge of ST among primary science teachers is the first gap found between the current practices and ideal practices of ST.

The lack of teachers' knowledge of ST has led to a shortfall in their pedagogical knowledge to infuse ST in primary science lessons. Teachers ought to know how to engage students in ST during science lessons. This includes knowing how to infuse ST in their lessons. Science lessons for young children are often loaded with fun activities and scientific investigations. This creates an interesting and exciting learning environment for students to get their hands on such activities. While it may seem that the students are actively engaged in fun science activities, however, it is a challenge for teachers to make them think about the observations during such activities (Kirschner et al., 2006; Zhai, Jocz, & Tan, 2014). When teachers do not make time to explicitly teach students how to analyse their observations or promote students to think how they know what they know from conducting science activities, students could not learn how to think about what they have learnt. This calls for teachers' knowledge in practices particularly on how to engage children in active ST during science lessons to further understand science concepts.

Figure 3.1 shows the second gap found in the literature related to teachers' pedagogical knowledge in teaching ST. According to Zohar and Schwartzer (2005), pedagogical knowledge in teaching thinking (including ST), would mean, firstly to know the wide range of cognitive abilities such as thinking, reasoning and metacognitive skills in science education. Secondly, knowing how to engage students in thinking tasks that would manifest students' thinking dispositions. The ideal practices proposed by Swartz et al. (2008) and Beyer (2005, 2008) in teaching ST are in line with the types of knowledge teachers should possess as described by Zohar and Schwartzer (2005). For example, teachers need to know how to engage students in analysing knowledge, actively ask good questions and inculcate metacognitive thinking during lessons.

Studies have been carried out on other aspects of teachers' pedagogical knowledge in the context of ST infusion. These include studies on classroom management, by organising the classroom to facilitate thought sharing and science talks in small group discussions (Nielsen, 2012; Oliveira, Boz, Broadwell, & Sadler, 2014). Teachers need knowledge on how to organise their classrooms to systematically engage students in discussions about science (Harris & Rooks, 2010; Peters, 2009).

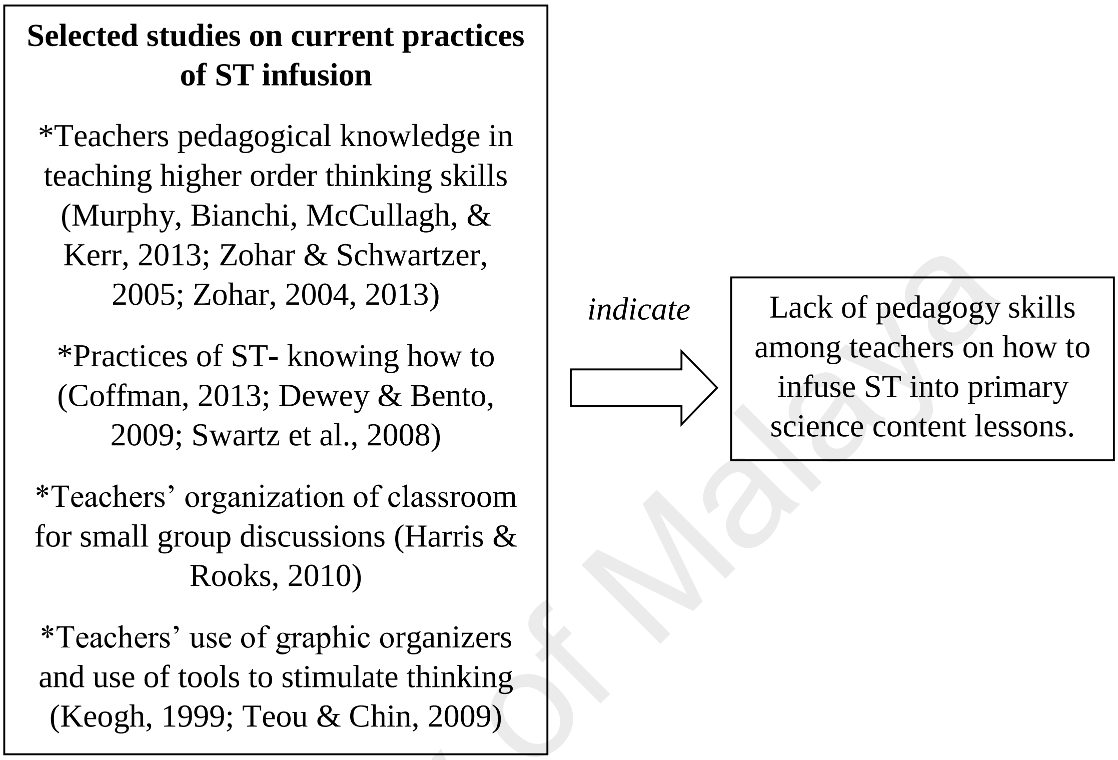


Figure 3.1. Lack of practices to infuse ST in primary science.

Using graphic organisers as tools for stimulating student thinking such as the use of concept cartoons to initiate thought sharing during group discussion, has proven effective for students to actively engage in thinking tasks (Chin & Teou, 2009; Gibson, 2009; Mercer, Wegerif, & Dawes, 2013; Swartz & McGuinness, 2014). This requires teachers firstly to use prompts to probe students' ideas about a certain science concept. Secondly, to teach students how to analyse discussed concepts by comparing, contrasting or predicting using graphic organisers. Further, teachers need to prompt students to make their thinking visible to others by asking questions and posing problems about the concepts. Teachers could also prompt students to adopt metacognitive thinking during whole group discussions.

According to Swartz et al. (2008), such practices are crucial in scaffolding student thinking. Reagan (2008) and Beyer (2008) have studied how teachers could infuse

ST in elementary American History and found that, with teachers' scaffolding, students are able to practice and transfer the skill into new contexts. Despite numerous studies on developing students' thinking skills, literature has shown that teachers still lack pedagogical knowledge in teaching ST in content rich subjects such as science (Colette Murphy et al., 2013; Reiser et al., 2012; Salmon & Lucas, 2011; Zohar & Schwartzer, 2005). Swartz et al. (2008) have suggested that teachers could infuse ST by adopting four steps: introducing specific thinking strategy, practising the learnt thinking strategy, promote thinking about the thinking strategy and teach to transfer the learnt thinking strategy into new contexts. However, how the suggested four steps can be adopted by primary science teachers to teach thinking skills simultaneously with science knowledge construction, remains under-researched.

Like students, teachers need to learn and acquire knowledge in ST. Literature on how to support teacher knowledge of a teaching approach has suggested that teachers could learn from educative curriculum materials (Beyer & Davis, 2009; Noh & Webb, 2015; Schneider, 2013). This is feasible for teachers who have not yet attended highly structured training or professional development programmes in teaching thinking skills to elementary students. This is the kind of support for teachers to scaffold their practices, by providing recommendations and the rationale behind those recommendations. Thus, teachers would be able to understand the necessity of an approach, so that they will internalise them into their teaching practices.

The use of educative curriculum materials designed for primary science teachers to teach ST is found to be lacking (Davis et al., 2014). Teachers need such materials that would provide ideas and adaptations to infuse ST into primary science lessons, enable them to recognise indicators of students' performance in ST besides educating them on how to measure the change in their own teaching practices (Beyer & Davis, 2009; Davis et al., 2008). According to Davis et al. (2008), one crucial form of support for teacher-learning is the educative curriculum materials. When using educative curriculum materials, learners (teachers) would be able to identify the weak points in their knowledge and thus, add new knowledge and form relations between ideas (Davis et al., 2008). Works by Grossman and Thompson (2008) and Remillard (2005) too have influenced the design of curriculum materials with goals to enhance both teacher and student learning. For example, by taking into account how teachers perceive the use of educative materials in teaching language arts, how using such materials change over time and most prominently on what learning opportunities these materials offer teachers.

Literature on educative curriculum materials has provided adequate understanding on how such materials should look like. Davis et al. (2008) suggested that educative material should comprise text or narratives to help teachers understand an approach. For example, in promoting teacher learning in the use of scientific models and modelling, Davis et al. (2008) have provided narratives on fictional teachers as effective cognitive tools. They have found that such narratives and vignettes are successful in making ideas more "intelligible and plausible through illustrating them with classroom examples" (Davis et al., 2014; Krajcik & Delen, 2017; Noh & Webb, 2015). In addition, educative materials should also provide general ideas which teachers could apply or adapt into new situations or topics. Some studies have highlighted the limitations of using such materials. Krajcik and Delen (2017) have argued how educative curriculum materials should be designed to facilitate teacher learning of an approach. They strongly asserted that educative curriculum materials should be modified and re-designed constantly according to teachers' current learning needs. This includes what kind of educative features should be in such materials or how many educative features are needed to deliver information regarding an approach. Therefore educative features in such materials should cater for teachers' current learning needs by understanding what they need to know if they were to adopt new instructional strategies into their practices (Bismack et al., 2014; Davis, Palincsar, et al., 2014; Krajcik & Delen, 2017).

In the context of ST infusion in primary science, what is lacking is teacher material with educative features that would work synergistically with teachers' teaching practices and enable them to infuse ST into their existing lessons. This is the third gap found related to ST infusion. As Krajcik and Delen (2017) argued, science teachers need collections of ideas and tools to change their practices into one which embraces the anticipated approach. Similarly, if primary science teachers were to infuse ST into their teaching practices, they would need support to scaffold their learning on how to do so. Such support can be teacher materials with educative features designed based on teachers' learning needs – what they know and what they need to know about ST, how they could adapt ST infusion into their existing practice and how to manage classrooms for students' active engagement in ST.

The three abovementioned gaps can be reduced by providing teachers with teacher educative material that could scaffold their current practices to infuse ST. Figure 3.2 shows the conceptual framework with descriptions of the current practices, ideal practices and the gap.

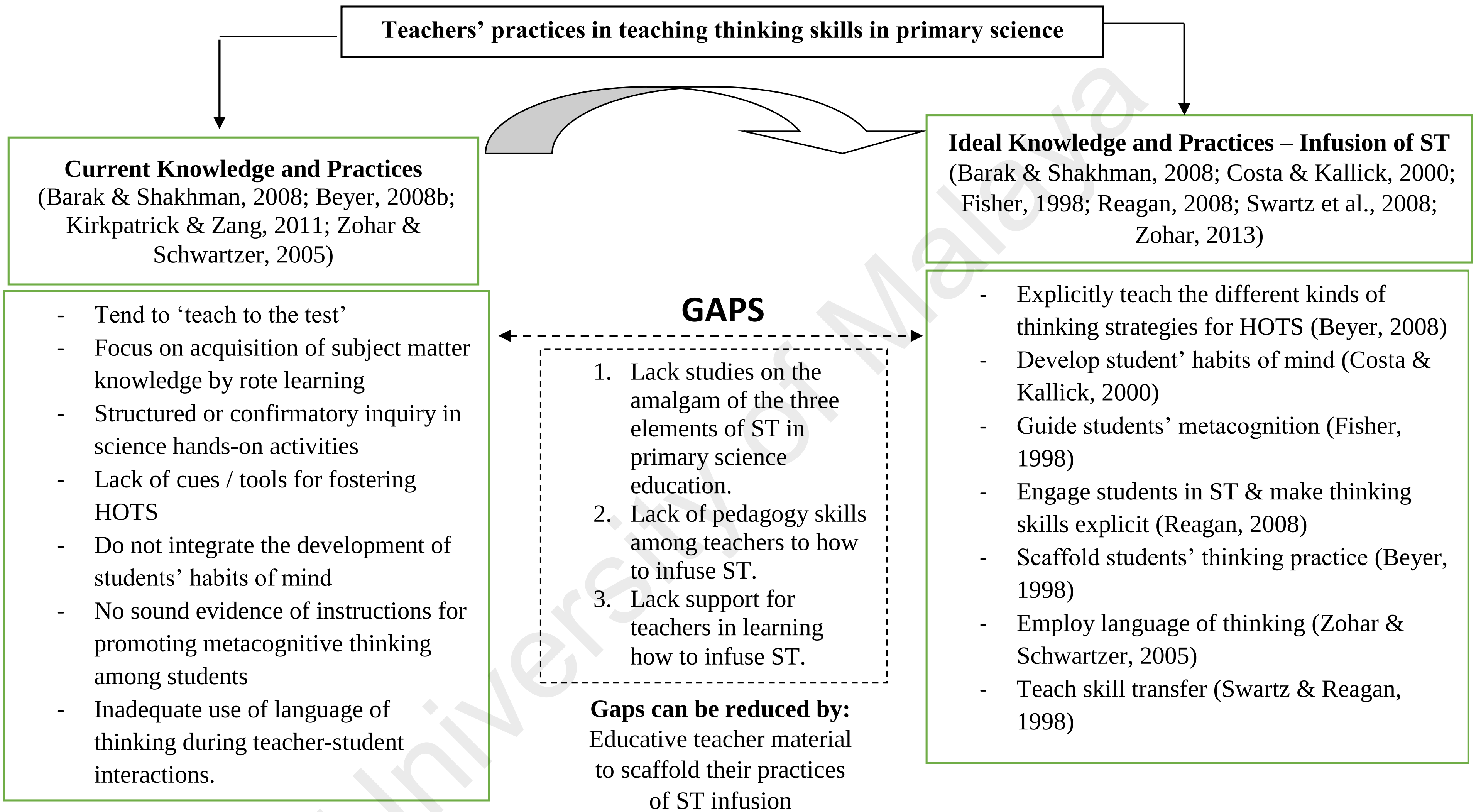


Figure 3.2. Conceptual Framework of the present study.

Theoretical Framework for the present study

The conceptual framework described earlier outlined several concepts such as teachers' knowledge and practices of ST, both current and ideal practices as well as the gaps found in between. Consequently, this section will describe the underpinning theories to explain the conceptual understanding of the present study. The theoretical framework consists of the adaptation of Vygotsky's (1987) socio-cultural developmental theory. Vygotsky argued that learning is embedded in language and culture (Vygotsky, 1986). Although Vygotsky claimed that there must be an interaction between learners and the person who teaches (like teacher-student), it can be between a human and an artifact (Bernhard, 2007; Virkkula & Nissila, 2014), such as learning process which is mediated by tools. Mediating tools or artifacts can be in the form of books, physical materials and even frameworks, which involves how learners interpret new ideas in 'situated social practices' (Svendsen, 2015).

Socio-cultural theory also articulates that tool-mediated action aids individual learning, and thus curriculum materials could serve as vital tool for learning (Grossman & Thompson, 2008; Remillard, 2005). For example, the way a tool explains to teachers on how they might look into learners' thinking, can affect the way teachers understand student thinking. Tool mediated learning, according to Vygotsky denotes semiotic mediation, which represents the connection between the social and the individual (John-Steiner & Mahn, 1996; Kozulin, 2004). Language, writing, schemas, diagrams, maps or modern tools such as computers, calendars and symbol system are among the examples of semiotic mediation (John-Steiner & Mahn, 1996). Cole (1998) claimed that artifacts demand continuous redesign to suit diverse learners, since the artifacts are created to remediate with the needs of learners. In an earlier study, the use of artifacts as mediating tools has been re-emphasised - that artifacts can be 'tools such as words, writing instruments and telecommunication networks' (Michael Cole, Goncu, & Vadeboncoeur, 2014). Drawn from the works of Vygotsky's (1987) socio cultural theory and Cole's (1996) argument on the use of artifacts, Bernhard (2007) has derived a framework as shown in Figure 3.3.

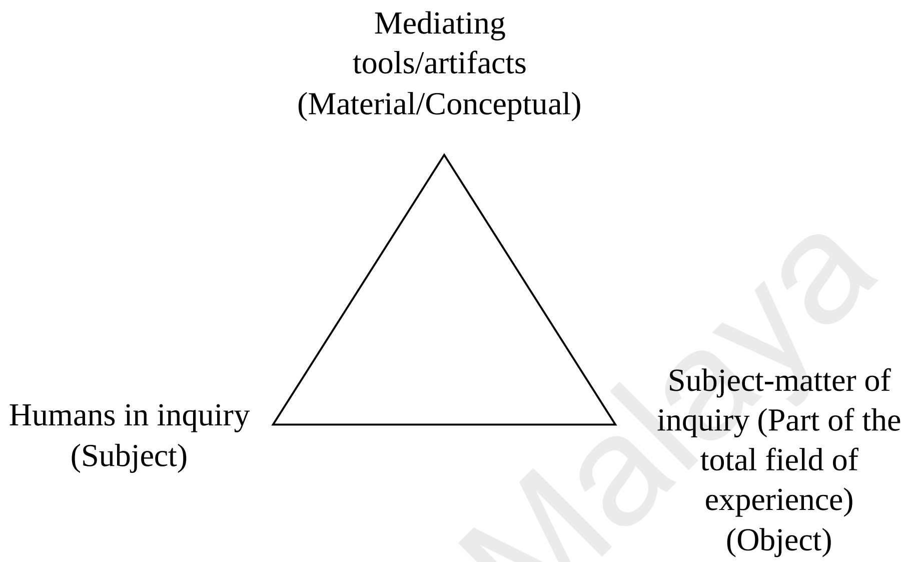


Figure 3.3. Basic mediation triangle by Bernhard (2007) modified from Cole (1998) and Vygotsky (1978).

Figure 3.3 shows the relationship between the learners in inquiry, mediating tools or artifacts and subject-matter inquiry or the learning experience. The subject is the human in inquiry or learners, the material is the mediating tool/artifact and the learning experience is the object. Adapting this framework into the present study has helped the researcher to situate teachers' learning process through the use of educative materials that scaffold teacher-learning. Using the original interpretation of the three entities; subject, material and object, the researcher modified the basic framework as shown in Figure 3.4. Here, the subject are the teacher as humans in inquiry, the mediating tool/artifact is teacher-material to scaffold teacher-learning and the field of experience (object) is the learning process reflected in teachers' classroom practices. In the present study, with teachers becoming learners, support for teacher learning to infuse ST is essential.

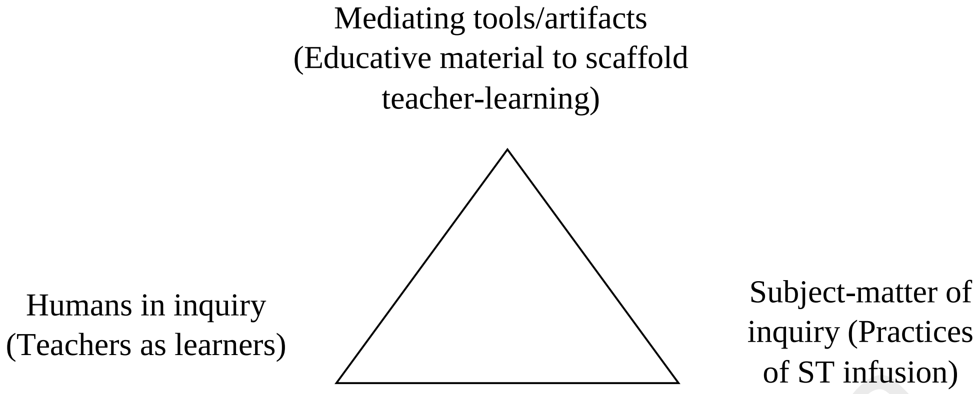


Figure 3.4. The modified version to show the connections between teachers, material and practices, adapted from Bernhard (2007), Cole et al. (2014) and Vygotsky (1978).

Such support can be highly structured professional development programmes for teachers or tools such as curriculum educative materials (Davis & Krajcik, 2005). Most scholars who design educative curriculum materials to promote teacher-learning, tend to use Vygotsky's socio-cultural theories to frame their works, because this theory focuses on the connections between the social interaction and learning process (Grossman & Thompson, 2008; Kelly, 2006; Remillard, 2005; Schneider et al., 2000). From this stance, educative curriculum materials become the artifacts or mediating tools because they deliver information that stimulates teachers as learners' thinking to think about ideas and apply new strategies in their teaching practices. However, the entity named 'practices' in Figure 3.4 refers to teachers' learning experience put into classroom practices. For example, what teachers learn about ST, from the educative material is applied into real-life classroom practices. Such practices involve not only teachers but the interactions with their students. Therefore, the researcher added another entity called student interaction with teacher. As teachers practice newly learnt strategies adopted from the material (mediating tool), they also get feedback from students. Based on this understanding, the researcher modified the framework as shown in Figure 3.4, to illustrate the theoretical framework for the present study. Figure 3.5 shows the modified version of the framework.

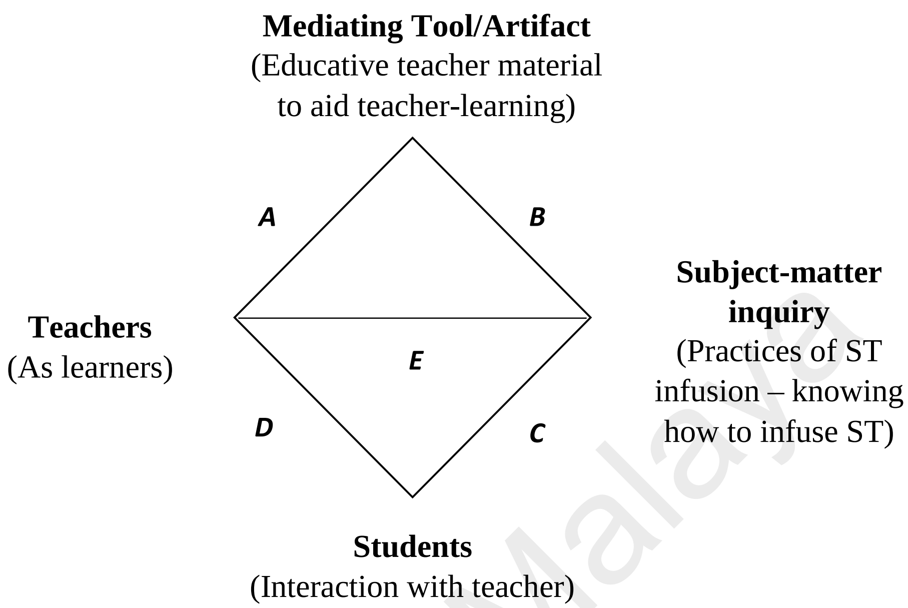


Figure 3.5. Modified framework for the present study based on Bernhard (2007) which was modified from Cole (1998) and Vygotsky (1978).

For the purpose of this study, the original mediation triangle (Figure 3.3) has been modified by adding another concept called 'student' to indicate teacher-student interaction as part of the learning experience for teachers. The teachers in the present study were learners in inquiry- teachers who have expressed interest in learning how to infuse ST. Thus, the mediating tool would be the educative teacher materials prepared to scaffold teacher-learning.

Upon using such material, teachers' practices would be the learning experiences. Arrow ***A*** represents the preparation of the material based on teachers' current knowledge and practices of ST. Preliminary research on what the selected teachers already know, or do not know, about ST, provides the baseline on what teachers need to know about ST infusion. Once the material is prepared based on this understanding and insights from literature readings, it will be ready for the selected teachers' use in classrooms. Therefore the two-way arrow, ***A***, shows the relationship between the teachers as learners in inquiry and the educative material which was prepared as educative as possible for teachers to enhance their knowledge about ST and apply them in their science lessons. Arrow ***B*** shows the phase in which the teachers read and use the material. The material provide teachers with suggestions and recommendations on how they might adopt them into their current practices to infuse ST. For example, how teachers can explicitly teach different thinking strategies during the learning of a science concept. Here teachers as learners internalise the educative materials, which provides the learning experiences.

When teachers think about how to enact lessons rich in ST elements, they apply that knowledge in their practices. However, students come into the picture by responding to their teachers. For example, when a teacher gives cues to stimulate students' thinking, students would respond. If this response does not meet teachers' goals, then teachers need to modify their cues until the students are able to respond accordingly. This is where the teacher modifies the recommendations provided in the material to address student needs. Each time teachers refer to the material and constantly adapt or modify the recommended lessons to suit their students, they would be able to learn how to infuse ST into their lessons (Arrow ***C***). Similarly, real classroom applications provide the learning experience for teachers when they apply what they learn from the material and how or to what extent they use the material. Classroom applications involve students, as teachers interact with students and modify the recommendations in the material as needed. This allows for the development of new knowledge on how teachers could infuse ST based on how their students respond to the new practice (Arrow ***D***). The relationships between the teachers as constant learners, the educative material as learning tool, practices of ST upon using the material and teacher-student interaction are a series of iterations. This is because teachers internalise the educative material and apply knowledge into practice and experience from practice makes them modify the recommendations (given in the materials) whenever they think they should (Arrow ***E***). The framework was further refined to build on the underpinning theories, such as Vygotsky's Zone of Proximal Development (ZPD) theory. Figure 3.6 shows the theoretical framework for the present study.

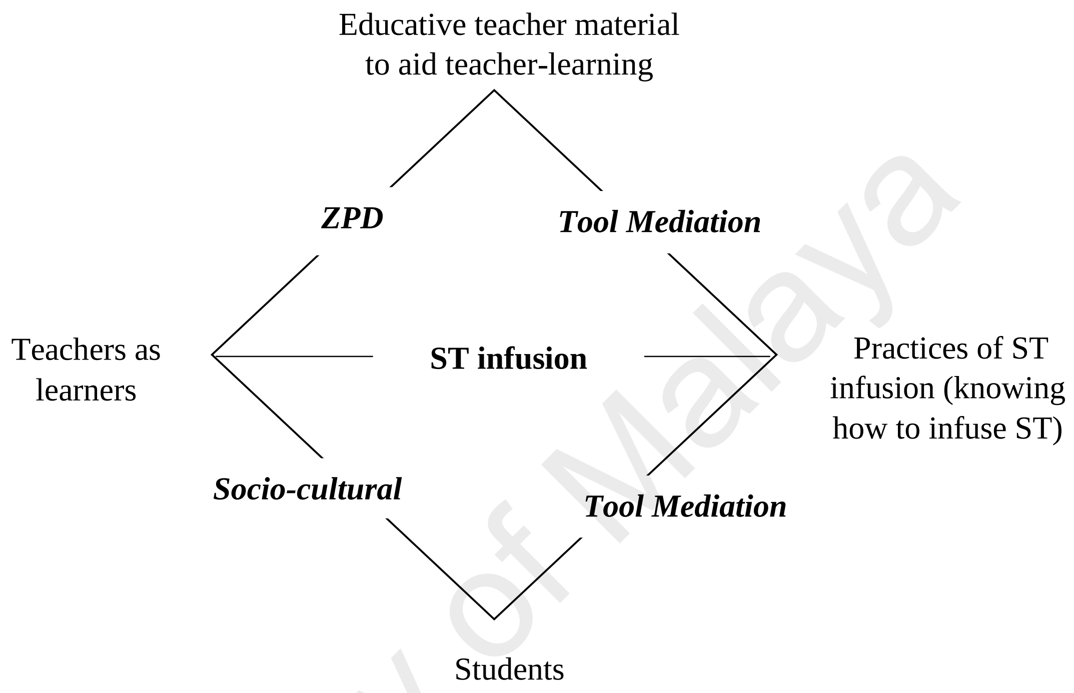


Figure 3.6. Theoretical framework for the present study derived from Vygotsky's ZPD (Zone of Proximal Development), tool-mediated learning and sociocultural theory.

Vygotsky's ZPD theory explains that ZPD is the zone from what a learner can do with guidance from what they can do without guidance. ZPD represents the distance between the ability a learner can achieve and the potential ability the learner achieves with guidance from an adult or peers. *The distance of between the levels of potential development and actual development* is termed as the *Zone of Proximal Development, ZPD* (Vygotsky, 1978). However, Vygotsky (1978) also has stated the role of tool mediation in learning process, in which learners could learn better with the use of tools or artifacts.

Therefore, it was important in the context of this study to gain information on what the selected teachers currently know and how they enact lessons to infuse ST. By understanding what they currently know and do, it would help to determine what the teachers still lack and the pedagogical aspects that need upgrading. Therefore, teachers need scaffolding learning the new teaching approach of ST infusion.

The term scaffolding, traditionally was referred to guidance from an adult peer who has higher knowledge than the learners to help them to achieve what they are capable of doing with guidance (Reiser, 2004). Resier (2004) had also asserted that the needs of learners should be addressed to create the appropriate scaffolding for them. This will include interactive tools or educative materials. In the context of this study, since teachers are the learners, educative tools could promote teacher-learning. Mediating tools such as educative materials provide the needed information and support in promoting teachers in learning to teach new approaches (Davis & Krajcik, 2005; Krajcik & Delen, 2017; Schneider, 2013).

The interaction between educative materials imitate the mediation as illustrated by tool-mediated learning theory. Mediation action by the use such teacher educative materials influences teachers' knowledge and practices. Features that are educative in nature will help teachers (as learners) understand what ST infusion is all about and how to infuse ST into primary science lessons. The key to describing this process of learning is by understanding how and to what extent do tools such as educative materials transform teacher knowledge and practices in the context of ST infusion. By developing educative materials with features to educate teachers and provide recommendations for teacher-use, teachers thereby would be able to create their own learning course on how to best infuse ST. This is because educative materials provide the space for teachers to adopt recommendations into their practices and reflect on what and how they have learnt about the proposed approach. When teachers understand the rationale behind why the proposed approach works better than the conventional methods employed before, it can be said that learning could occur. To deliver information about ST infusion, the educative material need to be prepared in learners' native language and take into account cultural aspects. In this way, designated information can be delivered to the respective learners. For example, the materials could include narratives on real-life classroom situations which are typical and familiar to learners' culture.

Therefore, teacher-tool interaction denotes information (recommendations and understanding) provided by the tool (educative material) and the information gained by the teacher from internalising the tool. According to John-Steiner and Mahn (1996), 'knowledge is not internalized directly' but it depends on the use of psychological tools. When knowledge is put into practice, the second level of learning occurs through interaction between the individual and social. This occurs when teachers (as learners) communicate with their peers and exchange ideas, based on the recommendations provided in the tool. This creates real-life classroom experiences for the teachers. In addition, teachers learn how to modify the recommendation to suit their students' ability, based on the interaction between the teachers and students. Their interaction with students influence their pedagogical decisions in adopting a recommendation provided in the material (Beyer & Davis, 2012). They learn from experiences and modify their pedagogical decisions as per needed. This would reflect the change in their pedagogical knowledge of a newly learnt teaching approach (Hollins, Luna, & Lopez, 2014).

Summary

This chapter discussed the concepts and theories related to the problem being addressed in this study. In the beginning of this chapter, the researcher described the three gaps identified in the literature review and suggested how these gaps can be reduced by preparing an educative material for science teachers to see how they could infuse ST elements into science content lessons. Towards the end of this chapter, the researcher described how Vygotsky's sociocultural theory and ZPD can be used to understand the role of the STEPS in developing the selected teachers' pedagogical knowledge in infusing ST.

CHAPTER 4

METHODOLOGY

Introduction

This chapter discuss the data collection and data analysis of this study. The general objective of this study was to explore how the selected teachers infuse ST into their science lessons, upon using the prepared *Skillful Thinking Educative Pedagogical Support* or STEPS. The research method, data collection and data analysis for the STEPS preparation and the implementation are described.

The Research Method

The research method for the present study consisted of two phases. Phase 1 was to prepare an educative material called the STEPS (*Skillful Thinking Educative Pedagogical Support),* based on the needs analysis of the selected teachers as well as from literature readings. Phase 1 consisted of three sections; groundwork, developing and reviewing of the STEPS.

The second phase (Phase 2) was to explore the selected teachers' practices of ST upon using the STEPS. Phase 2 was conducted when the teachers taught the topic 'Properties of Materials' in Year Four science. It was aimed at investigating how the selected teachers change their practices to infuse ST, upon using the STEPS. This phase was the focus of this study. The phases of research and flow of procedure are described in this section as shown in Figure 4.1.

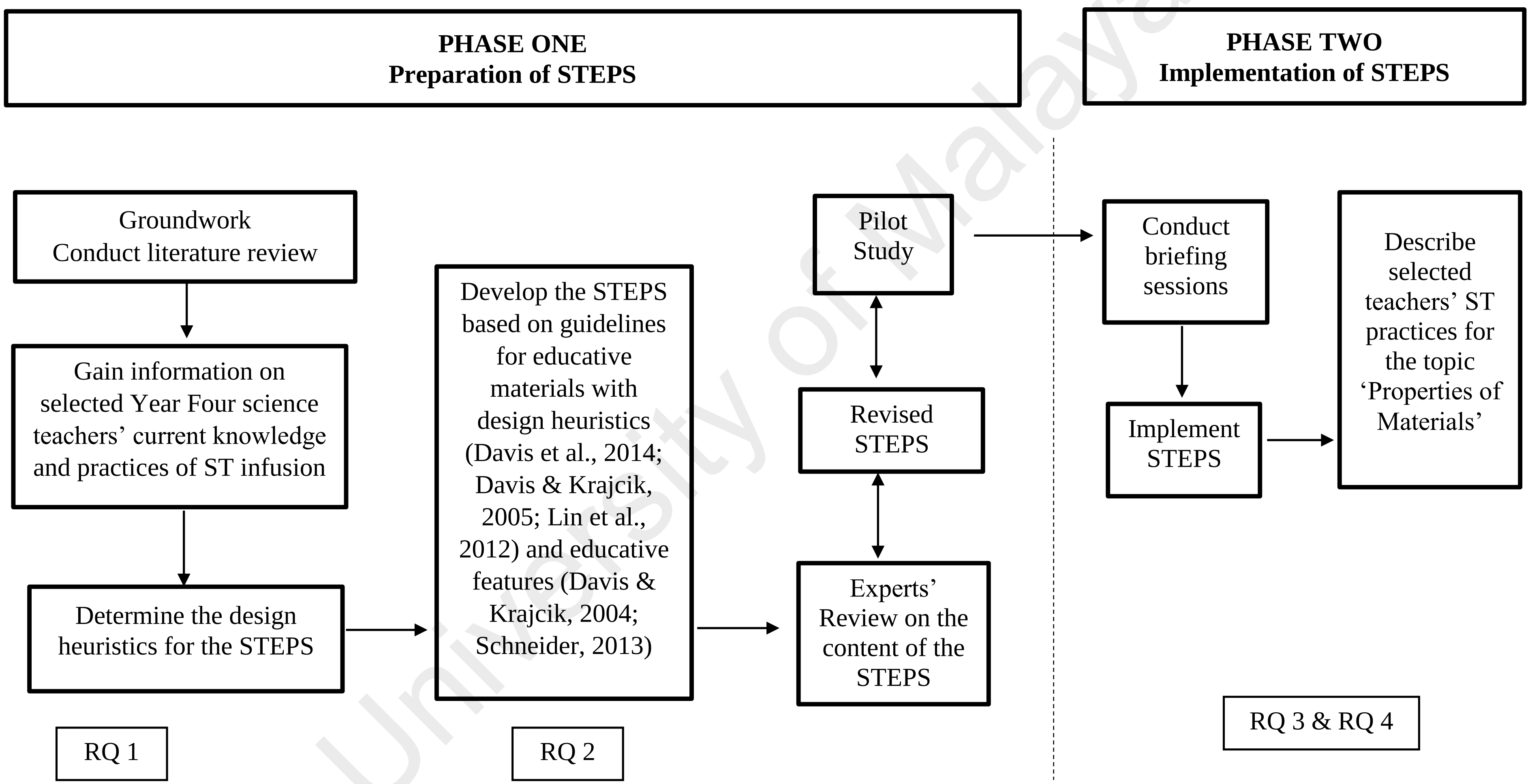


Figure 4.1. Research flow for the present study.

Methodology for Phase 1 (The preparation of STEPS)

Phase 1 aimed at gaining information on selected Year Four science teachers' current knowledge and practices of ST infusion. This was important to know if the selected group of teachers practice ST in their current Year Four science classrooms. It was also essential to highlight pedagogical areas in which the selected teachers need support. For example, what teachers know about the elements of ST and how they infuse these elements into their practice while teaching topics in Year Four science. Based on this information, the researcher was then able to identify the needs of these teachers in ST infusion, thus prepared the STEPS (Skillful Thinking Educative Pedagogical Support) as a pedagogical support for the selected teachers to infuse ST in the topic Properties of Materials.

Details on the participants for Phase 1, research sites, data collection techniques and how the analysis was done will be described. Phase 1 consisted of three sections; groundwork, developing and reviewing the STEPS. The groundwork section will describe the preliminary work to determine the needs for STEPS preparation. In the developing section, the researcher will describe how the STEPS was prepared based on needs analysis (groundwork). The reviewing section involves description on how the researcher revised the prepared STEPS based on feedbacks from a panel of selected experts.

Groundwork for the STEPS. Prior to developing the STEPS, the researcher conducted related literature review on the teaching of higher order thinking skills (HOTS) among primary science students. Based on the related literature review, the researcher found that by teaching ST to students, they would be able to foster HOTS in primary science (Beyer, 2008b; Swartz et al., 2008; Zohar, 2013).

Furthermore, related literature on science teachers' pedagogical knowledge in teaching ST revealed that they need to upgrade their pedagogical knowledge in teaching ST as among the efforts to improve the teaching of HOTS in science (Barak & Shakhman, 2008a; Zohar & Barzilai, 2013).

Based on these literature readings, the researcher decided to gain information about the teaching of ST in the Malaysian primary science curriculum. Specifically, the teaching of thinking skills, habits of mind and metacognitive thinking (elements of ST) in the Year Four science. Thus, the groundwork stage was carried also to meet the first research objective:

Research Objective 1: To gain information on selected Year Four science teachers' current knowledge and practices of ST infusion.

The researcher conducted document analysis on selected educational documents to see if infusion of ST was relevant to the local context.

Document analysis. Generally literature readings on ST showed larger scope of thinking strategies in HOTS, habits of mind and metacognition. For instance, there are sixteen habits of mind in ST (Costa & Kallick, 2000). To narrow down the scope of research, the researcher had to conduct deeper analysis on the Malaysian Year Four science curriculum specification document, to identify *which* elements of ST were focused upon, within the:

a) Type of higher order thinking skill that need to be explicitly taught
b) Habits of mind that needs to be developed
c) Level of metacognitive thinking, whether awareness, describing, evaluating or planning level, that needs to be promoted among students.

To analyse the documents, the researcher prepared a document analysis protocol (Appendix A). The protocol was prepared based on educative features suggested for educative curriculum materials (Grossman & Thompson, 2008). It included details about the documents such as title of document, how it was obtained, summary and importance of the document. There were two main reasons for analysing related documents. Firstly, it was to prepare an analysis to see whether the elements of ST were relevant in the Malaysian primary science curriculum and secondly, to see if these documents were made to facilitate teacher-learning to infuse ST.

The researcher began the document analysis with the Malaysian Primary Science Curriculum document and in there was a framework, called the Thinking Skills and Thinking Strategy Framework (TSTS) developed by the Malaysian Curriculum Development Centre (Curriculum Development Centre, 2012) as guidance for teachers to teach thinking skills. The framework outlines reasoning ability, critical and creative thinking skills as the major thinking strategies to perform complex thinking tasks such as conceptualising, problem solving and decision making.

The element of reasoning in the TSTS framework signifies the underlying process of logical, just and rational judgements, thus, facilitates the acquisition of critical and creative thinking skills (Curriculum Development Centre, 2012). As shown in Figure 4.2, teachers are expected to foster different thinking strategies, so that students would be able to think at higher level. Teaching different thinking strategies (the first element of ST) comprises comparing and contrasting, grouping, generating ideas and making inferences (CDC, 2013).

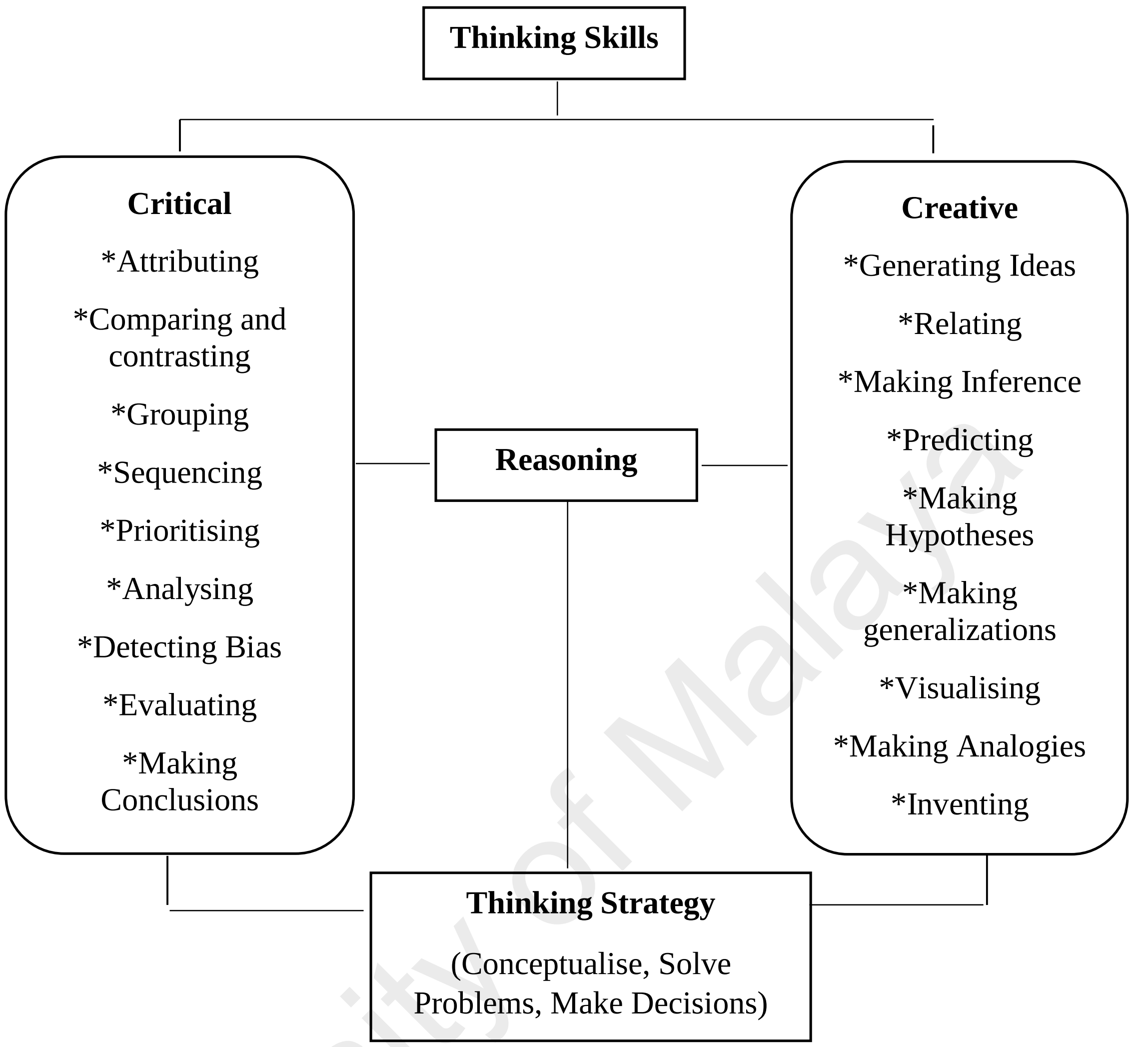


Figure 4.2. Thinking Skills and Thinking Strategy Framework (TSTS) (Curriculum Development Centre, Malaysia, 2012, p. 6).

With the information about the TSTS framework, the researcher then analysed other related documents. This included Year Four Science curriculum specifications, Year Four science teaching, teaching creativity and innovation, science process skills module, reasoning skills module and the Year Four science practical books (Curriculum Development Centre, 2012). These were the teaching resources available for Year Four science teachers, which were analysed to see if ST elements were emphasised (Table 4.1). The symbol (√) indicates that, the documents were designed to inform teachers about the elements of ST. All the analysed resources have information on the need to teach thinking strategies. Recent documents such as the *HOTS in pedagogy* (2015) and *DSKP* (2015) have stated that science teachers should develop habits of mind and metacognitive thinking, however not on how teachers might develop these elements.

Table 4.1

Comparison between Selected Existing Teaching Materials in Malaysian Primary School Education Based on Analysis Criteria adapted from Grossman and Thompson (2008)

Does the material consist these elements?	Year Four Science Curriculum Specifications (KSSR, CDC, 2013)	HOTS element in pedagogy (CDC, 2015)	Curriculum and Assessment Standard Document (DSKP, CDC, 2015)	Science Process Skills Teaching Module (CDC, 2011)	Reasoning Ability Teaching Module (CDC, 2011)	Year Four science Textbook / Practical Books (DBP, 2013)
Teach thinking strategies	√	√	√	√	√	√
Develop students' habits of mind	√		√			
Promote students' metacognition	√		√			

The documents were first collected and analysed using the Document Analysis Protocol, which included details on whether the documents have information on ST elements and if they were educative in nature to support teacher-learning. For example, the Year Four science curriculum specifications document has described the different strategies of thinking in all the thinking levels (knowledge, comprehension, application, analysis, synthesis, evaluation and creating). This was based on the original Bloom's Taxonomy on the levels of thinking used by the CDC in Malaysia. For analysis level, the document has stated that analysing which mean 'examining information in detail by breaking it down into smaller parts to find implicit meanings and relationships' (CDC, p.4).

The document also has stated that this level of thinking (analysis) would require teachers to teach different thinking strategies such as compare, contrast, classify, attribute and predict. These are the thinking strategies for analysing information and ideas, which are also proposed as specific thinking strategies in ST (Element 1). Since the document has stated about the first element of ST (teaching thinking skills), thus the researcher marked (√) in the prepared document analysis protocol for the specification document. On the contrary, less information was available on how to build students' habits of mind (Element 2) or metacognitive thinking (Element 3). In addition, the document appeared less educative for teachers since it was prepared not for teachers as teacher-learning materials, instead as reference of the Year Four science curriculum content. The focus is given more on students' outcomes and criteria to indicate students' progress in learning. Therefore, the researcher concluded that the Year Four science curriculum specifications, had information on the need to infuse ST, however with less emphasis on how teachers might explicitly infuse ST into their science lessons.

Another example would be an excerpt taken from the Creativity and Innovation in T&L by CDC (2012) as shown in Figure 4.3. This material was prepared as guidelines for teachers on how to incorporate critical, creative thinking and innovation into subject content matter. The material focuses on students' learning objectives, among which that states students should be able to generate creative and innovate ideas.

1.2 OBJEKTIF

Objektif pembangunan kreativiti dan inovasi dalam kurikulum persekolahan adalah untuk membolehkan murid:

i. Menghasilkan idea kreatif dan inovatif.
ii. Mempunyai keterampilan diri dan personaliti individu kreatif.
iii. Menguasai kemahiran dalam proses kreativiti.
iv. Berkebolehan berkomunikasi dalam menyampaikan idea.
v. Mengaplikasikan pengetahuan dan kemahiran secara kritis dan kreatif dalam menyelesaikan masalah, membuat keputusan dan mengurus kehidupan harian.

Figure 4.3. An excerpt from Creativity and Innovation in T&L (CDC, 2012, p. 2)

However, an educative material for teacher learning should also focus on teacher learning to incorporate critical, creative thinking and innovation among students. Indeed teachers should be well informed about students' learning outcomes; however, such materials, if prepared with goals to educate teachers on how to assist students in achieving those outcomes, would support teachers' development of pedagogical knowledge (Grossman & Thompson, 2008).

The excerpt cited states students' learning outcomes but does not elaborate or provide cues to achieve the anticipated learning goals. These were among the missing educative features for teachers found in the existing material. The purpose was not to explore what was missing in the documents, but to suggest that these documents can be made educative for teachers with features that would make them more aware of the recommendations proposed for teaching thinking skills in primary science.

Document analysis on the present year four science curriculum specifications. The researcher conducted document analysis on the Year Four Science curriculum specifications. The document is used by science teachers throughout Malaysia. It has five major themes. Document analysis was able to identify the most emphasised kind of thinking strategy, which was the analysis level of thinking. For example, as shown in Table 4.2, the learning outcome for the theme 'Life Science' is to analyse knowledge about photosynthesis.

Almost all the five themes in the Year Four science showed elements where analysing thinking is present. The corresponding kind of thinking in ST would be the skill of 'analysing information and ideas' as suggested by Swartz et al., (2008). Therefore, from the document analysis, the researcher could recognize that analysing information and ideas (knowledge) is the type of thinking skill that is needed to be explicitly taught by the teachers. Therefore, primary science teachers need to teach students to analyse their knowledge of different scientific concepts.

Table 4.2

Year Four Science Curriculum with Respective Learning Outcomes

Topic	**Learning Outcomes**
Life Science	5.2 Analyse knowledge about photosynthesis
Physical Science	6.9 Analyse knowledge about measurement using unit, tool and methods correctly
Material Science	7.1 Analyse knowledge about natural and synthetic material and its basic material
	7.2 Analyse knowledge about properties of materials
Earth & The Universe	9.1 Analyse knowledge about the Solar System
Technology & sustainability of life	10.1 Analyse knowledge about technology in daily lives
	10.3 Analyse the contribution of technology to mankind

Among the sixteen habits of mind listed by Costa (1999), the most prominent habits of mind found from the literature was the habit of questioning and problem posing (Chin & Osborne, 2008, 2010). For students to initiate scientific investigations, teachers must cater for the development of students' habit in questioning and problem posing. Developing this habit allows students to make their thinking visible by asking questions and posing problems (Chin & Osborne, 2008; 2010; Shu et al., 2013). Similarly, in the Malaysian Year Four science curriculum, teachers are encouraged to develop the habit of questioning among students (CDC, 2013).

Promoting metacognitive thinking among young children can be even more challenging than teaching basic cognitive abilities (Zohar, 2012). In science classrooms where ST is not among the educational goals, metacognitive thinking is not given much emphasis (Zohar, 2012). Teachers need to know higher levels of instructions, such as asking students to talk about their reasoning abilities and share what and how they think. In other words, teachers should acquire appropriate theoretical knowledge about metacognition and pedagogical knowledge to teach metacognition among young children while inculcating scientific thinking skills (Zohar & Barzilai, 2013). On the contrary, according to Zohar and Barzilai (2013) in their review on metacognition in science education, science curriculum specifications do not facilitate metacognitive thinking. Local science curriculum specifications however, did mention metacognitive thinking as part of developing higher order thinking skills, but did not emphasise how science teachers could go about promoting it (CDC, 2013). With this understanding, the researcher had to decide on an appropriate and suitable framework to inform the selected teachers about metacognitive thinking and how to promote it among students. Therefore, the researcher had adopted the ladder of metacognitive thinking by Swartz et al. (2008) that consists of naming, describing, planning and applying specific thinking strategy. They have asserted that the process of naming, describing, planning and applying means students are aware of their thinking. For example, in learning how to compare and contrast, the students know that they are performing compare and contrast, describing how to compare and contrast systematically, plan how to compare and contrast in a given task, and know when to apply to transfer the skill of compare and contrast into new contexts.

This is important for both teachers and students who are unaware of metacognitive thinking (Chatzipanteli et al., 2014). It was crucial for teachers to learn the fundamental process of promoting students' metacognitive thinking, which is to be aware of one's own thinking (Swartz et al., 2008). This means teachers must introduce students to be aware of their own thinking by naming, describing, planning and eventually applying learnt thinking skills into new contexts. Since promoting metacognition among young children requires active teacher-student participation in interacting with each other, teachers themselves should know what metacognition is before they initiate promotion of metacognitive thinking among their students (Zohar, 1999). Based on several literature readings science teachers could promote and assess metacognition among young children, posing questions about the way students think (Chatzipanteli et al., 2014; Whitebread et al., 2008; Whitebread, Almeqdad, Bryce, & Demetriou, 2010).

In parallel with this, the Year Four science specifications has also suggested that science teachers should promote students to talk about their science learning experiences (CDC, 2013). For example, teachers should encourage students to share what they have learnt on a daily basis. Therefore, the researcher focused on the promotion of metacognition as part of ST. Figure 4.4 shows graphical representation on the refined scope of ST for this study.

To gain information about teachers' current practices in ST infusion, the researcher identified nine teachers as participants. These teachers were from both urban and rural schools in the state of *Negeri Sembilan*, Malaysia. All of them were graduates in science education and were teaching Year Four science. They were selected based on purposive sampling (Creswell, 2012). For the context of this study, the researcher had two criteria for sampling. Firstly, the teachers do not have experience more than two years in Year Four science. They may have experience in other levels (Year 3, Year 5 or Year 6). These teachers have various years of teaching experiences but all of them have less than two years of teaching experiences in Year Four science.

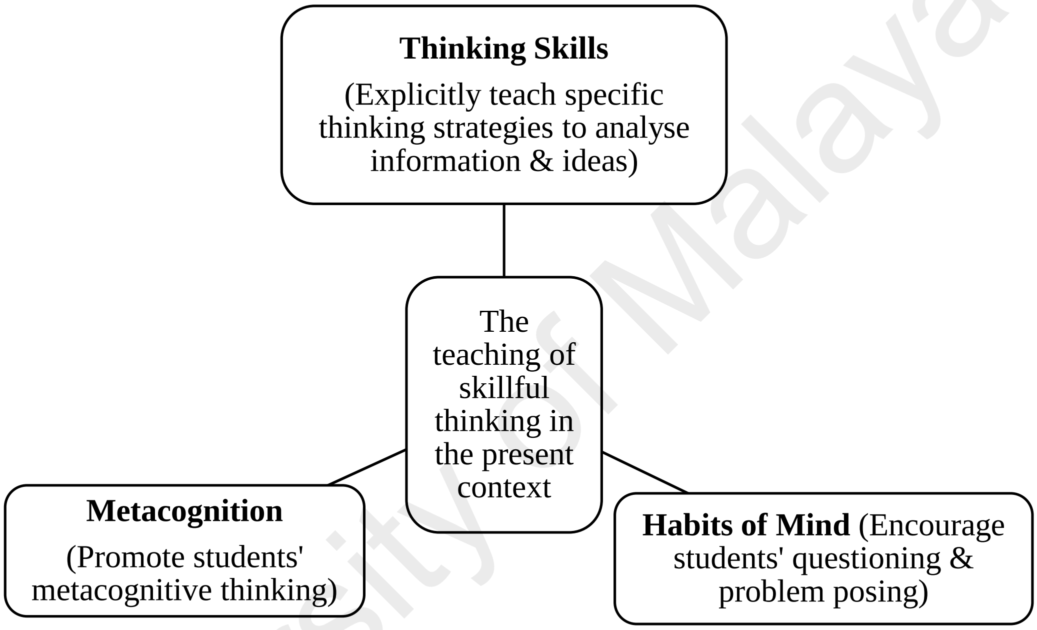


Figure 4.4. The identified key components in teaching of ST based on current Year Four Science curriculum specifications.

Teachers are considered as teachers who have experience about two years in teaching, are considered as novice or beginning teachers (Gatbonton, 2008). Secondly, they must not have attended formal training in teaching thinking skills. Initially, the researcher identified thirteen teachers who fit the sampling criteria. Among them, three teachers refused to participate due to other jobs commitments. Another teacher was transferred to a different school on the very day she was supposed to be interviewed by the researcher. However the remaining nine teachers agreed to participate. The teachers were teaching students who were mostly diverse abilities in academic performance.

Year Four students transit from Level 1 to Level 2 of primary school education in Year Four. Due to this transition, science teachers often face greater challenges to teach Year Four students (ten year old children) HOTS (higher order thinking skills) (Nair & Ngang, 2012), as it is a requirement to teach HOTS (Curriculum Development Centre MOE, 2012).

Apart from document analysis, other sources of data were collected for teachers' knowledge of ST and how they teach ST (practices) in their current science lessons. Therefore, qualitative data collection techniques were employed to gain information on the selected group of teachers' knowledge and current practices in teaching ST. This was to gain a rich source of information on how ST was implemented among the selected group (Creswell, 2012).

Before starting the data collection process, the researcher carried out formal procedures to gain consent from the respective departments. Consent letter to conduct research was obtained from the Education, Planning and Research Department (EPRD) (Appendix B). Once the consent letter from the EPRD was obtained, the researcher applied for consent from the Negeri Sembilan State Department (JPNNS) and was permitted to conduct this research (Appendix C). Selected school administrators were approached with a formal letter describing brief details of the research. Another consent letter was prepared to gain permission from the participants to participate in this study (Appendix D). This letter was prepared for each phase. These steps were taken to ensure that the data collection procedure meets research ethics requirements (Creswell, 2012). When permission from relevant authorities was obtained, the researcher started to collect data using three qualitative data collection techniques; teacher semi-structured interviews, classroom observations and document analysis. Protocols for teacher semi-structured interviews, classroom observations and document analysis were checked, reviewed and revised based on discussions with supervisors.

Teacher semi-structured interviews. Semi-structured interviews were carried out to gain information about teachers' current knowledge in ST and its implementation. Each teacher was interviewed based on convenience. This was because each of them taught in different schools. The interview sessions for each teacher were carried out to gain information on what the teachers could verbalise about ST. A semi-structured interview protocol was prepared (Appendix E) which consisted of questions on how teachers infuse ST, based on literature readings on ST and HOTS (Swartz et al., 2008; Swartz & McGuinness, 2014; Zohar, 2004). It comprised eight sections; teachers' details, knowledge of ST, lesson planning, practices in engaging students in thinking skill, habits of mind and metacognition, classroom management and challenges in teaching ST. Among the sample questions were:

1. *What approach do you employ in teaching thinking skills/HOTS to your pupils?*
2. *Do you encourage your pupils to think about how they think?*
3. *Do you find the existing teacher-guides helpful in planning and executing lessons to cater for both subject knowledge and thinking skills?*

Each interview lasted between thirty minutes to one hour. Most teachers were willing to share their thoughts and experiences openly and responded well to the researchers' questions. However, few others remained reserved about the way they teach ST and responded briefly. A total of nine interviews was conducted.

Classroom observations. Classroom observations such as classroom discourse (lesson transcripts) and field notes were done to gain information on the teachers' current practices in ST infusion. To assist in taking field notes, the research had prepared an observation protocol (Appendix F) that was derived based on the exemplary practices of ST infusion suggested in the literature readings (Swartz et al., 2008; Nair & Ngang, 2012; Zohar, 2012). The researcher was a non-participant observer in this study, seated at the back of the classrooms (Creswell, 2012). Each observation took approximately an hour (time period allocated for primary science per lesson). However, only five teachers were observed as they gave permission to do so.

Data analysis method for phase 1. Collected data for Phase 1 were analysed using constant comparative method (Kolb, 2012). Figure 4.5 shows the flow of data collection and data analysis for Phase 1 of the present study, followed by descriptions on how one of the themes; teachers' knowledge of ST, was derived.

Step 1: Preparing data for analysis. Data for the present study consisted of audiotaped classroom discourses, researcher's field notes, teacher interviews and existing teacher materials. The audiotaped lessons were transcribed into verbatim and saved as electronic form after each collection.

While preparing for coding process, all sources of data were given abbreviations for easy reference as follows:

Teacher – *T*, for example T3 is Teacher number 3 in Phase 1

Lesson Transcript – *LT*

Field Notes – *FN*

Document Analysis - *DA*

Teacher Interview – *INT*

Line in excerpts from data – *L*

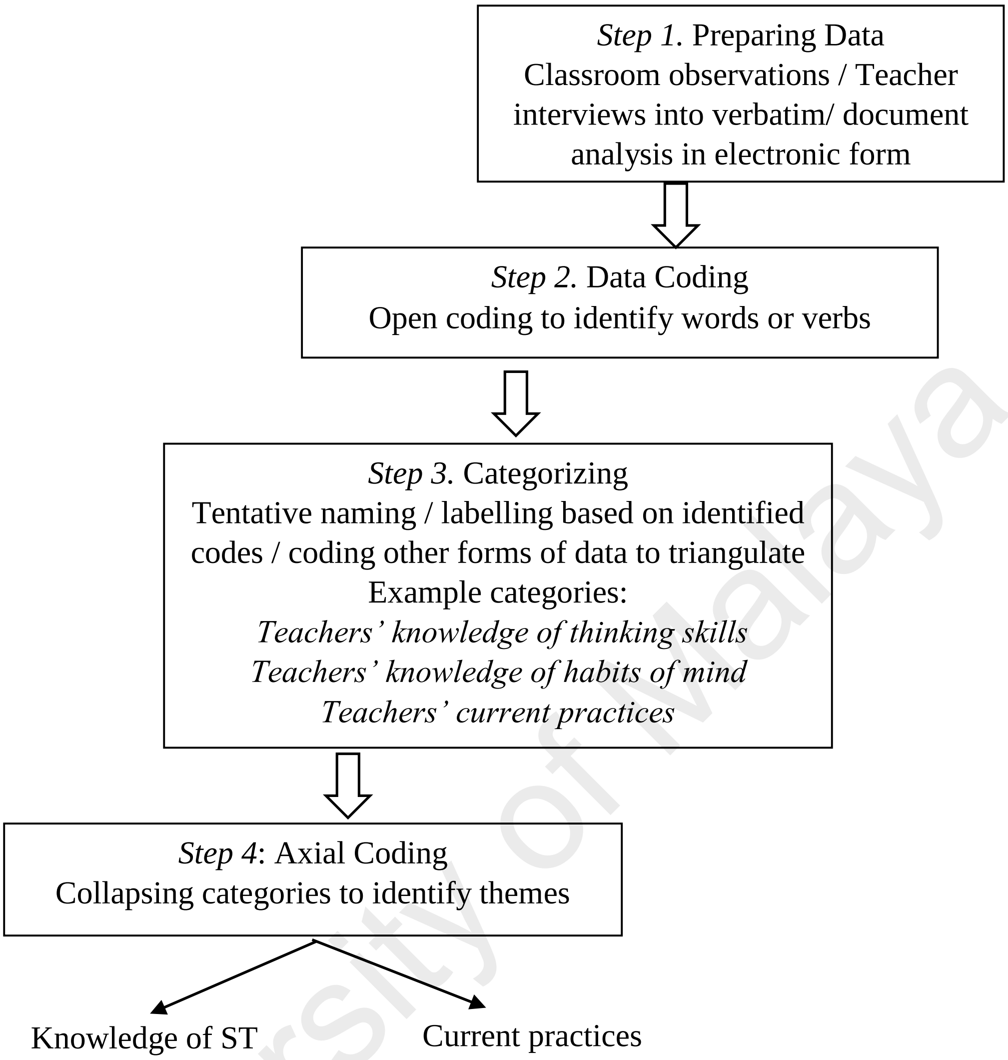


Figure 4.5. Steps in data analysis in Phase 2.

Step 2: Data coding. The researcher read through the data to get general picture of the data and wrote memos of initial ideas about the lesson transcripts, field notes and teacher interviews (Creswell, 2012). Text segments in the lesson transcripts, field notes and teacher interviews were assigned to corresponding codes for triangulation purposes. For example, the text segment that reads;

> '*Actually…I* ***think*** *thinking strategies are the same as science process skills…***but slightly difficult***...they (students)* ***need to think out of the box'***
>
> *T3, L82, INT*

This text segment tells that the teacher perceived thinking strategies as science process skills, however can be difficult to some extent. Since, it informs how teachers perceive thinking strategies, this text segment was assigned to the code called 'knowledge of different thinking strategies'. Similarly, there were text segments that denote teachers' perceptions on students' thinking skills. For instance, the following text segments were assigned to the code called 'teachers' perception on students' thinking'. Below are few examples of text segments from teacher interviews.

'They are very silent'	T2, L15, INT
'They hardly ask any questions'	T1, L31, INT
'I can't give them HOTS tasks because they cannot think at analysis level'	T2, L15, INT
'How to make them ask questions? If they are like that?'	T2, L26, INT
'They are very passive'	T3, L18, INT
'They don't answer'	T3, L34, INT
'They look confused'	T7, L75, INT
'They don't know that they don't know'	T8, L80, INT

The above text segments refer to the teachers' perception of their students, because they had verbalized what they observed about students during science lessons related to thinking abilities. For example, when the students seem to be very silent, hardly ask questions, passive, do not answer or look confused. It appeared that the selected teachers regarded such responses from students as 'missing thinking behaviours' and concluded that the students are unable to think at higher levels. This was perhaps because the students appeared passive in sharing their thoughts and ideas during group discussions. The selected teachers also perceived that the students were having difficulties in sharing their thoughts even when they were in groups with their friends and lack of motivation to think.

"They cannot analyse, sometimes it takes few days for them to think of an answer.'	T2, L20, INT
"They can't respond immediately"	T3, L16, INT
"The others cannot at all, need to motivate (respond)"	T8, L60, INT
"They don't know how to discuss, even with their friends'	T7, L15, INT

“Some of them don’t have the motivation to think in groups’   T2, L19, INT

These text segments were assigned to a code called ‘teachers’ perception about students’ habits of mind’. There were few other text segments assigned to the code – knowledge about habits of mind. It reads as;

> *“Thinking requires **motivation and effort**. The **students have no motivation to think.** Without effort to think…higher order thinking cannot be acquired.*
>
> *T5, L21, INT*

It shows T5 believes that habits of mind is the motivation to think which is essential in developing students thinking skills.

Text segments that describe what the teachers had verbalized about the concept of metacognition and what they perceived about students’ metacognitive thinking were also assigned in the same way.

> “*I have **never heard** of it [habits of mind and metacognition] before*”
>
> *T1, L23, INT*

> *“That’s difficult, **I don’t think** so my students could think at that level”*
>
> *T9, L101, INT*

Both text segments shows what teachers do or do not know about metacognitive thinking and how they perceive students’ ability in such thinking.

Step 3: Categorization of data. The third step was to locate codes to categories (Creswell, 2012). The categorization process was conducted by collapsing the codes into common categories that describe a matching concept. For example, the codes ‘knowledge about the different kinds of thinking strategies’ and ‘teachers’ perception on students’ thinking abilities’ describe similar concept – what they know about thinking strategies. This includes what they verbalize about thinking strategies, state how they teach these strategies, and what they think about students’ thinking abilities. According to Veal (2012), science teachers’ beliefs or perceptions of their students influence how they integrate knowledge about their students and their teaching practices. Thus, the above mentioned two codes describe the selected teachers' current knowledge about thinking strategies (category). Similarly, codes that describe same concepts were assigned to categories called teachers' knowledge of habits of mind and knowledge of metacognition.

Step 4: Identifying themes

The final step conducted was the axial coding in order to look for relationships between categories to form themes. The themes were predetermined based on insights from literature review on teachers' knowledge and ideal practices of ST (Swartz et al., 2008; Zohar & Barzillai, 2013). Categories such as teachers' knowledge of thinking strategies, knowledge of habits of mind and knowledge of metacognition were assigned to a theme named 'Knowledge of ST', because these categories describe what the selected teachers have claimed to know about the three elements of ST.

With the same analysis steps, another theme was identified – current practices. This theme describes the teachers' current practices in terms of what their actual teaching approach, classroom management, and the use of thinking maps for teaching thinking skills. The researcher, however had taken into account what teachers said about how they teach thinking skills during interviews. This was due to limited classroom observations whereby not all teachers agreed for their classroom practices to be observed. In the present study, the theme 'Knowledge of ST' denotes what teachers had verbalized about what they know of ST and their perceptions of students' thinking abilities. Consequently, current practices explains what the teachers had claimed to do in teaching thinking skills and their actual classroom practices as observed by the researcher. These sources of data were used to gain information on the selected teachers' current knowledge and practices in teaching thinking skills. Thus the analysis for data collected during 'groundwork phase' in Phase 1, revealed two themes; knowledge of ST and current practices. Table 4.3 shows the codes, categories and themes for Phase 1 analysis.

Table 4.3

Themes, categories, codes and explanations for Phase 1 findings

Theme	Categories	Codes	Example
Knowledge of ST *Explains what teachers were able to verbalize about the three elements of ST – thinking strategies, habits of mind and metacognition, and their perceptions of students' ability in ST.*	1. Knowledge of thinking strategies	*Thinking strategies *Teaching how to analyse *Views on students' thinking abilities	*"Thinking requires **motivation and effort**. The students have **no motivation to think**"* L21, INT, T5
	2. Knowledge of habits of mind	*16 habits of mind *Views on students' habits of mind	"*I have **never heard** of it [habits of mind and metacognition] before*" L23, INT, T1
	3. Knowledge of metacognition	*Metacognitive thinking *Views on students' metacognitive thinking	*"That's difficult, **I don't think so my students could think** at that level"* L101, INT, T9
Current practices *Explains teachers' practices of ST that were reflected in teaching approaches such as how they infuse ST (or do not infuse), how they manage students' discussions and the use thinking tools.*	1. Teaching approach	*Recipe-like lessons *Fully structured inquiry	*T5: This is wrong…papers absorb water right? Change it…*[the students quickly corrected his answer] *T5, L45, FN*
	2. Poor classroom management	*Whole group discussions *Interaction among students	"*Some groups were found to be **quiet** and some were **whispering** to each other*" *L20, FN, T7*
	3. Use of thinking tools	*Existing thinking tools *Limited use	*"**Do not copy from your friends**….do on your own"* *T8, L39, LT*

Based on these themes, which will be described in detail in Chapter 5 later, the researcher moved on with developing the STEPS.

Developing the STEPS. Based on the information gained from the selected group of teachers' knowledge and current practices as well as literature readings, the researcher then prepared the STEPS for the teachers to use while teaching the topic 'Properties of Materials'. During the 'groundwork' phase, the selected nine teachers were teaching two topics – life science and physical science. The next topic would be material science – properties of materials. Therefore, the researcher prepared the STEPS for the topic 'Properties of Materials'. The development of the STEPS were based on findings from the selected group of teachers' knowledge and current practices. The data collected during groundwork of the STEPS were analysed. Based on this finding, the researcher prepared the STEPS, with three design heuristics (Davis & Krajcik, 2005; Davis et al., 2014; Lin et al., 2012). For each design heuristic, there were several educative features developed to suggest ideas and rationale on how ST can be infused into lessons. Full description of the three design heuristics and educative features will be discussed later in Chapter 5 (Phase 1 Findings and Discussion).

Reviewing the STEPS. Once the prototype for the STEPS was ready, it was sent to a panel of experts for validity and improvements on the STEPS. The experts were asked to comment on the design heuristics and educative features in the STEPS. A sample of the returned comment from an expert is attached as Appendix G. The experts consisted of two experienced primary science teachers, two lecturers each from a teacher training college and a university in Malaysia and an education officer from the State Education Department. These experts were selected based on literature readings that provided criteria for the selection of experts (Bojadziev & Bojadziev, 2007; Thanabalan, 2011). As such, the researcher set the criteria for the expert panellist:

1. Knowledge in the field of primary science education (or/and)
2. Knowledge in teaching thinking in science education (or/and)
3. Experience in pedagogy with more than ten years of experience (or/and)
4. Experience in educational/curriculum material development (and)
5. Willing to participate in the research and contribute constructive comments.

Table 4.4 shows the list of experts who reviewed the STEPS and provided constructive comments to improve its design and content.

Table 4.4

The expert panel involved in reviewing the STEPS.

Expert	Description	Role
Expert 1	Lecturer in Teachers' Training Institute. Experience in teaching science and educating pre-service science teachers for 19 years. Involved in conducting talks and workshops in teaching higher order thinking skills for science teachers.	To review on the design and content of the STEPS
Expert 2	Science teacher with 15 years of experience in teaching Year Four Science.	
Expert 3	Science teacher with 12 years of experience in teaching primary science	
Expert 4	Head of Department of Quality Assurance, State Education Department. Involved in designing teacher-guides and materials for teachers to teach higher order thinking skills.	To review on the design of the STEPS
Expert 5	Malay Language lecturer in a university in Malaysia. An expert in teaching Malay Language to foreign students. Involved in designing learning modules for students in learning the Malay Language.	To review the STEPS prepared in the Malay Language.

Full descriptions on the changes made to the STEPS based on the experts' comments will be discussed in Chapter 5- Phase 1 Findings.

The pilot study. The researcher pilot tested the STEPS prior to the use for field study, to check for feasibility of the lessons suggested in the STEPS. It was important to see if teachers could follow the three sample lesson plans included in the STEPS. A teacher, called Hanna (pseudonym) with less than two years of experience in teaching Year Four science participated to pilot test the STEPS. Her comments and thoughts about the STEPS were gathered. From her classroom observations, it can be said that the time allocated for each step was suitable as Hanna was able to complete the recommended lessons within the suggested time. During discussions with Hanna, she raised several comments about the STEPS. She claimed that the STEPS was different from other teachers' guide materials she had, whereby she could actually see how explicit teaching of thinking skills can be slowly infused into content lessons. According to her, the tools such as thinking maps for classifying the properties of materials, was also different. Extra features added to the thinking maps like questions on why they (students) classify the objects into respective groups and the design for classifying are useful cues for teachers to scaffold students' thinking. Based on Hanna's constructive comments, the researcher prepared the final copy of the STEPS, which was ready for use in Phase 2 study.

Methodology for Phase 2 (Implementation of the STEPS)

In this section, participants, data collection and data analysis methods for Phase 2 are discussed. Phase 2 data collection was conducted to explore the STEPS implementation, particularly on how the selected teachers infuse ST upon using the STEPS. It was to meet research objective 3 (RQ3), which was to describe the selected

Year Four science teachers' ST infusion practices for the topic 'Properties of Materials', upon using the STEPS.

Research site. Phase 2 study was conducted in the national primary schools (*Sekolah Kebangsaan*) in Port Dickson, Seremban and Lukut districts. The list of schools was obtained from JPNNS (*Negeri Sembilan* State Education Department). Primary schools in these regions, are classified as semi-urban. The schools in these districts also have the criteria for this study; teachers with less than two years of experience in teaching Year Four science. Thus, the selection of research site was based on convenient sampling to save time, energy and travel expenses for data collection. This was to gain rich data source from the target group of teachers based on the purpose of the present study (Patton, 1990).

The participants for phase 2. Three teachers, Suzana, Hisham and Rosni (pseudonyms) participated in Phase 2. The following is a short introduction to the three participants.

Suzana

Suzana is a science education graduate. She is also the Head of Science Panel in her school. At the time of research, she was teaching Year Four science for the first time. There were 35 students in her class. Her students were mainly from the *Felda* areas (oil palm plantation estates). There were also several indigenous students in her class, who came from the surrounding *Orang Asli* settlements (indigenous people). Her students can be considered as active, focused and receptive students. They respond actively to their teacher. She asserted that teaching Year 4 students (10 year olds) would be a different experience since they were still in the transition period (from Year 3, lower to upper primary level). From her previous experience, Suzana affirmed that she was facing greater challenges teaching Year 5 and 6 because the students were taught to memorise scientific facts and to answer subjective questions (exam like questions). Therefore, she volunteered to participate in this study because she wanted to learn how to infuse ST, to change her conventional teaching method to one that caters for the development of students' thinking skills.

Hisham

Hisham is also a science education graduate. He had been teaching Year 4 science for one and a half years. Apart from that, Hisham is also the UPSR Examination Secretary for his school. He was in charge of the entire process of the UPSR public exam. Despite the additional workload of being the UPSR examination secretary, Hisham volunteered to participate in this study. This was his second year in teaching Year Four science. There were 29 students in his class that consisted of both active and less active students. During lessons, only a few students would actively volunteer to respond to their teachers' questions. The remaining students were normally either silent or only responded when their names were called to answer questions.

Rosni

Rosni is also a science education graduate. She is teaching in a primary school in an army camp, TDRM (The Malaysian Royal Army). The camp is highly secured by armed officials, therefore the researcher had to go through security checks during each visit to the school. Rosni had been teaching science to lower primary students in this school for the past five years, since her posting from teacher-training college. At the time of the research, Rosni was in her second year of teaching Year Four science. Her 24 students were more passive and did not respond promptly. Rosni was hesitant in the beginning to participate in Phase 2, because she claimed that her students were passive and might not respond positively.

Data collection techniques for phase 2. The researcher had employed qualitative data collection techniques to collect data for Phase 2. The data collection techniques for Phase 2 were semi-structured interviews with teachers, classroom observations, document analysis and semi-structured interviews with students.

Classroom observations. Classroom observations consisted of audiotaped lessons and field notes during lessons. The lessons were also audiotaped to capture teacher-student interactions during lessons. It was particularly to record teachers' conversation with their students, which might be overlooked during classroom observations. Each observation was one hour long. Suzana was observed for a total of eight hours (8 lessons), while Rosni and Hisham were observed for seven hours. They were observed until they completed all the lessons in the topic 'Properties of Materials'. Each teacher was equipped with an audio recorder. The teachers hung the audio recorder around their neck, therefore, their conversations with students as they walked around were clearly recorded. There were twenty-two audiotaped lessons. The researcher took field notes to record teachers' practices based on the framework for ideal ST practices (as in Chapter 3 of this study), suggested by Swartz and McGuiness (2014) and Zohar and Schwartzer (2005). The researcher wanted to see if the teachers were able to infuse ST elements into the topic 'Properties of Materials' upon using the STEPS. A sample of the researcher's field notes is attached as Appendix H.

Apart from audiotaped lessons and field notes, an audit trail was carried out by the researcher, to keep track of the data collection process. The audit trail was employed by the researcher to record thoughts and hunches during analysis of other sources of data, thus to improve the credibility of this study (Creswell & Miller, 2000). The researcher also entered day to day descriptions of the data collection process in the audit trail. This had helped the researcher to retrieve general information of each data collection. A section of the audit trail is attached as Appendix I.

Semi structured interviews with teachers. After the completion of the topic 'Properties of Materials', the selected teachers were interviewed by the researcher. Each interview lasted for one to one and half hours until saturation was attained. The semi-structured interview with questions that gained insights on the participants' thoughts upon using the STEPS. An interview protocol was prepared by the researcher (Appendix J). Questions in the interviews targeted on teachers' knowledge and practices for ST infusion (specific thinking strategies, habits of mind and metacognitive thinking) (Beyer, 2008b; Zohar, 2013). Examples of questions were as following:

1. *What are your thoughts about ST and its implementation in primary science?*
2. *Does ST approach helps you in teaching thinking skills to your students?*
3. *How do you find the recommendations in the STEPS?*
4. *Do you find the STEPS educative? If yes, can you explain?*

However, through the research duration, the teachers were also interviewed after each lesson. The interviews were carried out to clarify practices observed during the lessons. For example, the researcher asked how did the teachers feel after each lesson, or why did they employ specific instructions for their students. The teachers also shared their thoughts about weaknesses and strengths of the lessons and asked if they could make improvements. The interviews were audiotaped and transcribed. Several times, the researcher could not discuss in detail with the participants.

The interviews and lessons were conducted in the Malay Language, therefore back translation was carried out by translating previously translated transcripts back into the Malay Language (Temple & Young, 2004). A certified language translator had helped with the back translation process. An example of teacher's final interview transcript and how it was back translated is shown in Appendix K.

Interview with students. Focused group interviews were held with students from each participating class. Five students (one group) from each class, were chosen by their respective teachers based on their ability to share thoughts and were comfortable to be interviewed. This had helped to promote better conversation between the researcher and students during the interviews. Total of three focused group interviews were conducted. They were semi-structured interviews with questions pertaining to students' thoughts and views on the new teaching practices by their respective teachers. Students shared their opinions and experiences in performing ST elements, such as performing different kinds of thinking strategies, questioning and problem posing as well as metacognitive thinking. This data helped the researcher to triangulate data from field notes, teacher interviews and lesson transcripts. An example of students' focused group interview is shown in Appendix K.

Document Analysis. Students' work such as worksheets and thinking maps were analysed. They were analysed by tracing phrases or written evidence to show thinking dispositions. Phrases such as '*I know now how to*…'or '*I should have*…' were tracers to show that the student was thinking about his/her thinking. Similarly students' list of questions were analysed to see if the questions depicts higher levels of thinking such as 'How' and 'What if'. This was conducted for triangulation purposes with other sources of data; lesson transcripts, teacher-interviews, field notes and students' focused group interviews.

Data analysis method for phase 2. The data were transcribed into verbatim and saved as electronic data. The steps in data analysis were similar to Phase 1, however Phase 2 consisted of larger data. The steps involved in the data analysis process were data preparation, data coding and data categorization to form themes. The data were analysed to see if any changes have occurred in the selected teachers' ST practices, upon using the STEPS for the topic 'Properties of Materials'. Figure 4.6 shows the steps taken for Phase 2 analysis.

Preparing data for analysis
Audiotaped lessons, teacher and students' focused group interviews transcribed into verbatim / researchers' field notes, audit trails, students' work saved as electronic form.

↓

Open coding
Identifying words, verbs, teachers' practices (text segments in transcribed verbatim).
Example from l*esson transcripts – terms like 'what?* or *is it?' were used to probe students' knowledge about materials.*

↓

Categories
Tentative naming / labelling based on identified codes / coding other forms of data to triangulate.
Example category– *probe content knowledge*

↓

Axial Coding
Collapsing categories, refining upon commonalities to look for relationships
Example: *Probe content knowledge*
Gather information and ideas
Model thinking strategies
Transfer thinking
These categories refer to common concept – how teachers teach students thinking skill – Teach to analyse information and ideas (identified theme).

↓

Final Coding for categories to determine themes
Example Theme: Teach to analyse information and ideas

Probe content knowledge
(Unsatisfactory Practices)

Gather information and ideas
Model thinking strategies
Transfer thinking
(Satisfactory Practices)

Figure 4.6. Steps in Phase 2 data analysis.

Preparing Data. Audiotaped lessons (classroom discourses) and interview data were transcribed into verbatim. Field notes, students' work and audit trail were typed and saved as electronic form. Transcripts of the audiotaped lessons and teacher interviews were sent back to the participants for member-checking. For instance, the researcher clarified few issues observed during classroom observation with the respective teacher after the lesson. Teachers read through the lesson transcripts to check if they were accurately reported. A total of 66 documents were transcribed. Table 4.5 shows the total sources of data collected during Phase 2.

Table 4.5

The number of total documents collected for Phase 2

Type of Data	**Number of data for each partcipant**		
	Suzana	**Hisham**	**Rosni**
Audiotaped lessons	8	7	7
Teacher Interviews	6	7	6
Field Notes	8	7	7
Students' focused group interviews	1	1	1
Total documents		**66**	

All sources of data were given abbreviations for easy reference as follows:

Teacher Suzana – *S*

Teacher Hisham – *H*

Teacher Rosni - *R*

Lesson Transcript – *LT*, for example LT2 is Lesson Transcript number 2

Field Notes – *FN*

Document Analysis - *DA*

Teacher Interview – *INT*

Student Focused Group Interview – *SFG*

Line in excerpts from data – *L*

Data Coding. As for Phase 1 analysis the researcher reads through the data to get general picture of the data. Open coding process was carried out to identify phrases, terms or words that are pertinent to the elements of ST. Similar coding process was carried out for other sources of data that is, field notes, teacher interviews and students' focused group interviews. The original list of codes, before being collapsed into categories, is attached as Appendix L.

Data Categorization. The researcher assigned the codes to a named category, when similar codes were found across different sources of data to triangulate the codes (Berg, 2007; Creswell, 2012; Merriam, 2009). Codes from field notes and teacher interviews were compared to countercheck with those identified in lesson transcripts. A triangulation matrix was prepared to show the assigned codes and categories across different sources of data. This was carried out to avoid poor coding system. A section of the matrix is attached as Appendix L. The triangulation matrix was given to two critical friends to peer review the codes and categories. They had experiences in qualitative data analysis process. The reviewers wrote their thoughts about the codes. They commented on the text segments in classroom observations, teacher interviews, and field notes. Hence, the different sources of data were important to verify the coding process.

Memos were also written while analysing the data on weekly basis (Creswell, 2012). For example, when the researcher reads lesson transcripts, interview transcripts and field notes for Suzana, Hisham and Rosni in the first week of lessons, memos were written when there were similarities or differences in codes. The process was continued as part of data analysis until reached data saturation.

Axial Coding and Themes. List of categories were then collapsed based on commonalities. When the collapsed categories that were potentially relevant to a concept was formed, they were assigned to themes. For instance, 'probe content knowledge', 'gather information and ideas', 'model thinking strategies' and 'transfer thinking' were categories that refer to common concept or theme- how teachers teach students to analyse information and ideas. Thus, the identified theme for the mentioned categories was 'teach to analyse information and ideas'. Upon further analysis on the categories and based on insights gained from literature readings, two types of practices were identified; unsatisfactory practices and satisfactory practices.

Unsatisfactory practices refer to practices, in which the teachers could not explicitly show infusion of ST. In other words, when teachers were not able to consciously infuse ST elements, such practices were named as 'unsatisfactory practices'. For instance, in the beginning of the topic 'Properties of Materials', all three teachers could not show infusion of ST, mostly because of the passive response that they received from their students. The students were not able to share ideas systematically, pose good questions, or explain what or how they think (metacognition). Yet the teachers too did not try to rectify such issues, instead they went on completing the lessons, which showed unsatisfactory practices of ST.

In later lessons, the teachers designed and enacted lessons on their own, with guidelines provided in the STEPS. At this stage, they were able to show progress in the practices of ST. Eventually, by end of the topic, they showed satisfactory infusion of ST. Thus this was regarded as 'satisfactory practices', because such practices had all three elements of ST, which the teachers independently enacted based on the recommendations and ideas in the STEPS. Following are several examples of how the researcher coded and categorised the data for the theme – Teach to analyse information and ideas. There was one category assigned as 'unsatisfactory practice' and three categories for 'satisfactory practices' under this theme. This theme looks how the teachers taught (practices) their students to analyse information and ideas about properties of materials.

Category 1 – Probe Content Knowledge

The text segments below show that Suzana asked questions more than her students did. She used terms such as *what*, *who* and phrases like *third resource (asking students to recall the third resource of material).* Her sentences were more of questions to capture *what students already know* about materials.

*12) Suzana: **What is** the source of material?*
13) Student: From plants
*14) Suzana: **What's** the second resource?*
15) Students: Animals
*16) Suzana: **Who** can tell me the third resource?*
17) Students: Rock

S, L12, LT1

Hisham and Rosni also probed students' content knowledge about materials.

*8) Hisham: Okay, plastic and **what is** the resource of plastic?*
9) Student A: Metal… (Hisham just kept quiet and continued his lesson)
*10) Hisham: Others? **Is it** natural or man-made?*
11) Students: Man made *H, L8, LT1*

*12) Rosni : This is a purse that women normally use. Okay? But, **what is** found on the purse?*
13) Students: Leather 13)
*14) Rosni : Okay, the material is leather, this one is [showing other parts of the purse] iron…**what is source** of iron?*
15) Students: Metal…rock [source of metal]

R, L12, LT1

*Rosni spent about 35 minutes on **asking what students know** about different objects.*

R, L7, FN1

Hisham did not ask the student who wrongly answered the resource of plastic, whereby the student said it was metal. Hisham could have taken this chance to invite other students to respond and create further discussion about the resource for plastic. In addition, Hisham continued his lesson by asking different question, whether plastic is natural or man-made resource. The lesson went on 'probing' students' content knowledge on materials and their properties. Terms like *what*, *is it* and series of other questions to get to know what students think about materials are codes which were assigned to the category called 'probe content knowledge'. And because Suzana, Hisham and Rosni spent more time on only probing students' content knowledge instead of concurrently developing their habit of questioning and promoting metacognitive thinking, this practice was regarded as '*unsatisfactory practice'*.

There were also terms and phrases during subsequent lessons which showed satisfactory practices. Three categories, Category 2, 3 and 4 emerged for satisfactory practices under the same theme – *teach to analyse information and ideas.*

<u>Category 2 – Gather information and ideas</u>

Phrases that show connections between an object, the material it is made from and its resource were more apparent in later lessons. The teachers carried out lessons, in which the students need to gather more information about an object, such as the material it was made from and the resources of the named material.

123) *Students:* [Reading aloud together]….
Objects - wooden chair – resource is plants
127) *Students:* ***Objects – wooden ruler – resource- plants***

R, L123, LT 2

The students matched each object to its material and then to its respective resource. They gathered as many objects as they could and tabulated them into a certain sequence which reads - 'object-material-resource'. Some information about materials and resources of objects were gathered from group discussions and from school science text books. Apart from that, there were other terms categorized as 'gather information and ideas'. Phrases in the form of questions like '*any corrections?, 'right or wrong?'* and *'what are common features?'* are uttered by teachers so that students share ideas about objects/materials/sources.

Hisham: Is it correct? Anybody classified differently? Why are all these objects put into the same group? What is the material?

Students: [Various answers] *Wrong…wood for wooden splinter and ruler…balloon…to rubber…rubber bands...to rubber.*
H, L18, LT2

The term '*what are common features*?' stimulate students to gather more information and ideas by comparing and contrasting different objects. For example, students need to observe what is common about list of different objects and the materials they were made from, thus making generalisations. For example, ruler, paper, tissue, pencil and table are made from wood that comes from plants.

Category 3 – Model thinking strategies

Category 3 emerged from phrases such as 'Why did you choose…?' or 'How to make inference?' and 'Why is important to classify objects / materials?' were often uttered by the teachers. Rosni asked what her students know about making inferences and asked them to think as to why did made the choice of choosing an object (Pot A or B). This requires students to give reasons for the choice of object they had chosen.

Rosni: ***What is an inference…how to make inference****? We have learnt how to give inference in our first topic right? Choose an answer...Pot A or B...****Give me inference as to why did*** *you choose Pot A or Pot B.*
R, L49, LT5

Phrases such as 'What was (is) used for', 'what happens if' and 'any suggestions' were used to help students look at parts-whole relationships, predict and to give suggestions when observing an object. Suzana pointed at different parts of an object and asked students to relate them to their properties.

Suzana: ***Okay, look here, down here…what was used?*** [Pointing certain part of the design and asked students to identify the material it was made from]
Student 1: Paper…That's why it could float

S, L133, LT8

Suzana: ***What happens to this house then****?* [Showing the design made by the group]

Students: *Wet*
Suzana: *Okay,* ***any suggestions****?*
Student 3: Replace it with water proof material like cardboard [the student was showing a plastic board on the wall]

S, L138, LT8

In the cited interaction, Suzana asked 'what happens to this house then?' when she noticed that a certain part of the designed object (lamp house designed and built by a group of students) was made from paper. Other students predicted that that part of object would get wet. Suzana then asked them to give suggestions to improve the design. Hisham provided daily life situations and uttered the phrases such as 'what happens?', 'why' and 'Do you think...?' to model how to predict properties of materials. For example, during a lesson on classifying materials that allow light to pass through, Hisham asked:

Hisham: Now, ***do you think*** *you can see the shadow?*
Students: no…can't see...no cannot [crosstalk]
Hisham: ***Why? What's the difference****?*

H, L80, LT5

Here, Hisham not only asked his students to predict what will happen to the fence (placed around a small compound under shade beside the science room), but he made them give reasons for their predictions. When teachers uttered such phrases, students responded by giving their justification for how and why they had classified, selected objects or predicted in a certain way. Instead of giving direct instruction on how to classify objects, the teachers had provided cues (the uttered phrases) for students to think about what, how and why they came up with specific classification. Here, the teachers had modelled specific thinking strategies such as compare, contrast, predict and justify.

Category 4 – Transfer thinking

Compared to gather information and ideas (Category 2) and model thinking strategies (Category 3), the teachers showed more practices in which they engage students in transferring their learnt thinking strategies. This has made the students practice how to analyse properties of materials using different thinking strategies.

> *126) Hisham: Okay class. You have to remember that only in **our classroom, but also at home,** we have various kinds of objects made from different sources of materials. **How can we differentiate them**? **What did you do just now**?*
>
> *H, L126, LT2*

> *184) Suzana: Okay, so today we learnt about heat conductors and insulators and also electrical conductors and insulators. Look carefully, and tell me…**are the materials the same? What materials** conducts electric and heat?*
>
> *S, L184, LT5*

Most of the time, the teachers read aloud students' questions and initiated discussions among students. Based on students' responses to the posed questions, teachers provided more cues to for them to transfer what they have learnt. For example, during a lesson on learning to classify water absorbent and water proof materials, Hisham reads a question posed by Group 3. The phrase '*what is the difference between*..?' was used by Hisham when modelling how to compare and contrast based on sources of their materials. Hisham, however used the same cue for students to transfer thinking strategies on how to compare and contrast into other contexts.

> *Hisham: **What if…I put this fence outside under the Sun?***
> *Students: It will become hot...*
> *Hisham: **Why what happened? Why does it become hot?***
> *Students: Because it's iron...*
> *Hisham: So?*
> *Students: Mmm…* [Sound made while students looked at each other]*...it conducts heat..?*
>
> *H, L117, LT4*

The text segment cited shows that the teacher had uttered phrases that call for transfer of skill into new situation. Hisham provided a new situation (fence under shade outside the science room) and stimulated students to apply giving reasons for their predictions based on their knowledge about heat conductors.

Similar constant comparative method (Kolb, 2012) was used to identify the remaining two other themes; cultivating the habit of questioning and promote metacognitive awareness. Table 4.6 shows the themes, categories and example of text segments for the identified themes for Phase 2 data analysis.

Table 4.6

Themes, categories and example of text segments Phase 2 data analysis

Theme : Teach to analyse information and ideas	
Unsatisfactory Practices	
Categories	**Example Text Segment**
Probe Content Knowledge	*Suzana: **What** is the source of material?* *Student: From plants* *Suzana: **What's** the second resource?* *Students: Animals* *Suzana: **Who** can tell me the **third resource?*** *Students: Rock S, LT 1*
Satisfactory Practices	
Categories	**Example Text Segment**
Gather information and ideas	*Hisham: Your friend categorised eraser and wooden ruler together and wrote that the common feature …is that both objects are made from plants…**right or wrong?*** *Students: Right but eraser is rubber, ruler is wood, and both are plants...* *H, LT2* *Students: (Reading aloud together)….**Objects - wooden chair – resource is plants*** *Students: **Objects – wooden ruler – resource- plants*** *R, LT2*
Model thinking strategies	*Suzana: What does **classify mean?*** [Silence]*…For example, exercise book and textbook….**how would you classify them**?* [Again silence]*…**what can you observe?*** *Students: The textbook is thick* *Suzana: And??? **How about this one?*** [The exercise book] *S, LT2* *Hisham: Why glass bottles and marbles are put together in the same group?* *Students: They are made from the same material…which is 'glass'. H, LT2*
Transfer thinking	*Suzana: What **other topics can we use classifying**? Grouping and separating?* *Students: Animals...* *Suzana: **Give an example**….how do you classify animals? S,LT2*

Theme : Cultivate the habit of questioning	
Unsatisfactory Practices	
Categories	**Example Text Segment**
Low quality questions	*Student A:* ***What is*** *hanger made of?* *Student B: From plastic* *Student C: Bottle…***made of what?*** *Student D: Plastic* *H, LT1*
Satisfactory Practices	
Categories	**Example Text Segment**
Encourage student questioning	*She kept* ***reminding them to think of questions.*** *In the midst of activity, she distributed the "Lets' Ask" list for students to* ***write down any questions and problems*** *they wish to solve related to the topic.* *S, FN3* *Hisham: I notice my students' questions were all on the subject matter* [not the common questions they would normally ask]. *H, INT*
Model questions	*Group 6: Because it lighted up when shined with light…* *Hisham:* ***So you question is*** *…'why does the plastic bottle lit up when shined with light?* *H, LT5* *"***Ask questions like***…why it is not made of wood but plastic…or why it is different (material) for scissors…***this is how you ask questions"*** *R, LT3*
Model posing problems and solutions	*Rosni: Okay, using that broom and other things at home,* ***how can you help your mother*** *to clean the house? A broom is one of it…***others?*** *R, LT5* *Suzana: So your task today is* ***to identify a problem to solve and think of solutions****. For example, what was the problem I was trying to address just now?* *Students: Difficult to find things in stacked closed box.* *Suzana: Arrghh…yes...difficult to find things in a box,* ***so what were my options?*** *S, LT7*

Theme : Promote metacognitive awareness	
Unsatisfactory Practices	
Categories	**Example Text Segment**
Recall Content Knowledge	*So, **today you have learnt metals or irons** are both electric and heat conductors, right?* *S, LT4* ***Can you name the properties of materials** that we've learnt?* *R, LT3* *Hisham: Before you go out, **what did you learn today?*** *Students: **Water proof or water absorbent*** *Hisham: Okay, class is dismissed. You may go out.* *H, LT3*
Satisfactory Practices	
Categories	**Example Text Segment**
Recall thinking	*Suzana:* ***What does to classify mean?*** *Students:* ……..[No response from students] *Suzana:* ***okay…why did you classify these objects** into this group?* [Showing the worksheet the students had used to classify the objects] *Students:* ….. [After a while]*….we don't know…* *S, LT2* *Teacher:* ***What is meant by classifying**?* *Who can tell me what classifying means?* *Students: Arrange by category* *R, LT2*
Revisit posed questions	*Hisham: Okay, my question is **why do we need to ask questions?*** *Students: To understand easily…so that we think...so that we will be smarter…so that we can analyse questions (multiple answers)* *Hisham: Okay…throughout your activity on designing your creations, **how did it (questions) help you? Did it help you to think a**nd come up selections of materials for your design? Before you start designing, **what did you think about first?*** *H, LT7* *"We need **to think first**, before we ask questions, only then let the teacher know."* *Student A, L117, SFG*

Apart from pre-determined themes as described in an earlier section, another theme emerged from the data analysis. The theme called ‘Transferability of knowledge’ emerged from two categories. This theme explains that the selected teachers had shared their experience and knowledge about ST practices in science lessons. Table 4.7 shows the categories and emerged theme.

Table 4.7

Codes and categories for the emerging theme

Codes	Categories	Emerged Theme
P38: Final interview Hisham.docx - 38:45 *“Although I don’t teach Year 5 Science, but* ***I do share my new strategies with my colleagues****.*	Sharing learnt knowledge	
I told them *if they use this module [STEPS],* ***it will surely help their students in thinking”***	Recommend STEPS	Transferability of knowledge
P41: Suzana Final Interview.docx - 41:9 *‘The STEPS is very helpful and should be* ***made for other teachers to use as well’***	Make STEPS accessible	

Hisham claimed that he had shared his new approach of ST practices with other science teachers in his school and that he recommended them to use the STEPS. The term uttered by Hisham; ‘***I do share my new strategies with my colleagues***’ shows that Hisham was willing to share his new strategies in teaching thinking with his workmates. Therefore this phrase was assigned to a category named ‘*sharing new knowledge’*. Other phrases such as ‘***I told them***…’ and ‘***help their students in thinking’*** show that Hisham ensured that this strategy would help students to improve their thinking skills. Similarly Suzana uttered the term ‘***made for other teachers to use as well’***, which shows that Suzana recommended the STEPS to be made accessible for other teachers’ use. Therefore this code was assigned to a category called ‘*make STEPS accessible*’. These phrases describe similar concept; sharing of new knowledge, which shows that the selected teachers were willing to share their learnt knowledge about ST with their working colleagues. After peer-review for the categories and discussions with supervisors, however, the researcher renamed the theme as ‘**Transferability of knowledge’** to explain that knowledge about ST can be transferred to other teachers or student learning levels (Year 5 and 6), through the use of the STEPS. This theme is further described in a later chapter, Chapter 7 – Heuristics Nature of STEPS.

Summary

This chapter explained how the present study was conducted. The research design consisted of two phases. Phase 1 comprised the preparation of STEPS that included groundwork, developing and reviewing stages. It was conducted to gain information on selected Year Four science teachers’ current knowledge and practices in teaching thinking skills. Based on the findings from Phase 1, the STEPS was prepared to be used by the selected teachers for Phase 2-implementation phase (Attached in a compact disc as Appendix M). Phase 2 was aimed to describe the practices of ST infusion into the topic ‘Properties of Materials’ upon using the STEPS. A summary on the methodology for each phase is shown in Table 4.8. The next chapter describes the findings of this study.

Table 4.8

Matrix of research objectives, questions and method

Matrix of research objectives, research questions and method				
Phase	**Research Objectives**	**Research Questions**	**Data Collection Method**	**Sample**
Phase 1: Groundwork	RO1. To gain information on Year Four science teachers' current knowledge and practices of ST infusion in science lesson.	RQ1. What are Year Four teachers' current knowledge and practices of ST infusion in their science lessons?	Qualitative data collection technique: 1. Teacher semi-structured interviews 2. Classroom Observation / Field Notes 3. Document Analysis- existing curriculum documents, teachers' lesson plans and teaching modules	Nine in-service science teachers with experience less than 2 years in teaching Year Four Science in Negeri Sembilan national schools.
Phase 1: Developing & Review	RO2. To prepare the STEPS (Skilful Thinking Educative Pedagogical Support), with design heuristics for the selected Year Four science teachers to infuse ST for the topic 'Properties of Materials'.	RQ2. What are the design heuristics for the STEPS (Skillful Thinking Educative Pedagogical Support) for selected Year Four science teachers to infuse ST for the topic Properties of Materials?	Qualitative data Collection Technique: 1. Experts' written comments and discussion notes 2. Teacher Interview 3. Observation/Field Notes	*Expert Panel:* Experts from Primary science education, teacher education, curriculum development centre, MOE, expert teachers *Pilot Study:* One science teacher

Phase 2 Implementation of STEPS	RO3. To describe the selected Year Four science teachers' ST infusion practices, upon using the STEPS for the topic 'Properties of Materials'.	RQ3. How did the selected teachers' ST practices changed upon using the STEPS for the topic 'Properties of Materials'?	Qualitative data collection technique: 1. Audiotaped lessons 2. Teacher Interviews/Discussions 3. Student Interviews 4. Field Notes 5. Students' work	Three in-service science teachers in *Negeri Sembilan* national schools. Three focused groups of students.
	RO4: To describe the selected teachers' uptake of ideas in the educative features from the STEPS for the topic 'Properties of Materials'.	RQ4. How did the selected teachers' uptake of ideas in the educative features in the STEPS, support the teachers' ST infusion practices for the topic 'Properties of Materials?	Qualitative data collection technique: 1. Audiotaped lessons 2. Teacher Interviews/Discussions 3. Student Interviews 4. Field Notes 5. Students' work	Three in-service science teachers in *Negeri Sembilan* national schools. Three focused groups of students.

CHAPTER 5

PHASE 1 FINDINGS AND DISCUSSION

Introduction

This chapter starts from the findings of the selected Year Four science teachers' knowledge in ST and their practices of ST infusion. In the next section of this chapter, the researcher reports on the preparation of the STEPS which was based on the findings for research question 1. The design heuristics for the STEPS were derived both from literature readings and findings from the selected teachers' current practices.

Findings from groundwork for STEPS

Phase 1 was divided into three sections, groundwork, developing and review of the STEPS. The purpose of groundwork was to gain information on the selected group of Year Four science teachers' current knowledge and practices in teaching ST. Groundwork of the STEPS started with the analysis on the Malaysian primary science curriculum specifications in order to understand how ST is related to Year Four science.

Teachers were interviewed to gain understanding of their current knowledge and practices in teaching ST during science lessons. Interviews with the selected group of teachers revealed that generally they were lacking in knowledge about ST and the pedagogical knowledge to teach ST. The participants were represented by T*n*, whereby *n* are numbers from 1 to 9. T1, T2 until T9, represent the nine teachers who participated in Phase 1 of the study. Data analysis on Phase 1 revealed insights on the selected teachers' knowledge and current practices of infusing ST into Year Four science lessons. It was found that the teachers lacked knowledge of ST. Generally, the selected teachers had inadequate knowledge the three elements of ST; thinking skills, habits of mind and metacognition. What they claim to know about ST during interviews did not reflect adequate knowledge of ST infusion. Parallel to this, their classroom practices did not show ST infusion into Year Four science lessons.

Knowledge of ST. Teachers' knowledge pertaining to the teaching of ST was drawn from literature readings (Coffman, 2013; Hugerat, 2014; Zohar & Schwartzer, 2005). They include (i) knowledge of thinking strategies, (ii) knowledge of habits of mind or thinking dispositions and (iii) knowledge of metacognition. It was found that the selected group of teachers in the present study lacked in the abovementioned types of knowledge.

Knowledge of various kinds of thinking strategies. The teachers in general associated thinking strategies with science process skills, such as classifying, predicting, analysing or making hypothesis. For example, T3 mentioned that she perceived thinking strategies as science process skills, only much difficult, in which students need to think further.

> *"Actually…I think thinking strategies are the same as science process skills…but slightly difficult...they need to think out of the box…"*
>
> *T3, L82, INT*

T6 perceived slightly better understanding on the thinking strategies. She said that thinking strategies involve analysing skills, such as drawing conclusions to make sense of scientific observations.

> *"Data collected about photosynthesis ... and what students do with it … is actually [an] analysis skill … and for me [the] analysis skill means the student must know what they need to know and what can be concluded from their observation."*
>
> *T6, L102, INT*

Others view thinking strategies as higher order thinking skills, in which students must engage in deep thinking such as evaluating, synthesising and creating.

For instance, T2 said that, apart from merely identifying the gases humans inhale or exhale, if students could extend their thinking to think about the functions of each gas, then they are said to be engaged in higher order thinking.

> *"If students are asked to think at [the] higher order, they can think further ... for instance ... we know that we exhale carbon dioxide gas ... but by asking them* [about] *the use of carbon dioxide gas ... that would mean the students are engaged in higher order thinking skills..."*
>
> *T2, L72, INT*

T4 claimed that students have limited skills in thinking that results in the inability to think at higher levels. T4, however could not state how she would help students with limited skills to develop their thinking. Hence, she could not explain how she plays the role as a teacher in teaching her students to use different thinking strategies. She had also added that by having limited skills in thinking, students could not think out of the box. By limited thinking, she meant the use of senses; what students hear or see (observe). Making observations using senses is among the science process skills in learning science.

> *"They* [the students] *have limited skills in thinking. That's why they couldn't think at higher level"*
>
> *T4, L39, INT*

> *"Their* [the students] *thinking is about what they see, what they hear and what they 'get'...they can't think out of the box."*
>
> *T4, L50, INT*

In general the selected teachers perceived thinking strategies as either higher order level of thinking or science process skills. They seem to be lacking in knowledge on thinking strategies involved in making analysis. The terms '*they can't think out of the box."* and '*They have limited skills in thinking"* shows that T4 relates the teaching of higher order thinking skills to her students' inability to think at higher level. T1 claimed that she would limit learning goals and HOTS questions for group discussions among low achieving students.

"For group work, I limit the learning goals and the number of HOTS questions for low achievers."

T1, L52, INT

Upon being probed regarding why she would limit HOTS questions, T1 said that her students do not have the ability to analyse. She also claimed that the students do not respond to questions that require them to make predictions.

"I can't ask HOTS questions because these students do not have the ability to analyse … For example, when I ask, "What do you think would happen, if we consume this medicine?"… They cannot answer … or when I ask, "What happens if animals become extinct?"… They can't visualize or predict"

T1, L54, INT

"Or a simple question like, "What is the function of a clock? What happens if the clock has stopped functioning?"… They can't give any response"

T1, L57, INT

Likewise, T8 said that her students were unable to decide on the kind of thinking strategy to be employed while analysing information about any given science concept. When she provides them with thinking maps (eight I-THINK maps), they could not decide which thinking map to use on their own without teachers' assistance. She also believed that HOTS is unsuitable for low achieving students because they cannot share their views and ideas during lessons.

"When I give them thinking maps, I have to tell them which one to use, because they don't know which one to use on their own."

T8, L37, INT

"*It* [higher level thinking] *is not suitable for low achieving students…they can't even share their views or opinions in classrooms"*

T8, L97, INT

These teachers have perceived students, particularly low achieving students, as lacking the ability to think at higher levels. In general, the selected teachers could not explicitly describe the thinking strategies that they need to teach students when performing analysing skill. They also perceive HOTS to be suitable only for high achieving students. Yet, they could not verbalise how they implement the teaching of HOTS.

Knowledge of habits of mind. The Year Four science curriculum specifications has mentioned that the habit of questioning and problem posing about scientific phenomenon should be encouraged among students, as shown in Figure 5.1.

Thinker:	Able to think critically, creatively and innovatively; handle complex problems and make ethical decisions. Think about learning and themselves as pupils. Generate questions and are open to perspective, values and individual and societal traditions. Confident and creative in handling new learning fields.

Figure 5.1. An excerpt taken from Year Four Science curriculum document (DSKP, 2015, p. 17).

The excerpt in Figure 5.1 describes students' profile as a thinker, which includes the development of habits of mind, such as being able to generate questions and being open to different perspectives. These are among the essential habits of mind students need to acquire for meaningful inquiry learning in science classrooms.

It can be said that these teachers do have the knowledge of what habits of mind are, but they could not describe clearly how they develop the habit of questioning and problem posing among their students. Three of out of nine teachers defined habits of mind as motivation or driving force to think. T5 said:

"Thinking requires motivation and effort. The students have no motivation to think. Without effort to think…higher order thinking cannot be acquired. Not all are like that…but I think it [motivation] should be cultivated at early stage, from kindergarten"

T5, L21, INT

T5 asserted that thinking requires motivation and effort, and should be cultivated at early childhood. This shows that she is aware of the kind of habits of mind students must develop. However, she also claimed that her students do not have the motivation to think. Similarly, T2 mentioned that her students do not have the driving force to think and believed that peer influence might be the cause.

They do not have the driving force to think … Too much peer influence … I think that's their learning culture here.…"

T2, L45, INT

T7 had a much broader and deeper understanding of habits of mind in thinking. He perceived habits of mind as students' curiosity to ask questions, share views about scientific ideas, work as a team and listen with respect for peers. The description given by T7 was indeed among the habits of mind as stated by Costa (1999).

"Students should have the curiosity to ask questions, to share their views about scientific ideas, to co-operate during hands-on activities and to listen to their peers' opinions as well…"

T7, L19, INT

The term 'should' (or *"patutnya'* as translated from the Malay Language), indicated that T7 may possibly had assumed that students were supposed to have these habits naturally, which explains why the selected teachers, in general, could not elaborate on how they develop these habits among their students, despite knowing about habits of mind. The teachers perceive habits of mind as innate qualities that should come naturally from students. On the contrary, T1 claimed that she did not know about the two other elements of ST - habits of mind and metacognition.

"*I have never heard of it [habits of mind and metacognition] before*"

T1, L23, INT

According to T8 and T9, low achieving students do not ask questions; on the other hand, high achieving students ask a lot of questions. For example, T8 mentioned that:

> *"Low achieving students do not ask questions at all, we [teacher] ask, wait and we answer them ourselves, high achieving students ask a lot of questions until we [teacher] have to stop them.."*
>
> *T8, L68, INT*

Being able to pose questions and problems is one of the sixteen habits of mind that exhibits students' thinking (Costa & Kallick, 1996). However, T8 claimed that her high achieving students ask a lot of questions until she had to stop them from doing so. Instead of encouraging the students to discuss and seek explanations collaboratively in groups, T8 said that she would have to hinder them from asking too many questions. The teachers seem to believe that only high achievers exhibit habits of mind (as innate ability). This belief perhaps had hindered them from taking further effort to develop the habit of asking questions among low performing students.

On the other hand, T3 asserted that her students do not ask '*good'* questions. According to her, good questions are questions that exhibit students' thinking about the subject matter being taught, such as '*why, how, when, where, or what*'. T3 also said that questions such as "*Teacher, can you repeat the answer, please*?" or "*What are we supposed to do*?" are common in her classrooms, which have no direct connection with the subject matter being taught. When asked about what might have caused the low achieving students to ask such questions, T3 revealed that her students were afraid to talk and thus they do not ask questions.

> *"They are afraid to talk. They don't ask good questions'*
>
> *T3, L24, INT*

Similarly, T6 was found lacking in knowledge about habits of mind. She said that from her experience, students who think at higher level would normally '*think* *alone*". It seemed that T6 perceived thinking as a cognitive process that cannot be made visible to others. Although most teachers do have good understanding of habits of mind, however, there were a few, particularly T6, who could not identify behaviours among students that manifest habits of mind.

Knowledge of metacognition. The selected teachers seem to have limited knowledge about metacognition - the third element in ST. For example, T1, T2 and T9 confirmed that they do not know or had never heard of the term 'metacognition'. When the question was re-phrased, on whether they promote students to think about their thinking, the teachers confessed that they have not yet undertaken such effort.

> *"That's difficult, I don't think so my students could think at that level"*
>
> *T9, L101, INT*
>
> *"I'm not sure, and I never tried asking them to think about their thinking [metacognition]"*
>
> *T1, L97, INT*

T7 claimed that he encourages his students to reflect upon their learning after each lesson, which he believed was metacognitive thinking. T7 defined metacognition as an act of reflecting on what the students had learnt for the day, to countercheck with teaching and learning objectives. For example by asking "*what have we learnt today*?" (T7, L33, INT), at the end of each lesson. He related metacognition to the action of reflecting what one has learnt. T3 said that the term 'metacognition' sounded familiar to her, but could not recall its meaning.

> "*I remember learning about metacognition during my teacher-training program, but I couldn't recall what it is actually...I've forgotten....*"
>
> *T3, L31, INT*

T4 mentioned that even if she asked her students to think why they were unable to formulate conclusions and hypothesis, they would answer that they could not think.

> *"Normally, when my students tell me that they don't know (about a thinking skill such as drawing conclusion or formulating hypothesis)…I would ask them why they didn't know…and they would answer "I just couldn't think."*
>
> *T4, L36, INT*

When asked about how she would help the students to overcome their difficulties in thinking (as described in the previous excerpt), T4 replied '*I don't know how to help them'*. This was perhaps because T4 had inadequate knowledge on how to promote metacognition among her students. It can be said that the teachers do not possess adequate knowledge of metacognition. Teachers' knowledge of ST revealed that they need upgrading on ST elements and on how to infuse ST.

Current practices. Teachers' current practices were identified through classroom observations. These observations showed they were lacking in pedagogical skills for infusing ST into their lessons. This was because the teachers' current practices did not reveal sound infusion of ST during lessons. Perhaps this was because they lacked knowledge in teaching specific thinking strategies, developing students' habits of mind and promoting metacognitive thinking among them. Teachers' current practices can be described as teaching approach, classroom management and the use of thinking tools for teaching thinking in science lessons.

Teaching approach. The teachers had shown different approaches in teaching science. T5, T7 and T8 have employed confirmatory inquiry, in which they teach the topics in advance before allowing students to conduct scientific investigations. Even so, the scientific investigations appeared to be fully structured. For example, they provided written notes on the topic under discussion and how to conduct the investigation, much of a recipe style. With this, students would already know the outcomes of the activity, and the purpose of investigation was to confirm the already-learnt science concepts. For example, T7 was teaching about human breathing mechanism by conducting a project. The students were asked to build a model of the human lung from recyclable materials, to demonstrate the breathing mechanism. Students were required to follow guidelines from the science textbook on how to build the model. Apparently, T7 has already taught about the human breathing mechanism in previous lessons. The activity that was observed for the day, was to confirm how the human lungs function in breathing mechanism. The students were given time to build their models and demonstrate the breathing mechanisms. A few groups could not get their models to function properly. T7 checked the models and corrected their mistakes by helping them fix the faulty parts of the models. He then continued his class by giving them a worksheet for reporting their activity. Thus, T7 seemed to have missed the opportunity to engage his students in analysing their malfunctioned models to identify what went wrong. He could have asked them to question what was faulty with their models and to recommend solutions, instead of him identifying their mistakes and straight away providing solutions.

When questioned why he did not take up such opportunity, T7 revealed that there were several challenges. These challenges include time constraint and excessive workload, which hindered him from explicitly teaching the different kinds of thinking strategies. Because of such challenges, T7 argued, that he could not plan to explicitly infuse ST. However, what was more alarming was that he does not understand how exactly to infuse ST. He found it to be difficult to infuse ST elements into the lessons.

> *"Teaching students how to analyse? Mmmm…It's difficult…actually,* [paused for a few moments and then continued]*…I still don't understand…even my friends too* [friends also do not understand]"
>
> *T7, L40, INT*

Similarly, classroom observation on T5 could not reveal any instances to show the development of habits of mind among students. For example, when one of T5's students, classified paper into objects that do not absorb water, she quickly asked the student to correct his observation record – paper absorbs water.

> *T5: This is wrong…papers absorb water right? Change it…* [The students quickly corrected his answer]
>
> *T5, L45, FN*

She did not try to seek possible reasons as to why the student classified paper into the wrong group. She could have facilitated her student to evaluate his classifying strategies, so that he can be guided to improve himself.

T3, on the other hand, employed the structured inquiry approach, in which she provided questions and procedure, giving space for her students to discover the outcomes on their own. T3 was teaching the topic on classifying materials that absorb water. Her students were testing a given list of objects and recorded their observations in a readily-prepared table - worksheet. At the end of the activity, T3 posed questions such as '*Can you tell me which object can absorb water*?". Her students were able to identify the objects that absorb water based on their observations. Although such cues would stimulate students to analyse their observation and identify objects that absorb water, she did not ask them how they would make generalisations about objects that absorb water.

> *T3:* *Can you tell me which object can absorb water?*
> *Students:* *sponge…paper…handkerchief* [various answers from different students]
> *T3:* *So, what is the conclusion? How do you write conclusion?*
>
> *T3, L60, FN*

Even before the students could respond, T3 turned around to write the conclusion on the white board that reads:

"*Sponge, paper and handkerchief absorb water".*

T3 could have asked her students how they would classify the objects or what was similar about the objects that absorb water by relating them to their material or sources of material. T3 discussed the outcomes with her students, thus reminding them of the newly learnt science concept at the end of activity. The students tried to relate their observations from the investigations to what they already learnt about the topic beforehand.

T3:	*We already learnt that materials made from wood, paper, cotton….absorb water right?*
Students:	*yes…*

It seemed that T3 was more focused on teaching students how to write answers, such as writing conclusions and observations.

T4, employed slightly different approach from the other teachers. Like T7, she was teaching about human breathing mechanisms. T7, however, did not explain about human breathing mechanism beforehand; instead she carried out a lesson for students to build a model of lungs to show how humans breathe. By this, she attempted to create space for students to discover for themselves how humans breathe with the help of the model. As the students completed their task, T4 started to discuss the activity. She asked the students to make observations about the balloons (to represent lungs) in the model when the layer of plastic (to represent diaphragm) was pulled out. But the students could not answer. Then, she asked them to think about the consequences of not being able to make observations. She was trying to promote students to think about their thinking.

T4	*: So, what would happen if you are not able to make observations?*
Students	*: …..* [Silent for few seconds]*…becomes bigger…*
T4	*: Yes, the balloons become bigger because air from outside went into it….so it expands…that's why our lungs become when we breathe in…okay?*

T4, L27, FN

The excerpt shows that although T4 eventually answered her own question, she indeed tried to provide a cue to promote her students to think about how and why they should be able to make observations. When questioned about the rationale for her attempt, T4 mentioned that she wanted her students to understand the skill of 'making observations' because it was a difficult skill to acquire.

"I want them to learn to give observations and inferences…"

T4, L20, INT

T4 had also prompted her students to perform specific thinking strategies in analysing their knowledge on the human breathing mechanism. She had offered a ground for her students to compare and contrast the chest movements in two different situations.

T4:	*How do you know if someone is alive or dead? Will you look for his/her chest movement?*
Students:	*Touch him..*
T4:	*How about if you're not allowed to touch him, how would you know if he's still breathing?*
Students:	[Silent]
T4:	*How? If the person is dead…how will his chest movement?*
Students:	*No movement…*

T4, L34 and L37, LT

Subsequently, T4 had also prompted her students to perform another kind of thinking strategy- predicting.

T4 :	*What will happen to our lungs if there's no air?Why?*
Students:	*We will be dead…*

T4, L39, LT

T4 provided cues to stimulate students to use thinking strategies such as predicting, making observations and giving inferences. However, she did not encourage her students to pose questions or conduct small group discussions to discuss her questions. She was posing questions and students responded. It was a whole group discussion between T4 and the whole class. Therefore, it can be said, regardless of the teaching approach teachers had employed, the infusion of all three elements of ST seemed to be at unsatisfactory level.

Poor classroom management. To actively engage students in any given thinking task, teacher would need to manage students' group discussions, so that thought sharing would take shape. The teachers in the present study, however, could not manage classrooms for effective discussions. Although the students were seated in groups, there was less organisation in terms of group dynamics for collaborative learning. Students did their work (written worksheets) individually with limited space for thought sharing. On the contrary, the teachers showed preference for whole-group over small group discussions. The rationale given by the teachers for preferring whole-group discussion, was that small group discussions often consume longer time and cause discipline problems (noisy classrooms). Therefore, they were found to resort to students who are active communicators. For example, each group had one or two active communicators. These were the students who responded to the teachers' questions during whole group discussions. There were no active communication among the rest of them. During most of the lessons, students tend to either shout out their answers or just keep quiet. For example, at one point, T8 asked one representative to present his readings on measuring mass of different objects. One student read his reading. T8 said it was wrong and it should have been 1500g. Hearing this, another student from the same group shouted at the student. T8, who was aware of the situation responded by asking the group to stop arguing and continued with rest of the lesson. He did not try to enquire as to why the other student shouted at his friend.

Student: *I told you, its 1500g not 1500kg! But you wouldn't listen!*
T8 : *Please stop arguing...* [The students then sat down]

T8, L23, FN

The students could not discuss, share their thoughts or argue politely among themselves. This hindered active engagement in thinking tasks among students because the students do not know how to politely discuss in small groups. Some of the students were observed walking around the classroom aimlessly; thus these teachers spent time attending to discipline issues. On the contrary, students in other classes were found to be very quiet. The students complete their work (worksheets, thinking maps or experiment reports) quietly without active discussions among members of the groups.

> "*Some groups were found to be quiet and some were whispering to each other*"
>
> *T7, L20, FN*

It can be said that conducting small group discussions to engage students in mindful thinking tasks seems to be a challenge for these teachers.

Use of thinking tools. The teachers were found to know about the *I-THINK* thinking maps – a set of eight thinking maps to aid students' thinking skills. They too, acknowledged the use of these thinking maps. The 'I-THINK' thinking maps were launched in 2012 by the Malaysian Ministry of Education (MOE), as an advanced tool to assist students in acquiring HOTS. Still, through classroom observations, the use of thinking tools can be said to be minimal. For instance, at the end of her lesson, T5 provided a bubble map and instructed her students to complete it. She explained how to complete the thinking map with information on objects that absorb water.

> *T5 :Okay, this is a bubble map…right? I want you to complete this by putting in objects that absorb water...okay? Look here, write absorb water in the middle...*
>
> *T5, L67, FN*

The lesson went on by T5 further explaining how and what to fill in the bubble map. T5 had used the bubble map as an enrichment activity at the end of lesson. Students wrote what they have learnt about objects that absorb water, fully guided by T5. She did not use the bubble map to help students classify objects on their own. This perhaps was because these teachers believed that the thinking tools acted as the product of their students' thinking rather than using them to aid in the process of helping the students in active thinking. Teachers were found to use thinking maps at the end of lessons. T3, T5 and T8 pre-determined the kind of thinking map for students to complete, such as whether it was tree map, bubble map or brace map. They gave time for students to fill in the thinking maps with information about the topic newly learnt.

> *"Okay, I'm going to give a tree map. And I want you to complete it within 10 minutes…okay? Write 'life processes of human' in the centre of map...here [showing the map]"*
>
> *T3, L40, LT*

The lesson went on with T3 instructing students to complete the tree map. Students pasted their completed thinking maps into their science practical books. More often, due to time constraint, such thinking tools were given out as worksheets or homework for students to be completed later.

> *"To attract their [students] attention, I would give them comments such as, 'very nice work' if they hand-in their work on time and done correctly. Therefore, they compete to do the thinking maps and they colour them beautifully, and if they can't complete the thinking map, they try again and hand-in quickly.*"
>
> *T8, L093, INT*

This was similar in T7's class. T7 distributed a tree map at the end of the lesson. He provided all the details (facts) to fill in the tree map. Once the students had filled in the tree map, they handed it over to him before the class ended. In addition, the time allocated for students to 'complete' the thinking tools was rather too long and was used to keep students engaged in their task. Hence, being unable to use thinking maps and graphic organizers to their fullest potential can be considered as an issue that may have hindered the selected teachers from successfully stimulating students to think at higher levels.

Thinking tasks or worksheets that require them to provide scientific explanations (for newly learnt science concepts), were given as individual assignment rather than collaborative tasks. At numerous points, the teachers seem to ‘overlook’ the opportunities to encourage their students to jointly think and collaboratively construct scientific explanations. T8 allocated almost 25 minutes for her students to complete a given thinking map. While the students quickly engage in their task, a student shouted out, *“Somebody is copying someone else’s book”.* The boy was referring to another student who was copying the thinking map of the boy sitting next to him. Then, T8 responded from the front of the class, seated at teachers’ table;

> *“Do not copy from your friends….do on your own”*
>
> *T8, L39, LT*

T8 hindered the student from discussing with others during the task. These defeats the purpose of using thinking tools for group discussions. Teachers also do not seem to make use of classroom space to conduct conducive classroom discussions as they seem to be less knowledgeable about classroom practices, which is vital for ST infusion.

Upon further probing, the researcher found that the selected teachers needed support and guidance in terms of ST infusion into Year Four science lessons. Several other issues that these teachers encountered were insufficient time to conduct ST lessons and lack of knowledge of ST infusion. The lack of educative materials to aid teachers in learning to infuse ST in Year Four science classrooms seemed to be the major issue. Therefore, the researcher explored the genre of teacher-material that would be educative for the teachers to learn how to infuse ST.

Lack of educative resources for teachers. The infusion of ST into Year Four science lessons was seen as a challenge, because the selected teachers lack knowledge of ST and on how to infuse ST, thus they were unable to practice ST infusion into their daily teachings. One of the themes that kept reoccurring during data analysis on the teachers' lack of knowledge in ST, was the lack of educative materials.

In probing teachers' use of materials for teaching thinking skills, most of the selected teachers revealed that they did not have adequate teaching materials to help them foster the teaching of HOTS, what more for ST infusion. A few teachers confirmed that they limited the use of teaching materials because the materials were prepared according to compartmentalised facets of science teaching. For example, there were modules specifically prepared for teaching reasoning skills that were different from modules for teaching critical and creative thinking (CCTS) skills, or teaching subject matter understanding. The existing materials were either too prescriptive or too general in nature. Some teaching materials offered general approaches in teaching thinking for all subjects in a single resource, indicating that one size fits all. These different teaching materials that did not elicit the interconnection between the various facets of science education and the teaching of HOTS, seemed to 'interfere' in the teachers' selection of resources for their practice.

> "*However, we need modules, other supporting materials or reading materials for teachers that can guide us, but now we have different kinds of materials … it's confusing ... to choose which one is the best to be used … it would be better if we can have just one but can be used for all (teaching reasoning, critical thinking, creative thinking, higher order thinking skills, subject matter understanding, science process skills and 21st century learning) .. it would be much helpful.…*
>
> *T5, L76, INT*

T9 also expressed her weakness in teaching ST as being attributed to the teaching materials lacking guidance on implementation of ST, mainly on how teachers could plan, enact and reflect on their practices in teaching ST.

> "*Actually, I still don't know … When I discuss with my colleagues, we realize that we still don't fully understand the whole concept of HOTS.*"
>
> *T9, L34, INT*

Indeed these teachers were provided with readily available teaching materials to teach HOTS; however, the materials mainly focused on enhancing the students' learning; in contrast what teachers wanted was material to improve the teachers' learning to teach thinking skills. For example, from the document analysis (as described earlier in methodology- chapter 4), it was found that the materials the teachers were using comprised of samples of lesson plans and worksheets for several learning units in Year Four Science. Nevertheless these materials focus on students' learning outcomes rather on teacher learning in designing instructions to infuse ST in their content lessons. Recommendations on the instructional strategies needed to be taken by teachers in order to explicitly teach ST and the rationale behind these recommendations were not included in the teaching materials.

Based on document analysis conducted earlier and findings from teachers' current practices, it was found that these teachers need an educative material to guide them in learning to infuse ST. For example, the excerpt in Figure 5.2 was taken from one of the teaching materials called the Curriculum and Assessment Standard Document (DSKP). Apart from information on the syllabus to be covered, this document also highlights information on teaching thinking skills to students, particularly HOTS.

> HOTS can be applied in the classroom through activities in the form of inquiry, solving problems and projects. Teachers and pupils need to use the thinking tools such as thinking maps, mind maps, and Thinking Hats and high level questioning, inside and outside the classroom to encourage pupils to think. Pupils are accountable to their own learning.

Figure 5.2. Excerpt taken from Year Four Science DSKP (CDC, 2015, p. 15).

The document has recommended three forms of activities to encourage students to think at higher levels; solving problems, inquiry and projects. It also suggests the use of thinking tools such as thinking maps, mind maps and thinking hats. Another suggested tool was the cue such as question relating a concept found in and outside classroom. This means that teachers should help students to transfer knowledge into different contexts.

The sentence '*Pupils are accountable to their own learning'*, may perhaps denote that students need to be taught to reflect on their thinking and learning experiences, so that they would be able to take charge of their own learning. Based on the Year Four Science DSKP, teachers are provided with other guides and reading materials on how to integrate HOTS into pedagogy. In this material, a concept map on teachers' pedagogies is given (shown in Figure 5.3). Firstly, teachers need to refer to the science curriculum specification document to identify the elements of HOTS in learning outcomes. Secondly, they need to devise lesson plans taking into accounts explicit learning objectives, prepare activities and teaching aids to engage students in HOTS. Thirdly, they must enact lessons using suitable thinking tools, pose questions to stimulate student thinking and create classroom that caters for HOTS.

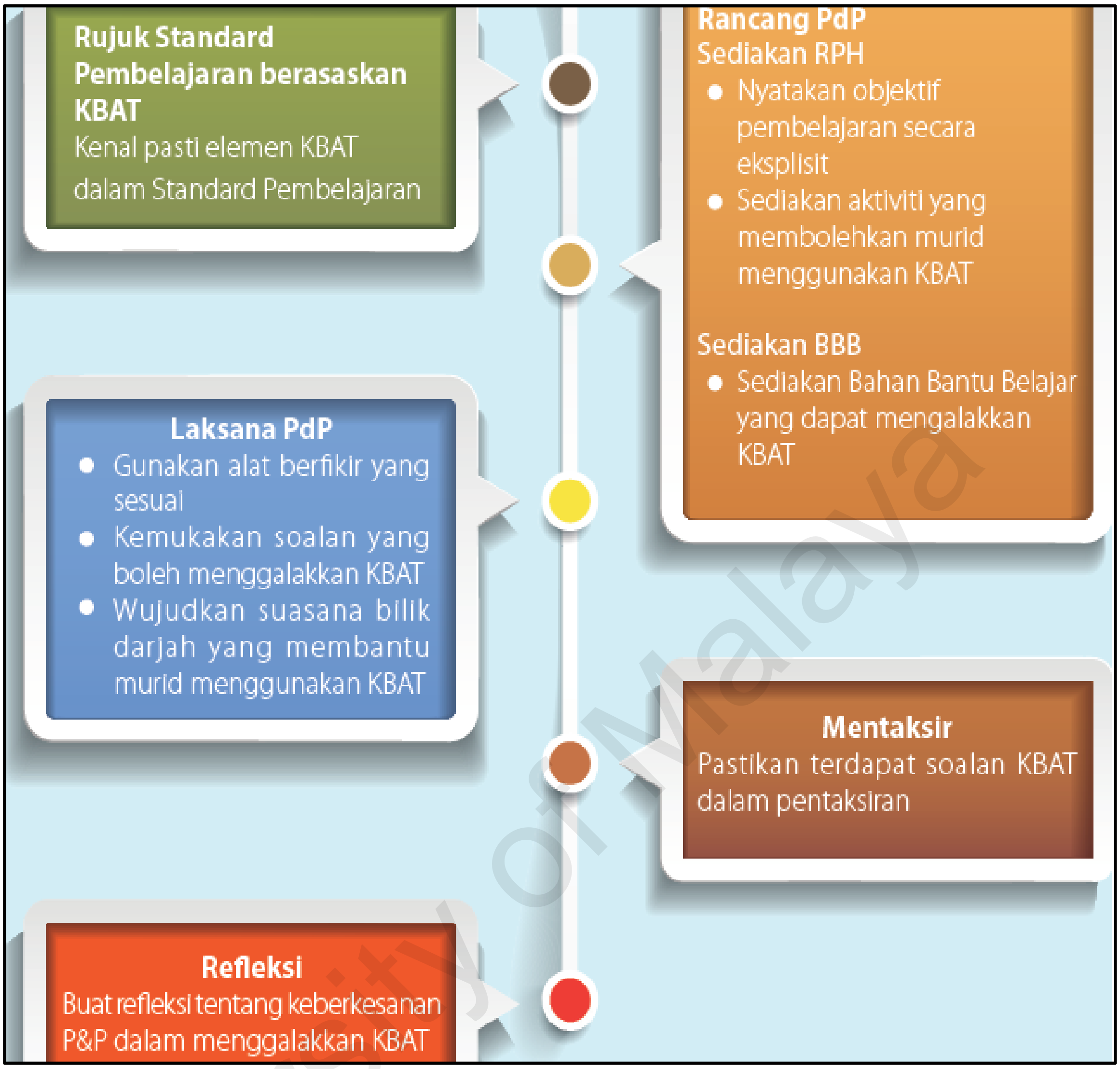


Figure 5.3. Concept map showing the integration of HOTS elements in teachers' pedagogy (Elemen KBAT dalam pedagogi, CDC, p. 3).

The fourth step is to ensure that assessment tools have questions on HOTS and finally teachers need to make reflection on their teaching and learning sessions on HOTS. The purpose of analysis on these documents was not to evaluate them, but to suggest ways to make them more educative for teachers. One of the ways is by including educative features such as vignettes and narratives that describe how teachers could teach thinking skills (Arias et al., 2016; Davis et al., 2014). For example, providing narratives that explain how a teacher can develop the habit of questioning and problem posing among students, so that teachers can envision the strategies suggested in the document.

These documents also have stated that teachers need to encourage students to think about the way they think and thus take charge of their learning. Perhaps the document could include educative features for teachers explaining practices on how to encourage students to think about their thinking. Another example would be educative features that illustrate challenges teachers might encounter with students while teaching thinking skills and suggest ways to overcome them. Such recommendations would perhaps create space for teachers to be well prepared to face challenges in teaching thinking skills. From analysing the existing teacher-materials, it can be said that generally, these materials can be improved by including educative features to educate teachers on how they might infuse ST into their current Year Four science lessons.

Summary on the findings of the groundwork of STEPS (Phase 1)

The previous section has disclosed information on the teachers' knowledge and current practices in teaching ST. Although the present study consisted of a relatively small number of Year Four science teachers for the Phase 1, the findings were crucial to the researcher in proceeding with developing the STEPS. The findings of the Phase 1 can be summarized as follows:

1. The selected teachers were found lacking in knowledge of ST (what is ST, why infuse ST). This include knowledge of thinking strategies needed to analyse information and ideas, knowledge of habits of mind and how developing this habit would help to sustain students' momentum in learning science and the knowledge of metacognition and why it is important to promote metacognitive thinking among young children.

2. They were also found lacking knowledge of pedagogies to infuse ST (how to teach and when to infuse ST). They could not explain how they explicitly teach thinking skills in science classrooms.
3. Thus their current practices did not show sound evidence of ST infusion. Most of them employed guided inquiry or highly structured inquiry methods to teach Year Four science focusing on subject matter acquisition instead of simultaneously teaching thinking skills.
4. The inability to implement ST may also be attributed to the lack of knowledge in organising small group discussions and using thinking tools appropriately to aid the process of student thinking.

Upon further probing, it was found that lack of educative materials was the major issue that may have hindered the selected teachers from implementing ST.

5. The selected teachers claim that despite the existence of various materials for different facets of thinking skills, they still need support and guidance.
6. Selected teaching materials can be made more educative for teachers by including educative features to aid teacher learning in ST infusion. Thus an educative material for teachers may help to supplement the existing curriculum documents.

Developing the STEPS (Skillful Thinking Educative Pedagogical Support)

The second part of Phase 1 consisted of developing the STEPS for the selected teachers in order to infuse ST into their current Year Four science lessons. This section answers the second research question:

"What are the design heuristics for the STEPS (Skillful Thinking Educative Pedagogical Support) for selected Year Four science teachers to infuse ST for the topic Properties of Materials?"

To determine the design heuristics for the STEPS, the researcher had to lay out what teachers need to know about the infusion of ST based on findings from the groundwork phase. By acknowledging these needs, the researcher was able to determine the areas of pedagogical knowledge in teaching ST.

Based on the findings of the teachers' current knowledge and practices, the researcher had identified two main areas that should be in the STEPS – teachers' knowledge of ST and their practices of ST infusion into Year Four science lessons. For example, to aid teachers' knowledge of ST, the STEPS should be able to deliver information (recommendations) on the three elements of ST. Therefore, the objective here was to design features in the STEPS that are educative in nature for teachers to understand the rationale behind the recommendations. For instance, teachers should be able to understand that there are three elements involved in ST; thinking skills, habits of mind and metacognition. They also need to internalise that these elements can be integrated into inquiry science lessons through the infusion method (Schneider, 2013). The challenge however, was how to make this information educative for teachers that would make them read, understand and adapt recommended ideas into their daily science lessons (Beyer & Davis, 2009). For this, teachers need to be well informed on the rationale behind the infusion of ST in science lessons (Davis et al., 2014; Lin et al., 2012). During the groundwork phase, the selected teachers kept using the phrases such as "*I want to learn more*"; "*I'm not sure*" and "*We need materials because we are still not sure on how to teach students to think".* This shows that they wanted more heuristic natured materials that address their needs in teaching thinking skills. These phrases perhaps indicate the criteria the teachers anticipate in the material, which helps them to learn more and not merely follow instructions for a new approach.

It was also found that the teachers were lacking in knowledge on how to organise their classrooms to facilitate effective discussions among students on a given thinking task. This was because good management on students' small group discussions may create the environment students need to be fully engaged in given thinking tasks (Oliveira et al., 2014). Furthermore, the selected teachers in Phase 1 were more occupied handling issues such as students moving around aimlessly, noisy classroom or lack of interaction among students for thought sharing. Therefore, this area of pedagogical knowledge called classroom management (Shulman & Shulman, 2004), was identified as one of needs for the selected teachers. This means that the selected teachers needed to learn how to organise their classrooms, particularly small group discussions, in a way that would engage students actively and collaboratively in thinking tasks. This would be highlighted in the STEPS, by providing teachers examples of classroom scenarios on how teachers could conduct students to organize discussions when engaging them in thinking tasks.

Hence, this section will discuss how these needs were derived from the findings of teachers' knowledge and current practices of ST, thus determining the design heuristics for the STEPS. Hence, the nature of the materials, have to be educative so that teachers can learn how to teach ST. With this information, the researcher then decided to determine the design heuristics and educative features that should be included in the design of the STEPS. Based on Phase 1 findings and relevant literature readings the researcher determined the design heuristics and corresponding educative features for the STEPS. The works by Davis et al. (2014), Davis, Nelson and Beyer (2008) and Lin et al. (2012) provided insights on how these educative features can be designed. These studies have provided new meaning in designing materials for teachers that promote teacher-learning, in learning to employ innovative approaches in their science teaching practices. The proposed design heuristics were in terms of support for teachers' pedagogical knowledge in teaching science topics, support for teachers' pedagogical content knowledge teaching scientific inquiry and support for teachers' development of subject matter knowledge. Using the suggested design heuristics and educative features recommended in the abovementioned studies, the researcher integrated these features to address the needs of the selected teachers.

Process of identifying design heuristics for the STEPS. Before embarking on identifying the design heuristics for the STEPS, the researcher determined the selection of topic, number of detailed lessons and teaching materials for the STEPS. These details were determined during the document analysis on the Year Four science curriculum specifications; the specifications explicitly state details on the topics that should be taught in Year Four science, along with the learning units.

Selection of topic. Based on document analysis, the most number of learning outcomes that require students to analyse knowledge falls under the theme "Material Science". There are three sub topics in the theme, in which students need to understand the sources of materials of objects, understand the properties of each material and build their knowledge into designing new objects.

1. Understanding source of materials of objects.
2. Understanding properties of materials
3. Design objects using knowledge

The learning outcomes for this theme comprise action verbs such as to classify objects according to materials of origin, identify the properties of materials by comparing and contrasting, give examples of other similar objects, decide on selection of materials and provide reasons and justifications for selecting the materials (CDC, 2012). This theme provides great opportunity for the teachers to gradually change their conventional practice in teaching this topic to one that incorporates ST elements.

Number of detailed lessons. The STEPS was designed with the aim to be educative, therefore only one lesson per unit was prepared in detail. Three detailed lesson plans were prepared as examples for teachers to follow in the beginning of each unit. The lessons contain details on the suggested steps on how teachers could infuse ST elements. Other details include notes for teachers on how they could modify the material to suit the students' level of understanding. The lessons also consist of relevant worksheets and graphic organisers for teachers' use. This was aimed at informing teachers on how the recommended tools provided in the beginning of the STEPS could be used as teaching aids for the selected topics. For example, in unit 7.2 (Understanding properties of materials), the lesson plan was prepared for teachers to teach students how to analyse their knowledge about materials that can and cannot absorb water and thus classify them into different categories.

Design Heuristics. Several scholars have recommended certain sets of rules for designing educative materials (Davis et al., 2014; Davis & Krajcik, 2004; Schneider, 2013; Shu Fen et al., 2012). The set of rules are called design heuristics, taking into account teachers' content pedagogical knowledge (Davis & Krajcik, 2004). The works of Davis and Krajcik (2005), Krajcik and Schneider (2002), Davis et al. (2014), Lin et al. (2012) have provided understanding for the researcher on how to prepare the STEPS with aims to educate science teachers. These works have taken into account inquiry based instructions that will assist in students' scientific knowledge construction. Other studies such as by Lin et al. (2012) have outlined the framework for designing educative materials that included support for teachers' knowledge and practices. Design heuristics can be based on teachers' challenges in teaching and are often illustrated in ways that are educative for teachers to meet their needs; for example, content on what teachers should know about ST, recommendations on how ST can be infused into Year Four science lessons and provide rationale for the recommendations, so that the teachers would be able to understand the designers' pedagogical decisions. Table 5.1 shows how the design heuristics for the STEPS were identified based on the identified needs of the selected group of teachers. The researcher prepared a table to display the four major issues pertaining to the selected teachers' teaching of ST. These issues were identified in their current knowledge and practices of ST infusion. The second row of the table displays the identified needs of teachers, based on the researcher's interpretation of the findings from the abovementioned issues. Table 5.1 displays the selected literature readings that provided insights for determining the design heuristics for the STEPS. The selected literature readings were most relevant to the design of STEPS, because these studies have discussed how a designer can set design heuristics when designing educative curriculum materials that would support teacher-learning.

In general, the teachers' knowledge and current practices did not display sound evidence to show that they employ pedagogies to explicitly teach ST. Using those ideas, the researcher prepared the STEPS, as a pedagogical support for selected Year Four science teachers in for infusing ST. The aim of the STEPS was as a stimulus that would initiate teachers' practices in infusing ST into the topic 'Properties of Materials'. Therefore, to aid teacher-learning to teach ST, three design heuristics (DH) were determined- support for teachers' knowledge of ST (DH 1), support teachers' ST infusion practices (DH 2) and support for teachers in managing group discussions (DH 3). Table 5.1 not only shows the process of identifying the design heuristics from the issues identified during the groundwork for STEPS, but also the link between the levels of process.

The first issue was that the selected teachers were found lacking in pedagogical knowledge in ST. Existing teacher-materials were found less educative to support teacher-learning to infuse ST. From the literature readings, it was understood that educative curriculum material designed for promoting teacher-learning can help science teachers develop knowledge and pedagogical knowledge in teaching thinking skills. The design heuristics form the framework for designing materials that would scaffold learners' knowledge, including knowledge of subject content, pedagogical knowledge (PK) and pedagogical content knowledge (PCK) (Davis & Krajcik, 2005). When teachers read the STEPS, they should be able to gain information about the rationale behind the recommended exemplary instructional practices that would help them teach ST.

Therefore, the design heuristic 1 (DH 1) would mean the framework for the content in the STEPS that would aid teachers' learning in developing knowledge of ST.

Table 5.1

The process of determining the design heuristics from the issues identified during groundwork for STEPS

	Teachers' current knowledge of ST	**Teachers' current practices of ST**		
Issues identified from selected group of teachers' current practices in teaching ST	*The selected teachers were found lacking in knowledge of ST (knowledge about ST and know on how to teach ST). *Existing teacher-materials were found less educative to support teacher-learning to teach ST	*Lack of systematic approach to infuse ST into science content lessons. * Teachers could not verbalise how they teach ST explicitly in their Year Four science lessons. Therefore their current practices did not show solid evidence that they know how to infuse ST into science lessons	*Thinking tools used at the end of session as a product of lesson. *Limited use of thinking maps for teaching thinking skills. * Teachers found to help students complete the thinking maps by merely instructing them on what to write (giving answers).	*Classroom management for students' thinking tasks were found to be poor. *Teachers spent great deal of time in disciplining the students rather on actively engaging them in thinking tasks.
The Needs (What do teachers need to teach ST in Year Four science?)	Address the development of teachers' knowledge of ST in Year Four science lessons. Understand why and how to engage students in ST	Recommend strategies which teachers would be able to use for infusing ST elements simultaneously into Year Four science topics	Tools that can be used by teachers to teach thinking strategies, develop students' habits of mind and metacognitive thinking along with subject matter acquisition.	Strategic and feasible classroom management, so that students would actively engage in thinking tasks by sharing and discussing thoughts in small group discussions

Corresponding Design Heuristics found in literature readings (How should the educative material be designed? What kind of information should be included to assist teacher-understanding?)	*Curriculum materials should inform teachers on teaching (Grossman & Thompson, 2008) *Educative materials contains educative features to support teacher understanding (vignettes, narratives), by systematically providing rationales for suggestions for teachers on how to adapt them into their practices (Davis et al., 2014) *Design heuristics should cover challenges teachers face and explain with illustrations for teacher-thinking (Davis & Krajcik, 2004).	*Make clear to teachers that they need to anticipate what students might think-ideas and recommend strategies to deal with students' ideas (Davis & Krajcik, 2005). *Explicitly explain the practice, build teachers' pedagogical knowledge, promote teacher-thinking on how to adopt the practice (Lin et al., 2012) *Provide rationale on how science teachers could engage students in scientific practices and thinking skills (Bismack et al., 2014)	*Teachers should model students on how to perform certain kind of thinking strategy using thinking maps or graphic organizers (Swartz et al., 2008; Swartz & McGuiness, 2014) *Four step strategy to infuse ST into science lessons (Swartz et al., 2008) *Provide rationale on why ST is related to primary science – in teaching thinking skills, habits of mind and metacognition (Zohar, 2013; Zohar & Barzilai, 2013)	*Concept cartoons can be used to initiate sharing of thoughts and arguments about science concepts systematically between learners in science lessons (Chin & Teou, 2009; Keogh & Naylor, 1999; Kruit et al., 2012) *Teachers should understand that setting ground rules during science talks among students is crucial for systematic and productive discussions (Hackling et al., 2011)
Identified Design Heuristics (What design heuristics should be in the STEPS?)	**Design Heuristic 1:** Support for teachers' knowledge of ST	**Design Heuristic 2:** Support teachers' ST infusion practices		**Design Heuristic 3**: Support teachers in managing group discussions

Showing the flow of process

Table 5.2 shows the design heuristics and educative features for the STEPS, derived from literature readings. This includes the type of support (shown in Table 5.2) which is divided into *rationale* and *guidance* (Lin et al., 2012). The term rationale means to inform teachers on the pedagogical decisions to infuse ST. For example, in DH 1, *rationale* means to explain what ST is (thinking strategies, habits of mind and metacognition) and to describe the importance of teaching ST in primary science lessons. The purpose was to make teachers aware of the need to infuse ST and how it influences students' content knowledge acquisition. On the other hand, the term *guidance* refers to recommendations for teachers on how they could infuse ST into their daily science lessons, particularly into the topic "Properties of Materials". Such kind of support provides teachers with suggestions on how to adapt and modify the recommendations if needed. However, it was essential to illustrate the recommendations using suitable vignettes and narratives as educative features (Davis et al., 2014). Therefore, the researcher adopted insights from the teachers' current knowledge and practices (groundwork phase) and suggestions from literature readings to develop the educative features.

Table 5.2

The Design Heuristics and Educative Features for the STEPS based on selected literature readings (Davis & Krajcik, 2005; Davis et al., 2014; Lin et al., 2012)

Design Heuristics	Categories/ Construct	Type of Support	Design Features
DH 1 : Support for teachers' knowledge of Skillful Thinking (ST) : Provide Interpretation and understanding of ST and its relevance to Year 4 Science learning units	A. Explain ST and its domains	Rationale	1. Explain what ST is and its domains. 2. Domains of ST: -Thinking Skills (TS) -Habits of Mind (HoM) -Metacognition (MeCog) 3. Explain Indicators for ST
	B. Explain the importance of ST	Rationale	1. Explain importance of ST in teaching thinking/HOTS in primary science education

			2. Explain the significance of ST approach on the TSTS Framework, scientific skills and scientific attitudes & noble values in Year Four science education
	C. Analyse specifications for Year Four science learning units & relate to ST domains	Rationale	1. Explain why a particular kind of thinking is appropriate for a certain learning unit. 2. Explain why various HoM and MeCog is appropriate for a certain learning unit
	D. Help teachers to integrate ST into content lesson	Guidance	1. Designing guidelines for teaching ST in content lesson
	E. Help teachers understand students' ideas or concepts	Guidance	1. Designing examples of concept cartoons to probe students' ideas and concepts
DH 2 : Support teachers' ST infusion practices: The infusion of ST into content lessons	A. Explain importance of instructions in ST	Rationale	1. Enhancing teachers instructional strategies for teaching thinking and scaffolding students' thinking
	B. Explain use of instructions in ST	Rationale	1. Explaining key techniques for infusion of ST: -making skills and mental habits explicit -scaffolding thinking practice -employing language of thinking
	C. Help teachers guide students engaging in ST	Guidance	1. Providing guidelines to use instructions systematically: -introduce students the kind of thinking -explain students how to actively practice the kind of thinking -help students reflect and assess their thinking practice (MeCog & HoM) -teaching students to transfer the skills in new context.

DH 3: Support for teachers in managing group discussions : Provide tools to manage group discussions and stimulate students' engagement in skillful thinking	A. Explain classroom management for group discussions	Rationale	1.	Explain that group discussion can be a challenge in teaching thinking
	B. Helping teachers managing classroom discussions for thinking activities	Guidance	1.	Explain how to provide conducive environment for thinking by setting ground rules for classroom discussions
	C. Help teachers adapt instructions for ST in content lessons	Guidance	1.	Providing teachers' thinking questions, thinking maps, graphic organizers & verbal communications

DH – Design Heuristics
ST – Skillful Thinking
TS – Thinking Strategies
HoM- Habits of Mind
MeCog- Metacognition

The educative features included in the STEPS were teacher-thinking questions (EF1), teacher-reflective writing (EF2), graphical representations (EF3), teacher-tips (EF4), teaching goals (EF5), content boxes (EF6), lesson planning cues (EF7), fictional teachers (EF8) and roadblocks (EF9). The purpose of designing teacher materials with educative features is to deliver information in ways that would enable them to envision how the recommendation might work in real classroom situations (Davis et al., 2014). For example, an educative material called a fictional teacher can be used to explicitly explain how the fictional teacher carried out a recommended strategy, say, teaching students to compare and contrast. It would be in a form of a short story with dialogues between the fictional teacher and students on how to compare and contrast a science concept.

By reading it, teachers as learners would understand the rationale behind the recommendation – to teach explicitly how to compare and contrast and thus adopt or modify the recommendations to suit their students. The following section will explain how the nine educative features were used for each design heuristic. The three design heuristics (DH) in the STEPS were support teachers' knowledge of ST (DH 1), support teachers' ST infusion practices (DH2) and support for teachers in managing students' small group discussions (DH3) as shown in Table 5.2.

Support for teachers' knowledge of Skillful Thinking – Design Heuristics 1. The first design heuristic in the STEPS was to support teachers' knowledge of ST. This was because, in the earlier section aimed at gaining information on selected teachers' knowledge about ST, it was found that teachers lack adequate knowledge of ST, and how ST is closely related to primary science education. Therefore, in this design heuristic, the researcher included educative features such as teacher-thinking questions, teachers' reflective writing, graphical representations and teacher tips to deliver information about the three elements of ST. The focus of this design heuristic was to deliver to teachers the information they need to know and understand about ST.

Educative feature EF1- teacher-thinking questions. Just as much as for students, teachers too need cues to think. However teacher-thinking involves thinking about how they could adapt recommendations provided in the STEPS into their own lessons. In the beginning of each chapter, there are a set of questions (cues) for teachers to reflect on their current practices of ST (Figure 5.4). This was because findings from Phase 1 revealed that the selected teachers lacked knowledge in teaching thinking strategies to analyse information and ideas, developing the habit of 'questioning and problem posing' and promoting metacognitive awareness among students. Therefore, it was essential to provide cues to stimulate teachers to think about the abovementioned elements of ST.

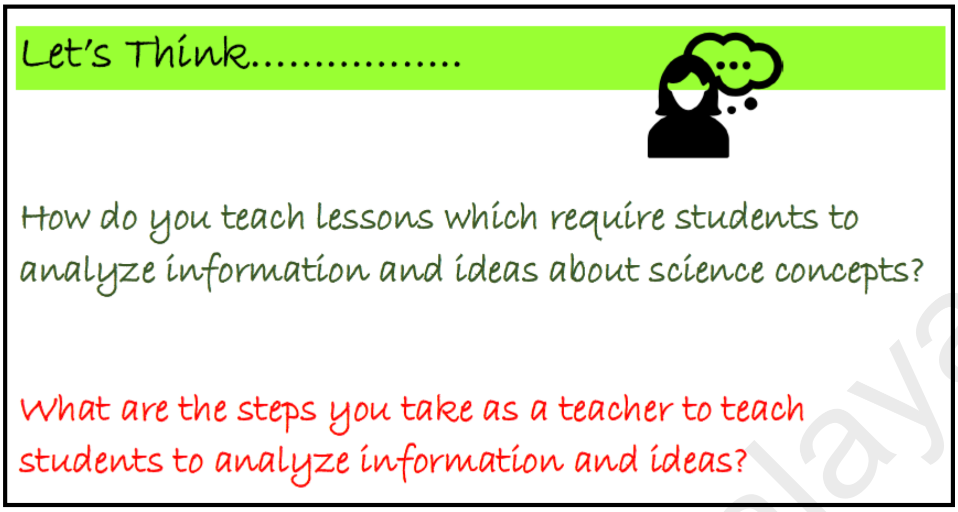


Figure 5.4. Teacher thinking questions.

For example, cues for them to think about how they teach students to engage in specific thinking such as analysing information and ideas about given science concepts. This was to help teachers envision on how they would plan and enact lesson that caters for the teaching of specific thinking skills. It would aid them to forward to explicitly teach specific thinking strategies involved in analysing information and ideas, apart from subject matter acquisition. There were also teacher-thinking questions in the end of each chapter. These questions were more on summarizing important ideas of each chapter in the STEPS. Figure 5.5 shows an example of teacher-thinking question on how they would develop students' habit of questioning and problem posing.

What would you do if….?

Let's say if you are the teacher teaching a class of academically weak students. You hardly give a chance for the students to ask questions assuming that the class would be noisy and out of control. What are the consequences to the students' thinking process if you hinder students from asking questions?

Figure 5.5. Example of teacher-thinking questions at the end of each chapter

The cue in Figure 5.5 started with a classroom scenario and ended with questions for teachers to ponder the consequences of the scenario. For example, stimulating teachers to think what happens if they do not provide the opportunity for students to pose questions and problems. Teacher thinking questions as such are educative for teachers because they help teachers to reflect upon their current practices (Lin et al., 2012). These are real-life classroom situations whereby teachers often fail to notice. It is essential to remind teachers of possible scenarios in classroom so that teachers would be prepared to overcome challenges in developing students' habit of mind.

Educative Feature EF2- teacher-reflective writing. The STEPS has provided cues for teachers to reflect upon their new practice- the infusion of ST. These cues include questions such as:

> *Did I successfully manage to introduce specific thinking strategy together with the topic to the students?*
>
> *What other strategies that I could use to engage my students in ST? How can I improve them?*

These questions were designed to stimulate teachers' reflective writing as part of their daily lesson planning (Figure 5.6).

The difference between cues for teacher-thinking and teacher-reflective writing was that the cues for teacher-thinking were given in the beginning of each chapter for teachers to reflect upon their existing practices. On the other hand, the cues for teachers' reflective writing were designed for teachers to reflect their lesson upon enactments of ST infused lessons. Another cue was also given in the STEPS to encourage teachers to write about their strengths and weaknesses when enacting ST infused lessons. These cues were provided to assist teacher learning experiences in ST infusion and make appropriate changes to improve their lessons.

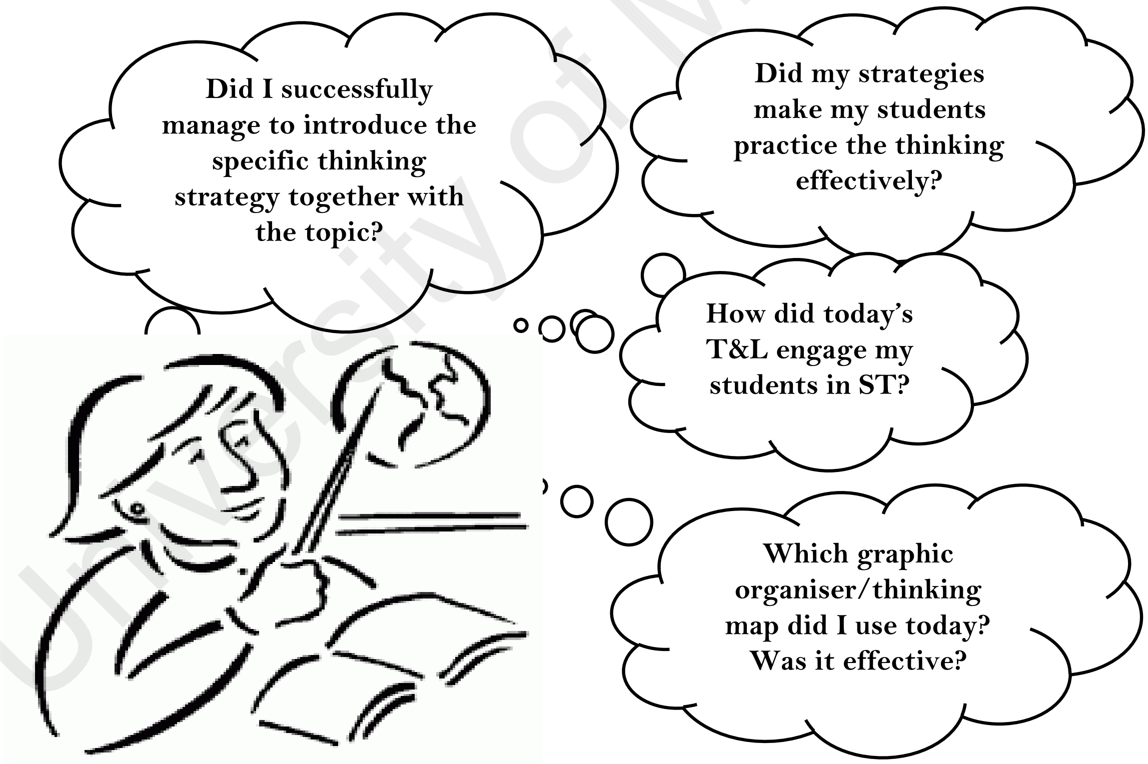


Figure 5.6. Cues for teacher-reflective writing

Educative feature EF3 - Graphical representations. In the STEPS, the researcher had modified lengthy texts into graphical representations such as concept maps, shown in Figure 5.7. Concept maps were used to describe the steps teachers could to take in order to infuse ST. Four steps were recommended as strategies for infusing ST into content lessons (Swart et al., 2008). Firstly, teachers need to explicitly introduce specific thinking strategies such as looking for similarities and differences among materials before classifying materials. This include step by step procedure of attributing, observing objects and materials for similar or different properties and giving inferences for observations. Secondly, teachers need to create space for students to practice the learnt thinking strategies. This is for students to familiarize with the thinking strategy until it become autonomous. Thirdly, teachers ought to promote metacognitive thinking by asking students to reflect upon their thinking strategies and identify ways to improve them. And finally, the fourth step is to teach to transfer the thinking strategies into new contexts. Here, teachers need to help students identify real-life situations in which students could transfer and apply the thinking strategies they have learnt. Figure 5.7 shows a concept map that displays the flow of steps taken to infuse ST as mentioned above.

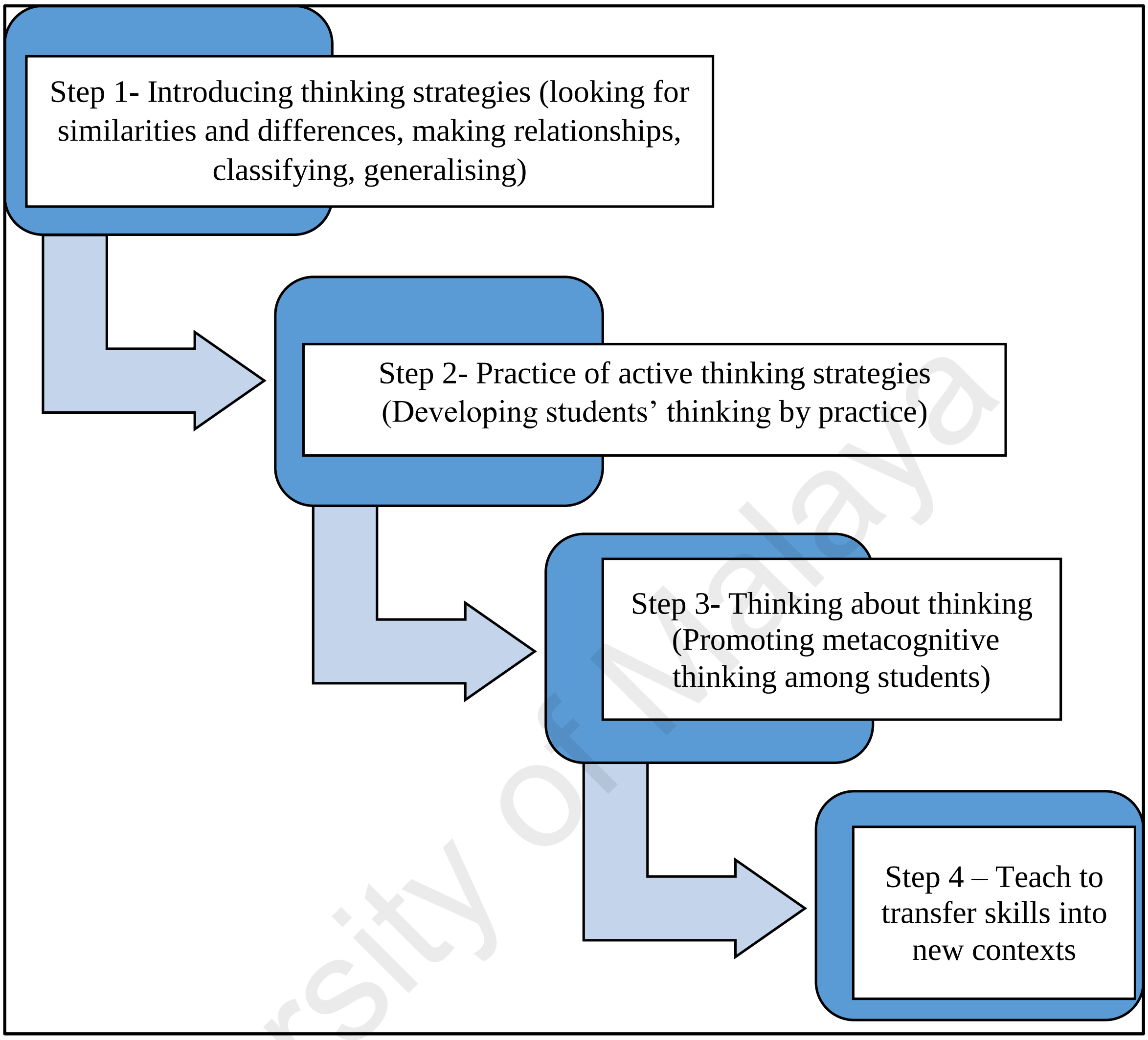


Figure 5.7. Example of concept map to show the process of suggested infusion approach.

Concept maps were incorporated into the STEPS to represent key ideas about ST infusion, which can be educative for teachers as learners (Ali Gunay Balim, 2013; Evrekli et al., 2011). This was also because the experts have suggested that a graphic (concept maps) would increase readability among in-service teachers who have limited time to read lengthy and words materials.

Educative feature EF4 - Teacher-tips. Teacher-tips in the STEPS were additional information for teachers. They serves two purposes. The first purpose was to provide extra resources for teachers to refer for more guidance. For example, list of online websites that teachers could visit if they need more information (Figure 5.8). The symbols beside the list of websites indicate useful online resources. The second purpose was to recommend teachers with supplementary ideas to engage students in ST.

Tips for Teachers 

Sometimes, students hesitate to ask questions in front a large audience/whole class. Therefore, try to make sure that the students list down their questions during small groups while they conduct science activities. The questions can be discussed systematically after the activity. This would hinder students from asking too many questions at a time which may end up as an uncontrollable situation.

Figure 5.8. An example of teacher tips in the STEPS.

For example, Figure 5.8 illustrates an example of teacher tips on how they could engage students in small group discussions to share and argue ideas about science concepts. Teachers could encourage students to set their own ground rules and take charge of their group discussions. Such ideas were drawn from literature readings (Peters, 2009; Teou & Chin, 2009). These ideas were given for teachers to adapt into their lesson where they found suitable and feasible.

Support teachers' ST infusion practices – Design Heuristic 2. Teachers need to know the appropriate instructional strategies to plan and enact lessons that would cater for the infusion of the thinking skills. In the context of this study, the researcher focused on analysing information and ideas about a given science concept. This includes knowing how and when to weave in the teaching of relevant thinking strategies that one has to master to be able to analyse information and ideas. Thinking strategies involved in analysing information and ideas are comparing and contrasting, analysing parts-whole-relationships, generalising and making inferences (giving reasons for observation). For example, it is stated in the Malaysian Year Four Science specification that students are required to analyse knowledge about various objects and classify them according to the materials they are made of. For this, teachers need to know how to explicitly introduce, practice and teach for transfer of skill. This includes teaching the steps needed to be taken in observing, comparing, contrasting and classifying materials.

In addition, the selected teachers need to develop students' habit of questioning and problem posing as well as metacognitive thinking simultaneously with subject matter. As beginners in teaching Year Four science, these teachers need a specific model of instruction to adapt into their current practices. Instructions on how teachers can develop students' habit of asking questions and problem posing explicitly by being aware of specific steps needed to be taken and also help students to adopt strong metacognitive strategies such as knowing what, why, how and when to use the thinking skills. As such, a model with instructions integrating ST elements into the existing teaching practice was proposed in the STEPS as guideline for the selected teachers.

Educative Feature EF5- teaching goals. Currently, the objectives stated in the Year Four curriculum specifications were based on subject content knowledge acquisition, whereby focusing on what students need to learn. Therefore, the researcher had added several objectives for the lessons. The set of additional objectives is a feature focusing on specific teaching goals that teachers should take into consideration when planning ST infused science lessons. The shaded region shown in Figure 5.9 shows the list of teaching goals for each ST element. For example, the teaching goal for the second element in ST (developing students' habits of mind), is to promote students to question about the classification of objects. This can be considered as additional learning outcomes for each lesson. These teaching goals were included to keep teachers informed of the focus on ST elements apart from subject matter understanding. These teaching goals were given in the sample lesson plans in the STEPS.

Content Standard	Analysing knowledge about natural materials and synthetic materials and their resources
Learning Standard	7.1.1 Identifying materials used to make objects and their natural resources 7.1.2 Classifying objects based on their resources 7.1.3 & 7.1. 4 Justifying if the objects are made of synthetic material/natural or through chemical processes.
Science Process Skills	Observing, classifying, communicating
Thinking Skill	Analysing information and idea analysis (classifying, justifying about the object and its resources)
Habits of mind	Questioning and posing problems about the classification of objects
Metacognition	Naming the way of thinking (classifying/identifying similarities and differences and evaluating)

Figure 5.9. Example of teaching goals in the lessons provided in the STEPS.

Educative feature EF6 - content boxes. Content boxes were prompts for teachers while planning lessons to infuse ST. The content boxes were not questions, but reminders for teachers to remember important key points. For example, Figure 5.10 shows an example of a content box. This informs teachers to assess students to ensure they are able to practice specific thinking strategy during such as justifying the way they classified materials. However, the content boxes only appeared in the sample lesson plans as additional recommendations as per needed. The teachers can use this later when preparing their lessons for subsequent units. This was because the content boxes were designed specifically to provide teachers with additional information and guidance in a form of vignettes (Davis et al., 2014).

Activity 2: Practice Thinking

Teacher: "Try to imagine a problem that you want to solve. For example, my eyes always tear up when chopping onions. That is a problem most people go through when peeling onions. I wish there is a device that could peel and chop onions easily for me, so that I don't have to cry each time I peel onions. What about you? Try discussing with your friends about a problem and how to solve it. Do not forget to write down the questions you have discussed"

Teacher provides a worksheet/Thinking Map for Decision. Teacher also provides a piece of paper for students to sketch their design.

> Students tend to design objects without good reasoning and justifications. Teacher must ensure that the students understand the functions of each part of their designed object. This will help students to choose the right material and justify their selection of materials.

Figure 5.10. Example of content box in a lesson plan.

Educative feature EF7 - Lesson planning cues. This feature, perhaps the most important feature in the STEPS was designed to provide essential information in planning lessons to infuse ST elements into the selected topic. The format of the sample lesson plan in the STEPS was adapted from Swartz et al., (2008) which was originally prepared for infusing ST into History lessons. The researcher adopted and modified the format for the lesson plans in the STEPS to suit the context of the present study. Figure 5.11 shows the designed lesson plan template in the STEPS. For each step of infusion, cues were given to stimulate teachers to think about while planning their lessons.

Before T&L

While planning the T&L of Skillful Thinking (ST)…

Consider these questions…

<u>Daily Lesson Plan Template to infuse ST</u>

<table>
<tr><td>Date:</td><td>Class:</td><td>Time:</td><td>Topic:</td></tr>
<tr><td colspan="2" rowspan="3">T&L Objectives: Learning Standard
What is the Learning Standard in the Document Standard of Science Year 4?</td><td>Teaching Aids</td><td>Evaluation</td></tr>
<tr><td>Science Process Skills</td><td>Scientific Behaviour and Moral Values</td></tr>
<tr><td colspan="2">Type of Thinking (HOTS)
What is the thinking strategy that you would like to teach in this lesson plan? What are your objectives in teaching the thinking strategy?</td></tr>
<tr><td colspan="4">T&L Steps:
S1- Introducing the thinking strategy
How do you plan and probe students' prior knowledge?
How would you introduce a thinking strategy in order for your students to analyse science observations?</td></tr>
<tr><td colspan="4">S2- Practicing on the thinking strategy
How do you plan to actively engage students in the thinking strategy?
What kind of activities would you plan?</td></tr>
<tr><td colspan="4">S3- Thinking about Thinking (Metacognition)
What cues would you give to the students to involve them in the thinking strategy?
What are the opportunities given to your students to think about the concept and thinking strategy that they had practiced?</td></tr>
<tr><td colspan="4">S4- Transferring skills into a new context
How would you teach your students to transfer the learnt the thinking strategy?
How do you ensure that the students could transfer the learnt thinking strategy into new contexts?</td></tr>
</table>

Figure 5.11. Lesson plan template with cues to stimulate teacher thinking.

This includes cues such as '*How do you plan and probe students' prior knowledge? How would you introduce a thinking strategy in order for your students to analyse science observations? How would you teach your students to transfer the learnt the thinking strategy? How do you ensure that the students could transfer the* *learnt thinking strategy into new contexts?* This educative feature was designed as guidance for teachers to carefully think about how they would carry out each step. To further assist teacher-learning, additional cues were given as shown in Figure 5.12. Figure 5.12 shows the rationale for the first two steps suggested in the lesson plan template.

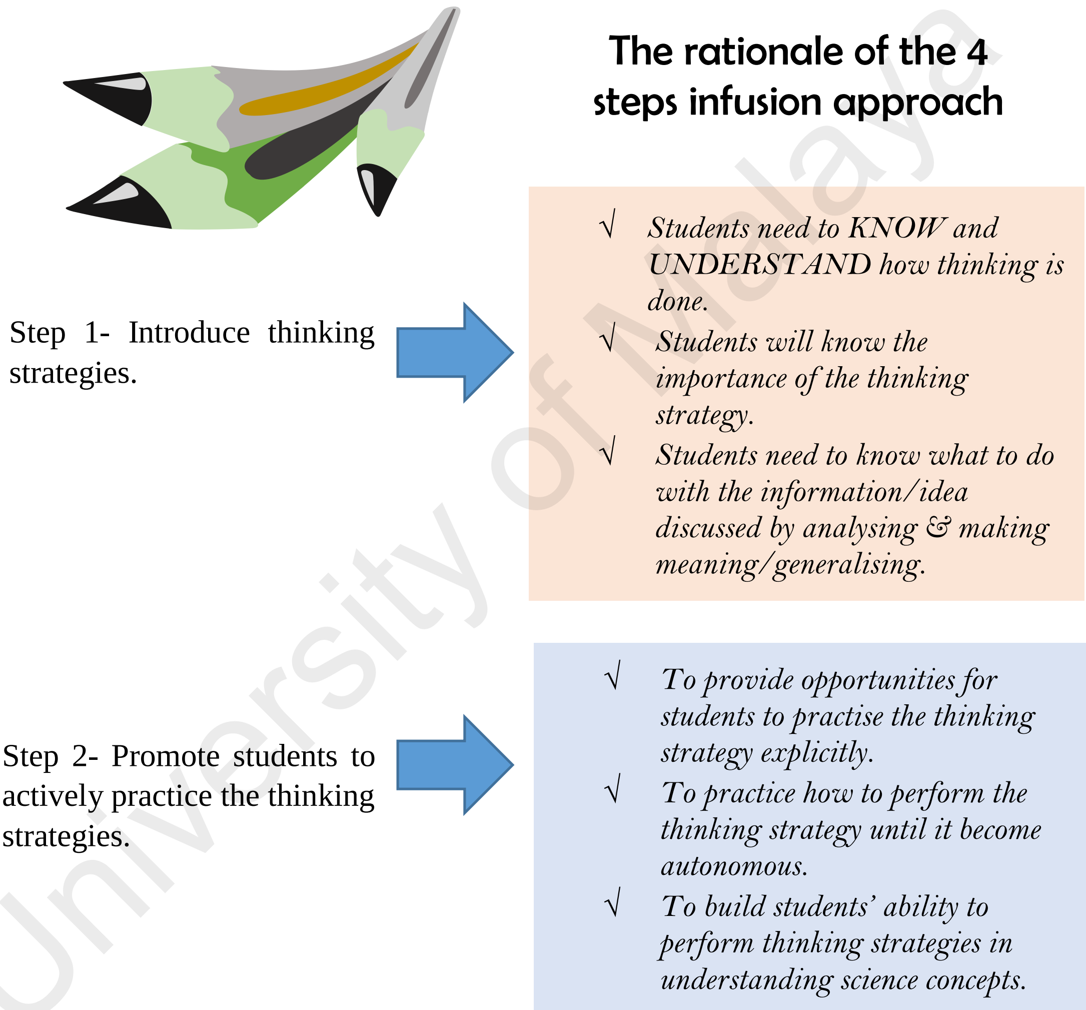


Figure 5.12. Rationale for the steps to infuse ST.

It shows the rationale for each step in the suggested infusion approach. For example, the rationale of step 1, which is to introduce specific thinking strategy, is to make sure that students know and understand how a specific thinking strategy is done. This would enable students to be aware of the importance of such thinking strategy, particularly when they need to make sense of their data collected during scientific investigations. However, the focus was on teachers-whereby this feature was designed to inform teachers on the rationale behind the four steps in infusing ST. This was because teachers need to understand as to why each step is important in infusing ST (Beyer & Davis, 2009; Bismack et al., 2014). This feature was designed to shape teachers' conceptions about what and why infuse ST into Year Four science lessons.

Educative feature EF8 – Fictional teachers. Fictional teacher is a narrative that can be used to illustrate an idea (Beyer & Davis, 2009; Davis & Krajcik, 2005). To create the fictional teachers, the researcher took excerpts from Phase 1 data (interviews and classroom observations). For instance, it was found that the teachers in Phase 1 had not used thinking maps effectively, whereby they dictated the answers for students to fill up those thinking maps. Taking this as an example, the researcher suggested ideas on how teachers can modify existing thinking maps by adding cues to aid students' thinking process. It would enable students to use the thinking maps based on cues. These excerpts were then illustrated to be educative for teachers, so that teachers would be able to envision how they might infuse ST elements into their current lessons. Figure 5.13 shows how a fictional teacher called *Pn Rohaya* had modified the existing thinking maps to help her students analyse information about the properties of materials and make generalisations.

Pn. Rohaya teaches students the topic classifying materials in class 4D. She uses thinking maps such as in page 45. However, Pn. Rohaya thinks that the thinking map does not involve students in higher level thinking activities. Pn. Rohaya then modified the thinking map by adding few cues (questions) which require students to analyse information and ideas about the materials they observed.

Figure 5.13. Fictional teacher, Pn. Rohaya in the STEPS.

In the beginning, Pn. Rohaya had instructed her students to use a tree map to classify the materials according to its sources. Therefore, Pn. Rohaya modified the original tree map by adding few sections as cues for students to use specific thinking strategy-compare and contrast.

Pn. Rohaya was not satisfied with the existing tree map. She found that the tree map did not prompt students to analyse students' classification of the materials. Pn. Rohaya added cues such as '*what are the similarities between the objects in this group? Why did classify the objects in this group? What are the characteristics of materials between this groups? What conclusion could you make based on characteristics of the objects*', to the existing tree maps (Figure 5.14).

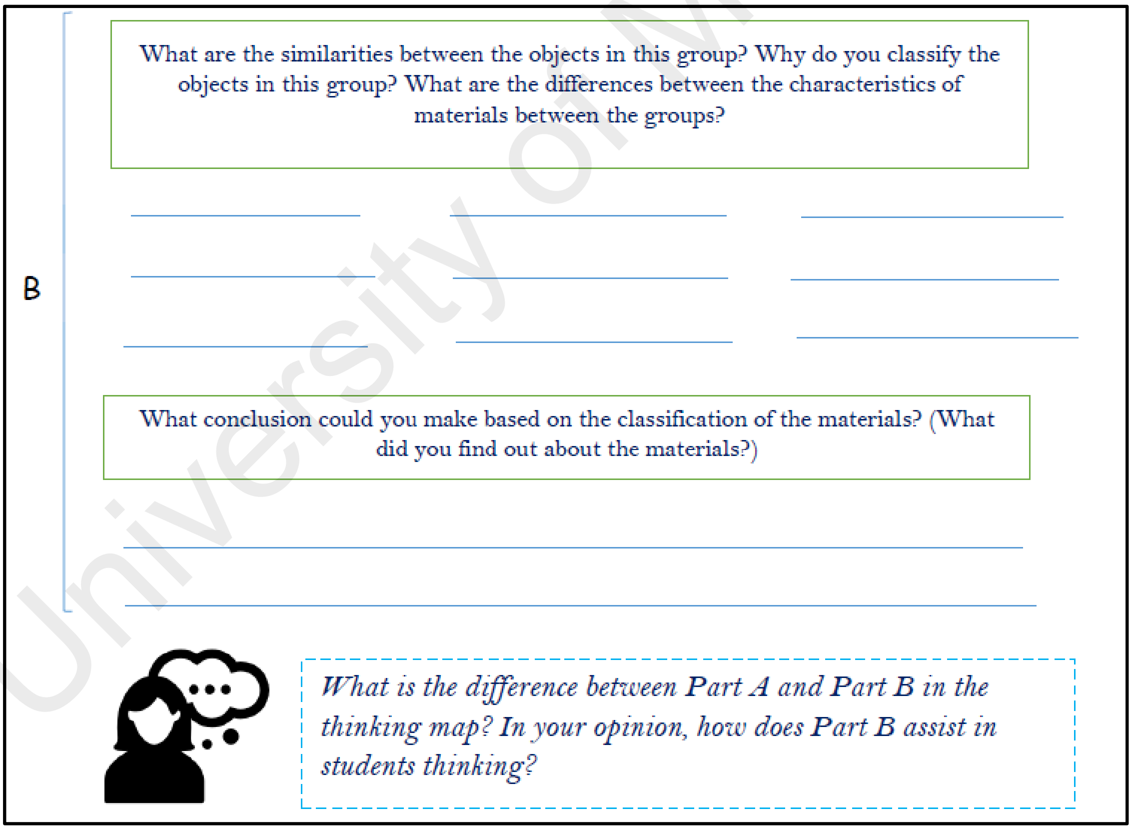


Figure 5.14 A section of the thinking map with added cues.

Figure 5.13 shows only a section of the modified thinking map. The original thinking map for students does not include the teacher –thinking question, shown at the end of Figure 5.14 that reads; '*What is the difference between Part A and Part B in the thinking map? In your opinion, how does Part B assist in students' thinking?* This particular section only appeared in teacher's copy for them to think about how by adding such cues to the existing thinking maps would help students' thinking processes.

Similarly, Figure 5.15 shows the modifications made by Pn. Rohaya to another thinking map. This thinking map was used to teach students how to look at parts-whole relationships between information. For example, analysing an object and its various parts respective to the materials they were made from. This was for students to understand why different parts of an object are often made from various materials. Students generalise the use of different materials for different parts of objects based on their specific functions. However, Pn. Rohaya modified the existing tree map by adding cues (questions) so that her students could further analyse as to why each part of the object is made of different material. The modified thinking map also stimulates students to relate the function of each part of the object to the selection of material of origin. At the end of the thinking map, there is a cue for students to generalise the whole object with the various materials used to make it (shown in Figure 5.15).

The use of fictional teacher in the STEPS was profound to illustrate teachers to internalise the rationale of modifying existing thinking maps in a way that could be used to stimulate students to analyse their observations about objects, parts of objects and the properties of materials used to make the objects. Among the cues added were; '*What would happen if this part does not exist?*', '*What are the functions of every part?*' and '*What can be said about the whole function?*' These cues were added to help students to think by predicting what would happen if a certain part goes missing from the object and to relate properties of materials to the function played by each part of the object. It also encourages students to discuss in groups on how they would complete the thinking map.

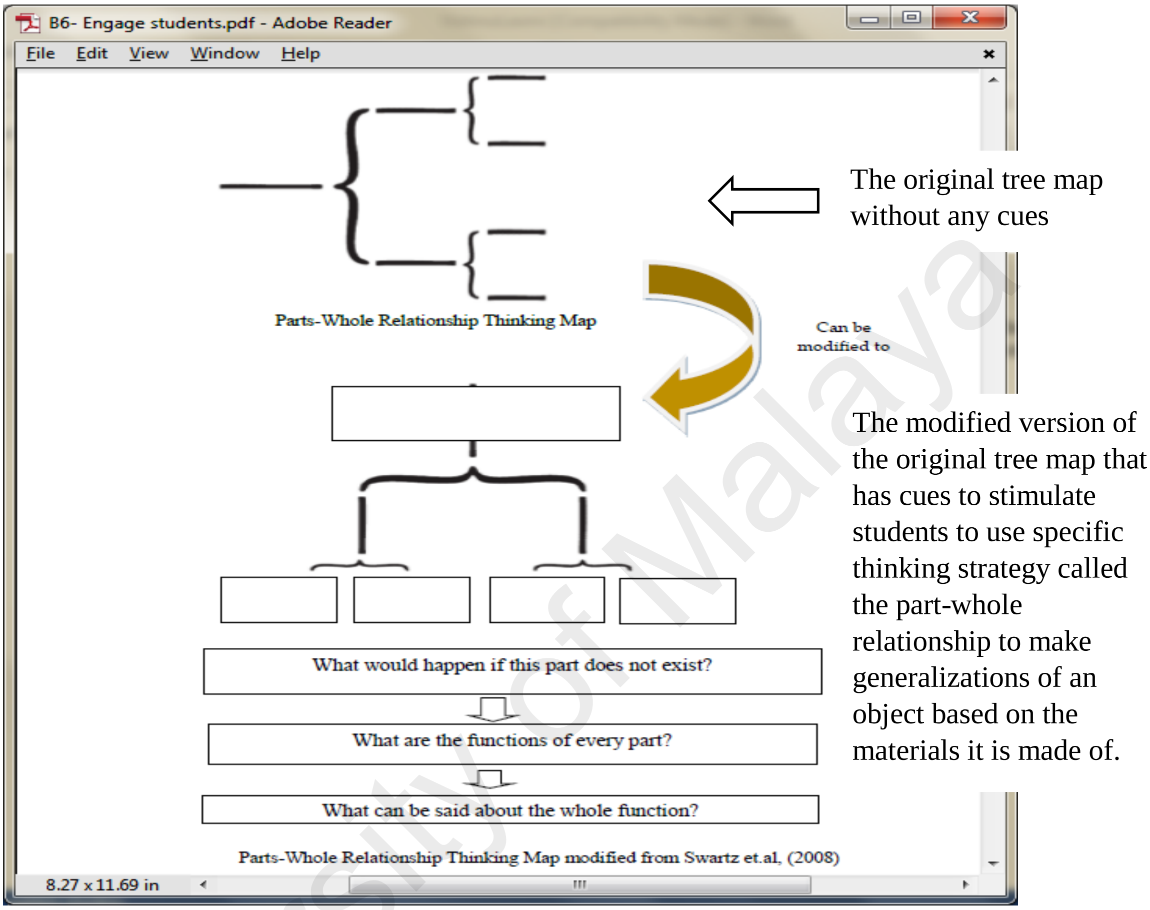


Figure 5.15. Modified version of another thinking map.

Support for teachers in managing students' group discussions – Design heuristics 3. Small group discussions are one of the most viable ways to teach students on how to ask questions and increase their problem posing abilities (Oliveira et al., 2014). Students would be able to discuss questions and problems posed by peers in the group. However, Phase 1 findings revealed that the selected teachers lacked pedagogical knowledge to manage small group discussions. Their classrooms were found to be either noisy, uncontrolled or quiet (students were not allowed to discuss). For students to actively engage in thinking tasks, teachers must set the stage for fruitful discussions. Teachers would need to set ground rules for group discussions so that students will be able to pose questions and problems comfortably related to given tasks while working collaboratively to engage themselves in thinking tasks. The ground rules suggested in the STEPS were derived from studies on children's science talk (Chin & Teou, 2009; Gibson, 2009; Mercer et al., 2004). These studies have suggested to use ground rules for small group discussions, so that students will be able to discuss science concepts systematically and with ethics. For example, when a member of group is sharing a view on a given science concept, the rest should listen with empathy. Hence, as an additional material, the researcher had prepared tags whereby the students could use them during discussions. Phrases such as 'group leader', 'quartermaster', 'presenter' and 'note taker' were written on the tags. Each student takes responsibility for the given task to ensure the group discussion is well organised.

Since it was also found that most teachers did not use any specific tools for ST infusion, the STEPS would also need to provide support for teachers to probe their students' thinking, through interesting and challenging tools in making thinking visible. Therefore, the STEPS has included extensive use of graphic organisers, thinking maps, concept cartoons and metacognitive logs for students to share their thoughts about science concepts and more importantly ones' own thinking. The use of these tools depends on teachers' reasoning and pedagogical knowledge on when, why and where to use in their lesson plans. Examples of graphic organizers were derived from studies related to ST and thinking skills in general. The graphic organizers in the STEPS were modified from Swartz et al., (2008), so that it can be used specifically for the designated topics (Properties of Materials).

The graphic organizers and other visual tools were designed to show the links between information gathered during hands-on activities. Apart from that, teachers also had requested for list of questions as cues for stimulating students to analyse knowledge (information and observations) using different kind of thinking strategies. This include performing compare and contrast, looking at parts-whole relationships, predicting, sequencing, and justifying. Another concern raised during Phase 1 was on motivating students to share their ideas. The teachers claimed that their students do not have the motivation or initiative to talk about their views on the subject matter. To provide support for teachers to probe students' thinking and argumentative skills, the STEPS offer the use of concept cartoons (Keogh & Naylor, 2010). The concept cartoons were designed by the researcher based on the topics of interest. Another educative feature – challenges for teachers in the STEPS illustrate challenges teachers encounter and suggest ideas on how they can overcome them.

Educative feature EF9 – roadblocks. The researcher designed a feature called 'Roadblocks' to illustrate real-classroom challenges that science teachers might encounter while infusing ST. The example in Figure 5.16, illustrates one of the teachers' challenges, which was to sustain students' motivation in thinking which hinders students from developing habits of mind in thinking. This feature also recommends a solution, which is to use concept cartoons as a tool to create 'cognitive conflict' among students, so that they would argue the conflict in their ideas about a given science concept (Keogh & Naylor, 1999; Teou & Chin, 2009).

Roadblocks:

Teachers face problems when students are not interested to 'think'. This is perhaps because students do not find the concepts or T&L interesting and challenging. This can be taken care of by creating a 'cognitive conflict'. Cognitive conflict occurs when an idea about a science concept conflicts with their existing ideas or prior knowledge. For example, the use of concept cartoons, whereby each cartoon portrays contradicting ideas about a science concepts. Teachers could engage students to argue out their own ideas about the science concept in the concept cartoons. By doing this, teachers could motivate students to 'think'.

Figure 5.16. An example of the feature that explains roadblocks in ST infusion.

This feature stimulates teachers to visualize possible challenges in ST infusion among young children and how to overcome them. It is educative in nature for the teachers because it provides scenarios for teachers so that they would be prepared if they encounter such challenges (roadblocks). The illustrated challenges were from day-to-day real-life classroom situations that most primary teachers are familiar with. However, teachers still need ideas on how they could engage students and sustain their motivation in thinking tasks. Another example (Figure 5.17) illustrates a common challenge that teachers encounter when managing group discussions.

Roadblocks:

One of the biggest challenges faced by teachers teaching in an academically weaker class are students who are not able to construct scientific sentences to explain a certain concept. This includes writing observations, inference and conclusions. Most students are able to pose scientific questions and ideas verbally but not in written form.

Suggestions to Teachers...

- This problem can be solved if the tasks/worksheets are made **collaboratively**. This means each group member is made compulsory to **contribute at least one word** in constructing sentences/scientific explanations.

Figure 5.17. An example of the feature that explains challenges teachers encounter during small group discussions.

The nine educative features also played more than one role for each design heuristic. Teacher tips (EF4), an educative features used in STEPS for supporting teachers' knowledge of ST (DH 1) are also used for supporting teachers' management of small group discussions (DH3) by recommending ideas on how to set ground rules for students' group discussions. Other educative features were used interchangeably across the three design heuristics. Figure 5.18 shows the nine educative features used in the STEPS.

EF 1

Teacher-thinking questions

Stimulate teachers to think how they could incorporate ST elements into specific units.

EF2

Teacher-reflective writing

Cues to promote teachers to reflect upon their lessons-about how they have infused ST into lessons and how they plan to improve it.

EF3

Graphical representations

Concept maps and graphics describe information about ST in systematic and appealing ways for teachers to read. The aim was to increase readability.

EF4

Teacher-Tips

Simple vignettes that provide additional information for teachers, such as useful websites and ideas that they can adapt into their lessons**.**

EF5

Teaching goals

Learning outcomes anticipated in a lesson, for example, students should be able to pose questions and seek for answers collaboratively.

EF6

Content boxes

Brief explanations / notes as reminders for teachers in pay attention in lessons. It contains recommendations to be more vigilant on students' learning.

EF7

Lesson Planning Cues

Cues/prompts provided for each step in lesson plans. These cues were for teachers to ponder while planning each step in infusing ST.

EF8

Fictional teachers

Illustrate how ST elements can be incorporated into specific units of lesson. Help teachers visualize how they might take up ideas in the STEPS and adopt them into their own lessons.

EF9

Roadblocks

Excerpts from Phase 1 findings were incorporated to inform teachers on challenges as roadblocks that they might encounter in infusing ST. This includes suggestions on how to overcome those roadblocks.

EF- Educative Features

Figure 5.18. The nine educative features in the STEPS.

Review of STEPS

When the prototype of the STEPS was prepared, it was sent for experts to review on the design. Reviews by the experts were then taken into consideration to revise and re-design the content of the STEPS. Their verbal and written reviews were re-typed and analysed as document analysis to fine tune the contents of the STEPS. To add strength to the review, the researcher had also communicated with experts regarding ST infusion as well as in designing educative materials for teachers. The online communication through emailing, has provided useful inputs into the design of STEPS.

The experts' comments were mainly on the content and representations featured in the STEPS. Most of the comments were positive, especially on the educative features included in the STEPS. For instance, Expert 4 who was from the State Education Department said:

> *"We (representing the whole department) never come across material for teachers like this…this is different…I liked your effort of educating the teachers to incorporate ST into science education…actually we need more materials like this…"*
>
> *Expert 4, DA*

Expert 4, who was the head of Quality Assurance Department, was highly experienced in conducting training sessions for teachers in teaching HOTS, both at national and state levels.

A summary on other experts' reviews and the changes made to the STEPS are given as in Table 5.3.

Table 5.3

Reviews given by expert on the STEPS

Expert	Characteristic	Comments
Expert 1	Lecturer in Teachers' Training Institute	1. The module is suitable for novice or beginner science teachers. 2. The graphics are not that appealing. 3. Need to include 4 levels of inquiry in teaching science
Expert 2	Science teacher with 15 years of experience in teaching Year Four Science	1. The pedagogical support material (STEPS) is helpful for teachers with examples that are "friendly' to teachers. 2. The material is well planned in detail. 3. Several graphics need to be re-designed more creatively to convey the message easily.
Expert 3	Science teacher with 12 years of experience in teaching primary Science	1. The module could help teachers and students in learning skillful thinking. 2. The module is not prepared based on students' level of learning. 3. More recommendations on how teachers could solve problems in teaching skilful thinking should be added. 4. Need more space for teachers to reflect upon their new teaching approaches upon using the material. 5. Lessons should facilitate 'open discovery' in learning science.

Expert 4	Head of Department of Quality Assurance, State Education Department	1. STEPS could help teachers to enable themselves in teaching higher order thinking skills among primary students. 2. The illustrations should be local, especially the pictures instead of Western elements. 3. The module has included attractive graphics and strategic questioning techniques structured systematically for teachers to stimulate students' thinking skills.
Expert 5	Malay Language lecturer in an International University	1. The lesson templates for teachers are easy to understand and follow. 2. Language can be made simpler, especially in long texts and graphics. 3. The language is suitable for teachers to understand.
Advice from experts through online communications		
Expert 6	An expert in teaching ST	1. Recommended that teachers should teach thinking through modelling. Model the thinking strategy in familiar subject matter. 2. Inclusion of repeated practices, reflecting sessions and review sharing with peers should be main concern.
Expert 7	An expert in educative curriculum materials	1. Suggested few articles that clearly explains how to determine design heuristics for educative materials specified for science teachers.

Changes made to the STEPS after experts' review. There were several changes made to the contents in terms of representations. Changes were made based identified criteria from the experts' review, such as wordy text, students' level of understanding, language, time allocated to complete the units, illustrations and teacher planning for lessons. Expert 1, from teacher-training institute described the content of the STEPS as '*not appealing*" since it was too wordy. Her views on the wordy texts and representations were based on her experience teaching teachers to teach science. She claimed that:

> *"I don't think so teachers, especially in-service teachers, who are busy at school would take the time to read all the wordy texts to understand what Skillful Thinking is…"*
>
> *Expert 1, DA*

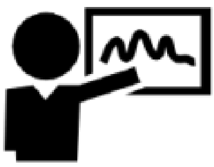
Figure 5.19 shows an example of such lengthy texts which was in the STEPS. The experts questioned the readability of the STEPS, claiming that teachers as readers might feel discouraged to read such lengthy texts. They suggested that such lengthy and less appealing texts should be represented in colourful graphics so that teachers may find it more interesting and easy to read. Therefore, as per her advice, the researcher then, re-designed the wordy texts into illustrations that were appealing and colourful. The aim was to provide teachers with a vignette that shows how the components of ST are relevant to every aspect of primary science education. For example, thinking strategies in analysing skill is relevant to critical and creative thinking skills (CCTS) and represent scientific skills as stated in the Year Four science curriculum as well as how it is related to the characteristics of 21st century learners (shown in Figure 5.20).

What is the connection between science skills and skillful thinking (ST)?

ST is the process of thinking skilfully which include three elements – specific thinking strategies, habits of mind and metacognition. A students is said to have acquired ST if he/she could perform different kinds of thinking strategies, manifest the 16 habits of mind and perform metacognitive thinking or reflect upon own thinking. This means that in teaching Year Four science, students should be perform different thinking strategies in analysing science concepts, able to pose questions and problems (one of the 16 habits of mind) and reflect upon their scientific thinking abilities. This is closely connected to science skills such as analysing, communicating, making inferences and classifying.

What is connection between the thinking skills in T&L of Year Four science and ST?

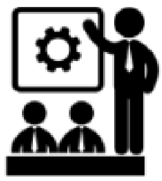
The Year Four science emphasis three major thinking skills-analysing, reasoning and conceptualizing (CDC, 2012). However, to acquire these thinking skills, students must be taught how to use specific thinking strategies such as comparing, contrasting and looking at parts whole relationships for example in order to analyse science information. They too need to know how to reason their scientific obsrevations to better conceptualize science knowledge. ST focuses on the acquisition of such specific thinking strategies among habits of mind and metacognition.



How is ST related to critical and creative thinking skills?

Critical and creative thinking skills (CCTS) are closely related to ST, whereby the specific thinking strategies mentioned earlier are actually CCTS. For example, one of the critical thinking in science education is compare and contrast science information. Similarly, this kind of thinking is also one of the important specific thinking strategies in ST. On the other hand, ST also emphasis students to generate ideas and evaluate them, which is an example of creative thinking.

How is ST related to 21st century teaching and learning?



The 21st century teaching and learning (T&L) focuses students' active participation in learning, develop habits of mind and taking charge of their own thinking. Collaborative learning environment is vital for 21st T&L. Similarly, ST targets the development of the 16 habits of mind and metacognitive thinking among students. Therefore, by learning to be skilful thinkers, students would experience the 21st century learning environment.

Figure 5.19. The original wordy text in the STEPS.

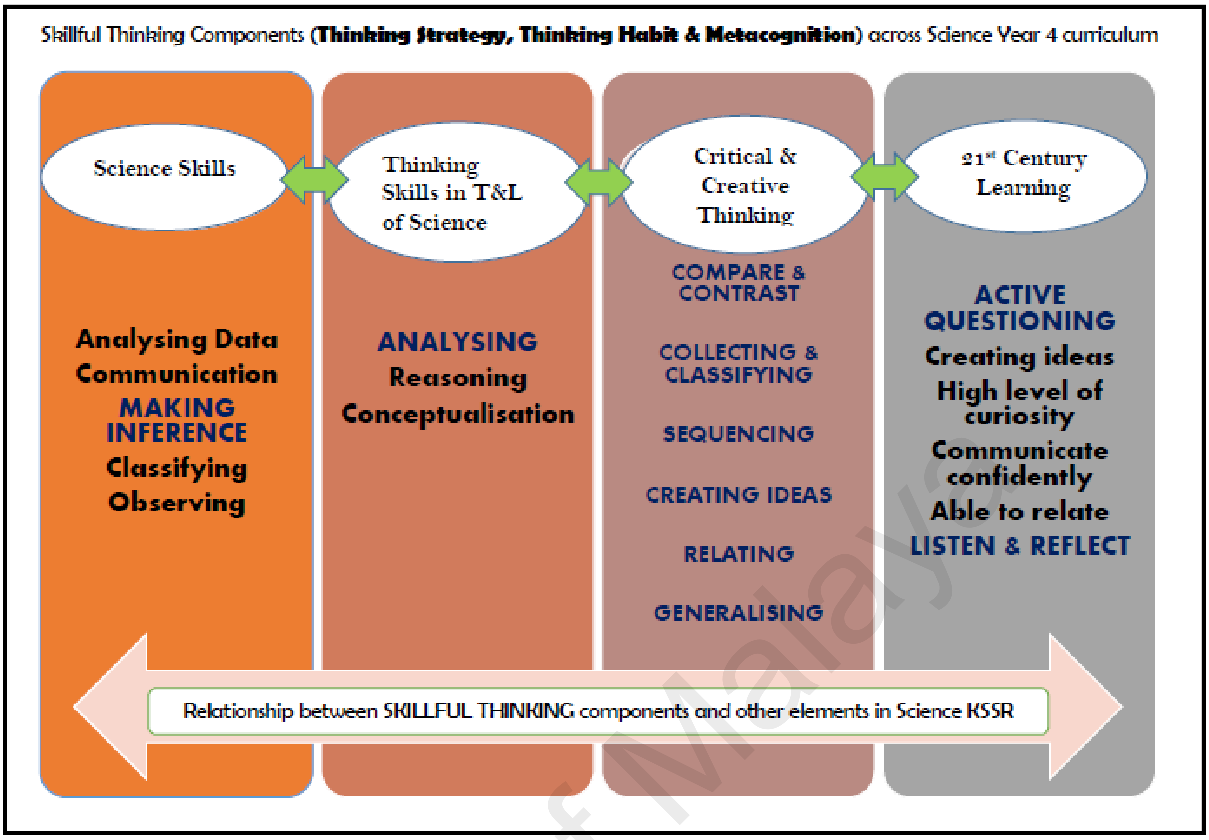


Figure 5.20. Graphical representation of the wordy text in Figure 5.19.

Wordy text changed into colourful illustrations with the messages intact. Figure 5.20 displays the interconnections between the different facets of primary science curriculum and ST, however in a more readable way. Other experts were more concerned in the content of the STEPS, whether in-service teachers, who are already busy would spend the time to read it. For example, expert 2 asked:

> *"Do you think the teachers will read the STEPS in one go? I think the content is too thick and wordy, but I like the fictional teacher columns. My concern is on whether the teachers are willing to spend time reading it…"*
>
> *Expert 2, DA*

With these comments in mind, the researcher then decided to prepare the STEPS into three different guide books. Therefore, the researcher decided to have soft landing for the implementation of the STEPS in Phase 3 later. To make it more user friendly, the content of the STEPS was prepared as three books. Firstly, Book 1was distributed for teachers to help them manage small group discussions by suggesting them to set ground rules for students to follow. It was prepared for teachers to read and use the materials provided so that the students would have the time to familiarise with new ground rules and start working collaboratively. For this, tags with distinctive roles for students to play during small group discussions were also prepared, such as ‘The leader”, “The writer” and ‘The Quarter master” (Figure 5.21).

Figure 5.21. Tags prepared for the teachers to organize small group discussions.

Secondly, Book 2 was prepared to be distributed to the teachers before the two-week mid-year school break. The goal was to give the time and space for the teachers to read through the STEPS. And thirdly, Book 3, which contains ideas on how to infuse ST into content lessons, to be distributed after the school holidays and one week before the teachers start teaching the topic ‘Properties of Materials’. Another criteria commented by the experts was related to genre of the concept cartoons and thinking maps used in the STEPS. The STEPS provides tools for teacher-use as teaching aids, however the images were more to Western culture as commented by Expert 3.

"I like the concept cartoons and self-reflection tools for students, but it don't represent Asian culture…I mean the images…"

Expert 3, DA

Hence, the images in the tools were then changed into ones that represent Asian characters or science phenomenon that are familiar to Malaysian children.

Figure 5.22. Concept Cartoon as in Keogh & Naylor (1999) p. 433

For example, the concept cartoons by Keogh & Naylor (1999) and several others (Cengİzhan, 2011; Sepeng, 2013; Teou & Chin, 2009) had Western influence, such as the use of snowman (Figure 5.22). On the contrary, Malaysian and most Asian countries are not familiar with snowman and may not be able to visualize the concept of heat. Therefore, the researcher modified the concept cartoon to suit Malaysian culture and daily situations which are more familiar with Malaysian children. An example of the modified version of the concept cartoons is shown in Figure 5.23.

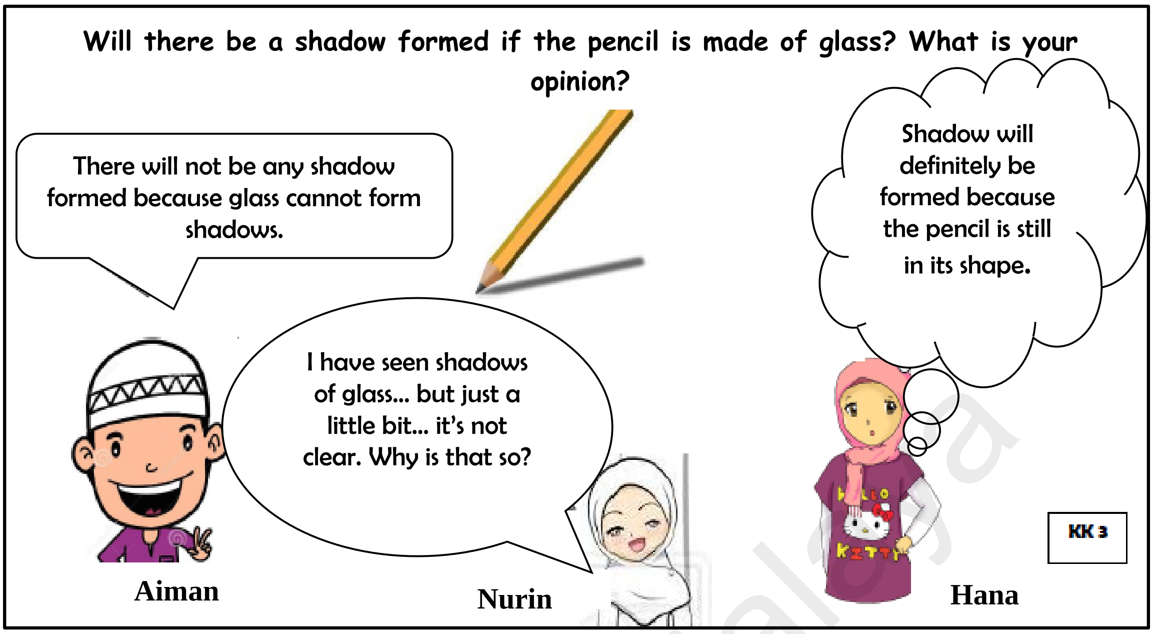


Figure 5.23. Modified concept cartoon with Asian characters and situation

The characters in Figure 5.23 are more familiar to Malaysian students with daily situations like the characteristics of pencils. Experts 2 and 3 had also commented that lesson plans in the STEPS were suitable for average level students (level in terms of academic achievement). They suggested that the lesson plans should also cater for students who are below and above average. For example, Expert 3 claimed:

> *"How about below or above average students? How to make them share their thoughts about their thinking? If you could come up with lessons for slow learners, perhaps would be very helpful for teachers..."*
>
> *Expert 3, DA*

To address this comment, the researcher decided to add features such as 'tips for teachers' in the existing lesson plans as in the STEPS. The aim was to give recommendations to teachers on how they could modify the suggested lesson plans to suit the students' level of thinking. For example, a content box offers recommendations for teachers on how they can help slow learners to make their thinking visible. Language was also one of the concerns raised by the experts. The STEPS was written in the Malay Language, as it was meant for teachers; the researcher consulted an expert (Expert 4) in the Malay Language lecturing in an international university. Expert 4 commented on the translated terms which were originally in English. She suggested to use terms such as *pemikiran mahir* (skillful thinking) and *tabiat berfikir* (habits of mind) for the Malay Language version. Thus, she had helped to verify these terms with Language Department in the university. She focused more on the terms in the Malay Language used in the STEPS rather on the content of STEPS.

The pilot study. To find out if the STEPS was feasible for teachers in Phase 2, the researcher had consulted one science teacher (Hanna – pseudonym) from the same research site to try a few lessons suggested in the STEPS. The aim of the pilot study was to countercheck the feasibility of the lessons, as one of the experts raised this issue. Hanna shared her experience on how the STEPS had helped to infuse ST into her lessons. She claimed that the STEPS was different from other teachers' guide materials she had, whereby she could actually see how explicit teaching of thinking skills can be slowly infused into content lessons. According to her, the tools such as thinking map for classifying the properties of materials, was different than the ones she was using. Extra features added to the thinking maps as questions on why they (students) classify the objects into respective groups and the design for classifying are useful cues for teachers to scaffold student's thinking.

> *"The thinking maps are different than the ones I would use normally…the questions added to the maps are very helpful…not only for the students but for me too….because there are cues for how and what questions to ask the students to think at higher level….normally would I use a table for students to classify the objects according to their properties…but this one is different…students have the freedom to classify in their own way.."*
>
> *Hanna, Pilot Study Interview*

As for the attempt at developing students' habit of asking questions and metacognitive thinking, Hanna was surprised to discover the list of questions her students had in store for her about their classification. They wrote down their questions on the *Let's Ask* list (the worksheet provided in the STEPS for students to write down questions). While Hanna was walking around inspecting the questions written on the list, a group posed a question to her. They were trying to classify scissors but had problem identifying which group it should belong to. The objects that they had earlier were made from only one material. The scissors, on the other hand, was made from two main materials; metal and plastic. Each student shared their ideas about how to classify the scissors. Thus, Hanna helped by suggesting them to look at parts-whole relationship to analyse the scissors before classifying it.

Student 1: *We don't know where to put* [classify the scissors]…*is it in metal or plastic?*
Hanna: *Why do you have a problem in classifying it? Which group does the scissors belong to? Metal or plastic group? What is your opinion?* [Whole class discussion]
Student 2: *Metal…*
Hanna: *Why do you say that?*
Student 3: *Scissors has more metal than plastic…*
Student 4: *It can belong to both groups…because it has both plastic and metal...*
Hanna: *Instead of looking at the scissors as a whole object…why don't you observe and compare the different parts of the scissors?*
Student 6: *The blade is made from metal…the holder is plastic…*
Hanna: *Ok…good…so…how can you classify it now?*

Hanna, Pilot Study, LT

The students then decided to classify the handle of scissors into 'group plastic' and the blade of scissors into 'group metal'. The lesson went on as Hanna asked the group to infer why the scissors was made from different materials. During post-lesson interview, Hanna claimed that she was unaware that, she (as the teacher) needs to teach students to perform various thinking strategies and give reasons for their classification.

> *"I didn't know that teachers are supposed to teach students how to classify using different thinking strategies and ask them to give reasons for it…"*
>
> *Hanna, Pilot Study, INT*

This shows that Hanna was now able to know about her role as a teacher in teaching students to classify. Hanna's comments were useful to fine tune the STEPS. It was found that the STEPS was feasible for teachers to implement in Phase 2.

Summary of the developing and reviewing phases

The findings for developing and reviewing of the STEPS can be summarised as:

1. The Skillful Thinking Educative Pedagogical Support (STEPS), as a pedagogical support for the teachers, consisted three design heuristics was prepared based on the findings from the groundwork phase. The three design heuristics in the STEPS were:

Design Heuristic 1:	Support teachers' knowledge of ST: Provide interpretation and understanding of ST and its relevance to Year 4 Science learning units.
Design Heuristic 2:	Support teachers' ST infusion practices: The infusion of ST into content lessons.
Design Heuristic 3:	Support teachers in managing group discussions: Provide tools to manage group discussions and stimulate students' thinking.

2. The STEPS was sent for experts to review. The experts reviewed the STEPS as:

- Suitable for novice or beginner science teachers.
- Contains helpful examples that are “friendly” to teachers.
- Well planned in detail (educative features).
- Aids teachers in learning how to infuse ST.
- Includes attractive graphics and strategic questioning techniques structured systematically for teachers to stimulate students’ thinking skills.
- Consists of lesson templates for teachers that are easy to understand and follow.

7. The experts also provided recommendations on how to improve the STEPS as follows:

- Avoid wordy and lengthy texts
- Coloured version of graphics
- Prepare the STEPS in sections for convenient use
- Lessons should cater for low academic achieving students

8. Hence, after modifications were made based on the experts reviews, the STEPS was ready for Phase 2 use.

Discussions on the preparation of the STEPS

Phase I was conducted to prepare the STEPS. The researcher started by gaining information on what the selected Year Four science teachers know of ST and their practices in infusing ST. It was found that they needed support to promote teacher-learning for infusing ST in teaching.

Within the teaching of science using inquiry, the infusion of ST to stimulate students in thinking at higher levels was found lacking among Year Four science teachers. This would hinder students from progressing to open inquiry approach, unless teachers support them with inquiry learning (Zion & Mendelovici, 2012). The present study found that there was no sound evidence to show that the selected teachers infused ST into their current practices. On the contrary, teachers have claimed that the level of their students' higher order thinking was unsatisfactory. Studies have shown that although teachers employ inquiry approach to teach science, they still lack practices in developing students' thinking skills (DiBiase & McDonald, 2015; Ku, Ho, Hau, & Lai, 2014; Madhuri, Kantamreddi, & Prakash Goteti, 2012). Therefore, infusion of ST becomes even a greater challenge. Zion and Mendelovici (2012) have asserted the need for further guidance for in-service teachers to infuse ST.

Regarding teachers' current knowledge in ST, the selected teachers did not possess adequate level of knowledge of ST nor do they have the knowledge of pedagogies to infuse ST. They could not associate specific thinking strategies, habits of mind or metacognition (ST elements) with the teaching of thinking skills in science education. As in the past studies, the selected teachers perceived ST as only for high-achieving students (Barak & Shakhman, 2008a; Rajendran, 2001; Yeung, 2015; Zohar, 2004b). Moreover, they could not verbalize the thinking strategies used in their instructions during science lessons. It was similar for the other two elements of ST; habits of mind and metacognition. They were also found more focused on science knowledge transmission than developing students' habits of mind. They could not make the connection between habits of mind and science learning nor understand the importance of developing students' habits of mind in learning science. This had led teachers to encounter difficulties not only in teaching specific thinking strategies but also in developing students' habits of mind (Burgess, 2012 Murray, 2016).

The teachers' current practices can be said to be either confirmation inquiry or structured inquiry, whereby recipe-like science activities were conducted. Hence, the inquiry approach was not at satisfactory level. Recent studies on inquiry learning also found that science lessons were found lack in inquiry practices (Al-Abdali & Al-Balushi, 2016; DiBiase & McDonald, 2015). Particularly, Al-Abdali and Al-Balushi (2016) in their study involving 22 science teachers in Oman, found that even in this era, teachers still use cook-book style science activities, rather than catering for higher levels of thinking. When inquiry in science classrooms was found unfavourable, teaching higher level thinking skills, such as ST, face much greater challenges (Zohar, 2013). For example, the teachers in this study did not teach students to compare and contrast the materials from which the objects were made of. Nor did they ask students to make inference on why these objects do or do not absorb water. They could have asked the students to compare and contrast the common features of the objects, before classifying them into different groups, so that the students would be able to justify their classifications. Therefore, it can be deduced that the selected teachers could not explicitly teach students how to analyse their observations using specific thinking strategies such as comparing and contrasting, or classifying based on common characteristics.

Many other studies have unearthed similar findings to show that science teachers, generally lack knowledge of instructions for metacognition and metacognitive experiences (Ben-David & Orion, 2013; Murray, 2014; Wilson & Bai, 2010). Coffman (2013) and Zohar (2013) have both argued that pre- service and novice in-service teachers were lacking in knowledge on teaching metacognition as part of teaching thinking. Colcott et al. (2009) has asserted that teachers should employ specific strategies to make students' thinking visible by developing their habits of mind. Beyer (2008a), on the other hand, has proposed that teachers need the knowledge of how to infuse the three elements of ST into content lessons, not as discrete, but as an integrated approach.

Another finding from the Phase 1 was the issues pertaining to ST infusion in Year Four science lessons. These teachers encounter challenges, namely, organising effective small group discussions and lack of educative resources for teachers to infuse ST. A recent study conducted by Yeung (2015) has confirmed this finding. Yeung (2015) conducted a study among Hong Kong Chinese teachers on their conceptions of teaching thinking skills. Yeung found that managing large class size, time constraint and topics to be covered in limited time frame were among the challenges encountered. Other studies have also identified these issues as among challenges encountered by teachers in fostering students' higher order thinking skills (Nair & Ngang, 2012; Yen & Siti Hajar, 2015; Zohar, 2013). Zohar (2013) acknowledged that teachers' lack of knowledge in the context of teaching specific thinking strategies and metacognition is indeed a challenge that needs to be addressed. Similarly, Yen and Siti Hajar (2015) have asserted that teachers were unsure of how to teach thinking skills.

Thus, it can be concluded that the selected teachers in this study were not only lacking knowledge in ST, but lacked knowledge on how to infuse ST. Information about the selected teachers' current knowledge of ST and their practices became the basis for the content of the proposed educative material for the teachers. Based on this finding, the researcher identified three design heuristics for the STEPS. It was aimed for teachers to adopt or modify the recommendations in the STEPS, to enable them to change from conventional to ST infused teaching practices.

Preparation of the STEPS (groundwork, developing and reviewing) was a long process, taking into account the selected teachers' knowledge and current practices. It was prepared with aims to educate the selected teachers on how to infuse ST into their existing science content lessons. Most materials for teachers to teach thinking skills were found prescriptive. In this study, however, the researcher attempted to prepare material for the teachers that suit their needs in learning to infuse ST, instead of being prescriptive. In the context of the present study, employing strategies to infuse ST among Year Four students was a new approach for the teachers. According to Schneider and Krajcik (2002), the role of educative curriculum material supports teachers' learning on new instructional practices, such as the ST infusion approach. Therefore, it was important to prepare material with features to educate teachers in infusing ST.

Experts' review has revealed that the STEPS was distinctive from the existing prescriptive teacher materials found locally. The experts agreed that the STEPS was indeed prepared to facilitate teacher-learning instead of student learning *per se*. The STEPS was not prepared to instruct teachers on what to do (recipe-like module), but to inform about the rationale behind why, what and how ST infusion can be implemented. This would leave the space for teachers to adopt and modify the recommendations suggested in the STEPS. Rationale for decisions on the importance of infusing ST in Year Four science and how to go about it are given in the STEPS. This was in line with many scholars in designing educative materials for teacher learning (Beyer & Davis, 2009; Mckenny, Voogt, Bustraan, & Smits, 2009; Schneider, 2013). These researchers have suggested that educative materials for teachers should make clear the developers' rationales for the suggested new approach.

The works of Davis et al. (2014) and Lin et al. (2012) have been resourceful to the researcher in determining the design heuristics for the STEPS. Their studies have suggested that an educative material should provide the guide for teacher thinking and allow independent decision making on how to incorporate a new or recommended strategy. It should also enhance teachers' pedagogical knowledge in terms of lesson planning, lesson enactment and group discussion management for teaching thinking skills. These were among the heuristics for designing educative materials (Arias et.al, 2017; Davis et al., 2014). This showed that educative curriculum materials should facilitate teacher-learning of a new approach in teaching. The researcher had prepared the STEPS based on the design heuristics recommended in the literature readings. Therefore the STEPS had several features to guide teacher thinking and independent decision making. Among them were the lesson plan template to provide the support in planning lessons to infuse ST. Example teacher thinking questions are '*what cues would you give to the students to involve in the thinking strategy*?' and '*what are the opportunities given for your students to think about the concept and thinking strategy that they practiced*?'

Another feature of the STEPS was the support for ST implementation guidance and information on how teachers can use them in their teaching. The four steps of infusion by Swartz et al., (2008) were informed to the teachers using another educative feature called 'fictional teacher'. Fictional teachers designed in the STEPS illustrated how each step can be enacted. It explains the challenges teachers might overlook in employing each step. These features were not textual, instead they were in the form of either illustration of classroom scenario or teacher-student dialogues. Similar features were used to clarify how a strategy can be employed in science lessons (Beyer & Davis, 2009; Davis & Krajcik, 2004). Most importantly, the STEPS has taken into consideration helping teachers understand why ST is important in teaching science, from pedagogical standpoint.

Summary

This chapter discussed Phase 1 findings. It can be inferred that the selected teachers lacked knowledge of ST and their practices showed inadequate infusion of ST. Lack of materials that caters teacher- learning in teaching thinking skills was found to be one of the most prominent issue. Thus, an educative material called the STEPS was prepared with aims to aid teachers in learning to infuse ST for the topic 'Properties of Materials'. This chapter also described how the STEPS was prepared for Phase 2 implementation. In the next chapter, findings for Phase 2 will be discussed.

CHAPTER 6

PHASE 2 FINDINGS AND DISCUSSION

Introduction

This chapter will begin with a brief introduction of the participating teachers, Suzana, Hisham and Rosni. The two main sections of this chapter explore the participating teachers' teaching practices and describe how they had infused ST. The first section describes briefly the background of the participants for Phase 2 of this study. Pseudonyms were used to represent each participant (teacher). In a later section, the researcher will describe three major findings based on the third research question:

> *Research Question 3:* How did the selected teachers' ST practices changed upon using the STEPS for the topic 'Properties of Materials'?

The participants of Phase 2. Three teachers Suzana, Hisham and Rosni participated in Phase 2 of this study, which is the implementation of the STEPS during the teaching of topic 'Properties of Materials'. What follows is a short introduction to the participants:

Suzana. Suzana was the Head of the Science Panel in her school. She had volunteered to participate in this study because she wanted to learn how to infuse ST in Year Four science lessons, since it was a new concept for her. Her students were mainly from the new urban residential areas around the school. Her class consisted of high academic achieving students. During class, Suzana had always appeared energetic. She would normally ask her students to bring a list of objects from home to do activities in the science room. She would ask many questions to probe her students' prior knowledge about science concepts. There would be replies from all directions in her class. The students were actively engaged during all her lessons.

Hisham. Hisham volunteered to participate in this study to learn about ST, since it is closely related to the teaching of HOTS. His students were average achievers in academics. They seem to enjoy Hisham's lessons. During each lesson, Hisham prepared apparatus for every science activity, including the materials and objects for the topic 'Properties of Materials', instead of requesting students to bring them from home. He appeared to be friendly with his students, as he always entertained their questions during lessons.

Rosni. Rosni was teaching low achieving students. They appeared to be passive and respond less during discussions. Therefore, initially, Rosni was reluctant to participate in this study, because she claimed that her students were passive and might not respond positively. However, she later agreed to give it a try, since ST was new for her.

Teachers' practices of ST infusion

This section will describe the selected teachers' practices upon using the STEPS. It was found that there was a change in the selected teachers' practices of ST infusion. This change can be described in two perspectives. The first perspective would be unsatisfactory practice and the second is satisfactory practice. The term 'unsatisfactory practice' means the practices of ST infusion among the teachers was at a superficial level. There were no depth in the ST infusion. On the contrary, 'satisfactory practice' refers to practices in which the teachers have shown sound infusion of ST. To describe the unsatisfactory and satisfactory practices of ST infusion, the researcher used three themes: 'teach to analyse information and ideas', 'cultivate the habit of questioning', and 'promoting metacognitive awareness'. Table 6.1 shows the three themes, corresponding categories and descriptions for each theme.

Table 6.1

Themes and Corresponding Categories that Describes Changes in ST practices Among Selected Teachers

Theme	**Categories / Subcategories**	**Description**
Teach to analyse information and ideas	1. Unsatisfactory Practices: - Probe Content Knowledge 2. Satisfactory Practices: - Gather Information and ideas - Model thinking strategies - Transfer thinking	The practices shown by the selected teachers to teach different types of thinking strategies in order to analyse information and ideas about properties of materials. Examples of thinking strategies were compare and contrast, looking at parts-whole relationship, classifying and decision making.
Cultivate the habit of questioning	1. Unsatisfactory Practices: - Low quality questions 2. Satisfactory Practices: - Encourage student questioning - Model questions - Model posing problems and solutions	Practices shown to develop students' habit asking questions about the properties of materials, giving examples of good questions and problems with corresponding solutions.
Promote metacognitive awareness	1. Unsatisfactory Practices: - Recall content knowledge 2. Satisfactory Practices: - Recall thinking - Revisit posed questions	Practices shown to promote metacognitive thinking among students, including being aware of the kind of thinking strategy that they are engaged in.

For each theme, the categories were divided into unsatisfactory and satisfactory practices. Which means, that in teaching students to analyse information and ideas about properties of materials, the teachers showed unsatisfactory practices, whereby they only probed students' knowledge about materials. This practice were generally observed at the beginning of the research but the teachers manage to develop more satisfactory practices upon using the STEPS. The teachers then extended their practices by teaching students to gather information about materials through hands-on activities and whole group discussions; thus this was called as satisfactory practice. Not only did they teach students to gather information and ideas, but they taught them to analyse information and ideas by performing different thinking strategies and taught them how to transfer the knowledge into new contexts.

Teach to analyse information and ideas. Teaching students how to analyse information and ideas about properties of materials would mean to explicitly teach them to perform various thinking strategies. These thinking strategies include comparing, contrasting, looking at parts-whole relationships, predicting, giving reasons and justifying selection of materials for designs of objects. Therefore, this section will look at how Hisham, Rosni and Suzana infused the teaching of these thinking strategies into the topic of 'Properties of Materials'.

Unsatisfactory practice in teaching to analyse information and ideas. In teaching students to analyse information and ideas, Hisham, Suzana, and Rosni spent most time in probing students' prior knowledge about materials. This does not mean that probing information and teaching to gather information are not good practices of ST infusion. But it means that the teachers have spent considerable amount of time on asking what students know about materials (content knowledge) leaving limited time for teaching how to analyse their knowledge about materials.

During the first week of the topic 'Properties of Materials', Hisham, Suzana and Rosni started their lessons by instructing their students to identify objects, the materials they were made from and the resource of materials. By doing this, they actually probed students' prior knowledge about objects and materials. In the introductory lesson, they asked their students to refer to textbooks to get an overview about the topic. Then they asked a series of questions to retrieve what the students have read from the textbooks. At this stage, students shared what they already know about objects and the materials they were made from. The first topic was about various objects, the materials they were made from and the sources of materials used to make the objects. There are four types of sources of materials students should learn about; plants, animals, rocks (natural resources) and petroleum (man-made resource). Suzana started her lesson by asking students about what they know about materials and their sources.

> *Suzana: What is the source of material?* [Teacher showed a book and asked a student to stand up to answer her question]
> *Student: From plants*
> *Suzana: What's the second source of material?*
> *Students: Animals*
> .
> .
> .
> .
> . *Lesson continued* ……..*Line 16 to 92.*

The lesson went on with such questions (from Line 16-92), to ask what the students know about objects, materials and sources of materials. Suzana spent most of her time during the one hour lesson asking students a series of generic questions such as '*what is the source of this object?', 'what is the source of this material?',* and '*what is the third source of material?'*

Suzana's questions were mainly aimed at asking what her students already know about objects and materials. This was similar with both Hisham and Rosni's first lesson. Hisham probed if his students knew where plastic comes from and if it is man-made or natural source. However, when students' answers were wrong, he did not probe further as to why they answered incorrectly. For example, in the following interaction, a student had answered that the source of plastic is metal, but Hisham ignored the student's answer and moved on asking other students until he obtained the right answer.

> *Hisham: Okay, plastic and what is the source of plastic?*
> *Student A: Metal*…[Hisham just kept quiet and continued on with his lesson]
> *Hisham: Others? Is it natural or man-made?*
> *Students: Man made*
>
> *H, L8, LT1*

Hisham also spent most of the lesson on asking students what they know about various objects, the materials they were made from and the sources of materials. Rosni also kept probing on what students know about different common objects, such as a purse. But her questions focused on various parts of the purse and the material they were made from.

> *Rosni: This is a purse that women normally use. Okay? But, what is found on the purse*? [Showing the exterior of the purse]
> *Students: Leather*
> *Rosni: Okay, the material is leather, this one is* [Showing other parts of the purse] *iron…what is source of iron?*
> *Students: Metal…rock* [source of metal]
>
> *R, L12, LT1*
>
> *Rosni spent about 35 minutes on asking what students know about different objects.*
>
> *R, L7, FN1*

With more time spent on asking about students' content knowledge, Suzana, Hisham and Rosni could not provide the space for students to carefully analyse the similarities and differences among the materials. Thus, their students failed to make sense of their observations (gathered information about materials). For example, teachers did not explicitly teach students how to compare and contrast before they classify the objects into their respective materials and sources. Nor did they teach them to make generalisations that objects namely furniture, wooden ruler, pencils, paper, tissues and cork are made from wood, which comes from plants (source of wood). At this level, although teachers probed students' content knowledge by asking questions yet they did not teach students to use specific thinking strategies such as compare, contrast, classify or make inferences to analyse information and ideas about materials and their sources. After a few lessons, however, several changes were found in teachers' practices, which can be regarded as satisfactory practices.

Satisfactory practices in teaching to analyse information and ideas. The teachers showed satisfactory practices such as gather information and ideas, model thinking strategies and transfer thinking when teaching students how to analyse information and ideas about properties of materials.

Gather information and ideas. Teach to gather information and ideas refers to teachers explicitly making it clear to students that they are gathering information and ideas about objects and materials during small group discussions. This process was assisted by the use of worksheets to record students' observations (during scientific investigations) or shared ideas among peers. In probing students' content knowledge, teachers mainly carried out whole group discussions and their students would shout out their responses or answers. On the other hand, in teaching to gather information and ideas, teachers encouraged students to write down what they observe about materials and their properties with the help of worksheets.

During a lesson on classifying objects, students were required to classify objects based on common features. They needed to observe given objects, look for similarities and differences in order to group the objects based on the common materials they were made from. Suzana's students struggled to classify the objects. Noticing this, she took two different books and asked her students to compare them.

When Suzana asked how they would classify the two books, the students remained silent. She then asked what they observe about the two books. Only a few said that the textbook is thick, yet they could not compare it to the exercise book. Suzana then showed the exercise book and asked what they observed.

> *Suzana: What does classify mean?* [Silence]*...For example, exercise book and textbook….how would you classify them?* [Again silence]*...what can you observe?*
> *Students: The textbook is thick*
> *Suzana: And??? How about this one?* [The exercise book]
>
> *S, L112, LT2*

They could identify the parameters or attributes to compare among the two books until a few more students compared the difference among the books respective to their sizes. Picking up on this response, Suzana explained that the two books can be put in separate groups based on observed attribute / parameter.

> *Students: This is small* [the exercise book] *and big* [showing the textbook]
> *Suzana: Two things that are different can be grouped according to size…small and big….but when you look* [at] *them together, what is same about them?*
>
> *S, L15, LT2*

Next she moved on helping them to look for similarities among the books. She uttered the word 'common feature' and asked for its meaning. Most of the students answered that common features are similar attributes. Suzana again asked what was similar about the two books. The students answered 'trees', pointing to the material of origin for both books.

> *Suzana: I want you to classify them according to common feature…who knows what common feature means?*
> *Students:Same*…[with doubts]…*what is same about them….similar..*
> *Suzana: Like the science note book and the text book, what is similar about them?*
> *Students: Trees…plants..*
>
> *S, L116, LT2*

The students could not independently compare and contrast the books. However, with some cues from Suzana, they finally were able to look for differences and similarities among the books. By this, Suzana had taught students to gather more information and ideas using their observing skills about objects and their materials. When students look for similarities and differences among objects or materials, they gather more information and ideas about them. It is essential to teach how to gather information and ideas about materials before the students could analyse them. Similarly, Rosni showed a chair and asked her students to share what they observe about the chair with reference to the material it is made of and the source of the identified material. The students matched each object to its material and then to its respective resource. They listed as many objects as they could and wrote them into a certain sequence which reads - 'object-material-source'.

> *Students:* [Reading aloud together]….*Objects - wooden chair – source is plants*
> *Students: Objects – wooden ruler – source- plants*
>
> *R, L123, LT 2*

During small group discussions, the students shared what they knew about objects, materials and sources of materials. Once the students could relate objects to the materials and the sources of materials, the teachers then helped students to group the objects according to the materials they were made from or to the source of materials. For example, Hisham was teaching how to group the objects based on the materials and sources of materials. His students were seated in different groups to discuss the activity. Hisham then encouraged students to justify their classifications by asking them to reason out why they classified bottles and marbles into the same group. The students answered that both bottles and marbles are made from the same material which is glass.

Hisham: Why glass bottles and marbles are put together in the same group?
Students: They are made from the same material…which is 'glass'.

H, L112, LT2

Then he called out another group of students and asked about their classification of different materials put together under the same source of material. Group 5 classified rubber bands, balloons, wooden splinters and rulers into a group called 'Plants'. Other groups have classified these objects separately; rubber bands and balloon into rubber and wooden splinter and ruler into wood. However, noticing that only Group 5 had classified these objects differently, but logically, Hisham picked up their classification to initiate discussion with the whole class. While showing the classification made by Group 5, Hisham asked:

Hisham: Is it correct? Anybody classified differently? Why are all these objects put into the same group? What is the material?
Students: [Various answers] *Wrong…wood for wooden splinter and ruler…balloon…to rubber…rubber bands...to rubber..*

Trying to calm down students' reaction, Hisham asked Group 5 to give reasons as to why they classified these objects into the same group. One student from Group 5 answered that they were made from the same material. Another student, however said that balloons, rubber bands and wooden splinters are from the same source of material.

Student 1 from Group 5: Same material
Student 2 from Group 5: all three are made from plants
Hisham: Yes…good…both materials….rubber and wood originate from plants? Right? [He looked around the whole class]
Students: Yes…

H, L118, LT2

Here, Hisham took the opportunity to show students that objects made from different materials can still be further grouped in different ways, in this case, it was grouping objects made from materials that comes from the same source. When Hisham used the terms such as '*any corrections?* and *'(is it) right or wrong?,* students shared more information and ideas during group discussions. They were encouraged to reason out their classifications. They were also able to identify wrong classifications and corrected them. Thus, Hisham, Rosni and Suzana provided verbal cues to enable their students to gather more information and ideas about materials/sources by justifying, correcting and matching objects to their respective materials/sources. This is the initial stage for analysing information and ideas about materials.

Model thinking strategies. Though Suzana, Hisham, and Rosni probed students' prior knowledge and taught them to gather information and ideas about properties of materials, what was more significant was how they teach students to analyse the information to make sense of them. Here teachers modelled and made students practice different thinking strategies such as compare-contrast, look at parts-whole relationships, look at possibilities, justify selection of materials, make inference, classify, predict, make operational definitions and make generalisations to analyse the properties of materials. Modelling thinking strategies means to introduce a thinking strategy and provide cues on how to perform it. This was done by teachers naming the specific thinking strategies and then giving examples on how to perform them.

In one of the units under the topic 'Properties of Materials', the students were required to design an object that serves a purpose and justify their selection of materials used for their designs. Here, teachers modelled students on how to make decision in selecting suitable materials and to justify their selection. They had utilized the concept cartoons and graphic organizers provided in the STEPS.

Rosni started her lesson by showing a concept cartoon that has two characters, named Ayu and Siti, each with contradicting views about a pot (Figure 6.1).

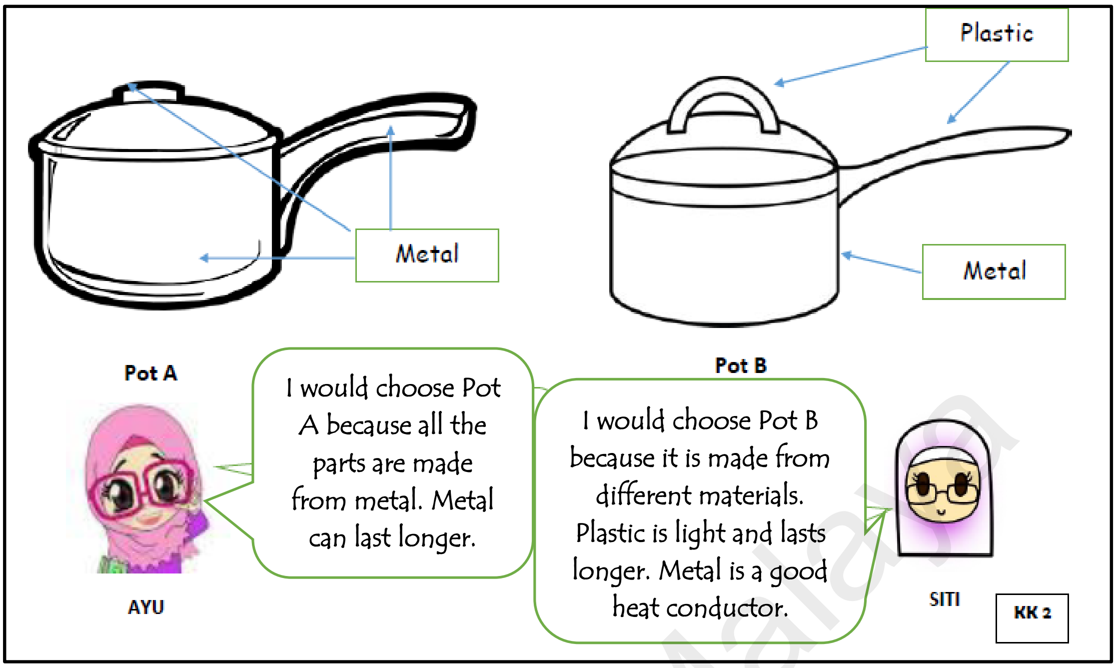


Figure 6.1. Concept Cartoon used by Rosni.

Ayu and Siti chose different pots made from different materials and justified their selection. One pot was made from all metal (pot A) and the other from a combination of metal and hard plastic (pot B). When Rosni handed over the worksheet (concept cartoon), the students were excited to see the cartoons. The students were divided into groups named after the planets of the Solar System. Rosni gave each group a few minutes to scan the concept cartoon before she started to explain it. She asserted that her students need to think about whose (Ayu or Siti) choice they agree with and provide reasons that justify their choice based on the materials the pot was made from. Students however, remained silent when asked to give inference for their choice of pot. Rosni then provided more cues for students to think about what inference means.

> *Rosni: Okay, whose choice is wiser?* [Referring to the concept cartoon] *Give inference for your choice* [Class was silent]
> *Rosni: What is an inference...we have learnt how to give inference in our previous topic right? Choose an answer...Pot A or B..Give me inference as to why you choose Pot A or Pot B.*
>
> *R, L49, LT5*

When the groups remained silent, Rosni called out *Group Neptune* which was seated in front of the classroom. The group chose Pot B and so Rosni asked their reason choosing Pot B. Group Neptune answered that Pot B would last longer. This reply was similar to the inferences given by previous groups. Therefore, Rosni did not probe further and moved on asking *Group Earth* to explain their choice of pot. Since *Group Earth* gave the same answer – 'last longer', she probed further to see if *Group Earth* can come up with better explanations for choice of pot. They said that Pot B is made from different materials. Rosni probed further to ask why they said that the materials were different.

> *Group Neptune: Pot B*
> *Rosni: Why did you choose Pot B?*
> *Group Neptune: Lasts longer*
> *Rosni: You chose it because it last longer? Okay, this group has also chosen Pot B because it lasts* longer [in a louder tone for whole class to listen]..*Group Earth, what did you choose?*
> *Group Earth: Pot B*
> *Rosni: Why?*
> *Group Earth: Because it's made of different materials*
> *Rosni: Why do you say that* [different materials]?
>
> *R, L51, LT5*

Group Earth replied that the materials used to make Pot B were plastic and iron. Not satisfied with this response, Rosni further gave cues to them to relate the mentioned materials to their specific properties. By asking students to relate materials to their properties, Rosni had given them the chance to analyse this information (different materials and respective properties). Thus the students were able to justify their selection of Pot B by making inferences that the pot would last longer because it was made from iron which is a good heat conducting material.

> *Rosni: Group Earth has chosen Pot B. The different materials are plastic and iron…so can you give your inference? Why did you choose Pot B?*
> *Group Earth: Good heat conductor*
> *Rosni: Good heat conductor? Which one? The plastic or the iron?*
> *One student from Group Earth: Plastic* [Low tone]
> *Rosni: Plastic?*

Other students from Group Earth: No...It's iron! [Corrected the student]
…The lesson went on

R, L57, LT5

Here, Rosni perhaps noticed that most of the groups had selected Pot B, so she asked them to come up with different reasons by looking at other possible properties of the pots. She continued modelling how to perform parts-whole relationship, another thinking strategy to look at different parts of the pots and relate these to their function as a whole. The students were able to analyse the different parts of the pots and provided alternative reasons for their selection. Upon this, Rosni then asked *Group Mercury* to share about their choice of pot. She again affirmed that they need to provide alternative reasons. *Group Mercury* compared pot A and B. Rosni read aloud their reason (written by the students), '*'because if I choose Pot A and touch the holder then I would feel hot'. Group Mercury* had compared the holders of both pots made from different materials (plastic – heat insulator) and iron (heat conductor).

Rosni: Okay…How about this group? Pot A or B? [Rosni pointed to Group Mercury]
Group Mercury: Pot B
Rosni: Ooo…Pot B too...why? I do not want replies that are already given…and Pot B is not fully covered with plastic only. Your reason to choose Pot B? [Rosni reads Edison's answer]*…'because if I choose Pot A and touch the holder then I would feel hot'*
Rosni: Give a big hand for Edison. [Class clapped]
Rosni: Very good inference…this is an example of inference that supports why choose Pot B, not just because you liked the pot since it was made of different materials. That is inaccurate.

R, L63, LT5

Rosni acknowledged the well thought reason (inference) given by Edison. The phrase 'very good inference' by Rosni shows that she helped students to identify an example of good inferences. She asserted that they should think about logical reasons and not simply make a choice based on variety of materials used to make the pot.

Instead they should give reasons based on the rationale behind the choice of materials. This was how Rosni had modelled how to perform making inferences and justifications in as part of teaching them how to analyse information and ideas.

Rosni then continued by asking if there were any groups who had chosen Pot A instead. *Group Mars* responded immediately that they chose Pot A and instantly provided their justifications without waiting for Rosni to ask them to do so.

Group Mars: Pot A because it will not burn easily…

A student from *Group Mars* grabbed the worksheet (concept cartoon) and read:

Student from Group Mars: I choose Pot A because it does not burn easily…and not Pot B because it has plastic and can burn easily…
Rosni: okay thank you, good…because there is no right or wrong answer here…

Rosni stated that there are no right or wrong answers when choosing the pots and before she could continue, *Group Neptune* interrupted and claimed:

Group Neptune: There's a holder on the lid… so it's easy..
Rosni: Why?
Group Neptune: Not hot...because this is plastic and it is a heat insulator..
Rosni: This inference is most accurate. Because he said that plastic is not hot and he also said that plastic is a heat insulator. Heat insulating objects do not conduct heat, so heat from the metal pot can't travel through the holder, so I can hold it. As for Pot A, we might feel hot when we hold the holder. Isn't it?
Students: Yes...

R, L67, LT5

Hearing this, Rosni then acknowledged the response. Again, Rosni made a clear point that the students have the freedom to choose a suitable pot as long as they could provide logical justifications for their choice. She also encouraged them that they need to be firm with their decisions because there are no right or wrong answers. Other groups mentioned different properties of the materials for both pots – plastic holder on the lid of pot which does not feel hot, easy to hold and light. But only this group managed to justify the use of plastic holder to its exact property – heat insulator. It seemed that Rosni focused more on justifications of the choice more than the choice of pot itself.

Before ending the session, Rosni asked if her students are now satisfied with their decisions and justifications. She asked '*Are you satisfied?*' Rosni stimulated her students to think further as to why they were given two choices, instead of just one. The students were able to rationalise the reasons for two choices, so that they would need to think before deciding the right choice.

> *Rosni: There are objects made of metal and other materials. But why are we given a choice to choose?*
> *Students: So that we make the right choice*
>
> *R, L87, LT5*

Rosni had actually modelled them how to perform thinking strategies such as parts-whole relationships, make inferences and justifications before they could make the right decision in selecting the pots. Several students could relate the choice of pot to their own needs. Picking up on this reply, Rosni went on explaining how to make decisions in choosing the pots, relating them to their properties and one's own needs.

> *Rosni: What else? Why are there two choices? If the pot made from a combination of metal and other materials is the best, then why there are pots made from only metal are also for sale?*
> *Students*: [After long silence] *Maybe they want us to choose what we need..*
> *Students: Maybe the pot made from only metal [Pot A], can last longer* [Cross talk – various answers from different groups]
> *Rosni: Yes…we need to choose the pot that suits our need. Maybe we would want to buy long lasting pot to save money…but we need to use a cloth to hold the pot...because its hot....so we buy Pot A…or maybe we would not want to use cloth so we buy Pot B because it has plastic holder which is a heat insulating material.*
>
> *R, L89, LT5*

In the lesson cited, Rosni provided prompts to model how to compare and contrast objects, make decisions, justify, look at parts-whole relationships (different parts of the pot) and look for other possibilities when choosing the pots. She was trying to explain that the students must consider an array of choices for materials and relate them to what they actually need. For example, if they need a pot that lasts longer, then they should opt for a pot made from metal only rather than combination of other materials. Another point that Rosni was trying to make was that justifying a choice may not necessarily be about choosing the right pot, but can be for matching customers' needs. Here, Rosni made them analyse the options of pot before making decisions in choosing the right one. She provided room for them to carefully compare information and ideas about the properties of materials found in the pots. The students were able to analyse gathered information and ideas to make decisions, which is a complex thinking task.

Like Rosni, Suzana was able to help students analyse gathered information and ideas by modelling various specific thinking strategies and by taking the effort to explain the rationale of performing different thinking strategies. In a lesson on classifying water absorbent and water proof materials, she provided cues for students to identify the rationale of being able to analyse such materials.

Suzana: *Why is it important to classify objects into water absorbent and water proof objects?*
Students: *If it is water absorbent, it will help us…..*[to absorb water]
Suzana: *Okay, will help us. If it is water proof, how does it help us?*
Students: *It will not penetrate if filled with water.*
Suzana: *Okay, good, so what do we do with such materials?*
Students: *We can store food in them.*

S, L63, LT3

In the interaction, Suzana was trying to engage her students to think about the importance of classifying objects or materials based on their properties. Students could share views that objects with different functions are made of suitable materials to serve the functions. Suzana had given cues for students to make sense of materials by analysing their classifications. The students were able to state that by knowing which material is waterproof or absorbent, they would be able to use it for the right purpose.

In a different lesson, Suzana's students have designed objects as a solution for a chosen problem. Suzana requested every group to present their designs and justify their selection for their choice of materials. One group designed the prototype of a house with a bright bulb in it called the 'Lamp House' that has a lighted lamp, useful when there is an electric power disruption. As the group presented their design, they explained about the materials. During the presentation, other groups asked questions. Picking up on those questions, Suzana created an opportunity for students to practice learnt thinking strategies. For example, she provided prompts for students to look at parts-whole relationship of the designed house, justify selection of material, predicting and looking for possible ways to improve the design. In the following interaction, the students were able to practice various thinking strategies guided by Suzana's prompts. Practising learnt thinking strategies is part of learning how to analyse information and ideas, until these practices become autonomous among students.

Suzana:	*Okay, look here, down here…what was used?* [Pointing at a certain part of the design and asked students to identify the material it was made from]	← Looking at parts-whole relationship
Student 1:	*Paper…That's why it could even float..*	← Inferring / Justify
Student 2:	*Why didn't you use wood?*	
Student 1:	*But if we use wood, then it would sink..*	
Suzana:	*But, if we play at wet area, since this is made of paper, what would you think will happen, if it hits the water?*	← Predicting
Students:	*It would get wet.*	← Inferring / Justify
Suzana:	*Why?*	
Students:	*Because it absorbs water*	

Suzana: *What happens to this house then?* [Showing the design made by the group]
Students: *Wet*
Suzana: *Okay, any suggestions?* [Inviting ideas to improve the design] ← Looking at other possibilities

Student 3: *Replace it with water proof material like cardboard* [The student was showing a plastic board on the wall]

S, L133, LT8

Upon introducing and modelling thinking strategies, the teachers spent a good amount of time in providing prompts for students to practice them. Another way for modelling and encouraging students to practice thinking shown by the teachers, was by picking up questions (posed by students) and using them to set the stage for group discussions. By doing so, the teachers have created more opportunities for students to practice their thinking. While teaching students to compare and contrast materials that can absorb water and their uses, Hisham's students posed several questions. A group called, *Group 3* asked if a pencil can absorb water. Pencil was not among the list of objects that the students had tested. So, Hisham encouraged the group to test if a pencil absorbs water by putting the pencil in a beaker filled with water. Then he asked them to describe their observation. The group did the simple experiment and claimed that the pencil got wet when put into the water.

Hisham: Group 3 asked a question [Hisham then reads the question posed by Group 3]*…'Can a pencil absorb water or not?" ….Okay, put the pencil into the water, hold it…on top...what can you observe?*
Students: wet
Hisham: So, can it absorb water?
Students: Can

H, L35, LT3

It was apparent that the students misunderstood the concept of materials that absorb water. The pencil was only covered with water droplets and was not soaked in water. Yet, it seemed that the students concluded that the pencil can absorb water based on the water droplets found on the surface of the pencil. Taking this situation as a small opportunity to rectify students' misconception of an object being coated with water and being able to absorb water, Hisham decided to clarify their misconception about the pencil. He then took a wooden pencil and asked the students to analyse the difference between the concepts of 'absorb' and 'wet on surface'. He put both the wooden ruler and the pencil into water. The ruler changed colour, becoming slightly darker, because it absorbed the water, whereas the pencil- although it has water droplets on the surface - did not change its colour. Hisham stimulated his students to give comparisons and think of reasons as to why the ruler absorbed water but the pencil did not although it appeared 'wet' as well.

Hisham: What's the difference between the pencil and the ruler? Both are made from wood.
Students: has cover [Pointing at the pencil]
Hisham: He says pencil has cover..[Sharing the students' response with other students]
Students: It is covered with layer....water proof..
Hisham: Yes because it is covered with a water proof layer right? How about this? [Showing the ruler]
Students: No… *H, L68, LT3*

This interaction may show that Hisham took questions from students and invited others to share their thoughts about the problem (if a pencil absorbs water). In helping his students seek for explanations to their questions, he made them practice learnt thinking strategies (compare and contrast) to learn more about the ideas of objects made from same materials but with different abilities in absorbing water. For example, the ruler made from wood alone could absorb water and when coated with waterproof material, it does not absorb water. His prompt has led the students to conclude that objects made from similar materials can change their properties when mixed with another material.

Hisham then reads another question, this time the question was from Group 4 which reads '*Why use waterproof objects*?' Using this question from Group 4, Hisham initiated a short discussion with other students. Hisham explained a scenario of choosing between a plastic or paper container to store chicken soup. It was clear that the students were able to identify plastic container as the suitable object to keep the soup. By asking why they had chosen plastic instead of paper, his students were able to make sense of the use of waterproof materials in daily life activities.

> *Hisham: Okay, I will give you a situation. Let's say, my mother cooked chicken soup and she said 'Firdaus, today I want you to bring this chicken soup for lunch to school. In your opinion, which bag would be suitable for me to bring the chicken soup to school?*
> *Students: Plastic….Paper...*[Crosstalk]
> *Students: It won't absorb water…*
> *Students: Plastic* [Some students argued]
> *Hisham : Why plastic?*
> *Students: Because it does not absorb water*
>
> *H, L97, LT3*

In the preceding situation, Hisham recognized opportunities from the questions raised by his students, to apply and transfer learnt thinking strategies into new situations. He made them decide on a suitable container to store food and made them justify their choice. Questions as such have steered fellow students to transfer thinking strategies such as to compare, justify and give reasons about materials and their properties.

During another lesson on investigating materials that allow light to pass through (materials transparent to light), Hisham made his students practice the learnt thinking strategies. This time, his students carried out investigations on different materials and classified them into transparent, translucent and opaque materials.

Hisham: *Okay now I want you to take out a 50 cent coin, one person please hold the coin and another hold a torchlight and place the coin near the torchlight and move the plastic bottle further away and now what do you see?* ← Making observations
Students: *Shadow*
Hisham: *ok what differentiates the plastic bottle and the coin?* ← Compare and contrast
Students: *the coin had shadow*
Hisham: *why does the coin form a shadow?* ← Justify / reasoning
Students: *because it is an object.*
Hisham: *What object? What is the difference between the coin and the plastic bottle?* ← Compare and contrast
Students: *bottle is transparent, the coin is opaque.*

Using the same example, Hisham created space for students to test objects made of a combination of different materials, and asked them to predict what would happen. Based on their knowledge about transparent, translucent and opaque materials, the students predicted that there will be no shadow formed if any of these materials were arranged in a straight line.

Hisham: Now, do you think you can see the shadow?
Students: no…can't see...no cannot [crosstalk]
Hisham: Why? What's the difference?
Students: opaque and light
Hisham: Which one?
Students: Book is opaque…plastic is transparent…
Hisham: So, can light pass through if you mix opaque object with translucent or transparent..?
Students: No…

H, L80, LT5

To find out if the students had predicted correctly, Hisham blocked the torchlight with a book and asked them to describe their observation. In the cited excerpt, students could predict that if an opaque object is arranged with non-opaque objects, light would not be able to pass through. This way, Hisham identified situations in which students could practice compare and contrast in making predictions. They had performed these thinking strategies to analyse the given situation.

This process of modelling different thinking strategies (comparing and contrasting, decision making, inference, and justifications) focused on cues to stimulate students to think instead of teachers providing the right answers. Teachers not only modelled different thinking strategies but provided opportunities for students to practice the learnt thinking strategies.

Transfer thinking. Apart from teaching to gather information and ideas about properties of materials, modelling how to perform thinking strategies to analyse the information and ideas, the teachers had also taught students to transfer the learnt skill. They teach to transfer learnt thinking strategies using real-life situations whereby students apply their thinking to different contexts. During a lesson on classifying given objects, Hisham asked how his students would classify objects found at home. He made them apply what they did when they compared and contrasted objects before classifying them into respective groups.

> *Hisham: Okay class. You have to remember that not only in our classroom, but also at home, we have various kinds of objects made from different resource of materials. How can we differentiate them? What did you do just now?*
> *Students: Divide into groups*
> *Hisham: How?*
> *Students: Look at similar material*
>
> *H, L126, LT2*

The lesson carried on with students classifying objects found at home based on their materials and sources of materials. During this activity, Hisham had stimulated students to transfer the skill of looking for similarities and differences before grouping objects into categories such as similar materials or similar sources of materials. In another lesson, this time on predicting heat conducting and insulating objects, Hisham pointed at a nearby fence which was placed around a small compound under shade. He then asked his students to predict what would happen to the fence if it is put under the hot Sun. His students replied that the fence would become hot. Upon hearing this, he continued by asking why did they say so (justify). The students related their prediction to the material the fence was made from, which was iron. Unsatisfied, Hisham uttered the word '*so*?' for the students to further explain their reason for saying 'iron'. Then students were able to relate the material (iron) to its ability to conduct heat.

> *Hisham: What if…I put this fence outside under the Sun?*
> *Students: It will become hot..*
> *Hisham: Why what happened? Why does it become hot?*
> *Students: Because it's iron..*
> *Hisham: So?*
> *Students: Mmm*….[Sound made while students looked at each other]*...it conducts heat..?*
>
> *H, L117, LT4*

Similarly, Suzana had encouraged students to apply learnt thinking strategies. She explicitly asked her students to name other topics where they can apply the skill of classifying after a lesson on classifying waterproof and water absorbent materials. The students were able to identify a few topics such as classifying animals and plants based on their physical properties. She then, explained that classifying is an important skill and that if they know the categories (or parameters), they would be able to classify.

Suzana:	*What other topics can we use classifying? Grouping and separating?*
Students:	*Animals..*
Suzana:	*Give an example….how do you classify animals?*
Students:	*hard skin…has furs* [Crosstalk]
Suzana:	*What else?*
Students:	*Plants..*
Suzana:	*How?*
Students:	*Flowering plants, fruits…rough leaves…smooth leaves…types of stem*…[Various answers – crosstalk]

S, L184, LT2

The students were able to give other examples of topics in which they could transfer the skill of classifying. Another lesson was about testing for materials that would conduct heat, grouping and classifying them into heat conductor or insulators. In an earlier session, they had already learnt how to classify materials that conduct electricity. This time Suzana prompted students to apply the same thinking strategies for classifying materials that conduct heat. Once the students had completed the task, Suzana continued with group discussions on how to analyse information and ideas about electrical and heat conducting materials. She asked the students to carefully look at their data (table for recording their observations during hands-on activities) and identify materials that showed similar ability.

Suzana: Okay, so today we learnt about heat conductors and insulators and also electrical conductors and insulators. Look carefully, and tell me…are the materials the same for both? What materials that conduct electric also conduct heat?
Students: metal
Suzana: or?
Students: Iron
Suzana: So, metal and iron are heat and electrical conductors? What is a conductor?
Students: That allows heat and electric to pass through

S, L48, LT5

Suzana provided cues for her students to analyse the information that they had gathered through hands-on activities on heat conductors and electricity conductors. They looked for materials that could conduct both; thus found that iron and metal conduct electricity and heat. By asking the students to apply how to analyse information, Suzana made her students generalize objects that have more than one property.

In teaching students to transfer the skill of analysing information and ideas, Suzana also used thinking maps from the STEPS. She used the thinking map for a lesson whereby students needed to discuss in groups on how to design an object to solve a problem. To help them apply learnt thinking strategies on how to analyse information and ideas about materials, they were given the thinking map as shown in Figure 6.2 (translated into English Language).

Name of Designed Object:					
Functions of the Designed Object (*Used for what?):*					
Parts of object (What are the functions of each)	Materials used to make each part (Choose the suitable material)	Inference in choosing the materials (Why did I choose this material to make this part?)	What would happen if this part is not in the object?	What other materials can I use to replace this material?	Did I make the right choice?

Figure 6.2. Thinking map used by Suzana.

It consisted of several columns and rows for students to write down what they think. Each column has a written cue for students to think about. In the first column students need to apply parts-whole relationship strategy to carefully lay out the functions of the parts involved in their designed objects. Next they need to decide and select the suitable material(s) that suit(s) the purpose of that part of the design. In column three, they need to justify their selection of material and in column four they need to predict what would what if the named part is missing to ensure that this part is essential to function as a whole object. Later, the students looked at other alternative or possibilities of materials for the same design. And finally decide if their selection of material for every part involved in their design is appropriate. Therefore, in performing this task, students had to apply thinking strategies that had learnt in previous lessons to analyse their knowledge about materials and design an object. Figure 6.3 shows the same thinking map (in the Malay Language) completed by Suzana's students.

Peta Pemikiran Untuk Membuat Pilihan Bahan Reka cipta Objek

Nama Objek Ciptaan: Pengorek menggunakan botol

Fungsi Objek Ciptaan (*Digunakan untuk apa?*): memudahkan kerja

Bahagian pada objek (*Apakah fungsi setiap bahagian?*)	Bahan yang digunakan untuk membuat setiap bahagian (*Pilih bahan yang sesuai*)	Inferens pemilihan bahan (*Kenapa saya pilih bahan ini untuk membuat bahagian ini?*)	Apakah yang akan berlaku jika bahagian ini tiada dalam objek ini?	Apakah bahan lain yang boleh saya guna untuk gantikan bahan ini?	Adakah pilihan saya tepat?
menyimpan barang di bawah botol	botol plastik	kerana ia tidak basah jika terkena hujan	bahan tidak lengkap	bekas plastik	ya
menampung habuk pensil	tapak botol	kerana ia tidak boleh tembus	habuk pensil bertaburan	penutop botol potato chip	ya
mengasah pensil	pengorek	kerana ia mudah mengasah pensil	tidak boleh mengasah pensil	pisau	ya

Figure 6.3. Thinking map completed by students.

As shown in Figure 6.3, the students have written down thoughts about their design, by applying what they have learnt in analysing information. Rosni, on the other hand, started her lesson by directly explaining what each column in Figure 6.3 means and what they need to do.

> *Rosni: To justify your selection means to give reasons for selecting the material, give logical explanation, why I choose this material for designing this model. Why didn't I select other materials such as wood or metal….why must I choose plastic…or your own arguments…means your own explanations…for making decisions..okay? I hope you still remember the concept cartoon…the one you chose the pots? You justified your choice right? You related them to properties of materials...isn't it "*
>
> *R, L14, LT6*

She related the term give reasons, justify, make decisions and arguments as cues to show that the students need to transfer these learnt thinking strategies into this task. She even asked her students to recall how they had justified and reasoned their choice of pot in a previous lesson, and apply them to the current task.

Therefore, in teaching students to analyse information and ideas about properties of materials, teachers have taught them to gather information and ideas, modelled thinking strategies to analyse the information and teach to transfer the strategies into new contexts.

Cultivate the habit of questioning. Developing students' habit of questioning and problem posing was a new venture for Suzana, Hisham and Rosni. This was because, during Phase 1 data collection, most of the teachers claimed that they never had encouraged their students to ask questions in class, simply because of their belief that passive or less responsive students are unable to ask good questions. In Phase 2, during the first few lessons, similar practice was observed. When the students could not come up with good questions, the teachers did not take efforts to help students improve their questioning skills. This was an unsatisfactory practice for developing students' habit in questioning and posing questions. This practice, however, had changed whereby teachers made attempts to encourage students to ask questions in later lessons.

Unsatisfactory practices in cultivating the habit of questioning. Unsatisfactory practices in cultivating students' habit of questioning and problem posing, refer to teachers' inability to rectify students' way of asking questions. In the beginning the students posed low quality questions. The teachers provided the *Let's Ask* list throughout the lessons for students to write down questions, yet students could not ask good questions or at least questions that indicate higher levels such as analysis level. Moreover, in the beginning, teachers spent almost the entire lesson asking more questions to probe students' content knowledge. It can be said that the teachers did most of the questioning rather than the students. Because of this, the students asked low quality questions to retrieve basic information about materials. It seemed that they have written down questions due to their teachers' instructions to do so. They imitate questions posed by their teachers to retrieve information about materials and their sources. Even so they could only write down one or two questions on the *Let's Ask* list. Among the questions asked by the students were:

- *What is the material to make marble?*
- *What is glass made from?*

An example of the *Lets' Ask* list written by a group of students is shown in Figure 6.4.

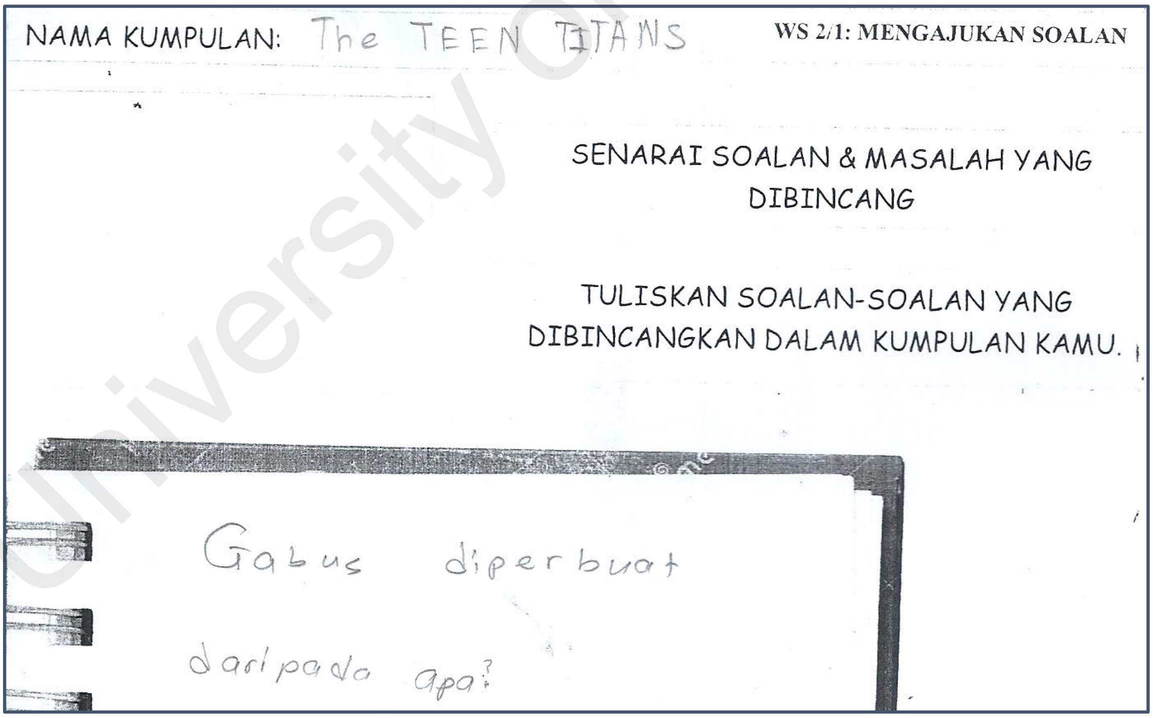


Figure 6.4 Sample of low quality question written by a group.

The translated version of the question written by the Group as shown in Figure 6.4 (*Gabus diperbuat daripada apa?*) reads as 'What is cork made of?' Even when the students were carrying out activities, they asked low quality questions such as:

Student A: What is hanger made of?
Student B: From plastic
Student C: Bottle…made of what?
Student D: Plastic *H, L31, LT1*

The teachers distributed the *Let's Ask list* for students (provided in the STEPS), but did not maximise the use of the list. The students came up with similar basic questions and the teachers would choose a few questions to answer. However, even that response was only between the teacher and the student or group that asked the question. For example, Hisham picked one or two similar questions and discussed with the respective group.

Teacher then discusses students' questions list (Let's Ask List). Teacher picked only one question to be discussed. Most questions by students were subject related (direct factual information).
H, L20, FN 1

Upon probing Hisham's perceptions on the low quality questions posed by his students, he acknowledged that now his students have started to ask subject related questions. This was because his students previously would only ask non-subject related questions like '*Do I need to copy this*?', '*Which page in the textbook*?' or '*Can I write on this page*?' Such questions were instruction related because the students were more focused on understanding teachers' instructions rather than consciously thinking of what to ask about the topic under discussion. In some situations other students do not respond to questions posed by their peers, mainly because the students asked factual questions and did not write down those questions in the *Let's Ask* list. It was apparent in Suzana and Rosni's classes, whereby students did not discuss the questions they wrote in the *Let's Ask* list, but left it unattended because they do not understand what to do with it.

> *"Students seem to 'treat' the Let's* Ask *list as a typical worksheet, because they keep asking their peers on what they were supposed to do with it. Students do ask a lot of questions mostly factual, however unattended by their peers. Questions were not discussed as a group but left unattended"*
>
> *S, L11, FN2*

Thus during the first few lessons, the students could not come up with good questions. Their questions were mainly on retrieving basic information, such as '*what is glass made of*?' or '*where does rubber come from*?' In addition, the teachers were unaware of students' difficulties in asking questions. They spent most of the time asking questions to probe students' content knowledge leaving the questions posed by the students unattended.

Satisfactory practices in cultivating the habit of questioning. While the first few lessons consisted of sessions where teachers questioned students, the subsequent lessons were found relatively the opposite. Hisham, Suzana and Rosni have started to encourage their students to ask questions to develop the habit of questioning and problem posing among students. This include *encourage student questioning*, *model questions* and *model posing problems and solutions*. These practices perhaps show satisfactory level in cultivating the habit of questioning among students.

Encourage student questioning. As an attempt to cultivate the habit of questioning and problem posing among students, Hisham, Suzana and Rosni tried to encourage students to ask questions and pose problems. They focused more on the questions listed by the students in the *Let's Ask* list. They started their lessons by allocating some time for students to list down questions on the *Let's Ask* list. Rosni had always read the questions asked by the students half way through her lesson, and then discussed the questions. Hisham and Suzana, on the other hand, saved the questions until the end of their lessons before discussing them. Meanwhile, they would run through the questions and choose the best ones they think suitable for whole classroom discussions.

Initially, the teachers would answer questions personally. For example, if a student from a particular group asked questions, the teachers would entertain the student by providing the answers directly. It was a closed conversation between the teacher and the questioner. Soon, Hisham, Rosni and Suzana started to encourage students to ask questions by reminding them to write down any questions they wanted to ask in the *Let's Ask* list. Soon, after several sessions, the teachers have noticed that their students ask more subject related questions.

> *Hisham: I notice my students' questions were all on the subject matter* [not the common questions they would normally ask].
>
> *H, L87, INT*

It seemed that from Hisham's point of view, there is a progress in the way and type of questions posed by the students. Similarly, Rosni and Suzana distributed the *Let's Ask* list and made sure that the students write down their questions.

> *She kept reminding them to think of questions. In the midst of activity, she distributed the "Let's Ask" list for students to write down any questions and problems they wish to solve related to the topic.*
>
> *S, L23, FN3*

The teachers responded to students' questions individually. They picked up a few questions and explained the answer only to the respective student or group which posed the question. But Rosni had a slightly different approach. She wrote the questions on the board and chose a few to discuss with the respective students or group.

> *Teacher gives 5 minutes for students to list down the questions about their observation. Teacher collects the questions and initiate discussion among students. Teacher plays* [role] *as a facilitator accepting all questions, writing them on the board before giving her own response.*
>
> *R, L36, FN3*

Rosni, Suzana and Hisham encouraged their students to pose questions and problems using the *Let's Ask* list provided in the STEPS. The teachers started to appreciate students' questions, which perhaps encouraged them to pose more questions. Yet, only a few students could come up with higher order thinking questions, such as 'what if', 'why not' or 'how'. Therefore, the teachers started to model good questions.

Model questions. Apart from encouraging students to ask questions, the teachers also modelled students on how to ask questions and explained the importance of asking questions. To model asking questions means to show examples of good questions, provide the rationale of asking questions and acknowledge good questions so that other students would be able to recognise good questions. The teachers had to make students understand what good questions are and clarify ambiguous and unclear questions. During a lesson on investigating materials that allow light to pass through, Hisham asked a group of students (*Group 6*) to read out their question. He had noticed an unclear question. Hisham sought clarification for the ambiguous question posed by the group.

Group 6: Why does the plastic bottle light up?
Hisham: Ok Group 6…that plastic bottle lighted up or …what does that mean?
Group 6: Because it lighted up when shined with light…
Hisham: So you question is..'why does the plastic bottle lit up when shined with light?
Group 6: Yes..

H, L83, LT5

Hisham clarified and rephrased the question posed by *Group 6*. In general, the students' command of the Malay Language (even as native language), was at unsatisfactory level, therefore they often have difficulties in constructing written questions to deliver what they actually meant. Thus, Hisham had to seek clarifications on what they actually wanted to ask by rephrasing their questions. Hisham had always encouraged his students to ask questions and seek answers by discussing with their peers in groups.

He also provided cues for students to think about the importance of asking questions. The students claimed that by asking questions they would be able to understand better and to determine if the question is right or clear. This was perhaps because they had noticed Hisham clarifying the question from *Group 6*. Unconvinced, Hisham gave more cues for students to reflect about their habit of questioning.

> *Hisham:* *okay what is the purpose of asking questions?*
> *Students:* *to understand and determine*....[By gathering more information]
> *Hisham:* *Hmm…okay in your group just now did you ask your peers questions? Usually if we don't know we need to ask and discuss. For example why we can see light when we use plastic bottle and why we could see the object…..in this situation can you ask yourselves- Is it important*….[To ask questions]? [Expecting students to complete his sentence]
> *Students:* *questioning* [responded to teacher]
> *Hisham:* *if we don't know?*
> *Students:* *ask questions*
>
> *H, L91, LT5*

Hisham explained that his students need to learn how to ask questions. He gave several examples of good questions such as '*why can we see light when we use plastic bottle*?' and '*why we could see the object*?' He also emphasised that if they do not know, they need to ask questions and rationalised why asking questions might help them better understand the topic.

> *Hisham:* *Okay, in class when you do science activities, you need to always ask questions. If you don't ask, you wouldn't be able to understand. Ask your friend, how he got this observation?...for example…*
>
> *H, L97, LT5*

The students responded to his explanation by sharing their ideas about the answers for the questions. They could respond that if they do not know or want to know something, they need to ask questions, especially when conducting science activities. It was not an easy task for Hisham, Suzana and Rosni to reach this point.

Especially, Rosni, who persisted in teaching her students to learn how to ask questions. This included differentiating good questions from simple questions, such as asking 'why, what if and how'. However, her students still could not pose questions. Yet, Rosni tried harder. This time, she wrote a few specific examples on the blackboard during a lesson on classifying materials. She also gave some examples of questions students could ask. She spent quite some time for her students to grasp what she wanted them to understand. She even went around inspecting the list of questions her students came up with and commented on how to improve them.

> *"Ask questions like…why it is not made of wood but plastic…or why it is different (material) for scissors…this is how you ask questions"*
>
> *R, L44, LT3*

> *'Rosni walked around the class glancing through students' written questions. She helped them to write their questions better – mostly on spelling and context'*
>
> *R, L34, FN 4*

Rosni also acknowledged and appreciated students' questions by saying '*It's a good question'* and '*this question will make you think out of the box'*.

> *Rosni: This question is from Group Earth that will make you think out of the box. The question is…why the tube of the stethoscope is made from rubber?..Okay..Group Earth, can you show the stethoscope and the tube that you have mentioned?*
>
> *R, L51, LT3*

Rosni not only acknowledged the good question but she clarified the question to show others what a group called *Group Earth* actually meant. *Group Earth* posed a question about the rubber tube found on stethoscopes. She asked the group to show which part of the stethoscope they meant. The lesson went with Rosni asking other students to infer why the tube of the stethoscope was made from rubber. Rosni again complimented the questioner from *Group Neptune* for asking why a pen was not made from wood.

> *Rosni: This is another good question – Why isn't pen made from wood? Mmmm…like a pencil made from wood?* [Looking at *Group Neptune* for clarification]
>
> *R, L65, LT3*

Suzana, on the other hand, overlooked the *Let's Ask* list prepared by her students in the beginning. She claimed that she often forgot to provide the *Let's Ask* activity sheet to her students. Even if she distributed it, she did not discuss the questions posed by students. Soon, after a few lessons, Suzana mentioned that she went through the questions and realized that her students had so much on their minds to ask. Hence, during subsequent sessions, Suzana started to pay attention to her students' questions. Since her students were naturally active in communicating, therefore, when given the space to ask questions, they made full use of the opportunity. They began to pose more questions because Suzana had started to acknowledge their questions by discussing them with the whole class. Figure 6.5 shows the list of questions posed by a group of students in Suzana's class.

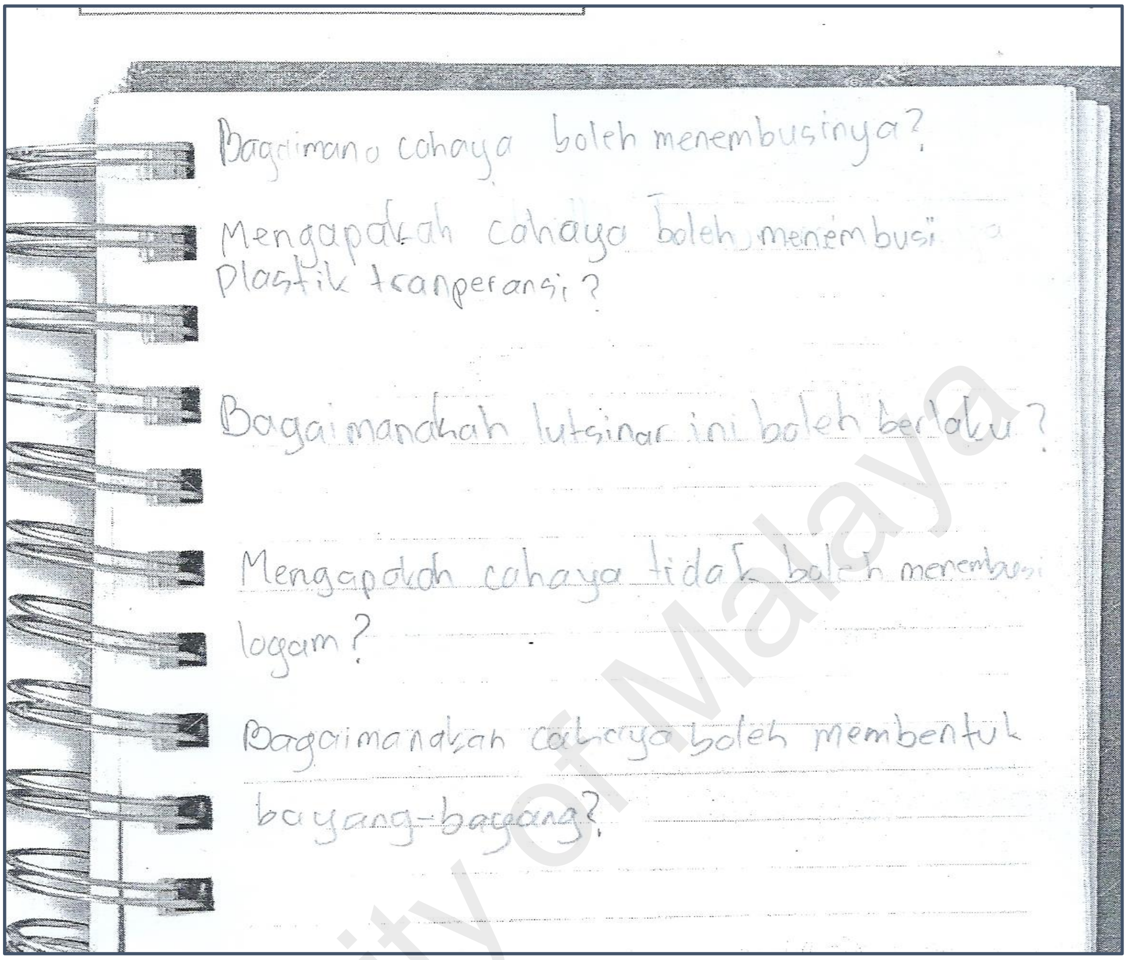


Figure 6.5. Questions posed by a group in Suzana's class.

The questions written in the *Let's Ask* list as shown in Figure 6.5 was in the Malay Language. The English version of the questions are as follows:

- *How does light penetrate it?*
- *Why does light pass through the transparent plastic?*
- *How does 'transparent' happen?*
- *Why doesn't light pass through metal?*
- *How does light form shadows?*

These questions show that the students were able to pose good questions that would open chances for other students to further investigate about the formation of light and shadow.

Apart from modelling how to ask questions, teachers also had modelled students on how to pose problems and solutions.

Model posing problems and solutions. Teachers encourage students to ask questions, and when realising that the questions were of low quality, they modelled how to ask good questions. With such practices, the students were able to pose questions that would initiate science investigations, such as the questions in Figure 6.5. Initially, when students were unable to ask good questions, the teachers had modelled how to ask good questions. When they were able to pose good questions, Suzana, Rosni and Hisham appreciated those questions. Given such compliments, students were perhaps more confident in asking questions. Posing problems to set the stage for scientific investigations, however, was far more challenging for the students. One of the lessons required students to identify a problem, design an object to solve the problem and justify their selection for the choice of materials used for their designs. Teachers spent sufficient time on teaching students to perform decision making skills in deciding on the objects to design for an identified problem. Therefore, teachers had to model posing problems and solutions. Suzana started her lesson by explicitly teaching them how to recognise a problem, understand the problem and devise solutions to solve it. She first described a problem. Suzana took a box and explained that she could not see the content of the box, since the lid was opaque. Therefore, it was a problem for her to know what is inside the box without opening the lid.

> *Suzana: My problem is….I have too many identical boxes. When I need to keep my things, I had to open each box to see what's in the boxes. I arranged the boxes for stationery, papers, coloured pencils, so I have problem to open one by one to put my things. This is my problem.*
>
> *S, L67, LT7*

She explained why the mentioned problem is an actual problem worth solving. Next, after explaining the problem she moved on asking students to suggest solutions for her problem.

> *Suzana: What is your suggestion to know what's inside each box without having to open it?*
> *Students: Make a hole..*
> *Suzana: Make a hole? Can….but how to see what's inside the box? Any other suggestions?*
>
> *S, L67, LT7*

The lesson went on by students giving suggestions on how to solve the problem. Some suggested to use a transparent lid, a glass and even make a hole. When a student suggested to use transparent plastic as the lid for the box, Suzana asked if doing so would solve her problem. This is a cue for students to examine if their suggested solution solves the problem. Another student agreed with this suggestion and added that the plastic is transparent and it would be easy to identify things in the box by just looking through the top. Again another student suggested different solution – a glass container. She responded to every suggested solution from her students without being judgmental.

> *Suzana: Arh…he suggested to put a transparent plastic cover… so did I solve my problem? How to see the things inside?*
> *Students: Just look from the top…Its transparent*
> *Students: use a glass..* *S, L70, LT7*

Both suggestions, the glass and plastic, are transparent which would allow Suzana to see the interior of her box. Since both are transparent, Suzana mentioned a different parameter for students to compare for the best choice. She stated that glass might be heavy and difficult to carry around. She provided cues for students to think about which object would be the most suitable one. At the end, she asked if they would be able to decide on objects to solve a problem by analyzing the objects based on their properties of materials.

Suzana: But…mmm…so we need to decide if we should use glass or plastic….glass maybe heavy and difficult to carry aroundright? Plastic? [Asking how plastic is different from glass]
Students: Light
Suzana: If you have a problem like me, can you do how we did today?
Students: yes..

S, L72, LT7

After providing the box analogy, only then did Suzana delegate the task for the day. The task requires students need to use their acquired knowledge about properties of materials and select suitable materials for their design, relating it to the function of their designed object. The conversation cited shows how Suzana modelled posing problem and solutions. She explicitly described what a problem and possible solutions would be like. Suzana made her students identify a problem, and consider available options for solutions by analysing their suggestions. Before she delegated the task, she asked students to recall the example problem she had explained before.

Suzana: So your task today is to identify a problem to solve and think of solutions. for example, what was the problem I was trying to address just now?
Students: Difficult to find things in stacked closed box.
Suzana: Arrghh…yes...difficult to find things in a box, so what were my options?

S, L74, LT7

On the contrary, students in Rosni's and Hisham's classes had two issues. Firstly, most of the students could not identify problems worth solving. Secondly, some students, on the contrary, could identify good problems to solve, but came up with imaginary solutions. Hence, Rosni and Hisham had to put extra effort in modelling how to identify problems that were worth solving and suitable solutions. They helped students to identify problems worth solving by asking them to think about the need to design an object. Hisham's students decided to design a wall clock, so he asked if there is a need to design a wall clock.

Hisham: *What are you designing?*
Students: *A clock*
Hisham: *A clock? You have to decide if there is a need to design a clock.*

H, L35, LT6

Hearing Hisham's response, the students quickly changed their decision. They wanted to design a bus instead. Again Hisham asked why the need to design a bus, which is an object already existing. It seemed that it is a problem when buses do not send them straight to the classroom.

Students: *I think we better change our mind, we want to make a bus* [a boy represented the group, the rest of the group members nodded in agreement]
Hisham: *Why bus? There are many buses around right?*
Students: *Yes, there are many buses around but they can't come here* [pointing the classroom].
Hisham: *Why do you want to design a bus that comes here? What is the purpose? You have to think of a problem that you can solve by designing something, like problems at home…like to help your mother cut onions without tearing. .*

H, L42, LT6

Hisham provided cues for students to think about the purpose of solving a problem, design something else other than what was already existing, such as the bus and clock. He gave an example problem – eye irritation when chopping onions and design an object to prevent from eye watering. Another group suddenly interrupted and mentioned that they would like to design an air balloon. Hisham again commented on their suggestion of design.

Hisham: *Air balloons are common, try to think of something different (new). For example, you want to go to a shoe store and choose a size, but you can't choose the size you wanted because it is difficult to see what's inside, so if we put a plastic…transparent plastic, we would then be able to see the shoe inside…*

H, L46, LT6

Hisham provided another example, explaining the problem and possible solutions relating it to objects and their properties of materials. His students could not identify problems that demand possible solutions or even to recognise a problem worth solving. However, Hisham did not give up on trying to make his students identify such problems. Hence, he walked around helping out his students, modelling problems worth solving. Another group decided to design a school shoe. The proposed design of the shoe was typical to existing store bought shoes. They could explain the reason for designing the shoe. Hisham then put forth a problem and asked the students to think if their proposed design is worth building. He then suggested solutions to make the design worth making for. The students showed a gesture that may indicate that they understood what Hisham was trying to explain.

Hisham:	*If your shoes get wet in the rain? So think of an object that you can use to protect your shoes from getting wet in the rain. For example, a protective layer made of* plastic [to protect from rain]*, which can be removed when it's not raining. Like your school shoes, why don't you design something to cover your shoes in the rain?*
Students:	*Owh*…[a gesture perhaps to show that they now understood what they were supposed to do]
Hisham:	*So now, can you see?* [Asking if they understood the task]
Students:	*Yes…*
Students:	*So can we design another object for that?*
Hisham:	*Sure, no problem at all. That was just an example.*

H, L81, LT 6

On the other hand, Rosni's students tend to come up with imaginative solutions instead of real solutions, like a flying car or miniature volcano. They could not differentiate everyday life simple tasks or problems that can be solved creatively. Hence, Rosni walked around the class, helping out groups to think of daily life tasks and identify how they can improve an existing device(s) to create new object. A group had planned to design a broom to help housewives to clean their house. However, they drew a device – broom that could fly, claiming that cleaning would be faster. They seemed confused with no idea that they actually need to build the designed object within a week and present it in class. Seeing this, Rosni attempted to help the group to identify problems worth solving. Instead of the flying broom, Rosni suggested more realistic solution for the design. She recommended them to combine the broom with other familiar cleaning tools to create a new device.

> *Rosni: You can use things at home, for example, like your friend here wants to help his mother at home to clean house, so think of a device that can be used..*
> *Student A: Broom..*
> *Rosni: Okay, using that broom and other things at home, how can you help your mother to clean the house? A broom is one of it…others?*
> *Student B: Feather duster?*
> *Rosni: Okay, now think if you want to combine the broom and feather duster or how you want to do it.*
>
> *R, L63, LT5*

Although this group of students could identify a simple problem – cleaning the house, however they needed cues to think about real solutions or designs that would serve the purpose. In the interaction cited, Rosni modelled how to convert imaginary solution (flying broom) into logical and applicable solution (devising cleaning tool for multitasking). In this particular lesson, posing problems and seeking solutions are much related. This was because students needed to identify a problem, design an object to solve the problem and justify their selection of materials for their designs. When students pose problems, they need to seek possible yet creative solutions, therefore by modelling posing problems, teachers implicitly modelled how to come up with suitable solutions. Once the students were ready with their proposed design, the teachers moved on by helping students to make decisions on the selection of materials for their designs.

And because the teachers had helped students to identify solvable problems and possible solutions, they were able to build models of their design and justify their selection. A group of students, named as *Group 3* designed and built a model of boat that multitasked such as to collect plastic bottles and containers in rivers. They claimed that rivers are being polluted with plastic bottles and containers (identified problem). As a solution to this issue, they designed the boat to clean dirty and polluted rivers. Once the presenter from *Group 3* finished with explaining about their boat, Hisham encouraged other students to ask questions. A student from another group noticed a small part of the box that was made from pieces of a box. He asked *Group 3* as to why they used a box and predicted that it would get wet. A representative from the presenting group suggested to use water proof material (masking tape) as a solution to rectify that problem.

Hisham: *Does anyone wants to ask questions?*
Student: *Why did you use a box for the front part, if you put in water, it will get wet right?*
Hisham: *Okay, let me rephrase the question. Why did you use a box?...How do you answer that?*
Group 3: *If don't want it to get wet, we can put masking tape on it.*
Hisham: *Okay, what is the property of the masking tape?*
Group 3: *Water proof..*

H, L29, LT7

Group 3 was able to identify a good problem (polluted rivers) and design possible solution (boat) to solve the identified problem. However, they wrongly selected pieces of a box for a small part of the boat. Other students were able to detect the wrong choice of selecting water absorbent material even for a small part of the boat. The student also put forth issues that may arise due to the wrong choice of material. Similarly, the presenting group was able to correct their decision (selection of material) and suggested how they would improve their design by applying waterproof material to prevent the part of boat from being soaked in water. Other groups have come up with designs such as follows:

Group 1 - A cleaning boat similar to Group 3 with better selection of materials
Group 2- Model of a battery operated heater to dry wet school shoes during rainy seasons.

Group 4- A pencil case made from box with different sizes of compartments to store large stationery items in one container.

Group 5- Miniature robot model that can hide small items that often go missing / misplaced at home

Group 6- A pencil case made from plastic bottle to store stationery in one container.

Hisham did not miss the opportunity to ask students to compare two alike designs (*Group 1* and *Group 3*). Since Group 3 had presented earlier, Hisham asked Group 1 to make comparison between the two designs.

Hisham: *This is similar to Group 3 right? Before I ask questions, does anyone wants to ask first?*

Students: *Why isn't your boat exactly the same with Zaiey (Group 3 has a student named Zaiey)* [*Group 1* remained silent, so Hisham helped to rephrase the question]

Hisham: *How is your design different from Group 3? Both are boats right?*

Group 1: *This one can pick up things* [Group 3 designed a boat that scoops things]

Hisham: *Apart from using a box (covered with plastic layer), what else can you use?*

Group 1: *Polystyrene container..*

Hisham: *Why? What's similar about them?*

Group 1: *Both are light and waterproof..*

H, L103, LT7

When Hisham asked Group 1 to compare their design with Group 3, he actually had stimulated students to review their choice of material relative to another design. This way, Hisham had provided cues to model how to compare solutions in choosing the most suitable solution for a similar problem. He might have also stimulated them to compare different ways in solving the same problem, for example, Group 3 designed a bowl-like structure to scoop things. On the other hand, Group 1 designed a crane-like structure to pick up things. Group 1 could also suggest alternative material (polystyrene instead of plastic) that would serve the same purpose – waterproof and light. With these cues, Hisham has modelled posing problems and solutions as part of effort in cultivating the habit of questioning among students. Therefore, in cultivating this habit, the teachers have encouraged students to ask questions, modelled how to ask good questions and how to 'pose problems and solutions'.

Promote metacognitive awareness. Unlike the other two ST elements- teaching thinking strategies and developing students' habit of questioning and problem posing, promoting metacognitive thinking was found to be more challenging to the teachers. The term promoting metacognitive awareness in the context of this study refers to how teachers promote students to be aware of their own thinking. This was carried out by introducing students to reflect upon their thinking and learning. In the beginning, the teachers were only able to make students recall facts about the topic they have learnt (content knowledge). However after several lessons, they were able to promote students to recall the kind of thinking strategy they had performed and revisit their questions as part of reflection upon one's own thinking.

Unsatisfactory practice in promoting metacognitive awareness. Most of the time, the teachers would give cues for students to reflect their knowledge about properties of materials, that they had newly learnt. This was to recall content knowledge. It was more of retrieving new information and ideas about properties learnt for the day. Teachers attempt to promote students to think at metacognitive level often at the end of lessons. Even so, they tend to focus more on students' content knowledge understanding rather than on the way their students think. And they mainly provide cues for students to revisit what they had newly learnt. But they did not provide the space and time for students to think about how they came to know what they know now. This was because the teachers tend to give cues such as;

Is there anything that you still don't understand about this topic?
Can you tell me what have you learnt today?

Suzana's lessons

What have you learnt today?
So, today you have learnt metals or irons are both electric and heat conductors, right?
Can you name the properties of materials that we've learnt?

Rosni's lessons

Ask yourself 'Have I understood today's lesson?'
What did you learn today?

Hisham's lessons

Such cues mainly resort to promote reflective thinking. These cues were helpful for students to recall glimpses of new knowledge about properties of materials. The teachers made the students revisit their learning outcomes, reflect upon what they have learnt, and how they grade their learning experiences. However, such process was not extended to think about how the students think or how they had performed a certain thinking strategy. For example, Suzana provided cues for students to recall content knowledge (properties of materials), instead of focusing on promoting awareness among students on how they think.

> *Teacher asks students to recall what they've learnt about materials and the sources they were made from as wrap up activity.*
>
> *S, L17, FN1*

> *At the end of class, teacher asked students to reflect upon what they had learnt about materials that can absorb water, with extra questions on the importance of the materials that can absorb water and those that are waterproof.*
>
> *S, L12, FN2*

Hisham asked what the students had learnt for the day. And they simply answered 'waterproof' or 'water absorbent'. Even so, Hisham did not ask the students to describe how they had compared waterproof or water absorbent materials.

> *Hisham: Before you go out, what did you learn today?*
> *Students: Waterproof or water absorbent*
> *Hsham: Okay, class is dismissed. You may go out.*
>
> *H, L122, LT3*

Rosni on the other had distributed the reflection log provided in the STEPS. The reflection log is a simple worksheet with emojis and a few questions, such as '*Can I name the kind of thinking I used today to classify materials?* Students rate their thinking by marking the best emoji that represent their response. A sad looking emoji was used to express 'I do not know' and a happy emoji was used for 'I know'. At the end of the worksheet, was a column for students to write out any problems they had encountered throughout the lesson. The students wrote down questions and problems that were subject related. A student called Edison wrote a few questions at the end of the reflection log. He could have written the questions in the *Let's Ask* list instead.

> *Rosni: Okay…Edison asked* [reading what was written in reflection log]*…"Why did light cloth sink?*
> *Students: Because it absorbed water* [so it become heavy and sank]
> *Rosni: Okay…smart….yes….because it absorbs water….okay…why does coin sink?*
>
> *R, L120, LT3*

Although Rosni had used the reflection log for her students to share their problems in learning, she did not show sound activities for metacognition. Instead, she carried out this session similar to the *Let's Ask* activity. She chose a few questions and discussed them with the rest of the students. She did not focus on students' thinking process but more on content knowledge acquisition. Rosni could have clearly described the purpose of the reflection log to her students, or on how they could use the cues in the worksheet to represent how they think during lessons. For example, what were the steps taken to classify the cloth or on how they could improve the way they perform thinking strategies to analyse information and ideas.

Satisfactory practices in promoting metacognitive awareness. At the initial stage, the teachers asked students to recall what they actually had learnt for the day, which was more on content knowledge. Eventually, they started to put more effort to encourage students to recall thinking by naming and describing how they performed a thinking strategy to analyse properties of materials.

Recall thinking. As time progressed, teachers focused on teaching students to identify the specific thinking strategies they were using. Suzana, Hisham and Rosni would ask their students to name the thinking they were learning. Then, they asked the students to describe the steps taken to perform a specific thinking strategy by asking them to explain how they classified a group of objects. In one of the lessons, Suzana asked students to state the meaning of classification.

Suzana: *What does to classify mean?*
Students: ……..[No response from students]
Suzana: *okay…why did you classify these objects into this group?* [Showing the worksheet the students had used to classify the objects]
Students: …..[After a while]*….we don't know…*

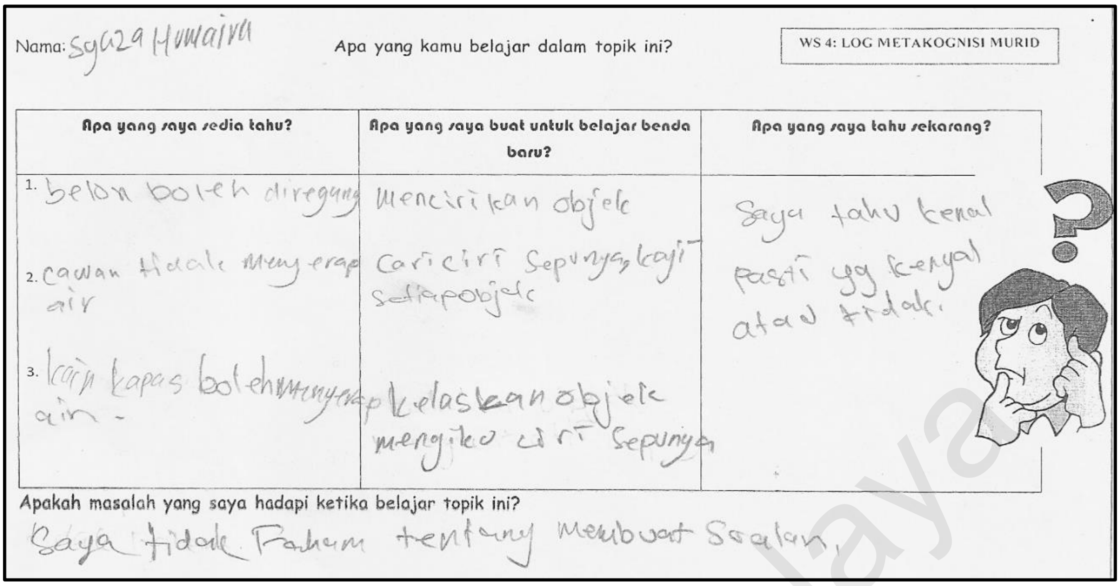
S, L133, LT2

When Suzana noticed that her students had difficulties in describing how they perform classifying, she explained what classifying means.

'To classify means to group objects based on similar traits'

S, L139, LT2

Few students, however were able to write about what they have learnt. The following Figure 6.6 shows another reflection log completed by one of the students in Suzana's class. The student has written what she already knew about properties of different objects such as balloons, cups and cotton clothes in the first column of the reflection log. And in the second column, she wrote what she did to learn new knowledge namely attributing, looking for common features and classifying objects based on identified common features.



Nama: Syaza Humaira

Apa yang kamu belajar dalam topik ini?

WS 4: LOG METAKOGNISI MURID

Apa yang saya sedia tahu?	Apa yang saya buat untuk belajar benda baru?	Apa yang saya tahu sekarang?
1. belon boleh diregang	Mencirikan objek	Saya tahu kenal pasti yg kenyal atau tidak.
2. cawan tidak menyerap air	Cari ciri sepunya, kaji setiap objek	
3. kain kapas boleh menyerap air.	kelaskan objek mengikut ciri sepunya	

Apakah masalah yang saya hadapi ketika belajar topik ini?

Saya tidak faham tentang membuat soalan.

Figure 6.6. An example of reflection log by a student.

In the third column, she has written that she knows to identify elastic and non-elastic objects. At the end of the reflection log, the student has written that she does not know how to formulate (or pose) questions. Suzana used this reflection log as a thinking map to promote students to think about how they performed specific thinking strategies.

Similarly, Rosni did attempt to promote students to be aware of their thinking. Rosni encouraged her students to recall how they had performed classifying by asking them what they understood about the term ‘classifying’. She kept using the term ‘anything else?’ to invite more response from students without commenting on their replies.

Teacher:	*What is meant by classifying? Who can tell me what classifying means?*
Students:	*Arrange by category*
Teacher:	*Anything else?*
Students:	*separate (objects) according to its characteristics.*
Teacher:	*Anything else?*
Students:	*Put (objects) in specific place (groups)*
Teacher:	*Put them according to what?*
Students:	*At the right place (groups)..*

Teacher: *Okay, we have three different answers...What to do before we classify?*

R, L130, LT1

In the foregoing interaction, Rosni tried to promote students to recall the steps taken when they performed a specific kind of thinking strategy-classifying using the same reflection log as shown in Figure 6.6. But the students could not clearly explain how they classify objects. In subsequent lessons, Rosni repeated the same activity. Realising that her students were still unable to write out their learning experiences and the way they think about the topic under discussion, Rosni had switched to a simpler reflection log provided in the STEPS. Figure 6.7 shows another example of reflection log, recommended for students who could have difficulties in writing down their thoughts.

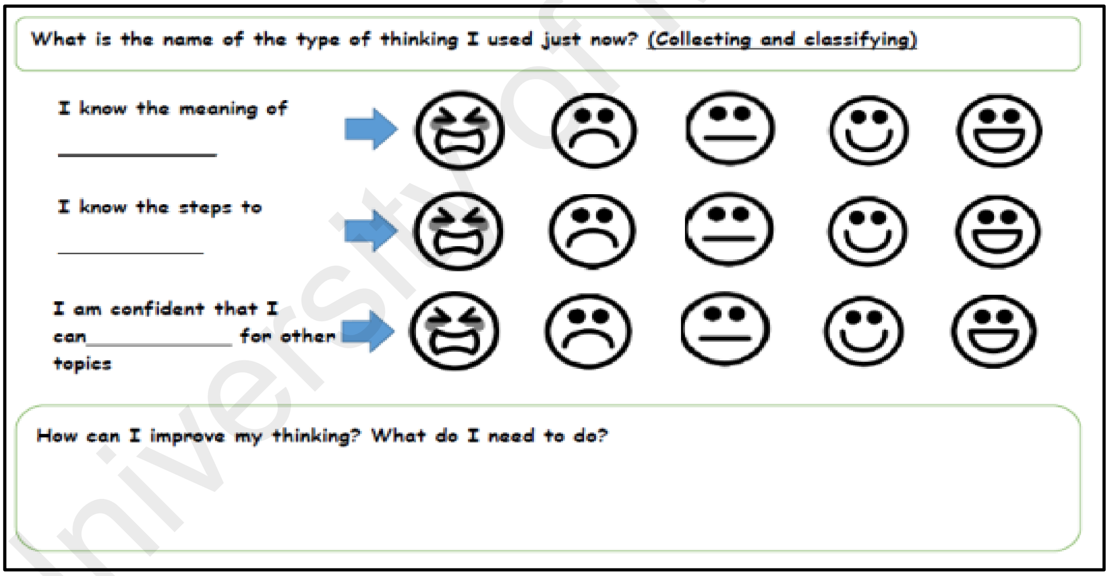


Figure 6.7. *Another metacognitive log used by Rosni.*

In the reflection log shown in Figure 6.7, students rate their knowledge about the thinking strategies they had performed. Students rate themselves to see if they were able to name the thinking strategy, to explain the steps taken to perform the thinking strategy and to express their feelings, if they have the confidence to apply the thinking strategy in other topics. The thinking map shown in Figure 6.7 is much simpler compared to the former (Figure 6.6). The former thinking map requires students to explain in writing about their thinking. On the other hand, students who have difficulties in writing about their thoughts used the simpler reflection log. Figure 6.8 shows how a student in Rosni's class rated his thinking.

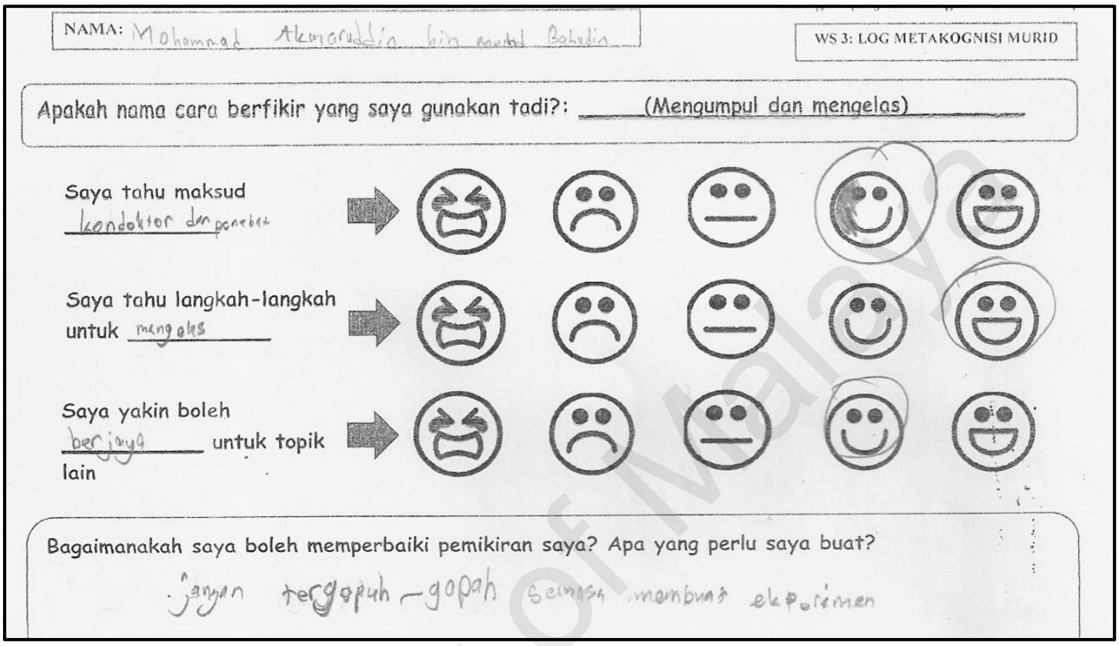
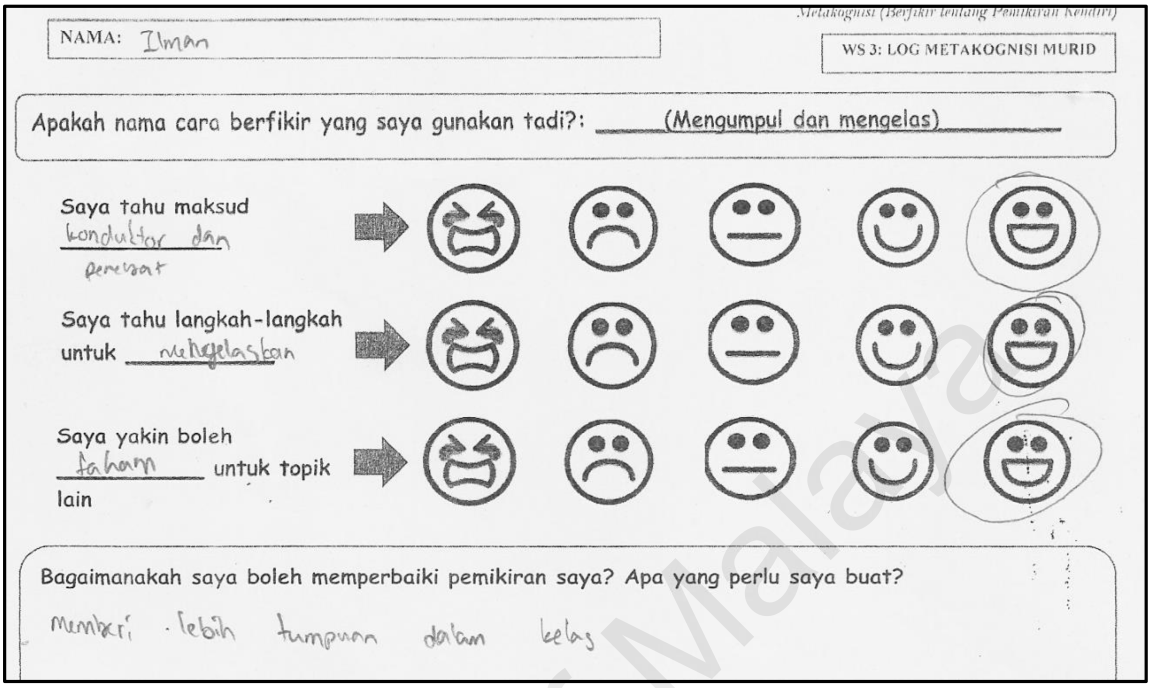


Figure 6.8. Reflection log by a student in Rosni's class.

He has written that he knows what conductor and insulator means and rated it with a smiling emoji. He also has written that he knows how to classify (very happy emoji), then concluded that he is confident because he now knows how to classify objects based on their materials (heat conductor or insulators). At the end of the worksheet, he has written that he should not be clumsy while conducting experiments. The student may perhaps have recalled his thinking – how he had classified objects, and rated his learning experience as shown in Figure 6.8. Hisham had also used this reflection log while attempting to promote metacognitive awareness among his students (Figure 6.9).


Metakognisi (Berfikir tentang Pemikiran Kendiri)

NAMA: Ilman

WS 3: LOG METAKOGNISI MURID

Apakah nama cara berfikir yang saya gunakan tadi?: (Mengumpul dan mengelas)

Saya tahu maksud konduktor dan penebat

Saya tahu langkah-langkah untuk mengelaskan

Saya yakin boleh faham untuk topik lain

Bagaimanakah saya boleh memperbaiki pemikiran saya? Apa yang perlu saya buat?

Memberi lebih tumpuan dalam kelas

Figure 6.9. Metacognitive log by a student in Hisham's class.

The student in Hisham's class as shown in Figure 6.9, has written that he needs to be more focused during lessons. Similar to the student in Rosni's class, he has rated his learning by marking the 'happy emoji' to indicate that he knows what conductors and insulators are, how to classify and is confident to classify other properties of materials for future topics.

Although some students in Suzana's class could write about what they had learnt, they could not explain in clear words how they would improve their thinking performances. On the other hand, students in Rosni's and Hisham's classes were only able to rate their learning experiences. But they could identify their weaknesses such as being clumsy during experiments, lacking in focus and unable to pose questions (*DA, Students' worksheet*). After several weeks, Suzana, Hisham and Rosni seemed to put further effort by explaining to students on the rationale of revisiting their posed questions.

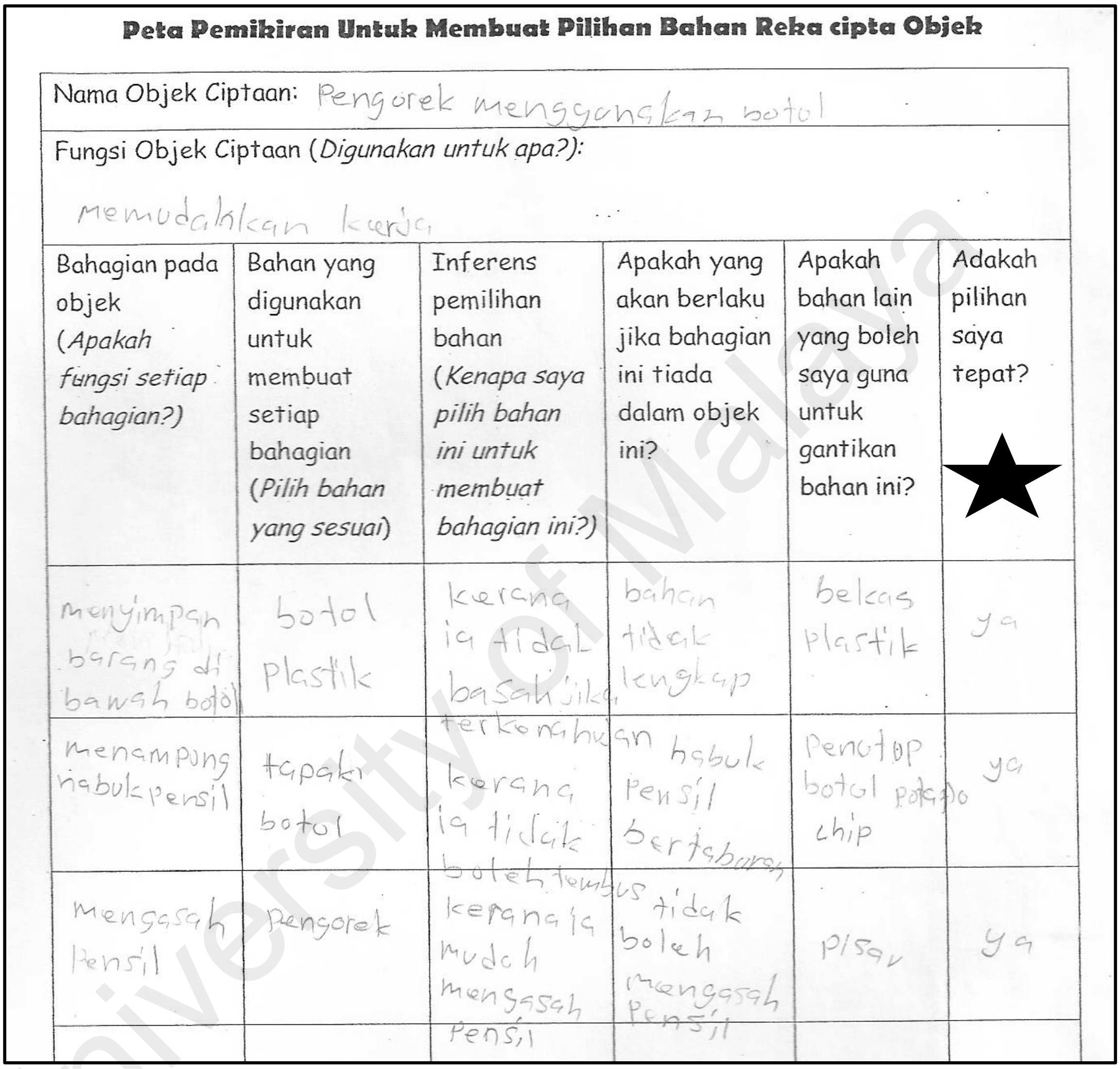
Revisit posed questions. Revisit posed questions is one aspect of metacognitive thinking where students are encouraged to revisit the questions that they have posed earlier. When students pose questions, it shows that they have been engaged with meaningful thinking. In the following interaction, when the students could not explain clearly the steps they undertook while making decisions, Hisham prompted them to think about why they need to ask questions. The students stated that questions help them to think better, understand better, become smarter and to analyse questions.

> *Hisham:* *Okay, my question is why do we need to ask questions?*
> *Students:* *To understand easily…so that we think...so that we will be smarter…so that we can analyse questions* [multiple answers]
>
> *H, L163, LT7*

Hisham further promoted students to think how the questions they had posed helped them in making decisions on selecting materials for their design. By asking them to recall the questions they had asked, Hisham had actually stimulated students to think about the questions they had posed before they designed objects.

> *Hisham:* *Okay…throughout your activity on designing your objects, how did it* [Questions] *help you? Did it help you to think and come up selections of materials for your design? Before you start designing, what did you think about first?*
> *Students:* *Thought about preparing materials...*
> *Hisham:* *Before that, what did you think about? If you want to create an object, what will you think firstly about?*
> *Students:* *Materials…*
> *Hisham:* *Okay, material…and?*
> *Students:* *Its place* [Parts of object and which material to use]
>
> *H, L163, LT7*

The students were actually reflecting what they did physically when designing the objects, which was discussing with friends on selection of materials. Hisham, Rosni and Suzana had distributed the thinking map for decision making (described in an earlier session). Apart from using the thinking map as a thinking tool, they used it as cues to promote students to revisit their decisions on the material selection for their designs. Figure 6.10 shows an example of the thinking map completed by a group.



Peta Pemikiran Untuk Membuat Pilihan Bahan Reka cipta Objek

Nama Objek Ciptaan: Pengorek menggunakan botol

Fungsi Objek Ciptaan (*Digunakan untuk apa?*):

memudahkan kerja

Bahagian pada objek (*Apakah fungsi setiap bahagian?*)	Bahan yang digunakan untuk membuat setiap bahagian (*Pilih bahan yang sesuai*)	Inferens pemilihan bahan (*Kenapa saya pilih bahan ini untuk membuat bahagian ini?*)	Apakah yang akan berlaku jika bahagian ini tiada dalam objek ini?	Apakah bahan lain yang boleh saya guna untuk gantikan bahan ini?	Adakah pilihan saya tepat? ★
menyimpan barang di bawah botol	botol plastik	kerana ia tidak basah jika terkena hujan	bahan tidak lengkap	bekas plastik	ya
menampung habuk pensil	tapak botol	kerana ia tidak boleh tembus	habuk pensil bertabur	penutup botol potato chip	ya
mengasah pensil	pengorek	kerana ia mudah mengasah pensil	tidak boleh mengasah pensil	pisau	ya

Figure 6.10. Thinking map for making decision used by students.

The last column in Figure 6.10 (marked with the symbol ★), reads as '*Did I make the right choice?*', was included in the thinking map as a cue for promoting students to revisit their decisions on the materials for their design. Using this thinking map, Suzana, Rosni and Hisham promoted metacognitive awareness among their students by asking them to name the kind of thinking strategies they were engaged in, and reflect upon how they had performed them. In addition, they also promoted students to justify decisions made for selection of materials and suggest ways of using alternative materials for their designs. The students themselves have shared their views about the questions they asked during lessons. They were able to acknowledge that they need to think before posing questions.

> *"We need to think first, before we ask questions, only then let the teacher know."*
>
> *Student A, L117, SFG*

Similarly, Student B claimed that she needed to think before she writes down her questions on the *Let's Ask* list and by doing so she believed it helps her to think forward. Upon hearing this, other students nodded in agreement with during student focused group interview.

> *"We need to think when we write* [The questions on the *Let's Ask* list] *and keep thinking further"*
>
> *Student B, L50, SFG*

It was apparent that Hisham, Rosni and Suzana have made the attempt to introduce students to be aware of their thinking. This was in line with the teachers' responses during interviews. Hisham mentioned that he could not visualise students' thinking but agreed that he had developed the other two elements of ST (analysing information and ideas and the habit of questioning). Hisham found that promoting metacognitive awareness was more difficult. However, it can be said that he could differentiate metacognitive thinking from the other two elements of ST.

> *"Its' the third element* [Metacognition]*…because this is students' thinking…I can't visualize it….but gradually I've built the skill, and at the end, they acquire thinking skills and now they ask a lot of questions. But the third element (metacognition) was indeed difficult…"*
>
> *H, L45, INT*

Similarly, Suzana was aware of the traits of metacognitive thinking. She mentioned terms such as '*how they think*' and '*whether they know what they think about*' to describe what she now understood about metacognitive thinking.

> *"I think it's the third element* [metacognition]. *How they think, and whether they know what they think about"*
>
> *S, L71, INT*

Teachers could not visibly measure the progress in students' metacognitive thinking (if any) as compared to the first two elements of ST. It can be said that Suzana and Hisham were aware of the need to promote metacognitive thinking. Despite being in agreement with Suzana and Hisham, Rosni sounded rather optimistic about teaching students to think about their thinking. She claimed that it was possible to promote metacognitive thinking, just like the different kinds of thinking strategies, provided she had the additional time needed to teach.

> *"I think it's difficult to make reflection on how they* [students] *think because it's like they don't know what to think about. Maybe they need more time compared to the first two elements"*
>
> *R, L21, INT*

> *"They do think but it's difficult for young children to explain what they understand about their thinking.*
>
> *R, L49, INT*

Rosni, seemed to believe that her students encountered difficulties in verbalising their thoughts on how they think, but could improve if more time was permitted. Rosni, Hisham and Suzana have encouraged students to revisit their thinking strategies, to see if they could name, explain how the strategy works and thus know where to apply a given thinking strategy. Apart from that, the students also have made efforts to reflect on their questions. In other words Suzana, Hisham and Rosni have created the pre-conditions for metacognitive thinking among their students within the given limited time (data collection).

Infusion of ST elements in teachers' satisfactory practices. The STEPS were used as educative material to support the selected teachers' learning to infuse ST while teaching about properties of materials. Based on the findings, it can be said that the selected teachers were able to elicit satisfactory practices that show the infusion of the three elements in ST.

In some lessons, teachers spent a lot of time modelling the different kinds of thinking strategies to analyse information and ideas. Information and ideas refer to students' observations during hands-on science activities and that which was shared during group discussions after the activities. Hence, teachers spent more time introducing, modelling and teaching to transfer a thinking strategy. However, they could not allocate time to encourage students ask questions and pose problems or to carry out activities for metacognitive thinking. These two elements of ST, developing the habit of questioning and problem posing as well as promoting metacognitive thinking, were less focused in the beginning. After several lessons, the teachers were then able to show satisfactory level of infusing all three elements harmoniously.

Figure 6.11 shows the satisfactory practices of ST infusion found among the selected teachers. The infusion of ST can be seen as a set with all three elements being a subset. This shows that the three elements of ST were infused simultaneously in teaching content knowledge based on the teachers' satisfactory practices of ST. For example, in teaching students to analyse information and ideas about properties of materials, the selected teachers had taught students to gather information and ideas, model thinking strategies and teach to transfer thinking strategies into new contexts. They also had provided cues for students to recall what they had learnt for the day (content knowledge) and reflect how they had performed the learnt thinking strategies. As shown in Figure 6.11, the infusion of ST elements can be represented by regions **A**, **B** and **C**.

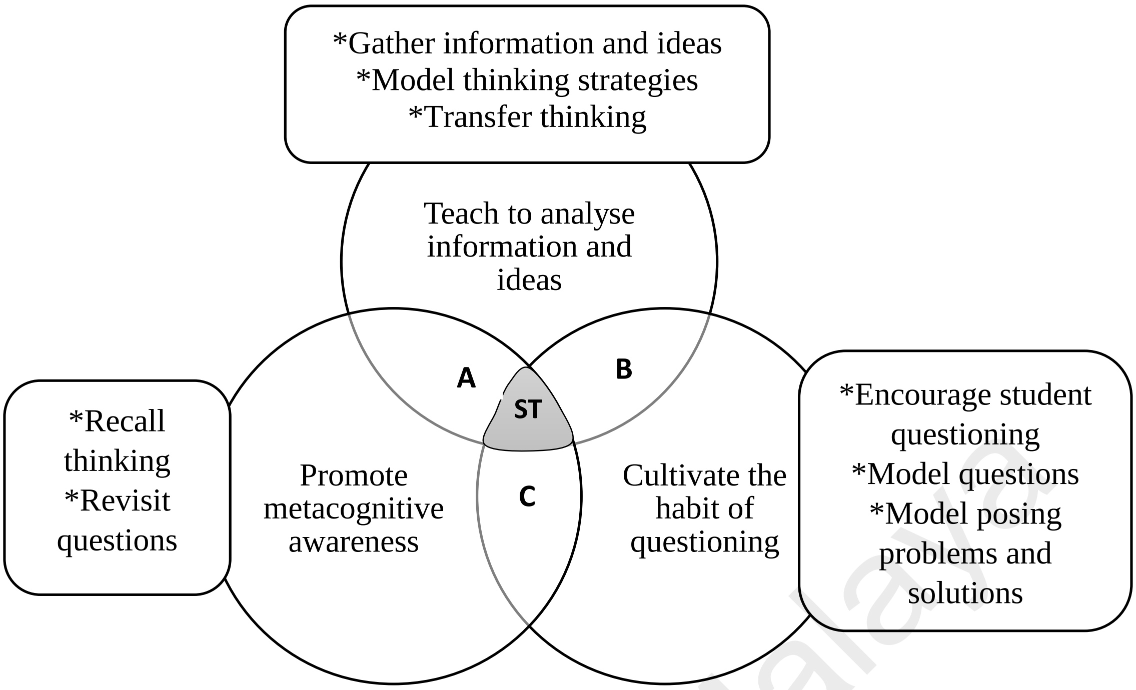


Figure 6.11. Graphical representation to show satisfactory practices of ST infusion among the selected teachers.

Region **A** denotes practices in which teachers had shown evidence that when they teach students to analyse about properties of materials, they also tried to promote students to recall information and reflect on their thinking. For example, when students were required to decide which materials they would choose for their design, Suzana, Hisham and Rosni had asked the students to recall how they would make skilful decision making. They also had triggered students to reflect if their decision – choice of material was correct. Since the teachers had modelled on how to make decisions skilfully using provided graphic organisers, they were able to ask students to describe how they had applied the skill of making decisions in selecting materials for their design. This perhaps has made the students reflect on how they had performed a learnt thinking strategy – making skillful decisions. The use of thinking tools (graphic organisers and concept cartoons) provided in the STEPS begin to fade away, because the teachers themselves appeared to provide auditory cues to stimulate students' thinking. This included cues such as '*How will you know? What have you learnt? How are the object similar or different? What can you say about..? Why did you say so? What happens if another material is used? How would you classify them?* These cues were given in the thinking tools and graphic organizers (in written form) which were used in the beginning. As teachers turn these written cues into auditory cues, it can be said that the students were aware and familiar with such cues.

In developing students' habit of questioning and problem posing, the teachers encouraged them to ask questions. Students were given enough time and space to write down their questions in a given worksheet. When the teachers were aware that the questions posed by their students were more to factual retrieval, they then modelled how to ask good questions. Thus, when students started to ask better questions, the teachers modelled how to pose problems and solutions by clearly explaining what a problem is, if it is worth solving, what a solution to a problem means and how to evaluate the solution. When students came up with questions and problems to solve, the teachers would create opportunities for students to practice and transfer learnt thinking skills. Region **B** in Figure 6.11 represents practices in which teachers use students' questions to engage students in ST more actively. For example, an interaction between Rosni and her students as follows:

> *Rosni: This question is from Group Earth that will make you think out of the box. The question is…why the tube of the stethoscope is made from rubber?...Okay..Group Earth, can you show the stethoscope and the tube that you have mentioned?* [Lesson went on discussing the material and its function].
>
> *R, L51, LT3*

In the cited interaction, Rosni acknowledged the questions posed by students and used them to expand the skill of analysing information and ideas about materials. Using this question from a student, Rosni was able to invite others to analyse the use of rubber for the tube in the stethoscope, by performing another specific kind of thinking strategy; looking at parts-whole relationship.

When teachers no longer feel obligated to answer each and every question from students, the way they respond to students' questions and answers have changed. They were seen to be more attentive to students' questions, turning them into opportunities for other students to share and argue their ideas. To arrive at this point, Suzana, Hisham and Rosni have encouraged students to ask questions, modelled how to pose good questions, rephrase unclear questions, give compliments to good questions and modelled how to pose problems. When students were able to ask good questions and pose problems, it shows a change in how students think. For example, questions such as '*What if a part of an object gets wet*? or '*Why didn't you use wood for your design*?' show that the students were actually performing different thinking strategies. Another instance is when Suzana had to explain how to identify a solvable problem before the students perform decision making on what design to propose. Here, teachers had to clarify the difference between posing solvable problems and logical solutions and imaginary problems and solutions.

Similarly, Region **C** denote practices in which the teachers have promoted students to revisit their questions. They gave cues that may perhaps stimulate students to think about the rationale and to understand the importance of asking questions. Cues such as '*Did your questions help you learn better?*' or '*Why is it important to ask questions?*' were frequently used to stimulate students' awareness of their thinking. Although there were less sound practices for metacognitive activities, the teachers have actually created the prerequisite for metacognitive thinking among the students. They made them recall how they think and revisit questions, thus promoting them to be aware of how they think. The amalgam of the three regions (**A**, **B** and **C**), is indicated by the abbreviation ST as shown in Figure 6.11. Here is where the teachers had infused all the three elements while teaching the topic ‘Properties of Materials’. This region shows the amalgam of satisfactory practices to infuse ST (region **ST**) into content lessons.

Discussions of teachers’ practice of ST infusion

In this study, the research aimed at describing the selected teachers’ practices in ST infusion upon using the STEPS. The findings showed that the teachers were able to show satisfactory level of ST infusion into the topic ‘Properties of Materials’. The study outcomes suggests that the teacher perhaps have developed the pedagogical knowledge in infusing ST into Year Four science.

This study shows that the ST elements; teaching students to analyse information and ideas, develop their habit of questioning and problem posing and promoting awareness in metacognitive thinking can be integrated and simultaneously infused into primary science lessons. While most other studies have investigated the elements of ST as separately in different subject matter (Beyer, 2008b; Goodell, 2014; Reagan, 2008; Shu et al., 2013), the present study had explored how teachers integrate the three selected elements of ST and infuse them into their current practices. This was also in line with Swartz et al. (2008) who claimed that the teaching of higher order thinking skills (HOTS), such as analysing should be extended to the development of students’ habits of mind and the promotion of metacognitive thinking.

In teaching students to perform different thinking strategies to analyse information and ideas about properties of materials, the teachers were found to introduce, model and teach to transfer into new context, as suggested by Swartz et al. (2008). The kind of thinking strategies that the teachers teach depended on the situation. Whenever students pose problems or ask questions, the teachers used students' questions as prompts for them (teachers) to introduce and make students practice learnt thinking strategies. For example, when students ask about why stones do not conduct electricity but metals do, the teachers used this opportunity to make their students practice compare and contrast strategy to analyse the different abilities of stones and metals in conducting electricity. This indicates that the teachers developed knowledge about the different kinds of thinking strategies in analysing information and ideas about the properties of materials. This is in line with Zohar (2013), whereby in a study on challenges science teachers encounter in teaching thinking, knowledge of different kinds of thinking strategies (particularly higher level thinking) was found important in fostering students to think further.

In accordance with explicitly developing students' questioning and problem posing skills, teachers' questioning strategies have changed. The teachers have acquired questioning strategies that prompt students to think further rather than retrieving basic information. They taught students to pose questions and problems, an advanced level to that of students simply asking questions (Chin & Osborne, 2008; Test et al., 2010). By developing students' habit of posing questions, teachers could come up with more open ended questions that invite others to respond. The teachers also provided cues for students to think about their questions and reflect on their learning process. Hence, it shows that teachers have given the privileges for authentic, sharing of reflections on teaching and learning, in which they used tools to see if their students were able to pose better questions (Duckor & Perlstein, 2014).

Teachers in this study achieved noticeable questioning skills in the given time (3 months of teaching the topic Properties of Materials), particularly the cues that they provide to stimulate students' thinking. Among the practices employed by the teachers in changing their practices to develop students' questioning habits, were modelling how to ask good questions and recognising problems to solve. The teachers made clear the rationale of asking good questions and to reflect upon the questions asked during discussions. These strategies have appeared to accelerate students' development of the habit of asking questions and posing problems without the fear of rejection. Thus, the students have shown the difference in the way they ask questions and the type of questions asked. The habit of questioning is argued important to facilitate inquiry learning (Chin & Osborne, 2008).

In the aspect of promoting metacognitive thinking among students, the teachers were found to perceive metacognition as the most challenging element to infuse into their lessons. The teachers have claimed that it may take more time to make visible how students think about the way they think. This is unlike for the first element of ST, which is teaching specific thinking strategies in analysing information and ideas about properties of materials, in which students clearly made their thinking visible to teachers. Teachers were able to identify traits to show that a student was thinking in a particular way. For example, if the students were able to list down the differences and similarities in properties among objects, they were considered to have acquired the thinking strategy called 'comparing and contrasting'. Similarly, by observing the way and type of questions students pose, the teachers were able to infer that their students have developed the habit of questioning and problem posing.

It can be said that there was less change in the teachers' infusion of metacognitive thinking among students, perhaps for two reasons. Firstly, they needed more time to promote metacognitive thinking among young children and secondly it was difficult for the students to verbalize their thoughts about their thinking processes to their teachers. Generally, teachers need more time and effort to promote metacognitive thinking among students; however they could perhaps start to infuse ST by asking them to name the kind of thinking strategies they were engaged in, asking them to explain the thinking strategies, state the steps taken in each thinking strategy, explain the rationale of thinking about thinking and teach them how to think about their thinking. These might be the prerequisites needed by the teachers in introducing young children to metacognitive thinking. They have created the conditions for their students to think at a metacognitive thinking level by being aware of the kind of thinking the students were engaged in. They did not proceed to the higher levels of metacognition, which are to promote students to evaluate and plan their thinking. Therefore, it can be said the teachers had actually promoted reflective thinking among their students, as a precondition for introducing metacognitive thinking. Other studies have also found that metacognition can be more challenging, mainly because stimulating young children to think at metacognitive level requires a more specific approach (Barak & Shakhman, 2008a; Salmon & Lucas, 2011b; Zohar, 2013). These scholars argue that teachers need to possess meta-strategic knowledge, the kind of knowledge about various kinds of thinking strategies, including thinking about thinking or metacognition. The works of Zohar pertaining to teachers' promotion of metacognition among students show that science teachers' knowledge of metacognition and knowledge of instructions for metacognition need to be addressed if the fostering of ST were to take place in science classrooms (Zohar, 2004b, 2013; Zohar & David, 2008; Zohar & Dori, 2003).

Summary

This chapter described and discussed the change in the selected teachers' practices from unsatisfactory to satisfactory practices of ST infusion upon using the

STEPS. It can be said that there were several satisfactory practices with regards to how they infuse the three elements of ST simultaneously while teaching about properties of materials. The selected teachers teach to gather information and ideas, model thinking strategies and teach to transfer skill into new contexts, in teaching students to analyse information and ideas. They cultivate the habit of questioning among students by encouraging them to ask questions, model how to ask good questions and model how to pose problems and solutions. In promoting students awareness of their own thinking, they provide cues for students to recall thinking and revisit the questions that they have posed.

CHAPTER 7

HEURISTICS NATURE OF THE STEPS

Introduction

The previous chapter has described the changes found the in the selected teachers' practices of ST infusion into the topic 'Properties of Materials'. Based on the findings on the selected teachers' practices, their uptake of ideas in the STEPS were explored, therefore, the fourth research question will be discussed.

> *Research Question 4:* How did the selected teachers' uptake of ideas in educative features in the STEPS support the teachers' ST infusion practices for the topic 'Properties of Materials'?

Therefore, this chapter will describe the educative features presented in the STEPS to bridge the understanding on how it might perhaps have been a contributing factor in supporting the teacher-learning process in ST infusion. The selected teachers' uptake of ideas in the educative features respective to the three design heuristics in the STEPS will be explored. Table 7.1 shows the design heuristics, relative educative features and examples of teachers' uptake of ideas in the STEPS. The three design heuristics in the STEPS were:

DH 1 - Support teachers' knowledge of ST

DH 2 - Support teachers' ST infusion practices

DH 3 - Support teachers in managing group discussions

Teachers' views of ST infusion, their satisfactory practices and students' work reflected teachers' uptake of ideas in the educative features, indicating that the educative features may have been helpful in learning to infuse ST.

Table 7.1

Teachers' Uptake of Ideas in Educative Features

Design Heuristics (DH)	**Educative Features (*EF*)**		**Teachers' uptake of ideas in educative features**
DH 1 - Support teachers' knowledge of ST.	*EF1* *EF2* *EF3* *EF4*	Teacher-thinking questions Teacher-reflective writing Graphical representations Teacher-Tips	Teachers' views of ST, on what they know about ST elements, how to infuse them into content lessons and their perceptions about their students upon using the STEPS. The teachers have claimed that they think about how to adopt recommendations suggested in the STEPS and understood the rationale behind those recommendations (EF1, EF2, EF3 and EF4).
DH 2 - Support teachers' ST infusion practices.	*EF5* *EF6* *EF7* *EF8*	Teaching goals Content boxes Lesson Planning Cues Fictional teachers	Teachers' satisfactory practices reflected change in their practices upon using the STEPS. They adapted the recommended teaching strategies from the fictional teachers (EF8), content boxes (EF6) and lesson planning cues (EF7) and teaching goals (EF5).
DH 3 - Support teachers in managing group discussions.	*EF9*	Challenges for teachers	Teachers' satisfactory practices reflected the use of teaching tools not only to aid students' thinking but to manage small group discussions. Teachers take up ideas in EF9 on how to use graphic organizers, concept maps and tags to engage students in meaningful group discussions.

Teachers' uptake of ideas in the educative features

This section will describe the selected teachers' uptake of ideas in the nine educative features for the three design heuristics designed in the STEPS.

DH 1 - Support teachers' knowledge of ST. The four educative features used for the purpose of supporting teachers' knowledge of ST were EF1 (teacher-thinking questions), EF2 (teacher-reflective writing), EF3 (graphical representations) and EF4 (teacher-tips). These four educative features were designed to inform teachers with theoretical understanding of ST elements and how to infuse ST into content lessons.

Literature review of ST and science education is vast, which may hinder teachers from spending the time to conveniently read if it is given in lengthy and wordy forms. Thus what information the teachers in this study needed to know was determined based on the Phase 1 findings and literature review (Chapter 5). Hence, the four educative features (EF1, EF2, EF3 and EF4) were designed to deliver the information or message in a reader-friendly way with fewer lengthy words. They were also aimed at stimulating teachers to think about how they might infuse ST into their existing lessons. Teachers' views and perceptions about what they know about ST may indicate their construction of knowledge in ST.

Not only did the STEPS lay out what teachers could do to infuse ST elements, it provided the rationale of why doing so is important in scaffolding students' subject matter understanding. Upon being probed on what he has learnt about ST from using the STEPS, Hisham mentioned that he no longer needs the STEPS for future lessons, as he understood the rationale of each step recommended for teachers to infuse ST.

> *"In the beginning, I felt that I should follow exactly the first lesson, but after some time, when I read the suggested activities that follows and understood the rationale behind it, it became easy. When I wanted to start the second, third and fourth lesson, I only refer [to] the book when I need to, because I knew what each activity aims for…and eventually,*

> *I understood the rationale of each activity (step) and for the last lesson, I didn't need to refer to the book* [STEPS] *anymore"*
>
> *H, L31, INT*

Rosni had shared what she now knows about ST and the three elements, which may denote that she internalised what ST is and why it is important to develop students' habit of questioning and problem posing. From the satisfactory practices in cultivating students' habit of questioning, discussed earlier in Chapter 6, Rosni selected students' questions, discussed them with the whole class and appreciated the students for posing good questions.

> *Rosni: This question is from Group Earth that will make you think out of the box. The question is…why the tube of the stethoscope is made from rubber?..Okay..Group Earth, can you show the stethoscope and the tube that you have mentioned?*
>
> *R, L51, LT3*

> *Rosni: This is another good question – Why isn't pen made from wood? Mmmm…like a pencil made from wood?* [Looking at Group Neptune for clarification]
>
> *R, L65, LT3*

Rosni's practices in cultivating her students' habit of questioning by modelling how to ask questions and appreciating questions reflect her knowledge of ST. She acknowledged the change in her students' questioning habit and thinking strategies.

> *"They have the courage to argue and ask questions and they know what kind of thinking strategy* [by naming it]*"*
>
> *R, L51, INT*

This shows that Rosni is aware that students were being courageous in posing questions, arguing thoughts and were able to identify thinking strategies as one of the traits of skillful thinking (ST). Rosni had also mentioned that when she scans through the STEPS, the educative features have provided her with some ideas and recommendations on infusing ST.

"There were many features [while showing the features in the STEPS]*, and when I scanned them briefly, I could grasp ideas from there and tips for teachers and the improved thinking maps were also very helpful"*

R, L13, INT

Suzana shared views about developing knowledge of ST by describing how the STEPS had helped her in using thinking maps for teaching students to perform thinking strategies and using metacognitive logs for promoting metacognitive awareness among students.

"The stimulants in the STEPS were very good, I think it's very helpful for me and my students to think and for my students to think about their thinking."

S, L20, INT

She claimed that before participating in the present study, she did not actually understand how to use them to stimulate thinking skills among students. She also stated that teachers need to be well prepared and know how to stimulate students to think.

"*Teachers are less exposed to teaching higher order thinking skills. And when, suddenly being introduced to thinking maps* [showing a fictional teacher in the STEPS], *but before that, we* [I] *don't know how to use them. But I'm lucky because I took part in this study. I know how teachers themselves must be ready* [well prepared] *and how to stimulate students' thinking"*

S, L52, INT

This might indicate that Suzana is aware that as a teacher, she needs to upgrade her knowledge in teaching students to think at higher levels. And by participating in the present study, she now knows how to stimulate students' thinking using thinking tools. Suzana further added that she could see positive changes in her students upon applying the strategies recommended in the STEPS.

"When I follow and continue the steps [strategies to infuse ST as recommended in the STEPS], *I could see positive changes in students"*

S, L60, INT

This shows that Suzana recognized the traits in her students thinking behaviours such as how they could name thinking strategies, ask questions, pose problems and recall how they had performed learnt thinking strategies (as described in Chapter 6). Suzana, Hisham and Rosni seemed to claim that they have developed knowledge about ST through using the STEPS. They spoke about the educative features that had informed them on ST elements and the need to upgrade knowledge in ST infusion. The following section will describe the teachers' uptake of ideas in the educative features as found in their ST infusion practices.

DH 2 - Support teachers' ST infusion practices. This design heuristic aimed at supporting teachers' ST infusion practices during the teaching of the topic 'Properties of Materials'. Educative features that were mainly used to aid teachers' practices were EF5 (teaching goals), EF6 (content boxes), EF7 (lesson planning cues) and EF8 (fictional teachers). EF5 (Figure 7.1) was designed to inform teachers that they need to include ST elements as part of their teaching objectives.

Objective of infusion of ST in the content of T&L:
By the end of teaching and learning session, students will be able to:

i. Analyse knowledge about objects and the materials used to make the objects and the natural resources using specific thinking strategies.
ii. Question about objects relative to the material it is made from.
iii. Make reflection about the thinking strategies used.

Figure 7.1. Example of teaching goals provided in sample lesson.

Teachers usually refer to the Year Four science curriculum specifications to set their teaching and learning (T&L) goals when they plan their lessons. EF1 was added to remind teachers of the need to set goals for ST elements apart from the existing T&L goals. For example what teachers need to expect from students. By end of the T&L

sessions, they need to ensure that their students analyse knowledge about objects and materials using specific thinking strategies, question about objects and materials and make reflection about the specific thinking strategies that they have learnt. Correspondingly, the teachers have shown that they made the effort to instil the three elements of ST into their teaching practice.

Examples of satisfactory practices described in an earlier section in Chapter 6, may perhaps show that by setting the goals to achieve the infusion of ST elements, teachers have attempted to teach students use specific thinking strategies such as comparing and contrasting and looking at parts-whole relationships. They also have made efforts to cultivate the habit of questioning and promoted metacognitive awareness among students. The teachers also have taken up the ideas postulated in content boxes (EF6).

Content boxes were provided to remind teachers of important key points while enacting lessons, often as a section in the sample lesson plans. For example, Figure 7.2 shows a content box (in a call out form) given in one of the sample lesson. The content box in Figure 7.2 explains the key points that teachers must remember. This was provided for the sample lesson on teaching students to design objects and justify the selection of materials for their design. Teachers were reminded that they need to ensure that students are able to justify their selection of materials because it hugely influences the choice of materials for every part of the object that they plan to design.

Activity 2: Practice Thinking

Teacher: "Try to imagine a problem that you want to solve. For example, my eyes always tear up when chopping onions. That is a problem most people go through when peeling onions. I wish there is a device that could peel and chop onions easily for me, so that I don't have to cry each time I peel onions. What about you? Try discussing with your friends about a problem and how to solve it. Do not forget to write down the questions you have discussed"

The teacher provides a worksheet/Thinking Map for Decision. The teacher also provides a piece of paper for students to sketch their design.

Students tend to design objects without good reasoning and justifications. Teachers must ensure that the students understand the functions of each part of their designed object. This will help students to choose the right material and justify their selection of materials.

Figure 7.2. An example of content box.

Suzana, Hisham and Rosni have taken up these key points when teaching this unit. As described earlier in Chapter 6, the teachers kept providing auditory cues for students to think about the choice of materials for their designs. In one of the lessons, Hisham was trying to make students carefully consider what and why they wanted to design the proposed objects.

Hisham:	*What are you designing?*
Students:	*A clock*
Hisham:	*A clock? You have to decide if there is a need to design a clock.*

H, L35, LT6

Hisham wanted his students to justify and provide good reasons for their design. This may perhaps have instigated the students to review their choice of object and change their decision to build another object. Again, Hisham provided cues for students to justify why they need to design already existing objects.

Students: *I think we better change our mind, we want to make a bus* [a boy represented the group, the rest of the group members nodded in agreement]

Hisham: *Why bus? There are many buses around right?*

Students: *Yes, there are many buses around but they can't come here* [pointing the classroom].

Hisham: *Why do you want to design a bus that comes here? What is the purpose? You have to think of a problem that you can solve by designing something, like problems at home…like to help your mother cut onions without tearing.*

H, L42, LT6

Soon, when Hisham realized that his students could not reason out solvable problems; he then gave an example of a problem worth solving.

Hisham: *Air balloons are common, try to think of something different (new). For example, you want to go to a shoe store and choose a size, but you can't choose the size you wanted because it is difficult to see what's inside, so if we put a plastic…transparent plastic, we would then be able to see the shoe inside…*

H, L46, LT6

Since Hisham focused on students' reasoning and justification on what the students wanted to design, he was able to identify their difficulties in thinking of solvable problems. Thus, he explained a few examples of problems that are worth designing objects to solve them. Hisham, Suzana and Rosni even encouraged their students to ask questions on the selection of materials when each group presented their design. The following excerpt is an example of interaction between students in Suzana's class. The students were allowed to ask the representing groups about their designs, mainly on why they choose particular materials for different parts of the objects.

Student (presenter): *This lamp is water proof, so if water flows on the roof of this design, nothing will happen.*
Student 1 (ask): *What if the water hits at the sides?*
Student (presenter): *Nothing will happen, because this plastic thing is here* [pointing at the side of the house]
Student 2 (ask): *But, what if the water flows on the roof?*
Student 3 (ask): *if it flows on the roof, the water would flow on the battery, then the battery would spoil.*
Student (presenter): *If the battery gets spoilt, we can still open it* [the compartment made from plastic]*, because it is made of waterproof material.*

S, L69, LT8

The presenter could present his design and could explain by justifying his selection of materials when other students posed questions on his design. Hence, by paying attention to the key points provided in content boxes, the teachers were able to make students practice learnt thinking strategies in new contexts which indirectly supported the teachers' practices to infusing ST. Along with EF5 and EF6, EF7 (lesson planning cue) was designed to help teachers in their ST practices. Sample lesson plans and teaching tools such as thinking maps, concept cartoons and *Let's Ask* list were recommended in the STEPS. Most of the time, teachers used the tools directly in their lessons. Rosni used the concept cartoon that discussed pots made from different materials to help her students learn decision making. She used the concept cartoon before the students planned to design objects for a designated problem. Using the concept cartoon, Rosni had created the space for her students to apply learnt thinking strategies such as making inferences, justifying choice and making decisions in choosing the right pot.

Rosni: *Okay, whose choice is wiser?* [Referring to the concept cartoon] *Give inference for your choice* [Class was silent]
Rosni: *What is an inference…we have learnt how to give inference in our previous topic right? Choose an answer...Pot A or B ...Give me inference as to why you choose Pot A or Pot B.*

R, L49, LT5

As Rosni went on probing students' inferences and justifications for their selection of pots, until the students were able to give inference for their choices.

> *Rosni: Okay…How about this group? Pot A or B*? [Rosni pointed to Group Mercury]
> *Group Mercury: Pot B*
> *Rosni: Ooo…Pot B too...why? I do not want replies that are already given…and Pot B is not fully covered with plastic only. Your reason to choose Pot B*? [Rosni reads Edison's answer]…*'because if I choose Pot A and touch the holder then I would feel hot'*
> *Rosni: Give a big hand for Edison.* [Class clapped]
> *Rosni: Very good inference…this is an example of inference that supports why choose Pot B, not just because you liked the pot since it was made of different materials. That is inaccurate.*
>
> *R, L67, LT5*

Here, Rosni has taken up the ideas of using concept cartoons as recommended in EF7 for helping her teach students to make decisions. When questioned the use of such concept cartoons in her lessons, Rosni mentioned that:

> *'Show the students some cartoons, each of them have their own views, that's why I like it. Earlier, they would just agree to opinion by one student, if the student put up his/her hand to choose pot A, then the rest would have had chosen the same. But now, I can see a balance* [some choose Pot A and others Pot B] *in their decisions and they can give reasons for their choice".*
>
> *R, L55, INT*

She found that her students were able to share their own views even if these differed from others'. Suzana also had used graphic organisers or thinking maps to help her teach students to select materials for their designs. Figure 7.3 shows an example of students' work, the thinking map that they had used to help them make the suitable choice of materials for their designs. These students have designed a sharpener that has different compartments such as collecting pencil dusts and to store small stationery items. They had reasoned out their existing sharpeners that can collect pencil dusts are expensive and difficult to fit into their pencil cases. Therefore they had designed an object that serves the purpose as pencil sharpener, pencil dust collector and small item case. As shown in Figure 7.3, the students have written their reasons for the choice of materials for each part of their design and had proposed alternative materials that can be used for the same function.

Peta Pemikiran Untuk Membuat Pilihan Bahan Reka cipta Objek

Nama Objek Ciptaan: Pengorek menggunakan botol

Fungsi Objek Ciptaan (*Digunakan untuk apa?*):
memudahkan kerja

Bahagian pada objek (*Apakah fungsi setiap bahagian?*)	Bahan yang digunakan untuk membuat setiap bahagian (*Pilih bahan yang sesuai*)	Inferens pemilihan bahan (*Kenapa saya pilih bahan ini untuk membuat bahagian ini?*)	Apakah yang akan berlaku jika bahagian ini tiada dalam objek ini?	Apakah bahan lain yang boleh saya guna untuk gantikan bahan ini?	Adakah pilihan saya tepat?
menyimpan barang di bawah botol	botol plastik	kerana ia tidak basah jika terkena hujan	bahan tidak lengkap	bekas plastik	ya
menampung habuk pensil	tapak botol	kerana ia tidak boleh tembus	habuk pensil bertaburan	Penutup botol potato chip	ya
mengasah pensil	pengorek	kerana ia mudah mengasah pensil	tidak boleh mengasah pensil	pisau	ya

Figure 7.3. Example of students' work – thinking map used for making decision.

With the use of this thinking map, Suzana had helped her students make better decisions in selecting materials, justify their selection, suggest alternative options and evaluated if their choice is right. Another thinking map applied directly to lessons was the modified tree map (Figure 7.4).

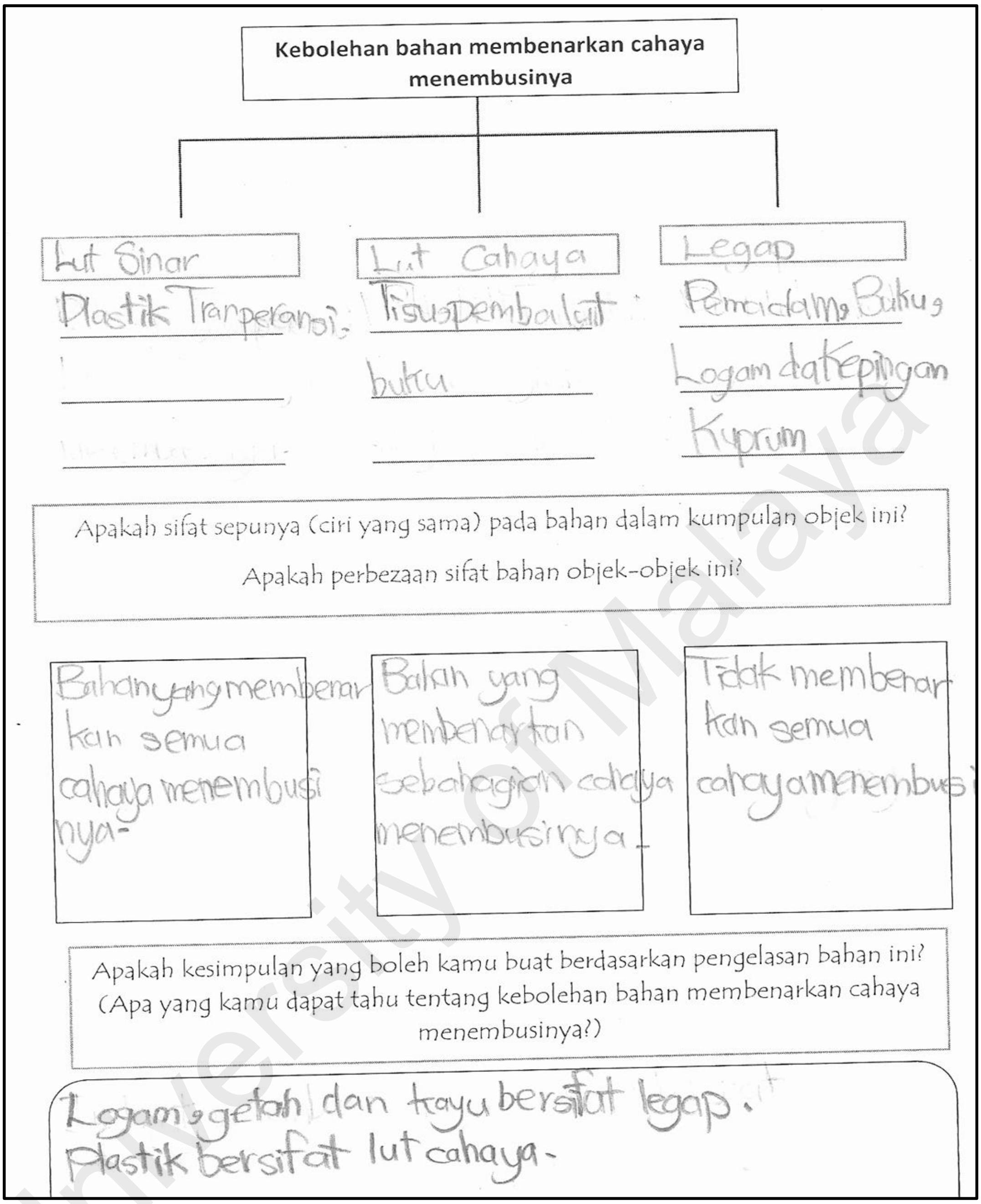


Figure 7.4. Example of students' work – thinking map used for classifying.

The tree map was modified and provided in EF7 for teachers to use when teaching students to classify objects and materials. The tree map shown in Figure 7.4 was prepared by a group of students in Rosni's class. They used the thinking map for classifying materials that allows light to pass through. Using this thinking map, the students were able to classify materials into transparent, translucent and opaque. They also have written their reasons for the classification by comparing the similarities and differences of the objects' ability to allow light to pass through. At the end of the thinking map, the students have made generalizations about materials that are opaque, transparent and translucent. Apart from concept cartoons and thinking maps, the teachers also had used the suggested *Let's Ask* list directly in cultivating the habit of questioning among students. The list was given to each group before starting the lessons. The teachers would then select a few questions to discuss with the whole class. Hisham often reads his students' questions and discusses them with the whole class so that the students could share their thoughts and ideas with others. Following excerpt shows one of satisfactory practices Hisham when he was making his students practice thinking strategies. He had used the question posed by the students. This excerpt also shows that Hisham appreciated questions posed by his students and used them for others to discuss.

> *Hisham: Group 3 asked a question* [Hisham then reads the question posed by Group 3]*…'Can a pencil absorb water or not?" ….Okay, put the pencil into the water, hold it…on top...what can you observe?*
> *Students: wet*
> *Hisham: So, can it absorb water?*
> *Students: Can* *H, L35, LT3*

When Hisham discussed the question posed by Group 3, he came to know about the misconception among his students. They claimed that pencils can absorb water because they were made from wood. The pencil was protected with a layer of waterproof material, yet upon observing water droplets on the surface of the pencil, the students affirmed that the pencil was wet. This situation had given Hisham the opportunity to rectify students' misconception about the term 'wet' and water absorbent. Hence, Hisham provided cues for his students to compare the difference between a ruler and pencil – both made from wood.

> *Hisham: What's the difference between the pencil and the ruler? Both are made from wood.*
> *Students: has cover* [Pointing at the pencil]
> *Hisham: He says pencil has cover*..[Sharing the students' response with other students]
> *Students: It is covered with layer....water proof..*
> *Hisham: Yes because it is covered with a water proof layer right? How about this?* [Showing the ruler]
> *Students: No…* *H, L68, LT3*

Using the *Let's Ask* list, Hisham managed to get students write questions that might elicit their thinking. And from those questions, he was able to identify students' misconceptions. The students were also requested to apply learnt thinking strategies to new contexts and this helped them to seek explanations for their questions. The use of the Let's Ask list recommended in EF7 was prominent in the teachers' practices. The students seemed to show interest when they would wait for their questions to be discussed with others.

> *A student requested her question to be discussed* [The teacher didn't discuss her question earlier] *which shows that she was waiting for her turn to discuss her question.*
> *H, L23, FN2*

EF7 had also recommended the strategies teachers need to take in order to infuse ST elements into lessons. Each strategy was accompanied with the rationale behind the recommended strategy. Based on the strategies recommended in EF7, the teachers enacted their lessons. Some strategies were used directly such as the use of thinking tools and some were modified. Suzana took up the idea suggested in EF7 on how to introduce a problem for students to design objects to solve the problem. Figure 7.5 shows the original activity recommended in EF7.

	*Activity 2: Practice Thinking* Teacher: "Try to imagine a problem that you want to solve. For example, my eyes always tear up when chopping onions. That is a problem most people go through when peeling onions. I wish there is a device that could peel and chop onions easily for me, so that I don't have to cry each time I peel onions. What about you? Try discussing with your friends about a problem and how to solve it. Do not forget to write down the questions you have discussed" Teacher provides a worksheet/Thinking Map for Decision. Teacher also provides a piece of paper for students to sketch their design.	

Figure 7.5. The original activity in one of the sample lessons.

The recommended activity in EF7 was to talk about peeling onions without tearing. But Suzana had modified the activity with 'Box Problem', however, she was able to explain her students on how to recognise a problem worth solving.

> *Suzana: My problem is….I have too many identical boxes. When I need to keep my things, I had to open each box to see what's in the boxes. I arranged the boxes for stationery, papers, coloured pencils, so I have problem to open one by one to put my things. This is my problem.*
>
> *S, L67, LT7*

In the cited lesson, although Suzana did not directly use the suggested example of problem, it can be said that she has up took the idea of explaining what a problem is and how to identify a problem worth solving. Upon probing her use of the 'Box Problem' instead of the 'Onion Problem', Suzana claimed that she thought if the onion problem was suitable, she decided to use another similar example (box problem) which she believed was more relevant to her students.

Another essential feature in the STEPS was EF8- fictional teachers. Teachers' uptake of ideas in EF8 can be seen in their satisfactory practices. Figure 7.6 shows an example of a fictional teacher called *Ms. Mala*.

While Ms. Mala was teaching about the Earth and Space, a student named Aiman asked her:

Aiman: Teacher, what would happen if an alien were to attack Earth?

Mrs. Mala: Alien? What type of alien is that?

Aiman: An alien with a huge spaceship, in the sky, covering the Earth. I watched it on TV the other day.

Mrs.Mala: Hmmm….Attention class. Your friend has a question to ask. Aiman, could you repeat your question to the class.

Aiman actually wanted to share his question with *Ms Mala* only, but to his surprise, she made him pose the question for the whole class to respond. Although Aiman was shy, but with a little motivation from his teacher, he was able to repeat his question loudly for others to hear.

Mrs.Mala: Alright class. What do you think? What would happen if a spaceship covers the surface of our Earth? Try to imagine.

Student A: Becomes dark.

Mrs.Mala: Why do you say so?

Student B: Because there is no sunlight…. It is blocked…

Mrs. Mala: What would happen if Earth suddenly becomes very dark? Try discussing in your groups for a few minutes. And we will discuss.

Figure 7.6. Example of fictional teacher called Ms Mala *(EF8).*

The fictional teacher shown in EF8 was designed to provide an idea on how teachers can use students' questions to initiate short impromptu discussions among them. The conversation between *Ms Mala* and Aiman show how *Ms Mala* appreciates questions from her students. She acknowledges the questions and invites other students to respond by sharing their thoughts about the question. Similarly, the teachers in the present study have taken up ideas in EF8 and used students' questions to create the space for small group discussions. When this often occurred, the students seemed to be able to pose questions confidently without fear of rejection or penalty. The following excerpt shows an example of how Rosni appreciated students' questions and discussed them so that other students could respond.

> *Rosni:* *This question is from Group Earth that will make you think out of the box. The question is…why the tube of the stethoscope [is] made from rubber?... Okay…Group Earth, can you show the stethoscope and the tube that you have mentioned?*
>
> *R, L51, LT3*

In the cited lesson, Rosni may perhaps have taken up the idea in EF8 or *Ms Mala's* way of appreciating students' questions and discussing them with others. By taking up the ideas recommended in EF8 (fictional teachers), the teachers were able to cultivate students' habit of questioning. They were also able to use students' posed questions to stimulate thought sharing among students. In promoting metacognitive awareness among students, the teachers might have perhaps taken up the ideas also in EF8. Another fictional teacher, Pn. Jamilah (see Figure 7.7), was trying to teach students on making inferences for scientific observations. However her students were unable to make inferences. Therefore, Pn. Jamilah asked her students to think about the importance of making inferences and what might happen if they fail to make inferences.

Pn. Jamilah, is teaching her students how to make inference. She explains the meaning of the word inference and gives a few examples. She notices that a majority of them do not possess the skill of making inference. Pn. Jamilah then questions her class about making inference.

Pn Jamilah: Is it very difficult to make an inference?

The students were immediately silent and listened to the teacher's questions.

Students: Yes, very difficult….
Pn. Jamilah: Why do you say that it is difficult to make an inference?
Student 1 : Because we need to give….reasons… why…
Student 2: Difficult to think of what reason…
Pn. Jamilah: Hmmm…..Why do you think it is difficult to give reasons (inference)? What would happen if we are not good at making inference?
The class became silent. Pn. Jamilah realises that her students are starting to pay attention to the situation.

Pn. Jamilah: If we are not good at giving reasons about why certain things happen, we will not be able to understand the situation. For example, if we observe the size of rabbit A is bigger than rabbit B, we would definitely like to know why is rabbit A bigger, what it must have been eating to grow so fast… right? Therefore, the inference for our observation is…. maybe rabbit A eats more than rabbit B… agree?

Figure 7.7. Fictional teacher called Pn. Jamilah *(EF8).*

By constantly asking students to think about the rationale of students asking questions, Hisham was able to help students understand the need of asking good questions. Hisham also had encouraged his students to ask questions not only when they have doubts, but to pose questions to their peers. Suzana might have taken up the idea of providing cues about the science concepts before students start hands-on activities, from another fictional teacher called *Ms Izatul*. This fictional teacher (Figure 7.8) provided questions as cues for students to think about what they know of the term 'elastic' before she started to teach about elastic and non-elastic materials. The cues to help her students to think about elastic materials were written on the whiteboard.

Ms. Izatul was teaching the unit called 'elastic materials'. Before the students carry out activities to test and classify objects and materials according to their ability to be elastic, she asked them what they know about the term 'elastic'. To help her students think, she listed down several questions on the whiteboard:

Are books elastic? How do I know if books are elastic? What materials are used to make books? What is the meaning of elastic?

After that, she asked the students to pose questions to their friends in groups and write them down in the worksheet given. Students were given the choice to choose which object they would like to test.

Later, Ms. Izatul asked *"How did you answer the questions asked by your friends in the group just now? Were the questions helpful to make you understand about elastic objects?"*

Figure 7.8. Fictional teacher called Ms Izatul.

Figure 7.8 shows the cues *Ms. Izatul* provided her students after an activity on testing elastic materials. She asked her students about the questions they have posed during the activity. She had used cues such as "*How did you answer the questions asked by your friends in the group just now?"* and *"Were the questions helpful to make you understand about elastic objects?"* This fictional teacher shows how teachers might ask their students to think about the questions they have posed and on how those questions helped them to better understand a science concept (elastic materials). Taking up this idea of providing such cues, Hisham gave similar cues to his students after they had completed an activity on decision making. After an activity on designing objects to solve a problem and deciding on selections of materials for their designs, Hisham provided cues for his students to think about how their questions have helped them in deciding selection of materials.

Hisham: *Okay…throughout your activity on designing your objects, how did it* [questions] *help you? Did it help you to think and come up selections of materials for your design? Before you start designing, what did you think about first?*
Students: *Thought about preparing materials...*
Hisham: *Before that, what did you think about? If you want to create an object, what will you think firstly about?*
Students: *Materials…*
Hisham: *Okay, material…and?*
Students: *Its place* [parts of object and which material to use]

H, L163, LT7

Although *Ms.Izatul* used the cues while teaching about elastic materials, Hisham, however have taken this idea and applied in different lesson. He adopted the recommendation of asking students to think about how their questions have helped them in learning; thus applied it for stimulating his students to think about how their questions have helped them in their decision making process. Hence, teachers take up ideas recommended in EF8 (fictional teacher) and applied them directly or adapted them into new situations for their lessons. Features such as EF5 (teaching goals), EF6 (content boxes), EF7 (lesson planning cues) and EF8 (fictional teachers) were educative in nature and were used to support teachers' practices of ST. By supporting teachers' knowledge of ST (DH 1) and supporting their ST practices (DH 2), the teachers were able to manage students' small group discussions (DH3).

DH 3 – Support for managing small group discussions. EF9, 'roadblocks' is another educative feature used to explain the challenges teachers would commonly encounter in real classrooms. These include how to engage students in meaningful discussions and thus reduce time spent on controlling students' discipline issues. EF9 has suggested teachers to use tags during discussions and help students set ground rules for systematic discussions to take place. Figure 7.9 shows an example of EF9.

Roadblocks:

One of the most frequent problems encountered by teachers while conducting experiments or hands on activities is the management of group discussions. Teachers spent much time controlling students' discipline issues due to lack of teamwork among them. Especially when students are engaged in thinking tasks which require cooperation between the members. This can be reduced by setting ground rules and provide tags with written duties that each student must comply with.

Figure 7.9. An example of a 'roadblock' (EF9).

Taking up the ideas suggested in EF9 as shown in Figure 7.9, the teachers had set ground rules and provided tags for students. Each student wears a tag, on which is written a duty that they need to carry out such as writer, time keeper, presenter and leader. They take turns to use the tags for each lesson. For example, a student who was the leader during Lesson 1 becomes the time keeper for Lesson 2 and presenter for Lesson 3. Hence, each student gets to carry out all the tasks by the end of the topic (between 6 to 8 weeks). The tags are shown in following Figure 7.10.

Figure 7.10. Tags used by the students.

During lessons, the students seemed to be comfortable wearing the tags and performing the duties assigned to them.

> *Students are wearing the tags. Time keeper reminds them of the time to do given tasks. Group leader delegates tasks to members. Writer writes down the questions posed by group members. Presenter presents the findings of investigations and the quartermaster makes sure that all science apparatus are cleaned and arranged properly.*
>
> *S, L23, FN 5*

There were no arguments on who and what to present during group presentations. Rosni often called out the whole group to accompany the presenter to present in front of the class, particularly during the lesson on designing objects and justifying selection of materials. When students from other groups pose questions, the presenter would answer the questions and when the presenter was unable to answer, the respective group members would help. *Group Mercury* came up with a devise to feed birds; it can be used when the owner is away from home. They had used plastic bottle as the feeding tray. Before *Group Mercury* presented, Rosni reminded the time keepers to check on the time for each group to discuss on how they plan to present their designs.

> *Rosni: Each group gets about 5 minutes to discuss how to present your design. Time keeper, do you have your stop watch?*
>
> *R, L11, LT6*

This shows that Rosni had also reminded the students of their duties assigned to them. A student volunteered to help the presenter with their sketch of the design. Others helped to carry the designed object. They demonstrated as the presenter explained their design.

Rosni: Why did you use plastic bottle for your design?
Presenter: Not heavy…
Rosni: Not heavy? [The presenter was silent, perhaps he had problems in elaborating his answer]
Another student: Plastic is light so it won't be too heavy to carry around.

R, L30, LT6

When the presenter could not elaborate further on his answer, another student from the presenting group helped to elaborate what the presenter meant by 'not heavy'. This shows how the students worked in groups to present their designs.

Following is another example of interaction, in which a presenter from Group A justified his selection of materials for his design (house with battery operated bulbs made from paper and plastic). During the interaction, Suzana did not intervene immediately; instead she allowed other groups to pose questions and problems about the design of the presenting group.

Student (presenter):	*This lamp is waterproof, so if water flows on the roof of this design, nothing will happen.*
Student 1 (ask):	*What if the water hits at the sides?*
Student (presenter):	*Nothing will happen, because this plastic thing is here (pointing at the side of the house)*
Student 2 (ask):	*But, what if the water flows on the roof?*
Student 3 (ask):	*if it flows on the roof, the water would flow on the battery, then the battery would spoil.*
Student (presenter):	*If the battery gets spoilt, we can still open it (the compartment made from plastic), because it is made of waterproof material.*

Only after the series of questions posed by students did Suzana interrupt to ask her own questions. However, the students could ask related questions from the questions posed by Suzana. For example, Suzana asked about the actual function of the 'lamp house' designed by Group A. And a representative quickly answered the question.

Suzana: My question is that…what is the exact function of this lamp house?
Student: The function is to light up the house…if the boy [statue in the model house] *is scared to sleep at night when there's no electricity. So the house will be bright enough…*

Another student from a different group posed different questions but based on the answer provided by Group A.

Student (from another group): At night, what if the light is not bright enough?
Group A: This light is enough for a room…this bulb can be transported from one place to another.
Student (from another group): How do you transport it? [The presenter demonstrated how he would change the position of the lamp]
Suzana: Okay, other questions?
Student: Why put outside (referring to the batteries)?
Group A: If it's outside, then very difficult to change the battery right...so if it's inside, easy to change it
Suzana: Okay, why put battery outside, so it's easy to change it, isn't it? Mmm...but if you want to put the battery inside, it's still possible right?
Group A: Yes, but we would need to make a hole.

S, L69, LT8

The members in Group A were cooperative when responding to questions posed by other students. They helped the presenter to answer those questions.

Group A managed to pose a problem – what to use to brighten a house when there is no electricity. Hence, they designed and devised model of a house with a lamp inside. They presented their design confidently and most importantly, other students posed questions, which indicate analysis level of thinking. Suzana's questions somehow weaved in with students' questions and the whole session appeared homogenous. This whole session was an example of how the students were able to discuss harmoniously with the use of tags. They did not ambush the presenting group with random questions but instead they politely put up their hands and waited for their turn to ask questions. Even when other students wanted to share thoughts, they waited patiently for their turn to speak. When students had familiarised with ground rules and taking responsibility (with the use of tags), they managed to discuss with ethics. Teachers were able to manage small or whole group discussions.

During one of the lessons, Hisham's students were conducting an experiment to classify objects based on their ability to allow light to pass through them. A student classified the ruler as transparent object; another student interrupted her and argued that the ruler was an opaque object and not a transparent one. They agreed to find out if any shadow had formed on the paper screen (an indicator of opaque object; it forms a shadow on the white screen). Hence, after repeating the experiment, her observations revealed there was no shadow, so she was able to accept her friends' observations. The students in that group showed some degree of open-mindedness and welcomed arguments from their peers. Similarly, during another lesson, the students decided to ask for help from their teacher, rather than raising voices at each other.

> *Student 1: Okay, let us start with glass first or rocks?*
> *Student 2: Okay, paper, wood and plants. Rubber band put in rubber..eya kot?* [The term 'eya kot' means not sure]*…put in plants. Cup put in plastic and plastic into petroleum.*
> *Student 1: marble…glass?*
> *Student 3: Yes…because it can break, try making sound using it*
> *Student 1: yes it has sound* [dropped the marble on floor]
> *Student 2: wooden stick made of wood right?*
> *Student 1: Yes, into plants*
> *Student 3: its glass lah…should go into rocks* [Showing the marble which was wrongly classified]
> *Student 1: Where got? Because when we drop it onto the floor, it didn't break…so…I think we better ask teacher…because we don't understand right?*

H, L55, LT6

In this interaction, there was a discrepancy between two students who argued if the marble was made of glass. Instead of raising their voices as they used to, to prove them right, these students have come to agreement to seek assistance from their teacher. Generally, the leaders and their group mates were able to discuss meaningfully. The leaders took time to listen to what their peers had to say. The groups were generally co-operative during small group discussions. This has led students to courageously share and argue out their ideas about materials during small group discussions, thus creating better group dynamics. Apart from the tags recommended in EF9, the teaching tools suggested in EF7 and EF8 had also supported the teachers in managing group discussions. When the students were given thinking tasks, such as completing thinking maps, discussing concept cartoons or writing down questions in the *Let's Ask* list, they were seen to be fully engaged with the tasks. They hardly walked around the class aimlessly; thus teachers need not spend time controlling students' discipline issues.

This section described how the teachers took up the ideas and recommendations in the STEPS in infusing ST into the topic 'Properties of Materials'. The selected teachers' uptake of ideas in the nine educative features may have influenced the change of their practices upon using the STEPS. It can be said that the design heuristics and their respective educative features may have supported the teachers' learning of ST infusion.

Transferability of knowledge. This section discusses the theme 'Transferability of knowledge' that emerged during data analysis (refer Chapter 4, page 152). This theme describes about why Rosni, Suzana and Hisham were willing to share their newly learnt knowledge (practices of ST infusion), with their colleagues upon using the STEPS. They had recommended that the use of STEPS should be made available for other levels of primary science. They were perhaps able to say so, based on their own learning experiences and their uptake of ideas from the STEPS.

The teachers were found to be confident in transferring their knowledge into different contexts of teaching and learning. In previous teaching years, they have asked their students to build prototypes of devices/objects on their own and present them. Most of the time, students could not complete the task, thus no room for discussions on the selection of materials used for their prototypes. Often the teachers would move on with succeeding topics. On the contrary, this time, they have up taken the idea of splitting the lesson into two, from the STEPS. Rosni, Hisham and Suzana have carried out the first lesson guiding their students to make decisions using suggested thinking maps in the STEPS. Here, the students discussed in groups to identify a problem and proposed devices to solve the identified problem. They were then given sufficient time (about a week), outside classroom hours, to further discuss and build the prototypes. The students then presented and justified their selection of materials during the second lesson. By doing so, there were enough room for students to work on their decision making skills and were able to justify their use of materials for their designs. According to Rosni, these lessons student-centered and were examples of the much recommended 21st century teaching and learning approach. She enthusiastically said (with her two palms closed together- a gesture showing confidence) that she now does not mind visits from the education officials, since she wanted to show them how 21st century learning should look like.

> *"The engagement of my students now....I think this [ST infusion practices]is student centered...the PPD officers [officers from District Education Office]often come ...and I don't mind if my school administers come to observe, because I want to show them that this is the 21st century learning"*
>
> *R, L131, INT*

Upon using the STEPS, Rosni was confident to model 21st century teaching and learning lessons to higher officials. She was willing to share her knowledge about ST infusion with others including experts from education departments. This may show that Rosni has attained a level of empowerment in infusing ST to manifest 21st century style lessons.

The teachers have also asserted that they have shared their new strategies (ST practices) and the STEPS with their colleagues. Hisham said that teachers in his school would meet up regularly to share ideas regarding the teaching of science (Professional Learning Community meetings). He had shared the ideas that he has up taken from the STEPS with his fellow science teachers. He further added that, other levels particularly Year 5 science teachers, should use the STEPS to learn how to infuse ST in teaching students to conduct scientific investigations.

> *"Although I don't teach Year 5 Science, but I share my ideas (about ST practices) with my colleagues and sometimes with the Head of Science Panel, share what they can do. I told them, 'if you use STEPS and teach students to conduct science experiments, it will help their students'…."*

Hisham had also shared opinions given by his colleagues about the STEPS. It seemed that Hisham had literally shared the STESP for other teachers to read and use in their own classrooms.

> *Even my friends [working colleagues] said that it was easy to adopt these [while showing the fictional teachers in the STEPS] compared to other books"*
>
> *H, L103, INT*

Similarly, Suzana thinks that generally science teachers should use the STEPS, because it offered the opportunity to learn about ST and how to infuse ST into their respective lessons. She further added that teachers should infuse ST to help initiate students to think, thus teachers should be prepared for that.

> *"If teachers cannot do it [infuse ST], surely students would not be able to think, because teachers are the initiator, and so when I look at this module [STEPS], I realize that teachers must be prepared first"*
>
> *S, L111, INT*

Suzana added that she thinks she is able to apply these ideas in subsequent topics in the Year Four Science curriculum.

> *"I think I can also apply in other topics like photosynthesis, earth and the universe…*
>
> *S, L125, INT*

The cited excerpts from the teacher interviews, perhaps show that Rosni, Hisham and Suzana have experienced professional growth in fostering the teaching of thinking skills among students in science lessons. The selected teachers did not only have up taken ideas from the STEPS, but were also willing to share these ideas among other teachers. It can be said that the STEPS could be used to promote transferability of knowledge in ST infusion among teachers with similar learning needs as the selected teachers.

Summary on the heuristics nature of the STEPS

It can be summarised that:

1. The educative features in the STEPS have assisted the teachers' learning in infusing ST. The teachers have asserted that the features in the STEPS were educative and promote understanding about ST and how to infuse ST.
2. The STEPS was found to be useful to teachers firstly, in thinking for ST infusion and secondly in utilising thinking tools to engage students in ST.
3. The teachers claimed to have the flexibility to adopt and modify the recommendations suggested in the STEPS. This was because the STEPS was prepared to be educative and not prescriptive.
4. Thus, teachers' uptake of ideas in the nine educative features was evident in their satisfactory practices of ST infusion.

5. The selected teachers were found to be willing to transfer knowledge about the infusion of ST to their workmates by sharing their teaching experiences and recommending the use of STEPS for broader groups.

Discussions on teachers' uptake of ideas in the STEPS

In this study, the use of STEPS among the selected teachers (Hisham, Suzana and Rosni) was found significant in learning how to infuse the three elements of ST. This may perhaps be because the STEPS had provided them with constructive ideas, rationales behind those ideas and tools to infuse the teaching of analysing information and ideas, development of the habit of questioning and problem posing and promoting awareness in metacognitive thinking among students. The STEPS was prepared based on design heuristics with educative features to inform teachers on how they might infuse the three elements of ST simultaneously while teaching the topic 'Properties of Materials'.

The findings on the use of the STEPS reveal that the selected teachers found the educative features stimulated their thinking, since ideas and recommendations to infuse ST were provided. This is in line with past literature on the roles of educative curriculum materials, that claimed educative materials for teachers should promote teacher-thinking as to how they could adopt new approaches into existing practice (Beyer et al., 2007; Davis & Krajcik, 2005b; Schneider, 2006). Even recent studies still investigate how educative materials aimed at in-service teacher learning, can be improved (Arias et al., 2017; Davis et al., 2014; Shu et al., 2012). They asserted that such materials should be designed with educative features that would stimulate teacher-thinking. What differentiates the present study from related studies was that the STEPS was prepared based on information gained about selected teachers' current knowledge and practices of ST (Phase 1) and literature review. The researcher gained some information about what teachers currently know about ST and identified what they need to learn for successful ST infusion into their practices. This was because teachers are the implementers of curriculum, bridging curriculum developers and students. Based on this insight, the STEPS consisted of three design heuristics, that were mainly drawn from the prominent studies by Davis and Krajcik (2005), Bismack et al. (2014), Grossman and Thompson (2008) and Davis et al. (2014). The selected teachers needed to understand the rationale behind ST and it would help them conduct meaningful science lessons. They too needed to internalise how ST can be infused into their daily lessons, so that they would be able to think how they might infuse ST, besides planning and enacting ST rich science lessons independently. Therefore three design heuristics with respective educative features were identified to meet these needs. In this way, the educative features in the STEPS were found to cater for teachers' thinking for ST infusion.

The lesson plans and tools for thinking in the STEPS were also found helpful, particularly for Rosni, who was hesitant in the beginning to participate due to her students' inability in ST. By the end of this study, however, she confirmed that she had the confidence to infuse ST. Similarly, Suzana shared her thoughts about how she perceived ST practices. She believed that teachers play a major role in fostering students' thinking skills regardless of students' academic achievement levels. These teachers have shown empowerment in ST infusion as a means of promoting higher order thinking skills among students in science lessons. Their improved teaching practices confirmed what they have said about their thoughts. The teachers have also shown interest in the proposed STEPS, as an educative material in learning to use instructions for thinking, as much as for knowledge transmission. The STEPS had provided them with the support they needed in fostering students' higher order thinking skills. Such materials were found to create space for teacher empowerment in adapting new instructional strategies (Beyer & Davis, 2009; McKenny et al., 2009; Shu et al., 2012). The role of educative curriculum materials, such as the STEPS, in teacher learning has been confirmed by other studies as well. For example, Noh and Webb (2015) have found that Mathematics teachers attained ability to explore complex situations upon using educative curriculum materials.

It can be said that the selected teachers have shown their uptake of ideas in the educative features applied them to their conventional practices. The role educative features play in teacher learning has been confirmed by other studies over the years (Beyer & Davis, 2009; Davis, Nelson, & Beyer, 2008; Schneider & Krajcik, 2002). Even recent studies have found that educative features can promote conceptual change among teachers about teaching thinking skills (Arias et al., 2016; Davis et al., 2014; Davis et al., 2017; Schneider, 2013). Davis et al. (2017) in their study on science teachers' uptake of ideas in educative features have claimed that content boxes, content story lines, concept maps, fictional teachers and other vignettes were found to be useful in implementing recommended strategies.

Apart from that, this study was also found to be in line with studies that explore ST infusion (Al-Abdali & Al-Balushi, 2016; Huang, 2015; Oliver & Venville, 2017). These studies showed that when teachers upgrade their knowledge and skills in teaching thinking skills, the students were able to manifest higher levels of thinking behaviours. In addition, the students in the present study have shown systematic group dynamics in accordance to their teachers' change in teaching practice. In another study, Bismack et al. (2015) identified evidence in students' work based on teachers' use of educative materials. They have also found that teachers used the supports provided in the designed materials and concluded that how teachers use such materials will influence student learning. This is parallel to another study that investigated the role of educative materials on student learning (Arias et al., 2017). Arias et al. (2017) found positive effects on students' engagement in science argumentation when teachers use educative curriculum materials. Similar outcomes were evident in the present study as well, in which the students were found able to argue and share ideas and discuss thinking tasks systematically by end of this study. This was because the teachers have claimed that they uptake educative features in the STEPS. Learning to teach new approaches such as the ST infusion requires teachers to have freedom to adapt recommendations, rather than being trained in a certain way (Murphy et al., 2013). In a nutshell, teachers can learn about and practice ST infusion in Year Four science lessons, by using teacher-material prepared with adaptations of design heuristics and educative features aimed at promoting teacher learning.

Summary

This chapter described the heuristic nature of the STEPS relating it to the enhancements of the teachers' practices of ST infusion. It was found that the selected have taken up ideas in the educative features from the STEPS. The conclusions and implications of this study will be discussed in next chapter.

CHAPTER 8

CONCLUSION AND IMPLICATIONS

Introduction

This study explored and described selected Year Four science teachers' practices in ST infusion in teaching the topic 'Properties of Materials'. Phase 1 was conducted to gain information on selected teachers' knowledge about ST and their current practices in teaching ST, to prepare the STEPS (Skillful Thinking Educative Pedagogical Support). Phase 2 involved the implementation of the prepared STEPS. In following section, the researcher will re-capture the journey of the present study.

The Journey

. This study was started with Phase 1, the groundwork, preparation and reviewing of the STEPS. The groundwork consisted of literature readings, identifying the problem and document analysis on educational documents such as Year Four science curriculum specifications. Here, the researcher had identified a researchable problem to further embark on this study. Nine selected teachers participated in this phase to provide information on what these teachers currently do know or do not about ST elements and how they practice ST infusion. However, Phase 1 findings revealed that these teachers lack knowledge about ST and thus showed inadequate pedagogical knowledge in ST infusion. Thus, the STEPS was prepared with three design heuristics drawn from needs analysis and literature readings with aims to educate teachers to infuse ST. Once the STEPS was prepared, it was reviewed by a panel of experts, revised by researcher and was ready to use for Phase 2.

The STEPS was implemented in Phase 2, whereby selected three science teachers participated. Their lessons were observed and they were later interviewed throughout the topic ‘Properties of Materials’. Findings showed that the selected teachers were able to independently infuse ST into the topic ‘Properties of Materials’, with the use of the prepared STEPS. Thus, the researcher described teachers’ uptake of ides in the educative features based on their satisfactory practices of ST infusion in their lessons. Figure 8.1 shows a graphical representation of the journey of this study.

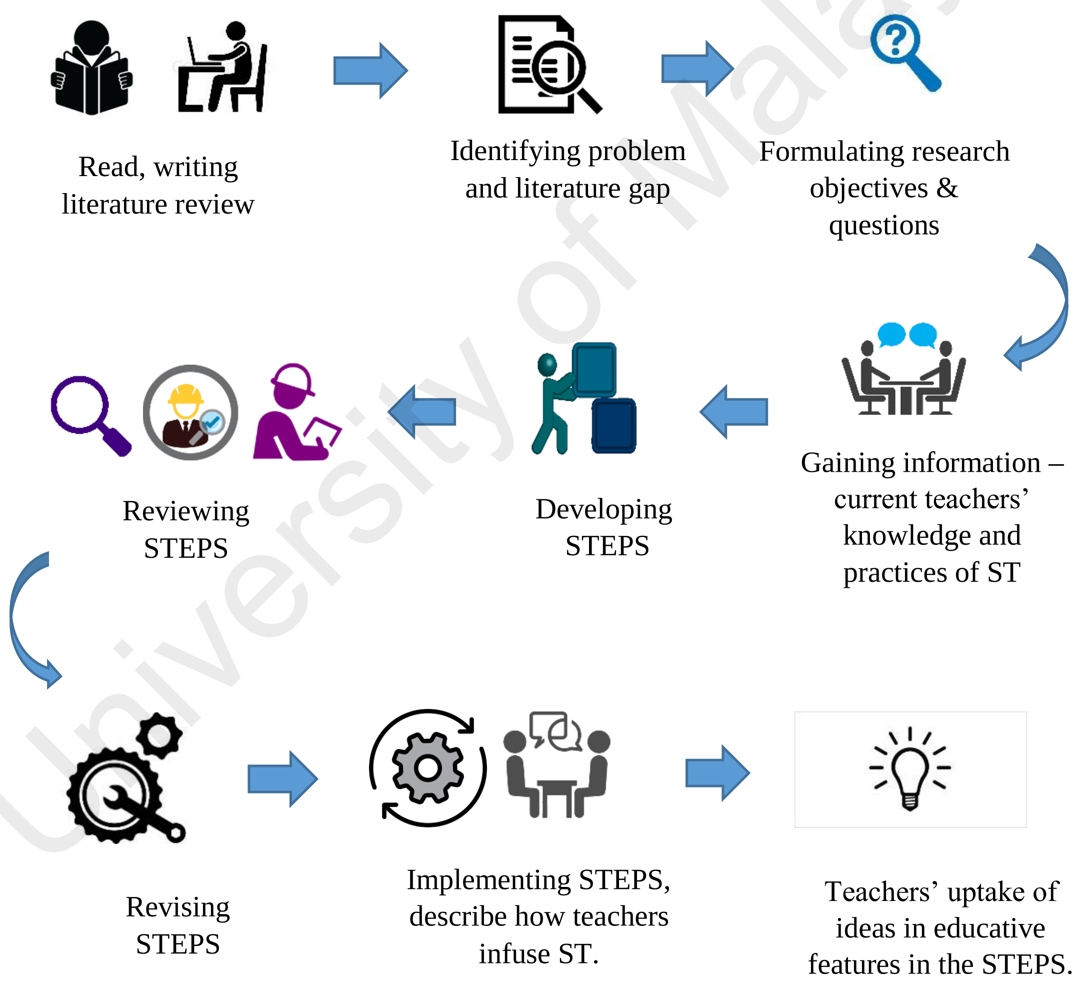


Figure 8.1. Graphical representation to illustrate the journey of the present study.

In this study, the teachers have shown satisfactory practices of ST infusion. For example, teachers had allowed students to firstly gather ideas, new information and even contradicting information about properties of materials. Secondly, they created space for students to share their thoughts and ideas about materials during peer discussions. Here is where the teachers explicitly taught students to analyse what they have observed and gathered through their senses. Teaching them to use various kinds of thinking strategies to analyses information and ideas about science concepts would help them become better at science process skills, such as observing, classifying, making inferences and communicating. As much as science teachers foster cognitive skill development among children, they had refocused their lenses to developing students' affective domain – habits of mind. In this study, with the help from STEPS, teachers were able to cultivate the habit of questioning and problem posing among children; even passive learners have started to ask questions about materials and their properties. Students were given the space to pose questions and guided on how to carry out scientific investigations to seek answers to their questions. This way, the students' active engagement becomes the source of motivation for teachers. Teachers were empowered to teach science when students actively engage in thinking tasks.

Metacognition being the highest form of cognitive thinking was seen as the most challenging. However, the teachers could at least create opportunities for students to be aware of what they think and how they think, thus relating it to the questions students have posed. Teachers walked the extra mile by explaining to students why it is important to pose questions and how it helps them to better understand the topic under discussion. Teachers diversified their lessons when opportunities emerged in the classroom. For instance, when students posed questions, teachers spent a few minutes for students to carry out simple activities to seek answers for their quest. This had allowed the teachers to be more responsive and aware of opportunities for engaging students in ST. The teachers have also shared their new experiences about ST infusion. They claimed that they never thought their students had many questions to pose during science lessons. By allowing the students to pose questions, teachers get to learn better about how their students think. Thus, questions posed by students were the stimulus for teachers to create situations to engage students in various thinking strategies about properties of materials. It can be said that these teachers have learnt how to infuse ST into existing Year Four science lessons, by teaching students to analyse information and ideas about a given science concept, cultivating the habit of questioning and posing problems and promoting the awareness of metacognitive thinking among students.

From these findings in the present study, it can be inferred that, in order for less experienced teachers infuse ST in their lessons, they must first understand the rationale of infusing ST into primary science lessons. Particularly, on how ST elements are closely related to primary science curriculum specifications, acquisition of science process skills, scientific skills and higher order thinking skills. When teachers internalise the holistic framework of these facets of primary science with the infusion of ST, teaching science to children would be more meaningful. The transition from unsatisfactory to satisfactory practices, as described earlier, may indicate the learning process for the selected teachers. With this transition found, the researcher attempted to show the link between the design heuristics in the STEPS and the transition from unsatisfactory to satisfactory ST practices. The STEPS, a guide book, may seem to provide theoretical knowledge about ST; however, when prepared with educative features, the teachers were able to internalise the rationale of ST infusion. For example, educative features, such as the ‘fictional teacher’ narrate how ST elements can be infused into lessons, in the form of a story with dialogues between the fictional teacher and students. Another example would be the ‘teacher challenge’ feature, whereby challenging situations were described and recommendations on how teachers might tackle the situation were provided.

With the help of the STEPS, these teachers were able to enact science lessons independently, that integrated satisfactory practices of ST infusion. Thus, this could provide a working understanding on how less experienced teachers learn to infuse ST into primary science lessons. Although only three teachers participated in Phase 2 of this study, the findings showed how primary science teachers can actually acquire pedagogical knowledge to infuse ST into their content lessons, with the support of an educative material such as the STEPS, tailored for teachers according to their learning needs. With the recapture of the journey of the present study, the subsequent sections will highlight the summary of findings for each research question. This chapter will also discuss the concluding remarks and implications of this study.

Summary of findings

This section of the summary highlights only the main findings of this study. There were several points for each research question addressed.

Research Question 1:

What are Year Four teachers’ current knowledge and practices of ST infusion in their science lessons?

Phase 1 was carried out to gain information on a selected group of Year Four science teachers’ current knowledge and practices. From Phase 1, it was found that three types of teachers’ knowledge were identified in this study; knowledge of thinking strategies, knowledge of habits of mind, and knowledge of metacognition. Most of the teachers were found lacking in knowledge on how to infuse the three ST elements.

Therefore, their current practices did not show sound infusion of ST. However, only a few teachers have confirmed to have certain degree of knowledge of ST; yet their practices did not support their claim. Further probing revealed an important issue which may have hindered the teachers from infusing ST. They were found lacking in teacher materials for learning how to infuse ST into Year Four science lessons.

Therefore, it can be concluded that during Phase 1, the selected teachers were lacking in knowledge of ST (*knowing what ST is about including its three elements: specific thinking strategies, habits of mind and metacognition*). This finding corresponds to their lack of practices in ST. This reflected their pedagogical knowledge in ST infusion, because they could not explain how they infuse ST nor do their current practices reveal any relevant evidence. Earlier findings on the Phase 1 revealed that the selected teachers needed support in terms of teacher materials as stimulus in learning about ST. They need support in the form of educative curriculum materials to promote teacher learning to infuse ST.

Research Question 2:

What are the design heuristics for the STEPS (Skillful Thinking Educative Pedagogical Support) for selected Year Four science teachers to infuse ST for the topic Properties of Materials?

The researcher determined the design heuristics for the STEPS based on literature readings on educative curriculum materials for science teachers (Beyer, Davis, & Krajcik, 2007; Davis & Krajcik, 2005; Gess-Newsome et al., 2011; Schneider, 2006). However the three appropriate design heuristics were determined based on selected literature (Davis, Sullivan, et al., 2014; Schneider, 2013; Shu Fen et al., 2012). The three design heuristics were:

Design Heuristic 1:	*Support teachers' knowledge of ST: Provide interpretation and understanding of ST and its relevance to Year 4 Science learning units.*
Design Heuristic 2:	*Support teachers' ST infusion practices: The infusion of ST into content lessons.*
Design Heuristic 3:	*Support teachers in managing group discussions: Provide tools to manage group discussions and stimulate students' thinking.*

Research Question 3:

How did the selected teachers' ST practices changed upon using the STEPS for the topic 'Properties of Materials'?

Teachers' infusion of ST can be categorised into two types; unsatisfactory practices and satisfactory practices. The teachers' satisfactory practices of ST infusion upon using the STEPS were described in terms of how they:

a) teach to analyse information and ideas

b) cultivate the habit of questioning

c) promote metacognitive awareness

Teachers were able to show positive changes in the way they teach students to analyse information and ideas about properties of materials. They teach to gather information and ideas, modelled specific thinking strategies and teach to transfer thinking into new contexts. In cultivating students' habit of questioning, the teachers had encouraged students to ask questions, modelled how to pose questions and modelled how to pose problems. The promotion of metacognitive thinking among students was seen as the most challenging ST element. In promoting awareness in metacognitive thinking, the teachers encouraged students to recall their thinking strategies and to revisit the questions they had posed. This can be regarded as the precondition for promoting metacognitive thinking among ten year old children.

In agreement to teachers' practices of ST infusion, students have also shown changes in several traits:

- √ Students were able to share and argue their information and ideas about properties of materials
- √ Students showed systematic group dynamics during small group discussions.
- √ Students were able to justify their selection of materials for their design

Based on teachers' satisfactory practices, teachers' uptake of ideas in the educative features was evident.

Research Question 4:

How did the selected teachers' uptake of ideas in the educative features in the STEPS support the teachers' ST infusion practices for the topic 'Properties of Materials'?

Overall, it can be said that the selected teachers have up taken ideas in the educative features from the STEPS.

- √ The selected teachers were able enact ST infused activities in their subsequent lessons. This was due to the flexibility to adopt and modify the recommendations suggested in the STEPS.
- √ They focus on the process of developing students' thinking, rather than the product of learning, with the use of the thinking tools. The use of restructured thinking maps aided their students' thinking to better understand the subject matter. Teachers' uptake of ideas in educative features from the STEPS can be seen in their satisfactory practices.

√ They were able to manage students' group discussions with the use of tags and ground rules for science talks among students. The use of thinking tools such as *Let's Ask* list, graphic organisers and concept cartoons has also contributed to better group discussions.

Thus, it can be concluded that the selected teachers were able to infuse ST into Year Four science lessons at satisfactory level, by up taking ideas in the educative features from the STEPS.

Implications of the Study

This section discusses the implications drawn from the present study. Even though the number of teachers participating in this study was small, the implications involve theoretical, pedagogical and methodological implications.

Theoretical implications. In this section, the researcher attempts to revisit the theoretical aspects of this study. Theoretical and conceptualisation of study has already had been described in Chapter 3 (conceptual and theoretical frameworks). The underlying theories were originally adopted from Shulman's theory of teachers' pedagogical knowledge (PK) and teachers' general pedagogical knowledge (GPK). The component of GPK was then expanded based on literature readings on teachers' pedagogical knowledge in the context of teaching higher order thinking skills (Justi & van Driel, 2006; McCormick, 1997; Swartz et al., 2008; Zohar, 2004). The expansion of Shulman's GPK was based on the assumption that the selected teachers in the present study had adequate content knowledge of the subject matter; Year Four science.

During the Phase 1, it was significant that the teachers had adequate content knowledge of the subject; however they lacked pedagogical knowledge in infusing ST simultaneously with the subject matter. In general, the teachers were found to employ various hands-on activities and scientific investigations as the best approach to teach science. Although most of these activities were carried out as either confirmatory inquiry or structured inquiry investigations, however, the teachers seem to have missed the vital element of fostering students to think at higher levels about the subject matter. Thus, one way to foster higher order thinking skills among young learners is by the infusion of ST (Swartz et al., 2008; McGuiness, 1999). This requires that teachers possess higher pedagogical knowledge in teaching thinking skills, than merely general pedagogical knowledge.

For example, teachers need to know of the specific instructions for infusing ST into the existing content lessons. This was argued by Zohar (2004), in her many other seminal works pertaining to teachers' pedagogical knowledge in the context of teaching higher order thinking skills over the years (Zohar, 1999, 2013; Zohar & Barzilai, 2013; Zohar & David, 2008). The issue regarding what science teachers know about teaching ST and how they teach ST kept expanding, despite many other studies which attempted to provide deeper insights (Baumfield, 2006; Beyer, 2008b; Jones, 2008; Murphy, Bianchi, McCullagh, & Kerr, 2013). These studies argue that teachers not only need to have knowledge about thinking skills (including the various kinds of thinking strategies) and the associated facets of thinking skills, such as habits of mind and metacognition, but also the knowledge of practices in teaching ST. Knowledge of practices denotes that teachers should know how to use appropriate instructional strategies to infuse ST.

The findings in the present study, suggest the strong association between teachers' knowledge of ST and knowledge of practices in teaching ST as postulated in the theoretical framework (Figure 3.5, p. 102). It can be said that pedagogical knowledge in teaching ST does not merely mean to tell students how to think but to transcend the experience of ST through specified instructions. It is about teachers knowing how and when to create such experiences by identifying the opportunities that emerge during lessons.

In bridging the two components of teachers' pedagogical knowledge in infusing ST (knowledge of ST and knowledge of practices to infuse ST), the use of an educative curriculum material had been shown to influence the selected teachers' change in their teaching practices. This shows that teacher guides to infuse ST can be made more educative rather than prescriptive, based on teachers' needs. This will include providing the support for teacher learning about ST and its relevance to Year Four science, learning how to infuse strategies to teach ST elements and knowing the content of the subject units in which ST elements can be practiced. Based on the findings, these might be the components of teachers' pedagogical knowledge that need to be upgraded, particularly among primary science teachers. Although this study investigated the practices in infusion of ST among only three teachers, the findings may indicate the need to investigate the areas of teachers' knowledge that still need to be upgraded, such as metacognitive knowledge.

Relating this finding to the use of the STEPS, it is important to revisit the theoretical framework of the study. Figure 8.2 shows the theoretical framework which was used to describe the theories involved in Chapter 3. From the framework, the connection between the teachers as learners and the use of the STEPS as an educative material was apparent in the findings (***A***). The teachers have uttered phrases like 'I learnt', 'I know now' or 'I understand what ST is all about' show how they were informed of what ST means and the rationale of ST infusion.

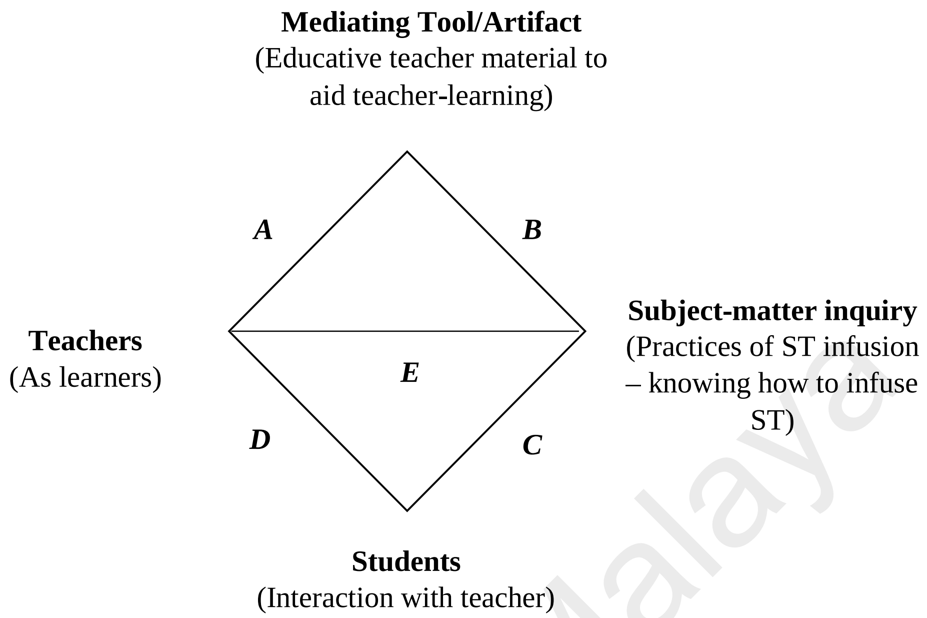


Figure 8.2. Theoretical framework of the present study as described in Chapter 3 (Figure 3.5, p. 106).

When teachers use and adapt the recommendations provided in the STEPS, they learn how to infuse ST into different sub topics, which explains the connection for the use of STEPS and practices of ST (***B***). This phase provided the learning experience of applying what they were informed by the STEPS. The design heuristics and educative features were found to be helpful in stimulating their thinking on how to enact ST infused lessons on their own. The students' responses had influenced the way they infuse each element. Questions and problems posed by students were used as a platform for teachers to create opportunities to make their students practice and transfer the learnt skill (***C***). This shows teachers' uptake of ideas in the educative features whenever appropriate situation appeared. Teachers up took the idea of using questions posed by students as a platform for students to transfer learnt thinking strategies. Based on these experiences, the teachers keep enhancing their practices. For example, from encouraging students to ask questions, teachers modelled asking good questions, then proceeded with modelling posing problems. This chain of satisfactory practices was influenced by what the teachers were informed of ST (from STEPS) and their interaction with students. Soon, this has led to teachers' change in perception about their students' ability in ST (***D***). Upon using the STEPS, the teachers were found to be more confident to infuse ST in new topics. When teachers understand the rationale of ST and were well informed on how to infuse ST through using educative materials such as the STEPS, they could change their unsatisfactory practices into satisfactory practices. The use of STEPS, as an educative material to aid teacher learning has provided the beginning stage for acquiring the proficiency in ST infusion (***E***). The teachers can be said to have developed knowledge and were able to change their current practices to ST rich practices. This can be associated with the upgrading of teachers' pedagogical knowledge in the context of infusing ST into primary science lessons.

Pedagogical implications. Primary science teachers should be made aware that their pedagogical knowledge must be continuously upgraded, even among beginning teachers. Teachers should have general ideas about the elements in ST and how it is embedded in the teaching of higher order thinking skills (HOTS). However, without understanding the rationale of infusing ST into science content matter, teachers might not be motivated enough to learn how to infuse ST. This is because past research has shown that teachers' beliefs and knowledge about teaching HOTS strongly influences their practices in teaching science (Coffman, 2013; Mansour, 2013; Zohar, 2013; Zohar & Dori, 2003).

The findings of this study suggest several other pedagogical facets that primary science teachers should take into consideration. For example, practices to teach the different thinking strategies, developing students' questioning and problem posing (habits of mind) and promoting metacognitive thinking among students. It can be said that theses pedagogy components are needed to frame teachers' conceptual, procedural and curricular knowledge in infusing ST. In accordance to this understanding, the researcher has described the pedagogical implications that involves teachers, school science panels, teacher-educators and curriculum material developers.

Implication 1: Teachers should be made aware of ST and possess the pedagogical knowledge in ST infusion

Science teachers are often encouraged to employ the inquiry discovery approach in teaching science coupled with hands-on activities or scientific investigations. Generally, the science curriculum has emphasized the teaching of scientific skills as the means to better acquire science knowledge. However, it is equally important for teachers to possess knowledge in teaching students how to think skilfully in generalising scientific concepts to build science knowledge. The findings about teachers' knowledge of ST and their current practices in the present study seem to indicate that primary science teachers should be made aware about the elements of ST in teaching science. They should also be able to transfer this knowledge into real-life classroom situations. This includes having the knowledge and practices of ST infusion. This means that teachers ought to know how to teach to infuse the three elements of ST into one lesson or series of lessons, while simultaneously develop subject matter understanding among students.

However, this can be made possible if teachers are responsive to their practices in teaching each element of ST. Teachers should understand the importance of teaching ST as a means to foster HOTS among young students. Building upon knowledge of ST would facilitate teachers' knowledge of practices, so that they know why, when and how to enact a lesson that supports students to think skillfully. This also indicates that teachers need to change their perception about teaching HOTS. The selected teachers have all employed hands-on and scientific investigations to aid inquiry learning.

Teachers need to pay extra attention to explicitly teach the different thinking strategies in analysing information (from observations or discussions). They also should extend this effort to develop students' habits of mind especially questioning and problem posing skills. This is because questioning and problem posing skills are among the important skills for inquiry learning as well as to initiate argumentative abilities (Chin & Osborne, 2008, 2010). Another element of ST that teachers need to promote is metacognitive thinking among students. The findings of the present study suggest teacher need to promote students to reflect upon their thinking and learning, as a precondition for metacognitive thinking. Therefore, it is crucial for primary science teachers to be aware of ST elements, and be able to create situations where students could practice them.

Implication 2: Teachers should be able to identify opportunities for practicing and applying ST in content lessons

To develop pedagogical knowledge in the context of ST infusion, teachers require a lot of practices in infusing each ST element. As the teachers in the present study practiced the infusion of ST over eight weeks' time period, during this period, they have shown positive change in infusing the three elements. There was a series of practices employed by the teachers to infuse ST elements. There were series of practices employed by the teachers to infuse ST elements. In general, the practices indicate that teachers should be able to identify opportunities for practicing and applying the teaching of ST in their content lessons. Knowing which topic is relevant for practicing certain thinking strategies or developing particular habits of mind is crucial as well.

Similarly, knowing how to turn students' questions and posed problems into challenging tasks for students to think further, is equally important. These are the opportunities in which teachers could constantly create the space for students to keep practicing learnt thinking skills and transfer knowledge into new contexts. With this finding, primary science teachers can foster HOTS among young students if they are able to identify opportunities in science lessons, thus creating the experiences in ST. The science content knowledge can be the platform in which students practice their skills such as analysing information and knowledge or reflection upon their thinking performance.

However, emphasis should be given on teaching students *how to think* rather on what to think. For example, the topic of 'Properties of Materials' was the platform to think about, nevertheless, focus was given on teaching them how to think-by performing specific thinking strategies to analyse knowledge about the different properties of materials around them.

Implication 3: Teachers need to emphasise students' thinking as process rather than as product of learning

In Phase 1, some teachers were found to use the I-THINK maps for facilitating student learning. The rest did not show any evidence of using any kinds of thinking maps in their lessons. Either way, the use of thinking maps or graphic organisers are under-utilized or misused by the selected teachers. The selected teachers perceived thinking maps as a product of learning, thus they helped students to complete the thinking maps at the end of lessons. Based on Phase 2 findings, teachers' use of the graphic organisers has changed from being the product of learning to a tool that assist students' thinking. This implies that primary science teachers need to focus on students' thinking as process rather than on knowledge transmission. Completing graphic organisers at the end of lessons, without students understanding them, is not the anticipated learning outcome.

Existing graphic organisers should be re-structured by adding features such as cues to stimulate students to think in a particular way (like comparing or making generalisations). With a little help of these cues, teachers might be able to gauge students' thinking process. This is to prevent teachers from focusing too much on students completing graphic organisers at the end of learning as learning outcome. Completing graphic organisers should not be the aim of learning, instead organisers should be used as tool to aid the process of students' thinking to understand subject matter content. Therefore, it is crucial for science teachers to know how to modify existing thinking maps to suit subject content. However, the use of thinking maps and graphic organisers should dissipate gradually, as such students be able to think autonomously without keep depending on thinking maps.

Implication 4: Teachers' practices in the infusion of ST into science lessons

Past researches have proven that the infusion method proposed by Swartz et al. (2008) is another effective approach to foster students' higher order thinking skills (HOTS) by teaching students to think skillfully. To think skillfully requires teachers to infuse the elements of ST into content lessons, so that students will be able to simultaneously develop various thinking skills, build habits of mind, think about thinking and attain subject matter understanding. The four steps infusion strategy by

Swartz et al. (2008) has led to new configurations of infusion among beginning science teachers during the transition from their conventional teaching to ST rich teaching practices. The configurations in the practices have given insights into how teachers can learn to infuse ST.

Therefore, this study proposed the practices in the infusion of ST into primary science lessons, based on the findings from three different science teachers. Although the sample might be small, the findings have implications for science teachers' experience in learning to teach ST. This study uncovered how selected teachers have changed their practices -- how they infuse the three elements of ST. These practices have outlined a number of pathways to show how employing a certain pedagogy leads to another pedagogy to infuse an element. It showed the possible trails which teachers could follow to transform their existing science lessons into ST rich lessons. It articulates how a strategy for teaching a specific thinking strategy could be used to make students reflect their experiences in performing a given thinking strategy. If teachers are able to recognise these pathways in their instructions, then they would be able to devise and enact lessons that focus on both subject matter understanding and explicit infusion of ST.

The practices undertaken by the teachers in this study can be informed to other teachers who need upgrading of their practices and knowledge in teaching HOTS. The practices were found to be dependent on each other, which means, teachers adapt the infusion of all three elements in a single lesson. Although the practices did not differentiate beginning teachers with experienced ones, it can be informed by teachers to adapt the instructional strategies proposed in the practices. However, it is important for teachers to clearly understand that by infusing ST elements, students would be able to better understand science concepts.

Implication 5: School science panel should continually upgrade their pedagogical knowledge in infusing ST at different levels (Year 1 to Year 6).

One of the findings in this study was that the selected teachers claimed that they shared the new knowledge (infusion of ST) with fellow teachers. They even suggested to other science teachers who teach higher levels, such as Year 5 and 6 to use the STEPS in learning to teach ST. This shows that teachers were willing to share their ideas and learning experiences with fellow teachers.

School science panels should constantly share new learning experiences among science teachers to deliver information about learnt teaching approaches. They could also collaboratively plan ST rich lessons and compare the enactments of their lessons. It would create professional learning experience among science teachers. The panel should also focus on upgrading both novice and experienced teachers in adapting ST into their science lessons. This is to ensure that the gap within novice and experienced teachers in teaching thinking skills during science lessons can be reduced. Learning does not end in teacher training colleges; it needs to be continued during in-service teaching years.

Implication 6: Curriculum materials designers for teachers should include educative features to assist in-service teacher learning.

The preparation of the STEPS has provided a few insights into preparing learning materials for teachers. As much as students, teachers too need support for learning. The STEPS was prepared with aims to promote teacher-learning and develop pedagogical knowledge in teaching ST. Prior to the preparation of the STEPS, the researcher conducted a Phase 1 to gain information on what teachers already know about ST, so that the STEPS can be prepared based on teachers' current knowledge as basis of new knowledge construction. Similarly, information on the teachers' current practices, has helped the researcher to locate areas of pedagogical knowledge that need to be addressed in the STEPS. For example, it was found that the teachers were unable to engage their students in thinking tasks due to poor classroom management. Therefore, the researcher had included recommendations on how teachers could manage their classroom to actively engage students in any given thinking tasks.

The STEPS was not built to instruct teachers on what to do to infuse ST, but educate teachers with the use of educative features. These features such as the fictional teachers in the form of interaction between teacher and students, were found to stimulate teacher thinking. Lesson templates included cues for teachers to think about how they could infuse each ST element. The teachers in the present study also have confirmed that the STEPS was new to them as compared to their existing teaching modules.

Educative curriculum materials should be designed to address the different needs of Year Four science teachers to support learning to teach ST. It should be noted that curriculum material designers and science teacher educators should consider challenges in teaching ST, while designing supports for teachers in teaching ST in primary science classrooms. Therefore, it is important to support teacher-learning materials with goals to educate teachers. Curriculum material designers should design educative curriculum materials for teachers to support teacher learning, based on their needs and not on a "one size fits all" basis.

Methodological implications. Although the selected teachers' practices in the infusion of ST was central, the preparation of the STEPS was important as stimulus for teacher learning to teach ST. By this, the researcher was able to describe the satisfactory practices in the infusion of ST among the selected teachers upon using the

STEPS. Therefore, the research design was divided into two phases, Phase 1 and Phase 2. Phase 1 comprised the groundwork, developing and reviewing of the STEPS. This phase was conducted to gain information on the selected teachers' knowledge and current practices in ST infusion. By adapting this method, the researcher could generally describe what the selected teachers do (or do not) know about ST and if their current practices were rich in the teaching of ST. With this information, the researcher were then able to prepare the STEPS with aims to educate the targeted group to learn how to infuse ST. Although this study did not mainly focus on the preparation of the study, the outcomes of the Phase 1 (the preparation of the STEPS) was indeed prominent.

Another modification on the methodology of this research was the use of design heuristics in preparing the STEPS. While designing educative curriculum materials, design heuristics act as the rules to prepare materials that would serve the purpose-which was to educate teachers. The researcher adapted the design heuristics proposed by Davis et al., (2014), however only that were relevant to the present study. Therefore the STEPS was prepared based on how the researcher had understood the idea of educative curriculum materials, drawn from past studies. By integrating design heuristics based on literature readings, could help to prepare tailor-made pedagogical support for science teachers.

Suggestions for Future Research

In this study, selected Year Four science teachers' practices in the infusion of ST were investigated and described. To stimulate the change in teachers' practices, the researcher had prepared pedagogical support for teacher-learning based on the findings from Phase 1. It was found that science teachers have shown satisfactory practices of

ST infusion, through the use of STEPS. This study investigated primary science teachers and their needs in learning to teach ST. Future research might perhaps look into how experienced teachers change their conventional practices to practices that indicate the infusion of ST. The satisfactory practices by the selected teachers in the present study could provide working understanding of ST.

Although the researcher had prepared the STEPS as a support that provides recommendations on how they could infuse the three elements of ST, among the three elements, promoting metacognitive thinking among young students was still seen as a challenge for the selected teachers. This shows that a few more educative features need to be added in the STEPS for future use. Past research on educative curriculum materials mostly focused on science teachers' learning to teach the nature of science (Shu Fen et al., 2012), science inquiry (Schneider, 2013) and the role of such materials on students' work (Bismack et al., 2015). Perhaps, future studies could investigate how educative features in curriculum materials for teachers can be designed to facilitate science teacher learning to promote metacognition in primary science lessons.

Future research might also use the findings of the present study to evaluate what science teachers do or do not know about ST and their pedagogical knowledge in infusing ST, on a larger scale. This is important to revise existing teaching and learning materials for teachers, so that the materials can be improved to upgrade in-service teachers' pedagogical knowledge. The present study investigated how the selected teachers infuse instructions to develop the habit of questioning and problem posing. This is only one among the sixteen habits of mind (Costa, 1999). Future research could focus on how students pose questions and problems among themselves and discuss them to seek explanations in groups. Upcoming research might further investigate the presence of other habits of mind among young students and how teachers develop them in science classrooms. This could perhaps provide insights into how science teachers could weave in various habits of mind holistically in science lessons.

Conclusion

The present study has investigated how selected Year Four science teachers changed their conventional practices to practices that show ST infusion during the teaching of topic ‘Properties of Materials’. Their practices reflected a positive change in their pedagogical knowledge in infusing ST. The notion of pedagogical knowledge in the context of this study was reflected by the teachers’ satisfactory practices of ST infusion. Teachers’ knowledge of ST would mean to know what ST involves, the three elements of ST, and understanding the rationale of infusing ST in Year Four science. Knowledge of practices in ST infusion, on the other hand, means knowing how, why and when to teach ST. Similarly, from the teachers’ shared thoughts about infusing ST, it can be concluded that the teachers have gained more information about ST. The selected teachers’ knowledge of ST varied from each other, with different levels of understanding in implementing ST. The gap between the selected teachers’ knowledge and implementation can perhaps be reduced by the support of educative materials for teacher-learning to infuse ST. By learning to infuse ST, the primary science teachers would be able to engage ten year old children in analysing information and ideas, pose questions and problems and even be aware of how they think. It is crucial for in-service primary science teachers to reframe their pedagogical knowledge in infusing ST. Highly structured professional development programmes may not be feasible for all teachers. In such stance, educative curriculum materials, such as the STEPS can help teachers to learn to infuse ST into existing science lessons.

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