Science and Mathematics Education Centre

The Use of Metacognitive Interventions to Enhance Secondary Students' Metacognitive Capabilities and Their Achievements in Science

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Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of my knowledge and belief, this thesis contains no material previously published by any other person except where due acknowledgment has been made.

Signature:

Date: 13 – 9 – 13

ABSTRACT

This study was designed to conduct and evaluate the effectiveness of a repertoire of interventions aimed at enhancing secondary school students' metacognitive capabilities in science and their achievement in science. The action research study that started in term two of the first semester of 2009 (April-June 2009) was conducted in 3 cycles.

The participants in the first cycle were 35 Year 9 students. The interventions conducted included providing students with clearly stated focused outcomes, collaborative group work and concept mapping. The second cycle was conducted in the second semester of 2010 (July-December 2010) with 19 Year 7 students and twenty Year 9 students. After reflecting on the first cycle, the interventions conducted in the second cycle were similar to those in the first cycle except for the inclusion of reflection journals. The third cycle was conducted in term two of the first semester of 2012 (April-June 2012) after presenting the findings from the first and second cycles at an International Conference and reflecting on the outcomes. The participants in the third cycle were 26 Year 7 students, 25 Year 8 students and 24 Year 9 students. The interventions conducted in the third cycle were similar to those in the second cycle with some modifications. For example, students' reflections were conducted with strict reference to the focused outcomes.

In all the three cycles, the quantitative data about the changes in students' perceptions of their metacognitive strategies and support was obtained by using two metacognitive strategies and support questionnaires in pre-tests and post-tests. In the first cycle the qualitative data about students' metacognitive strategies was obtained from written interviews. After reflecting on the research findings, oral interviews were used in the second and third cycles. Reflection journals were also used as sources of qualitative data in the second and third cycles. In the first and third cycles the students' achievement in science was assessed by using pre-post-tests. However, in the second cycle, students' scores in the first and second semester examinations and assignments were used to assess the students' achievement in science.

The quantitative data from the pre-post metacognitive questionnaires did not show significant gains in students' perceptions of their metacognitive strategies and support except in the first cycle. However, most of the mean scores of the scales were above 3 (out of a maximum of 5 on a Likert-type scale). The qualitative data obtained from reflection journals in the third cycle showed gains in metacognitive strategies among the average and high achieving students. In the first cycle, generally students gained in post-tests in the first tiers (choice of answer) but modest gains were made in the combined tiers. In the second and third cycles, there were no significant gains in the pre-post-tests. In all the three cycles, in the pre-post-tests, students' means scores in the first tier items were higher than combined tiers. However, in the third cycle the gains in the combined tiers were greater than the gains in the first tier items though the means scores of the first tier items were still greater.

Nevertheless, this action research study succeeded in improving metacognitive strategies among the high and average achieving students in Years 7, 8 and 9, as evidenced by their responses in their reflection journals and oral interviews in the second and third cycles. There was also a general improvement in the students' achievement in science, especially in the first tier items, of the pre-post science tests in all the year levels. However, gains in the Year 9 classes, in both metacognitive strategies and achievements in science, were modest in comparison to the Year 7 and 8 classes.

Qualitative data instruments (oral interviews and reflection journals) are more sensitive to changes in students metacognition in science classroom, and therefore would provide more useful data than quantitative measures (metacognitive questionnaires) which only give a general assessment of students' metacognition and require large samples to be reliable.

DEDICATION

Sanyu and Suubi

my daughters who have been tolerant with my frequent absences from family activities

Augustine and Sarah Namutete

my parents who instilled in me the love for knowledge

and finally

Elaina

my wife, my friend and professional colleague

for all your love, patience and encouragement

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RATIONALE OF THE STUDY

1.1 Introduction

This study focuses on the effectiveness of a repertoire of teaching interventions to enhance students' metacognitive capabilities, and their achievement in science. This chapter provides a background to the study (Section 1.2), the relevant secondary school science curricula employed in this study (Section 1.3), the conceptual framework for this research (Section 1.4), the significance of this study (Section 1.5) and the importance of teaching metacognitively (Section 1.6).

1.2 Background to the Study

The word metacognition is composed of two words: "meta" and "cognition". The prefix meta comes from the Greek language and means "about" (Kolencik & Hillwig, 2011). So, metacognition means 'knowledge about one's own thinking'. Metacognition has a long and rich history. The speculation on the capacity of humans to reflect on their own thinking can be traced back to Plato and Aristotle. However, the word metacognition was first coined by Flavell in the 1970s, who referred to it as knowledge concerning one's own cognitive processes and products or anything related to them (Dutke, Barenberg & Leopold, 2010; Phelps, Ellis & Hase, 2001). Psychological and educational research literature over the past two decades considers metacognition to be key to deeper, more durable, and more transferable learning (Dutke et al., 2010; Hacker, Dunlosky & Graser, 1998; Huff & Nietfeld, 2009). Metacognition involves: (1) awareness of one's thinking, (2) active monitoring of cognitive processes, (3) regulation of cognitive processes, and (4) application of heuristics to organise problem-solving. Metacognitive strategies are employed by a person in a process of purposeful enquiry (Schraw, 2009). Thus, there is much promise that interventions aimed at enhancing student metacognition might lead to corresponding improvements in conceptual understanding of curricula content.

To teach science metacognitively, teachers need to be aware of the sources and characteristics of students' alternative conceptions, to select strategies to overcome their alternative conceptions, and to evaluate the extent to which such conceptions have been replaced by scientific conceptions or integrated into conceptual beliefs more like those of scientists. Conceptions can be regarded as the learner's internal representations constructed from external representations of entities constructed by other people such as teachers, textbook authors or software designers (Treagust & Duit, 2008).

In the Programme for International Student Assessment (PISA) (OECD, 2001), scientific literacy is seen as the capacity to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity. Such an ambitious definition of scientific literacy may only be set into practice if the multi-dimensional conceptual change perspectives provide the framework for instructional design (Treagust & Duit, 2008). A wealth of research evidence is now available to show that one of the marked differences between more and less successful students is their metacognitive capability. Nevertheless, students need help in developing metacognitive knowledge and processes to engage effectively in planning, performance and evaluation of learning (McCombs, 1989; Meichenbaum, 1985; Murray-Harvey, 1993).

1.3 Curricula and Education Policy Employed in the Study

1.3.1 The Northern Territory Science Curriculum (NTC)

In the first cycle, the students in Years 7 and 9 followed the NTC. The essential learning outcomes of the NTC lay the foundation for 'connected life-long learning'. The essential learnings in the NTC curriculum are inner learner, creative learner, collaborative learner and constructive learner. Of all the essential learnings in the NTC curriculum the one that is directly linked to the development of students' metacognitive capabilities is the inner learner. The inner learner outcome is to enable students to become self-directed and reflection thinkers. This outcome is essential to the development of the other domains. The inner learner demonstrates capabilities and inclinations to reflect on one's thinking and learning processes (metacognition) (NT Curriculum Framework, Essential Learnings, 2006. p.17-20).

According to the NT Curriculum Framework (2006), Students in Years 7-9 who have well developed metacognitive processes were expected to exhibit the following skills shown in Figure 1.01.

- Decide on a performance that demonstrates a preferred way of learning and appraise the process and the product, e.g. poster, video clip, oral presentation
- Consider the pros and cons for pursuing learning and select appropriate course of action
- Describe in detail how a problem or task is thought through and explain how the awareness of this thinking process enhances performance
- Create action plans that incorporate own preferred learning style in order to complete tasks successfully
- Select best pieces of work completed and/or in progress and explain why these are valued in terms of their preferred way of learning
- Use a wide variety of self-assessment strategies, e.g. rating scales, learning portfolios

Figure 1.01: Skills expected to be exhibited by Years 7-9 students with well-developed metacognitive processes. (Adapted from NT Curriculum Framework, 2006, p. 22)

The science learning area in the NTCET is designed to develop scientific literacy that is described as the capacity for individuals to be: (1) interested in and understand the world around them, (2) engage in the discourses of and about science, and (3) be sceptical and question scientific matters claimed by others.

Learners need an understanding of the processes of science, how science knowledge is generated and validated and how it is used to solve real-life problems. The NTC states that science should be linked more often and more closely with local and wider communities and science should be studied in community settings that represent contemporary science practices and concerns. This is the social constructivist perspective of learning. Figure 1.02 illustrates the learning management questions required to foster independent learning in the NT curriculum.

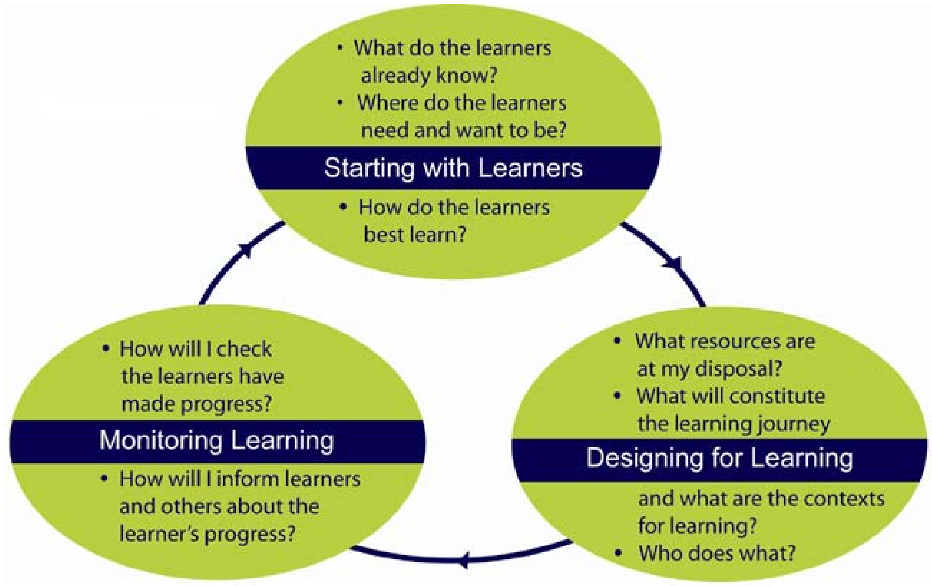


Figure 1.02: Learning Management Questions in the NTC (Adapted from the NT Curriculum Framework, 2006, p. 5)

These design questions are about starting, monitoring and evaluating the students' learning journey in science. An effective design for the learning journey emphasises learner engagement and inquiry, based on teacher questions and discussion**.** Teachers use exploration and experience to introduce science concepts and terms in ways that have meaning to science students, address the learners' naive or alternate conceptions and guide activities to address such conceptions and build on them (NT Curriculum Framework, Science Learning Area, 2006, pp.1-7).

1.3.2 The International Baccalaureate Curriculum (IB)

In the second cycle, the science teaching programmes for students in Years 7, 8 and 9 (2010-2012) followed the 2007 IB curriculum. The Middle Years Programme (MYP) of the International Baccalaureate Organisation (IBO) is a course of study designed to meet the education requirements of students aged between 11 and 16 years. The curriculum may be taught as an entity in itself, but it is flexible enough to allow the demands of national, regional or local legislation to be met. The MYP has been designed to guide students in their search for a sense of belonging in the world around them. It also aims to help students to develop the knowledge, attitudes and skills they need to participate actively and responsibly in a changing and increasingly interrelated world. This means teaching them to become independent learners who can recognize relationships between school subjects and the world outside, and students learn to combine relevant knowledge, experience and critical thinking to solve authentic problems.

The eight subject groups provide a broad, traditional foundation of knowledge, while the pedagogical devices used to transmit the knowledge aim to increase the students' awareness of the relationships between the subjects. Students are encouraged to question and evaluate information critically, to seek out and explore the links between subjects, and to develop an awareness of their own place in the world.

A common curriculum model applies to all the IB diploma programme science subjects: biology, chemistry, physics and design technology. The aim of the IB curriculum is to develop internationally minded people who recognize their common humanity and shared guardianship of the planet in order to help to create a better and more peaceful world. IB learners strive to be inquirers, knowledgeable, thinkers and reflection as explained in Figure 1.03.

Inquirers - develop their natural curiosity. They acquire the skills necessary to conduct inquiry and research and show independence in learning. They actively enjoy learning and this love of learning is to be sustained throughout their lives.

Knowledgeable learners - explore concepts, ideas and issues that have local and global significance. In so doing, they acquire in-depth knowledge and develop understanding across a broad and balanced range of disciplines.

Thinkers - exercise initiative in applying thinking skills critically and creatively to recognize and approach complex problems, and make reasoned, ethical decisions.

Reflective learners - give thoughtful consideration to their own learning and experience. They are able to assess and understand their strengths and limitations in order to support their learning and personal development.

Figure 1.03 Features of the IB Curriculum (Adapted from IB learner profile, 2007)

1.3.3 The Australian National Science Curriculum (ANSC)

In the third cycle, the science teaching programme for students in Years 7 and 9 followed the Australian National Science Curriculum (ANSC). The draft of the ANSC in Years 7-10 (typically from 12 to 15 years of age) caters for many components of metacognition even though the word ‘metacognition’ is not mentioned. The three major strands in the ANSC are science understanding (knowledge), science inquiry skills (regulation of knowledge) and science as a human endeavour (motivation).

The ANSC states that teachers need to provide time for students to build a knowledge base. Knowledge construction is a key strategy in promoting meaningful and long-term learning. It suggests the need for a unification of ideas in order to foster a deeper appreciation of explanations and theories. The ANSC also states that it is important to include contemporary contexts in which science can be learned because it is current research and it is human uses that motivate and excite students. Motivation as a component of metacognition is crucial in promoting independent learning for students of all abilities (Australian National Curriculum, 2008, pp. 4-7).

1.3.4 Education policy and metacognition

A significant number of intervention studies (Hartman, 2001; Magno, 2010; McLoughlin & Taji, 2005; Zimmerman & Schunk, 2011) show an improvement in students’ metacognition by the end of the intervention period and also show an improvement in various performance and outcome measures. However, these gains are rarely maintained over longer periods of time. Many students in secondary schools and universities still find reflecting on their thinking difficult and even frightening (Larkin, 2010).

Many secondary school students develop ways of thinking that enable them to pass examinations necessary to get into higher education institutions. However, they rarely have to link their knowledge to knowledge about themselves in any overt way. While some teenagers do reflect on their own values and morals, and develop opinions about the world around them, they rarely reflect on their thinking in terms of learning science. They tend not to reflect on why they find some science topics easy or interesting; on what wider contextual factors may have influenced their opinion. (Hartman, 2001; Larkin, 2010).

1.4 Towards a Conceptual Framework for this Study

1.4.1 The research problem

According to research (DETYA, 2000; Millar, Leach & Osborne, 2000), there is a decline in the number students who take science subjects in the post-compulsory years of schooling. Consequently, this decline will lead to shortages of scientists in Australia (Dekkers & de Laeter, 2001; DETYA, 2000; Luntz, 2001; Pockley, 2001). In addition, any society in which progress and change are common features requires its people to be independently capable. The explosion in the expansion of specialist knowledge, puts a premium on giving people confidence in their own ability to learn and shows how futile it is to try to sustain the formal transmission of the knowledge model. Organisations will increasingly feel the burden of ongoing training costs and will favour employees who are able to learn and adapt to new technologies without continual intensive training investment (Phelps et al., 2001). In contexts of rapid change, learners' metacognitive strategies provide distinct advantages, and may be more important than skills themselves. When confronted with novel situations, the specific cognitive skills and learning strategies we have available become more critical than the limited content knowledge we may possess (Etmer & Newby, 1996; Phelps et al., 2001). Thus metacognitive teaching approaches can empower students for life-long learning in turbulent and rapidly changing contexts. However, metacognition does not seem to be finding its way into the everyday classroom practices or curricula of teacher educators, and there is little evidence that the quality of students' learning of science has improved over the past decade (Thomas, 2012).

The purpose of this study was to investigate the effectiveness of a repertoire of interventions aimed at enhancing secondary students' metacognitive capabilities in science, and the relationship between secondary students' metacognitive capabilities and their scores in tests and assignments. In the first cycle of this action research, interventions were conducted to enhance secondary students' metacognitive capabilities in Year 9, and in the second cycle, interventions were conducted with students in Years 7, 9 and 11 at a high school in the Northern Territory of Australia. The interventions conducted in the first cycle included providing students with focused outcomes of the topics to be covered, concept mapping, collaborative group work and real-life examples or experiences of the topics studied. In the second cycle the same interventions, as in the first cycle, were employed in addition to writing reflection journals. The effectiveness of the interventions conducted in the first cycle were analysed by using metacognitive surveys, interviews and tests; whereas the effectiveness of the interventions in the second cycle were analysed by using metacognitive surveys, test results, assignment results and reflection journals.

1.4.2 Research questions

In addressing the purpose of this investigation, the following research questions are addressed:

RQ1: What was the effect of the interventions on the students' perceptions of their metacognitive strategies in science?

RQ2: What was the effect of the interventions on the students' perceptions of their metacognitive support in science?

RQ3: What was the effect of the metacognitive interventions on the students' achievement in science?

1.5 Significance of the Study

This study is significant because it investigates students' metacognitive capabilities in science, and the effectiveness of a repertoire of teaching and learning interventions for enhancing their metacognitive capabilities. The development of students' metacognitive capabilities is designed to foster self-directed and life-long learning, and thereby not only increases the prospects of Australia's future in the fields of science and technology but also in other domains.

The research is innovative because to achieve a deep understanding of scientific content, students must reconstruct the concepts within their own personal network of knowledge and this research incorporates metacognition in the teaching and learning of science in secondary schools. Limited research has been conducted to specifically investigate the effectiveness of a repertoire of interventions to enhance secondary school students' metacognitive capabilities in science, and the correlation between students' metacognitive capabilities and their achievements in science. This study applies a constructivist approach to understanding how students learn and how teachers can address these learning needs by adopting specially designed teaching approaches in their instructional repertoires (Kolencik & Hillwig, 2011; Treagust, Duit & Fraser, 1996). With this constructivist approach, learners intentionally construct their own knowledge based on their experiences, and thereby are able perceive the world in ways that are coherent and useful to them (Kolencik & Hillwig, 2011; Sinatra & Pintrich, 2003).

1.6 Importance of Teaching Metacognitively

Improved student metacognition enhances understanding of science content. Improved secondary student understanding of science is essential for Australia to be at the cutting edge of science (OECD, 2001). Subsequently, enhancing students' ability to explain what they know and can do is a valuable national asset. It produces citizens with excellent analysis and explanatory skills such as investigating, understanding and communicating. Fostering metacognition is also essential to developing wise and thoughtful citizens since it involves thinking about different perspectives, reflecting on the sources of knowledge and abstracting from the surface level of thinking to draw connections between different bodies of knowledge (Larkin, 2010).

Improved metacognition will benefit not just education but training, industry and commerce by showing how to better learn and communicate important ideas by analysing the inherent underlying nature of the concept (Treagust, Chittleborough & Mamiala, 2003). The speed of technological, economic and social change means our jobs and circumstances change more frequently and less predictably than before. Teaching metacognitively can assist students to become 'expert learners', thereby empowering them for life-long learning in turbulent and rapidly changing contexts (Phelps et al, 2001).

1.7 Operational Definitions of Terms

Metacognitive interventions are the teaching approaches used to enhance students' metcognitive capabilities. These include provision of focused outcomes for the topic being taught, collaborative group work, concept maps and reflection journals.

Metacognitive strategies are sequential processes that a learner uses to control cognitive activities and to ensure that a cognitive goal has been met. The major components of metacognitive strategies for the purpose of this study are cognitive strategy use (CSU), self-regulation (SR) and cognitive self-consciousness (CSC). CSU refers to the extent to which students use strategies to learn. SR is the extent to which students plan, monitor and modify their cognition (Pintrich & Groot, 1990). Cognitive self-consciousness is the extent to which students monitor their thoughts during the learning process (Cartwright-Hatton et al., 2002).

Metacognitive support refers to classroom characteristics or learning environment which enhances metacognition. The characteristics relevant to a learning environment which supports the development of metacognitive capabilities are metacognitive demands (MD), student-student discourse (SSD), student-teacher discourse (STD), student voice (SV) and teacher encouragement and support (TES). MD refers to the extent to which students are asked to be aware of how they learn and improve their learning in science; SSD refers to the extent to which students discuss their learning processes in science; STD is the extent to which students discuss their learning processes in science with the teacher; SV is whether students feel it is legitimate to question the teacher's pedagogical methods; and TES refers to the extent to which students are encouraged by the teacher to improve their learning processes in science (Thomas, 2003).

Achievements in science refer to the increase in students' scores between the pre-and post-tests. The changes are analysed by using paired t-test scores and are considered to be significant when $p<0.01$.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents the literature review by addressing five broad sections to help guide and frame the design of the study. These areas are the theoretical and conceptual models of metacognition (Section 2.2), metacognitive strategies (Section 2.3), a review of metacognitive support (Section 2.4), a review of the assessment of metacognition (Section 2.5), the use of multiple methods (Section 2.6), students' achievement in science (Section 2.7), and the conclusion (Section 2.8).

2.2 Theoretical and conceptual models of metacognition

The concept of metacognition gained significant recognition in the 1970s with Flavell. He defined metacognition as cognition about cognition or thinking about thinking (Hartman, 2001; Hofer & Sinatra, 2010; Larkin, 2006; Zohar & David, 2009). However, Flavell's definition was too general. Over time, metacognition has been re-defined by various researchers in more specific ways but this domain still lacks coherence. According to Wilson and Bai, (2010), metacognition can be categorised into two major parts: knowledge of cognition and regulation of cognition. Knowledge of cognition refers to having knowledge and understanding whereas regulation of cognition refers to control and appropriate use of that knowledge. According to Pintrich, Wolters and Baxter (2000), self-regulated learning (SRL) involves being active, constructive, setting goals for learning and making a deliberate effort to monitor, regulate, and control cognition and motivation, guided by the goals set. During learning, students may assess whether or not particular strategies are effective in achieving their learning goals, evaluate emerging understanding of the topic, and make necessary changes regarding their knowledge, strategies, and other aspects of the learning context (Azevedo, 2009). The changes to the learning approach, based on continuous monitoring and comparison with standards for learning, facilitate students' decisions regarding when, how, and what to regulate. This example illustrates the intricate nature of metacognition and SRL. Metacognition is also viewed as a supervisory system that controls and receives feedback from normal information processing (McLoughlin & Taji, 2005; Zimmerman & Schunk, 2011). This definition is similar to that of Jacobse & Harskamp (2012) who stated that metacognition refers to meta-level knowledge and mental actions used to conduct cognitive processes.

There are still problems in the conceptualisation of metacognition and self-regulation, which are often used interchangeably and in some cases hierarchically, with metacognition subordinate to self-regulation or vice-versa. There is need to provide clear definitions so that methods consistent with the definitions may be used in research, and then linked to educational outcomes (Hofer & Sinatra, 2010; Thomas, 2006b; Zohar & David, 2009).

2.2.1 Components of metacognition

Although researchers have not clearly articulated a universal theoretical model of metacognition, it has often been conceptualised by many researchers that metacognition comprises two main sub-components referred to as knowledge of cognition and regulation of cognition (Hartman, 2001; Ku & Ho, 2010; Magno, 2010; Schraw, Crippen & Hartley, 2006; Wilson & Bai, 2010; Zimmerman & Schunk, 2011).

Knowledge of cognition

Knowledge of cognition refers to what the learner knows about the task at hand, and it includes three subcomponents: declarative knowledge, procedural knowledge and conditional knowledge. Declarative knowledge is factual in nature, such as awareness of what the learner understands or does not understand in a topic (Hartman, 2001; Schraw et al., 2006; Weinert & Kluwe, 1987). Whereas procedural knowledge refers to knowledge about strategies or procedures. Procedural knowledge can be represented as a set of production rules, which are condition-action pairs. For example a student may be able to identify a producer or a primary consumer in a food chain or food web (declarative knowledge) but may experience difficulty in constructing a food chain or food web when given a list of organisms in a particular ecosystem. Procedural knowledge and declarative knowledge are often considered to be domain-specific because they generally refer to a domain specific knowledge (Schraw et al., 2006; Weinert & Kluwe, 1987; Zohar & David, 2008). Finally, conditional knowledge includes knowing why and when to use a particular strategy. Students with a high degree of conditional knowledge are more effective in assessing the demands of a specific learning situation and, therefore, select strategies that are most appropriate for that situation (Schraw et al., 2006; Zohar & David, 2008). For example, a student may be aware that there are energy losses as you move up the food chain and that the number of organisms decreases as you move up the food chain. However, when presented with a question to explain why a poisonous pesticide sprayed on certain plants would be more harmful to organisms at the top of the food chain, he or she has to decide which knowledge to use to explain this phenomenon (conditional knowledge).

Regulation of cognition

Regulation of cognition means the application of activities to help students to control their learning. Although there are a number of regulatory skills, the three essential skills in the classroom are: planning, monitoring, and evaluating. Planning involves the selection of appropriate strategies and effective use of resources to enhance performance. Examples include breaking down tasks into smaller manageable components, time management, being focused or blocking out any form of distraction. Monitoring refers to the ability to periodically self-test while learning. Research studies show that monitoring ability improves with training and practice. Evaluating refers to appraising the outcomes and efficiency of one’s learning. For example it involves analysing the learning strategies used in relation to their effect on the student’s goals. Many research studies suggest that metacognitive knowledge and regulatory skills are related to evaluation (Hartman, 2001; Leutwyler, 2009). In summary, metacognition consists of knowledge and regulatory skills that are required to control one’s cognition.

2.3 Metacognitive Strategies

The three sub-components of metacognition that are important for classroom performance are self-regulation, cognitive strategy use, and cognitive self-consciousness (Cartwright-Hatton, 2002; Pintrich & De Groot, 1990; Thomas, 2003).

Self-regulation includes planning, monitoring and evaluation (Ku & Ho, 2010; Leutwyler, 2009; Magno 2010; McLoughlin & Taji, 2005; Pintrich & De Groot, 1990). Planning involves setting goals, activating prior knowledge, and time allocation. Monitoring involves the self-testing skills necessary to regulate learning. Expert learners monitor at both the local level, such as an individual test items, and the global level, such as all items on a test (overall performance). Evaluation means appraising the products and a regulatory process of one's learning. For example, re-evaluating one's goals, revising predictions, and consolidating intellectual gains (Ku & Ho, 2010; Magno 2010). In an empirical study by Pintrich and De Groot (1990), univariate tests showed that there was a significant correlation between students' achievement and their self-regulation ($r = 0.17$, $F(1, 164) = 4.80$, $p < 0.03$, $MS_e = 0.43$), According to Leutwyler (2009, p.113), self-regulated learning is a pro-active, deliberate, and reflexive form of learning that is based on a sense of an individual student's responsibility for learning. Self-regulated learning occurs when the student possesses a repertoire of strategies that can be used adaptively and used intentionally. These included cognitive, behavioural and motivational strategies.

Cognitive strategies that students use to learn, remember and understand the concepts taught include, rehearsal, elaboration, and organisational strategies. These strategies enable students to actively engage in learning and result in higher levels of achievement. In an empirical study by Pintrich and Groot (1990), with grade 7 students, higher levels of cognitive strategy use were associated with higher levels of achievement on all assignments. Also, there was a correlation between higher levels of cognitive strategy use and higher levels of self-efficacy ($r = 0.33$, $p < 0.01$, $N = 173$) and intrinsic value ($r= 0 .73$, $p < 0.01$, $N = 173$). Examples of activities in the science classroom that require cognitive strategy use include: classifying, analysing causal relationships, carrying out scientific inquiry processes such as formulating and testing hypotheses, making generalisations or drawing a valid conclusion (Leutwyler, 2009; Pintrich & Groot, 1990; Zohar and David, 2009).

Cognitive self-consciousness involves monitoring one's thoughts. Scores on this scale in the metacognition questionnaire, developed by Pintrich (2002), have shown it to be highly correlated measures of anxiety, and particularly of worry. Selective attention to internal events is believed to be a key factor in the development of anxiety and other emotions. It is thought that a decrease in cognitive self-consciousness may be caused by an avoidance response. This has been evidenced by low scores on cognitive self-consciousness by young anxious people in sample studies (Cartwright-Hatton, 2002). Empirical studies by Cartwright-Hatton et al., 2004 suggest there is a correlation between CSC and anxiety ($r = 0.35$, $P < 0.001$, $N = 141$), and also studies by Pintrich and Groot (1990), suggested that there was a correlation between higher levels of test anxiety and lower levels of performance on exams and quizzes ($r = -0.21$, $p < 0.01$, $N = 173$). Cognitive self-consciousness has a strong effect on motivational factors such as self-esteem and self-efficacy which facilitate learning, sustain effort and attention, and enable completion of activities (Leutwyler, 2009).

2.3.1 Metacognitive strategies in relation to age

Research findings suggest that declarative metacognitive knowledge evolves before procedural components of metacognition (Leutwyler, 2009). In other words knowledge about knowing the products develops earlier than knowledge about knowing the processes. Research has also strongly suggested that continuous progress in students' use of metacognitive learning strategies occurs between the ages of 11 and 15 (Larkin, 2006; Veenman & Spans, 2005; Veenman, Wilhelm & Beishuizen, 2004). In Australian secondary schools this is the age group in Years 6 to 10. This indicates that the use of metacognitive strategies is strongly connected with students' age until the end of middle school. However, there were a few research studies which contradicted these findings. Veenman et al. (2004) reported one research study where there was a significant increase in the use of metacognitive learning strategies between the ages of 14 and 22 whereas Baumert (1993) reported no further increase between the ages of 16 and 18, and Zimmerman and Martinez-

Pons (1990) reported a decline in the use of metacognitive strategies between age 14 and 17.

Like the findings of the 1990s, research studies by Leutwyler (2009) showed no overall development in students' self-reported metacognitive strategies use during high school. This study also contradicts the research findings by Veenman et al. (2004) that showed a linear increase in the use of metacognitive strategies between the age of 14 and 22. This is because the studies by Veenman et al. (2004) and Veenman and Spans (2005) used on-line methods, such as observation and think-aloud protocols, for assessing the use of metacognitive strategies whereas the studies conducted in the 1990s and the Leutwyler (2009) study used data obtained from self-report assessments such as interviews and questionnaires. This finding suggests that self-report data reveal different aspects of metacognition from data obtained by using on-line methods.

2.3.2 Distinction between cognitive and metacognitive strategies

Despite two decades of research, most researchers do not clearly distinguish between cognitive and metacognitive strategies. Cognitive strategies tend to be encapsulated within particular subject areas whereas metacognitive strategies span multiple subject areas, even when those subject areas have little in common (Hartman, 2001; Schraw et al., 2006). Metacognition should also not be confused with critical thinking even though critical thinkers will most likely employ some metacognitive strategies, sometimes if not often, unknowingly. Metacognitive strategies can be employed with higher cognitive levels, such as analysis and synthesis, and lower cognitive levels of Bloom's Taxonomy, such as knowledge and comprehension (Kolencik & Hillwig, 2011).

A cognitive strategy is one formulated to simply to get a student to aspire for some cognitive goal or sub-goal. For instance, a cognitive strategy for solving a problem that requires the sum of a list of numbers would obviously be to add them up. The goal is to find the sum, and in order to achieve that goal the numbers are added. In this case, a metacognitive strategy might involve adding the numbers a second time to be sure the answer is right. If it is something as important as an income tax return, one might even re-check by adding the numbers up a third time. The purpose of the second and third addition is somewhat different from that of the first. The purpose is no longer to reach the goal (cognitive strategy), but rather to feel absolutely confident that it has been reached (metacognitive strategy) (Robson, 2006; Veenman & Spans, 2005; Weinert & Kluwe, 1987). In secondary schools science a student may complete an experiment report on the due date and address the research question appropriately (cognitive strategy) whereas another student may complete the same assignment a few days before the due date and check their performance against the criteria on the marking rubric so that they can make the necessary amendments to their work before handing in the final draft (metacognitive strategy).

There is a general agreement that metacognition does not depend strongly on IQ, at least as it correlates with group administered, paper-and-pencil tests (Greene & Azevedo, 2010; Hartman, 2001). IQ is mostly important in the early stages of skill acquisition, but during later stages of learning it becomes far less important as other skills such as task-specific strategies and general metacognitive knowledge come into play. Well organised lessons or the use of metacognitive strategies may in large part compensate for differences in IQ. In many cases, sustained practice and teacher modelling enables students to acquire the relevant task-specific knowledge as well as general metacognitive knowledge that is either independent or moderately correlated with traditional IQ scores.

In general, metacognitive knowledge improves as expertise within a particular subject area improves. Many researchers believe that metacognitive knowledge is task-specific initially (Hartman, 2001; Ku & Ho, 2010). As students acquire more metacognitive knowledge in a number of subject areas, they may construct general metacognitive knowledge that cuts across a range of subject areas. Therefore, as students advance, they gain more metacognitive knowledge and use it in a more flexible manner, particularly in new areas of learning. For example it would be expected that Year 9 students have more metacognitive knowledge in science than Year 7 students.

Metacognitive knowledge may compensate for low ability or lack of relevant prior knowledge of phenomena. Schraw (2001) made two important findings. Firstly, there is no significant correlation between metacognitive knowledge and ability (based on IQ tests), although there does appear to be a modest, positive relationship between the two. Secondly, metacognitive knowledge has a significantly bigger contribution to successful problem solving than IQ and task-relevant strategies (Kolencic & Hillwig, 2011; Schraw, 2001).

However, all metacognitive activities heavily draw on cognitive processes. For example, planning requires sequencing processes while evaluation involves comparison processes. This is why metacognitive skills are considered to be inseparable from cognition (Zohar & David, 2009). According to Veenman (2006), "metacognitive skills are higher-order agents overlooking and governing the cognitive system while simultaneously being part of it by using both top-down and bottom-up processes". Lastly, in the classroom metacognition is more of a "slippery than a fuzzy" concept because it is difficult to know how students are progressing metacognitively since most academic tasks are designed to assess cognitive rather than metacognitive processing (Larkin, 2006).

2.3.3 Categorisation of students' metacognitive capabilities

Students with high metacognitive capabilities possess a more elaborate repertoire of learning and studying strategies than low metacognitive capability students (Kurtz, Schneider, Carr, Borkowski & Relinger, 1990; Murray-Harvey, 1996, Zohar & David, 2009). Students with high metacognitive capabilities exhibit accurate knowledge about when, where, and why to apply specific strategies, including the ability to adapt them to new task demands. High metacognitive students are aware of whether they do or do not know something (Labuhn, Zimmerman & Hasselhorn, 2010). Research has shown that students with well-developed metacognitive capabilities have core characteristics shown in Figure 2.01 (Evans, Kirby & Fabringar, 2003; Kurtz et al., 1990; Murray-Harvey, 1996).

- Confident in their own skills and abilities.
- Patient and persistent, determined and calm.
- Reconstruct information to make it personally meaningful. Have well-organised, highly interconnected units of knowledge about content. They rely less on memorisation and re-writing information.
- Risk takers, courage to experiment, try new things and not afraid to make mistakes.
- Methodical logical thinkers. They carefully monitor their own problem-solving strategies and processes.
- Enthusiastic and motivated. They read more and show highly efficient problem solving; when time constraints are imposed, they solve problems more quickly than do novices.
- Have large, rich schemes containing a great deal of declarative knowledge about a given domain.
- Spend proportionately more time determining how to represent test problems than they do in search for and in executing a problem strategy.
- In problem-solving they are more likely to think about the task, analyse it, and choose an appropriate strategy, which they may abandon or modify if it does not yield the expected results (Evans et al., 2003; Hartman, 2001; Murray-Harvey, 1996).

Figure 2.01: Characteristics of high metacognitive capability students

- Find lessons boring.
- Read less.
- Employ few self-help strategies.
- Lack interest and motivation.
- Are less aware of factors that mitigate against effective learning.
- Use repetition as the primary learning strategy.
- In problem-solving they are likely to seize on the first strategy that occurs to them and stick to it, regardless of outcomes (Evans et al., 2003; Hartman, 2001; Murray-Harvey, 1996).

Figure 2.02: Characteristics of low metacognitive capability students

Students with high metacognitive capabilities see 'failures' as challenges to be met and conquered. They delight in the fact that learning does not stop because there will always be a new challenge to conquer. However, the differences between high and low metacognitive capability students, in terms of strategy use, invite speculation as to whether students with low metacognitive capabilities, whose core characteristics are shown in Figure 2.02, are generally not aware of the range of strategy options that are available to them, or whether they are knowledgeable about their strategy options and just do not want to use them (Phelps et al., 2001). For example in Year 9, after three years of high school, some students develop a negative attitude towards science because they have the perception that since it is not part of their future career plans there is no need to learn or use any metacognitive strategies taught in the science class.

2.4 Metacognitive Support

Students can maximise their learning success when they have access to vast learning repertoires in addition to insights into their own capabilities. Therefore it has been suggested that, if students' metacognition can be improved, then it should be possible to improve their learning outcomes. Research shows that metacognition is malleable and responsive to interventions that are skilfully implemented (Kolencik & Hillwig, 2011; Thomas, 2003). Unfortunately, classrooms across a range of subject areas do not have a learning environment necessary for developing and enhancing students' metacognition, and place an overemphasis on memorisation and lower-order thinking and learning. A learning environment's metacognitive orientation is defined as the extent to which that environment supports the development and enhancement of students' metacognition.

2.4.1 Learning environment with metacognitive orientation

According to Thomas (2003, 2006a), the characteristics of a metacognitively oriented learning environment involve five dimensions: metacognitive demands, student-student discourse, student-teacher discourse, student voice, and teacher encouragement and support.

Metacognitive demands refer to whether or not students are asked to be aware of how they learn and how they can improve their science learning. In a research conducted by Thomas (2006a), students' responses suggested that teachers often tell students to find ways to learn science but seldom explain how to learn science. In order to improve students' achievements in science teachers need to model metacognition and explicitly teach metacognitive strategies such as elaboration and organisational strategies (Pintrich & De Groot, 1990; Thomas, 2003).

Student-student discourses refer to whether or not students discuss their science learning processes with each other. Collaborative group work is not only about learning the social skills of working in groups. Interactions with other students can provide the stimulus needed by an individual student to become aware of their cognitive processing (Larkin, 2006). Students need to be given opportunities to discuss learning itself in addition to the material to be learned. Since all students possess some metacognitive knowledge, it is important to give them opportunities to critique their metacognitive knowledge and beliefs about teaching and learning against the views of their peers as they trial new strategies. According to a research conducted by Thomas (2003, 2006a), student-student discussions are more often related to content and less to metacognitive strategies. Unless students are frequently given opportunities to interact in the classroom, it may be difficult for them to practice their metacognitive strategies (Larkin, 2006).

Student-teacher discourses refer to whether or not students discuss their science learning process with their teacher. Research findings suggest that most student-teacher discussions are often about the consequences of learning and less on the processes involved (Thomas, 2006a). It is essential that regular discussions about learning and learning processes occur. Students need to be given opportunities to explain and discuss their metacognitive knowledge with their teacher.

Student voice refers to whether or not students feel free to question the teacher’s pedagogical plans and methods. According to research findings by Thomas (2006a), many students have the perception that since the teachers plan the lessons beforehand, they know better and therefore do not need help to decide what to do. There is a need to create a social climate in which students benefit from questioning the teacher’s pedagogical plans and methods, and are able to collaborate with the teacher to plan and assess their learning as they develop into autonomous learners and self-regulated learners. Students need to be given increased control over their classroom activities so that they can apply strategies that they have found through practice to be effective in helping them meet their learning goals (Thomas, 2003).

Teacher encouragement and support refers to whether or not students are encouraged by the teacher to improve their science learning processes. Research findings suggest that teacher encouragement is often more general in nature and is not specifically related to particular metacognitive strategies (Thomas, 2006a). To facilitate this aspect of metacognitive support, students need to be made aware of the language of learning and encouraged to develop and use such language in their classroom as an initial step to developing a shared language of learning with their students. The aim of using such a language is to inform students about what it means to learn science, how to form opinions and make informed decisions about how they learn, how they can improve their learning, and how they can communicate with others about their processes of learning science (Thomas, 2003, 2006a).

In addition, environments that support metacognitive development include a number of components that are designed to function as a system in the sense that they are mutually supportive. The components are: (1) a focus on learning outcomes that emphasize deep understanding of key concepts in the subject-matter content, (2) the use of logically structured scaffolds to support the students, (3) regular formative self-assessments, revision, and reflection, and (4) social organisations that promote collaboration and a striving for high standards (Greene et al. 2010; Hacker et al., 1998).

Classroom factors which limit metacognitive development include: (1) pre-determined syllabus, (2) long established expectations for appropriate student participation, (3) lesson development, and (4) classroom management (Baird, 1986; Greene et al., 2010). Lastly, it is often difficult to know how students are progressing metacognitively because most academic tasks are designed to assess cognitive rather than metacognitive processing.

2.4.2 Teachers' pedagogical understanding of metacognition

Within the last two decades, the perspective on teaching and learning has shifted from one grounded in behavioural psychology to one grounded in cognitive psychology. The pedagogical understanding of metacognition refers to teachers' knowledge of what is required for the teaching of metacognition (Wilson & Bai, 2010). A teacher's pedagogical understandings of metacognition require that teachers have declarative, procedural, and conditional knowledge (Hartman, 2001).

Declarative knowledge is a teacher's subject matter knowledge. Procedural knowledge is knowledge of how to approach the teaching or conduct a lesson. Conditional knowledge is the understanding that the teaching of metacognitive strategies varies depending on the situation and that particular situations require the use of particular teaching strategies (Hartman, 2001; Wilson & Bai, 2010).

Teacher knowledge can also be defined as an integrated system of internalised information acquired about students, content and pedagogy. These components of teacher knowledge can make a difference in instructional practice and student learning. Generalisations regarding beliefs that have emerged include descriptions such as: (1) personalised form of dynamic knowledge that constrains the teachers' perceptions, judgements and behaviour, (2) interpretative filters through which new phenomena are interpreted and meanings ascribed to experiences, and (3) implicit assumptions about content, students and learning. It would appear from these works that beliefs, though different from knowledge, share attributes similar to knowledge (Hartman, 2001; Robson, 2006).

Metacognitive components of different teachers generally fall within two main groups: teachers with developed metacognitive skills and teachers with underdeveloped metacognitive skills as shown in Table 2.01.

Table 2.01: Summary of metacognitive components of two categories of teachers (Adapted from Hartman et al., 2001)

Components	Teachers with developed metacognitive skills	Teachers with underdeveloped metacognitive skills
Knowledge of students	Reveal specific knowledge of student's prior knowledge, experiences, abilities, attitudes and interests.	Reveal general knowledge of students in relation to the content.
Knowledge of content	Reveal conceptual and procedural understanding of the content. View content in relation to entire unit and past and future study.	Reveal procedural understanding of the content. View content in isolation of past and future study.
Knowledge of pedagogy	Reveal understanding of how students learn. Anticipate	Focus on time saving management strategies to

	specific areas of difficulty and plan suitable teaching strategies.	cover the content.
Beliefs - Students role	View students as active participants in lessons who must think, reason, discover, communicate and take responsibility for learning.	View students as passive learners who must pay attention and stay on task.
Beliefs - Teacher role	View themselves as facilitators of student learning by selecting problem-solving tasks and asking questions that challenge students to think for themselves and interact with one another.	View themselves as dispensers of information and role models for how to do problems.
Goals	Want to help students construct their own meaning so that they will develop conceptual as well as procedural understanding and will value the science and feel confident in their abilities.	Want to cover the content and help students acquire procedural skills.
Lesson planning	Focus on problem-solving processes and conceptual meanings and underlying procedures and results. Sequenced the tasks to build on previous student understanding and arouse students' interest and curiosity.	Focus on the procedures to be learned and the results to be arrived at. Sequence the tasks illogically where there were large leaps between concepts and confusing examples.
Monitoring	Observe, listen to and elicit participation of students to increase participation and assess student learning and disposition toward science for the purpose of adjusting instruction.	Elicit participation of students for the purpose of keeping them on task.

Incorporating higher-order cognitive skills in teacher education may help foster teachers' metacognition by supporting thinking that emphasises self-monitoring and awareness of their own thinking and reflecting processes (Hartman, 2001; Wilson & Bai, 2010). Professional development courses that include asking questions, problem-solving, and conceptualisation of key concepts may enhance teachers' knowledge, control and awareness of their use of such cognitive processes. The goal is that teachers will then transfer these metacognitive skills into their own classroom practice (Hartman, 2001; Leou, Abder, Riordan & Zoller, 2006).

However, there are discrepancies between what teachers know they should do and what they practice. According to research conducted by Wilson and Bai (2010), many teachers have the declarative knowledge of what is necessary for teaching students to be metacognitive; but in most cases value activities that are not highly correlated with helping students to become metacognitive. Many teachers feel pressured to follow mandated programmes that may not reflect a rich pedagogical understanding of metacognition because they feel stressed by the amount of material they need to cover. The idea of providing a student with the time and space to discuss his or her thinking sounds good, but quite often teachers do not implement it in the classroom (Hartman, 2001; Wilson & Bai, 2010). Incorporating higher-order cognitive skills in teacher education may help foster teachers' metacognition (Leou et al., 2006). Teachers need support to implement metacognition as an integral part of their lessons (Leou et al., 2006; Wilson & Bai, 2010).

2.4.3 Methodologies and metacognitive interventions used to enhance students' metacognitive capabilities

Through action research a repertoire of interventions can be conducted in the science classroom to enhance students' metacognitive capabilities in science.

Action research

Action research unifies the process of developing theory and practice (Barret, 2011). Action research was initially promoted by Kurt Lewin in the mid-1940s with the intention of applying research to practical issues occurring in the everyday social world. The idea was to enter a social situation, attempt change, and monitor results (Coolican, 2009). Action research has two major components: action in practice and knowledge generation through rigorous research. Action research is often conducted to bring about change in practice, while generating new knowledge at the same time. These combined characteristics make it useful in bringing about improvement of practice, or to propose new solutions to practical problems.

Action research is usually carried out in cycles as shown in Figure 2.03, where later cycles are used to refine insights and results from previous cycles. The cyclic feature of action research can be used not only to propose theory but also to test theory. However, action research is usually concerned with single situations, for example, a single group of students. Therefore, although the approach can generate theoretical positions that go beyond single situations, action research is often perceived as an inappropriate approach to test the general applicability of theories.

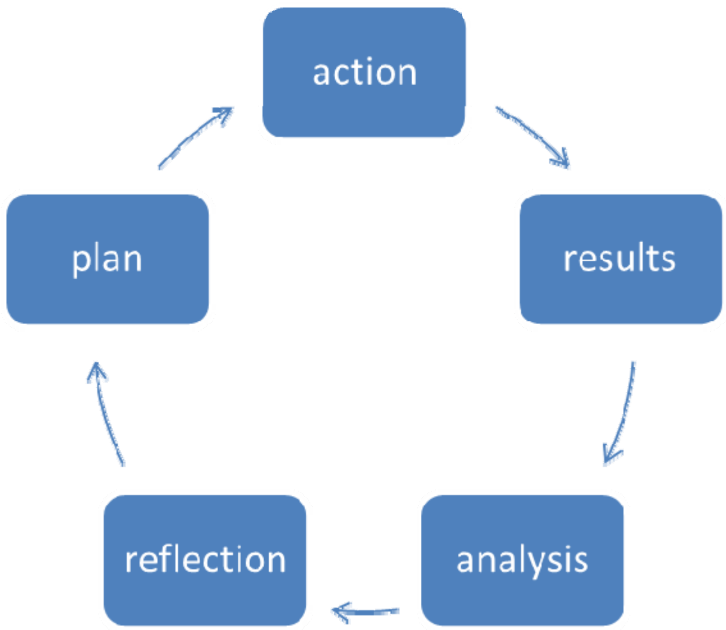


Figure 2.03 Example of an action research cycle

Action research is critically reflective. The need for critical reflection is the reason why action research is cyclic. Reflection based on experiences of action is a fundamental part of each cycle. The action research cycles function like mini-experiments in practice. In each cycle, the result indicates whether or not what was intended worked, and thus if it can be used as basis for further refinement, or if it needs to be changed (Coolican, 2009; Williamson, 2002).

Strengths and weaknesses of action research

Action research as it name suggests, is about research that impacts on, and focuses on, practice. The purpose of action research is not merely to understand situations and phenomena but also to change them. It seeks to emancipate the participants.

Action research recognises the significance of contexts in practice-locational, ideological, historical, managerial and social situations. It accords power to those who are operating in those contexts, for they are both the engines of research and of practice. It gives the participants a voice, participation in decision making and control over their environment. However, action research might be relatively powerless in the face of mandated changes in education. In this case, action research might be more concerned with intervening in existing practice to ensure that mandated change is addressed efficiently and effectively (Creswell, 2005). Since action research has a practical intent to transform and empower, it should be examined and perhaps tested empirically. For example, it claims to be empowering, that is a testable proposition.

Action research has a deliberate agenda; the task of the researcher is not to be an ideologue or to have an agenda, but to be objective. Action researchers have to generate a positive agenda, but in so doing they are violating the traditional objectivity of researchers.

Claims have been made for the power of action research to empower participants as researchers. Giving action researchers some power to conduct research in their own chosen situations, has little effect on the decision making because the real locus of power often lies outside the control of action researchers (Creswell, 2005; Williamson, 2002).

Teaching metacognitively

Teaching metacognitively, including knowledge about the use of cognitive strategies to improve learning efficiency, checking and monitoring skills, and the importance of tailoring strategies to task demands, is important for the development of students' cognitive and metacognitive capabilities. However, little is known about teachers' use of metacognitive strategies in teaching. Teachers often conduct lessons in the same way they were taught rather than adopting appropriate approaches to address the learning needs of their students. It has been observed by researchers that many teachers are so eager to begin a lesson that they skip over communicating the lesson's objectives (Kurtz et al., 1990; Wilson & Bai, 2010). The long-established practice in education, especially in the sciences, is the transmission of information from teacher and text to students as generalised, idealised, logically organised knowledge (Ward & Wandersee, 2002). There is a need for teachers to self-regulate their instruction before, during and after conducting lessons in order to enhance their effectiveness with students. Research on teachers' perceptions has also indicated that teachers make reasonably truthful predictions of students' cognitive strategy capabilities, but not of their metamemory, monitoring, or control skills, and teachers' metacognitive evaluations of students are biased by the students' achievement levels (Carr et al., 1990; Leou et al., 2006; Wilson & Bai, 2010). In most classrooms, the tasks given require lower-order cognitive skills such as memorisation, recall, and application of algorithms to familiar situations rather than encouraging inquiry and problem-solving. The questions which require reasoning or transfer of information across disciplines or to new situations are rarely given to students (Leou et al., 2006).

Teaching metacognitively includes reflecting on intended learning outcomes, students' characteristics and needs, content level and sequence, teaching strategies and materials related to curriculum, instruction and assessment. Teaching for metacognition means that teachers think carefully about how their instruction will stimulate and develop their students' metacognition, or their own thinking processes as learners. In teaching for meaningful learning in science, four broad principles, as shown in Table 2.02, have been identified that are useful for science teachers to help them think about their teaching (Hartman, 2001; Wilson & Bai, 2010). The relationships between instructional strategy and metacognitive processes (Schraw et al., 2006) are also shown in Table 2.02.

Table 2.02: Instructional strategies to increase metacognitive processes

Instructional strategy	Metacognitive processes
Inquiry	Improves explicit planning, monitoring and evaluation
Collaboration	Models self-reflection
Mental models	Promotes explicit reflection and evaluation of the proposed model

Adapted from Schraw et al., 2006.

The instructional strategies and metacognitive processes shown in Table 2.02 would be enhanced by the use of metacognitive teaching strategies such as concept maps, modelling, students' reflective journals, provision of focused outcomes and collaborative group activities.

Provision of focused outcomes

These serve as a road map to learning. Learning metacognitively is a proactive and constructive process whereby students set clear goals for their learning and monitor, regulate and control their cognition and behaviour guided by their goals (Azevedo, 2009). The provision of focused outcomes, before a topic is taught, in the science classroom enhances the students' capabilities to monitor and control their learning, which fosters their metacognitive capabilities. Focused outcomes are even more beneficial if they are organised in a time-ordered sequence that the teacher and the students follow. Clearly stated focused outcomes enable students to set meaningful goals and determine which strategies to use given the task conditions. Students may also generate motivational beliefs based on their previous experiences with the concepts in the topic.

Concept maps

Early uses of concept mapping were mostly in the context of science classrooms but more recent uses have widened to explore the nature of learning in many other subject areas. Concept mapping was first developed by Novak and Gowin in the 1960s. The theoretical framework that supports the use of concept mapping is consistent with constructivist cognitive psychology. Concept mapping is a method to visualise the structure of knowledge (Asan, 2007; Ritchhart, Turner & Hader, 2009). A concept map is a graphical representation of the relationship among terms or concepts (Vanides, Yin, Tomita & Ruiz-Primi, 2005). It involves the construction of a diagram that emphasizes relationships between concepts. Concepts are in boxes or circles, with labelled connecting lines identifying relationships as shown in Figure 2.04. The most common approach in the classroom involves providing students with only the major concepts in the topic at hand, and their task is to connect a pair of concepts with a one-way arrow, then label the arrow with a word or short phrase that describes the relationship between the two connected concepts (Vanides et al., 2005). The concepts are listed only once but the student may make multiple connections between concepts. Concept mapping can be used by individual students and in groups with concepts, events, and social relationships, with younger students (middle school) and older students (senior school), with teachers, researchers and managers, and in everyday life. Furthermore, concept mapping varies from being very simple to complex, which makes it applicable by a wide range of learners. Although there are many ways concept maps may be designed, open-ended activities that give students the latitude to construct their own concept map structures are the most revealing about students' cognitive processes. Highly sophisticated concept maps are indicative of internalised highly integrated knowledge structures, which are important because they facilitate cognitive activities such as problem solving (Asan, 2007; Vanides et al., 2005).

Concept maps help students to understand the relationship between concepts, and reduce the need for rote learning. In other words they help students to move from a surface to a deep approach to learning. They also can enable teachers to negotiate meanings of key concepts with students and design better teaching programmes. The mental models exhibited by the students' concept maps can provide the basis for future teaching (Hartmann, 2001; Ritchhart et al., 2009). Many other benefits of concept maps cited include, providing an effective tool for capturing students' thinking processes, understanding super-ordinate and sub-ordinate relationships between concepts and improving collaborative group work. They also help students and teachers to recognise misconceptions from valid conceptions, reduce anxiety and improve self-confidence. Lastly, concept maps also naturally integrate literacy and science by providing a starting point for writing scientific terms. Especially young and low achieving students who still struggle with spelling scientific words benefit greatly from concept mapping. According to research, middle school science students taught to use concept maps performed better on tests than students who were not taught these strategies. This is because students remember information better when it is represented and learned both visually and verbally (Asan, 2007; Hartmann, 2001; Ritchhart et al., 2009; Vanides et al., 2005).

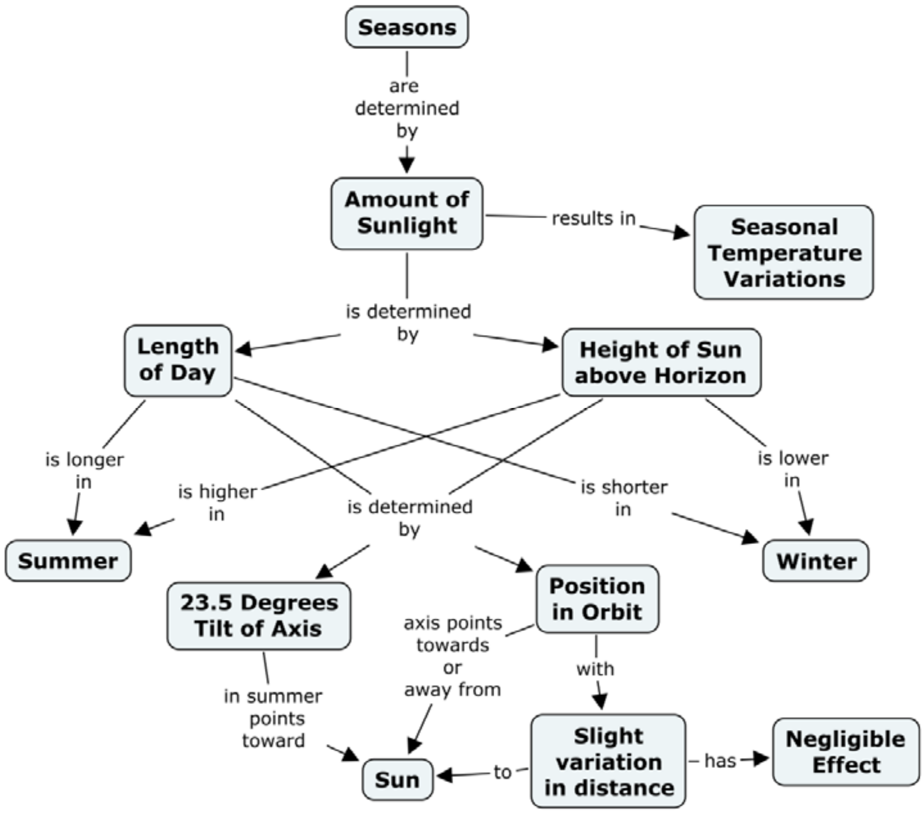


Figure 2.04: Example of a concept map on seasons (adapted from Novak & Canas, 2008)

Modelling metacognition

An effective strategy for developing metacognitive skills in science is for teachers to provide models of metacognition in the classroom. Modelling is based on Bandura and Walters' (1963) theory which highlights the importance of observation, identification, imitation and motivation in learning. Teachers can think out loud to externalise their thought processes, so that students can hear effective ways of using metacognitive knowledge and skills. Many students appreciate seeing models of higher-level metacognitive strategies, especially those involving everyday life experience (Kolencik & Hillwig, 2011; Zimmerman & Schunk, 2001).

Reflective journals

Reflection is a more general term than metacognition. Reflection is the deliberate consideration of an experience in light of particular learning goals. Reflection serves as a link between experience and theory. In reflecting, the student engages in active, persistent and careful consideration of learning experiences to seek a deeper understanding and a broader and more reasoned point of view (Wilson & Jan, 2008). Students' reflective journals provide a way for students to express their thoughts and feelings about their learning experiences. Reflective journals help learners to develop habits of reflection which lead to greater understanding of their own skills and more effective functioning as problem-solvers (Bringle & Hatcher, 1999; McLoughlin & Taji, 2005). Effective reflection should observe the following guidelines: (1) reflection should clearly link the learning experience to the learning goals, (2) structured in terms of focused learning outcomes and the criteria for assessing learning, (3) occur periodically so that students can develop the capacity to engage in deeper and broader reflection, and (4) promptly provide feedback to the students about some of the reflection activities so that they learn how to improve their critical thinking and develop from reflective practice. There are variations in how easily students engage in reflection and how quickly they mature in their ability to learn from reflecting (Bringle & Hatcher, 1999; Kolencik & Hillwig, 2011).

To facilitate genuine reflection, teachers have to make time for it and guide students' efforts until they become comfortable with the process and its benefits. The teachers must consider carefully the moments in the course of a day, week, or term that are most conducive for deep reflection. Also, by having the students share their work and reflections makes the practise of reflecting on one's work a valued one in the classroom community (Block, Mangieri & Barnes, 1994; Wilson & Jan, 2008).

Research findings strongly support the use of reflective journal writing as a metacognitive strategy. Writing down what is experienced, observed, or thought about enables the brain to organise and make sense of very complicated, multifaceted pieces of information. In addition, journal writing sets up a self-provided feedback system (Kolencik & Hillwig, 2011).

Students when reviewing previous journal entries are able to monitor their own metacognitive growth. Self-reflection may result in positive or negative effects. In case of failure, self-reactions may stimulate the student to modify their approach to the next learning episode: changing their learning goals or try some new cognitive strategies. Students learn to distinguish between effective and ineffective performance and to detect the adequacy or inadequacy of a cognitive strategy (Kolencik & Hillwig, 2011; Schmitz & Perels, 2009). Change occurs after a series of applications of reflection journals combined with other metacognitive interventions.

Collaborative group work

One aspect of collaborative group work in science involves students doing experiments and using the data collected for shared knowledge construction. Interactions between students provide the stimulus needed for them to become aware of their cognitive processing. Collaborative group work enables students to understand and agree with contributions of their peers in order to construct knowledge together. It also provokes the need for students to reflect on their thinking. It involves constructing new thoughts and collaborating to understand and influence the cognitive and motivational states of oneself and other group members. Integrating collaborative learning with inquiry learning can foster students' inquiry learning process and improve their learning performance (Saab, Van Joolingen & Van Hout-Wolters, 2011). Students need to be given opportunities to interact with each other at a substantive cognitive level in order for them to practice or elaborate on metacognitive strategies or to gain feedback about their own cognitive processing (Larkin, 2006).

However, students often find it difficult to go through the inquiry process efficiently. Collaboration without means of support may often not lead to an effective collaborative learning process. There is need to provide a set of communication guidelines which support students' collaboration process. These guidelines could include sentence openers that structure students' communication, and tools that can be used to present a shared conception of the problem whereby students externalise their ideas based on this shared conception. Explanation Builder and the Collaborative Hypothesis Tool are some of the examples of tools that support both the inquiry learning process and the collaborative process (Saab et al., 2011).

2.5 Assessing Metacognitive Capabilities

Many action research studies have been conducted to assess the effectiveness of various interventions on students' metacognitive capabilities (Pintrich & Groot, 1990; Schraw et al., 2006; Thomas, 2002). At several conferences many papers have been presented about the topic of methods for measuring metacognitive strategies (Schellings & Van Hout-Wolters, 2011). However, apart from observation, the majority of current metacognitive measures are conducted by using self-report instruments. These include questionnaires, interviews and reflective journals. The most common characteristic of self-reports is that the students themselves deduce their own activities.

A distinction has also been made between off-line and on-line measures of metacognition. Off-line measures are conducted before or after task performance whereas on-line measures are conducted during task performance. Off-line methods include questionnaires and interviews whereas on-line measures include observation, think-aloud method, eye movement measurement and performance assessment. Educational practice and research often use off-line methods because on-line methods are more difficult to use in large groups and processing of these data is more time-consuming and expensive (Schellings, 2011).

Each method has its strengths and weaknesses, and suitability for different contexts. Individual metacognitive self- reports at best reveal only a small portion of the metacognitive capabilities (Gay, 2002). Off-line measures are often aimed at general learning or learning from one specific task whereas on-line measures are bound to the task performed within the assessment. Hence, the results of each method need to be replicated with other various measures to provide deeper analysis of metacognition (Greene, 2011; Hofer & Sinatra, 2010; Schellings & Van Hout-Wolters, 2011; Veenman, 2011).

2.5.1 Observation

Observations are the most obvious way of assessing students' metacognition. It is easier to observe students working in collaborative group settings on open-ended tasks, working towards a joint goal, because these situations are more likely to require metacognition and the group nature of the task requires that thinking is revealed, shared and co-constructed. In order to assess metacognition through observation, some kind of observation check list or schedule is required (Anderson, 2004; Azevedo, 2009; Williamson, 2002). Whether or not the data obtained from observations are deliberately included in the research report, this method cannot be completely ignored in action research.

Strengths and weaknesses of observation

Observation has the benefit of tapping into the metacognition that students are actually displaying in natural classroom settings. It avoids the difficulty of asking children to verbalise their thinking out of context and consistent observation over a period of time can provide a developmental profile of metacognition in individual students across different settings. However, real time observation is time consuming and difficult to maintain. It is easy to lose concentration when observing for long periods of time. It is difficult to record all instances of metacognition apparent in group discussions. Only a few of the metacognitive behaviours may be overtly displayed. Students move in and out of metacognitive reflection, begin to talk about thinking and then change to some off task behaviour, or are interrupted by other students. Also, agreement as to what is considered to be metacognitive behaviour can reduce the usefulness of observational data. For example, using some kind of check list deciding when one metacognitive episode begins and ends is difficult (Gay, 2002; Larkin, 2010). Video recordings of students working collaboratively could be used to analyse the interactions later through repeated viewings. However, the natural flow of a conversation is not necessarily amenable to being sectioned up into different meaningful units and the act of videotaping the interaction will have an effect on the outcome. When the researchers are physically present, the concept of the researcher as non-participant, though sociologically correct is psychologically misleading. It is impossible to remain at a distance and adequately record the students' interactions. Thus observations by class teachers, who are normally present, are likely to be just as effective as those by the unknown researcher. Students view teachers as judging behaviour and may alter their behaviour in the presence of the teacher, with the expectation that the teacher will guide the discussion (Larkin, 2010). While observation may be the most relevant way of collecting information about students' metacognitive behaviour, other methods should be used to produce a more complete picture.

2.5.2 Metacognitive questionnaires

The most common research instrument is the questionnaire. It is principally used to collect quantitative data, but can also be used for qualitative data in a simple, timely and cost efficient manner. It is most closely associated with the survey to the point that many people call the instrument a ‘survey’, rather than a ‘questionnaire’. This is not strictly correct, because a survey is a particular research design, the major instrument for which is usually the questionnaire (Anderson, 2004; Williamson, 2002).

Typical questionnaire questions can be classified in different, but sometimes overlapping, ways. Factual questions are straight-forward questions that give respondents a number of categories from which to choose answers that are correct for them. For example, “Does your teacher discuss with you about how you learn science?” - (5) almost always (4) often (3) sometimes (2) seldom (1) never. With questions of fact, it is best not to place too much strain on people’s memories. Opinion questions are often measured by a Likert scale, for example, “Are you satisfied with the support to complete assignment in your science classes?” - very satisfied (5), satisfied (4), undecided (3), unsatisfied (2) very unsatisfied (1).

Questionnaires used in surveys are often constructed for the specific research topic and tend to assess for current opinion or patterns of behaviour. The scales used in questionnaires are usually intended to be more permanent measures and are seen as technical tools, equivalent to the ruler or voltmeter of ‘hard’ science (Coolican, 2009). Questionnaires are frequently used in metacognitive research. These differ depending on whether they are prospective or retrospective, in other words whether they ask questions about what students normally do or they ask students to reflect on a task they have completed and report on their thinking at the time (Schraw, 2009).

Strengths and weaknesses of metacognitive questionnaires

Questionnaires are relatively convenient (compared with interviews) and allow a larger sample, and the collection of a large amount of data in a relatively short time. They are useful in the collection of quantitative data, if the researcher’s interest is to analyse a breadth of data from a random sample from which to make generalisations.

Questionnaires are also simple to administer and easy to analyse (compared with data from interviews) (Williamson, 2002).

However, questionnaires are not appropriate if the research interest is to collect in-depth data, or where it is important to allow the participants to modify and develop their initial perceptions. Complex data cannot be collected. Questions must be simple and straight-forward. Even then, there is a possibility of misinterpretation of the questions by the respondent. This issue was addressed by encouraging students to respond to one section at a time and by explaining the meaning of the questions to them. Secondly, the use of questionnaires creates difficulty in obtaining responses from a representative cross-section of the target population because non-respondents may differ in characteristics from respondents. For example, in a secondary school situation it would be difficult to make generalisations from such data because the proportions of high and low achieving students vary in each class. Thirdly, questionnaires do not allow respondents to qualify answers or for researchers to probe for further information. The former is particularly important if respondents perceive questions to be ambiguous, or feel they do not quite fit into any of the categories offered. The latter means that most questionnaires do not uncover causes or reasons for respondents' attitude, beliefs and actions. Fourthly, researchers are unable to control how the questionnaire is answered. There is uncertainty as to whether the respondents have been conscientious about filling in their responses. This is especially difficult with students who are aware that their responses have no effect on their grades. Lastly, in questionnaires the learners are asked to give retrospective accounts of how they perform academic tasks. However, it is unlikely that they have retained an accurate record in long-term memory of the mental processes that were involved (Anderson, 2004; Schellings & Van Hout-Wolters, 2011; Williamson, 2002).

2.5.3 Semi-structured interviews

This technique is useful for collecting qualitative data. It can be used to supplement survey data. Interviews are used in a survey if the information sought is complicated and is therefore difficult.

The aim of interviewing in naturalistic research is to understand people from their own point of view. In semi-structured interviews a standard list of questions is prepared, but the interviewer is also allowed to follow up on leads provided by participants for each of the questions involved. The semi-structured interview has more similarities with the unstructured, in-depth interview, than to the structured, standardised form.

The purpose of in-depth interviewing is to capture the respondent's perspective on a situation or event under study. This is in keeping with the central precepts of interpretivism. The respondent is encouraged to talk expansively on the main subject, raising topics within it in any order s/he wishes.

Usually in-depth interviews are tape recorded. The more accurately any interview is recorded in the respondent's own words, the better analysis and conclusions will be. Tape recording of interviews also avoids the disruption to interviews which results from the need to take notes (Anderson 2004; Schellings and Van Hout-Wolters, 2011; Williamson, 2002).

Strength and weaknesses of interviews

In semi-structured interviews complex and complete responses are more likely because probing can be used, and explanations and clarifications can be provided to the respondent. The interviewer can attempt to ascertain that the respondent has understood and interpreted the question the way intended by the researcher. The number of don't knows and non-responses are usually quite small. Secondly, the interviewer has the opportunity to observe the respondent. This can add to the understanding of the respondents' viewpoints. The validity of information can also be checked on the basis of a respondent's non-verbal cues. Thirdly, face to face interaction assists in the establishment of rapport and a higher level of motivation with respondents. The interviewer can be a powerful stimulus, more powerful than words on paper. Fourthly, interviewers have the opportunity to control the context of the interview to some extent and try to ensure that they elicit responses relevant to the issues at hand. Fifthly, interviews have the advantage of obtaining responses from people who are unable to fill in questionnaires, for example students with low literacy levels. Lastly, interviews can provide more detailed data than questionnaires.

Research reports are made richer by the opportunity to quote the actual words of respondents (Anderson, 2004; Williamson, 2002).

2.5.4 Reflective journals

Reflection occurs after engaging in a task and is directly related to the student's performance. Reflection involves self-judgements and self-reactions. Self-judgement is self-evaluation, and involves comparing the learning outcome with a goal or standard. This comparison results in a reaction with effects such as satisfaction or dissatisfaction (Labuhn et al., 2010). Reflective journals represent a good source of text data for a qualitative study.

Strengths and weaknesses of using reflective journals

Reflective journals have the advantage of being in the exact words of the participants, who have usually given thoughtful attention to them. They can also be analysed without the necessary transcription that is required with interview data.

However, reflective journals may be incomplete or inaccurate. Also, the handwriting may be hard to read, making it difficult for the researcher to decipher the information (Creswell, 2005). This particularly is a problem with younger students with learning disabilities, such as dyslexic students, whose handwriting and spelling are often of a lower standard. Secondly, students are less likely to engage diligently in reflection activities if the outcome is not awarded a score that contributes to their grades. However, if a grade is awarded students may not express their genuine learning experiences but may write down what they think is right just to get them a high score.

2.6 Multiple Methods

A solution to the challenges of measuring metacognition is to use multiple methods (Hofer & Sinatra, 2009). According to Dinsmore, Alexander and Loughlin (2008), neither quantitative nor qualitative approaches reveal metacognitive strategies, but some combination may be required. With this approach the power of each method is used to obtain a broad picture and deep insight into the students' use of metacognitive strategies.

However, different types of measuring methods may lead to differing results. This may create difficulty in deciding which set of results has greater value than others. Interpreting the combination of data may also be time consuming and expensive (Hofer & Sinatra, 2010; Schellings & Van Hout-Wolters, 2011).

2.7 Assessing Students' Achievement in Science

2.7.1 Pre-post tests

The students' prior conceptual knowledge of a science topic is assessed by the use of written pre-tests, and an identical set of measures are used during the post-test to assess the degree to which the students' understanding has changed as a result of the metacognitive interventions (Greene et al., 2011). These measures have been used successfully in several previous studies. Pre-post-tests tend to focus on one element of metacognition, such as metamemory, theory of mind or mental rotation. It is difficult to find tasks that draw particularly on metacognitive rather than cognitive skills and which do not require a high level of verbal fluency. However, some computer-based studies which track students' thinking as they make various moves through a problem-based task may provide one kind of solution to direct assessment of metacognition. It has been suggested by Schraw (2001) that computer based testing provides greater control over administration of the test, so that individuals receive exactly the same amount of information over the same time period, thus eliminating some of the difficulties of producing a fair test to different participants. It also enables the collection of a great deal of data about how the participant behaves on the test and can produce accurate timings for different aspects of the test session. The other benefit is that data from one test can be selected for different purposes.

The use of processed questions helps to minimise the limitations of content knowledge. Processed questions test students on key scientific areas of interpreting data, applying data and high order skills which include investigating, reasoning and problem solving.

2.7.2 Research assignments

Student science assignments at secondary school level involve planning, monitoring and evaluating. There are two main categories of science assignments: issues investigations and practical reports. The assignments often are given to students with a marking rubric attached to enable students to monitor and evaluate their progress throughout their research. This provides a good measure of students' metacognitive capabilities. The level of achievement in science assignments is more dependent on students' metacognitive capabilities than their achievements in science tests, which are dependent mostly on students' cognitive capabilities.

2.7.3 Data analysis

The data from questionnaires are usually too complex to analyse by hand. They require a system by which the responses can be entered into a computer file. Students' responses to the metacognitive questionnaires are translated into numerical codes. This is followed by the use of SPSS software to determine the mean, standard deviation, t-scores, effect size and alpha reliability of the metacognitive questionnaire.

The qualitative data from the interviews and reflective journals are analysed by using a combination of interpretational, structural and reflective analyses to identify themes or patterns that emerge.

2.7.4 Reliability of instruments

The validity of the data is checked by entering it twice and comparing the two entries for accuracy. This is followed by the use of SPSS software to determine the standard deviation and Cronbach's alpha reliability of the scales of the instruments. Cronbach's alpha is a measure of reliability. However, it is not robust about missing data. Standard deviation is a measure of variability. It shows how much variation exists from the average. A low standard deviation indicates that the data points are very close to the mean whereas a high standard deviation is indicative of data points which are spread out (Coolica, 2009).

2.8 Conclusion

- Metacognition is important because it enables students to monitor their knowledge and skill levels, plan and allocate limited learning resources with optimal efficiency, and evaluate their learning (Schraw et al., 2006; Ku & Ho, 2010).
- The possibility of developing a curriculum that enhances students' metacognitive provides hope for an alternative to deficit models of cognition that so often view students' learning potentials as pre-determined and unchangeable. However, metacognition still remains a fuzzy concept that lacks coherence and is defined differently by various researchers. This is evident within the science education literature where metacognition has been defined as knowledge, control and awareness of cognitive processes and the ability to think about one's thinking. Confusion still exists in the conceptualisation of metacognition and self-regulation that are sometimes used interchangeably and in some cases hierarchically, with metacognition being a component of self-regulation, or the reverse (Hofer & Sinatra, 2010). The relationship between metacognition and self-regulation and the actual learning processes that students use should be made clear wherever possible because while it is of interest to look at metacognition as a 'stand-alone' concept, it does not influence learning outcomes in isolation but rather is related to other elements of cognitive theory (Thomas, Anderson & Nashon, 2008; Zohar & David, 2009). It would be beneficial to examine how students actually choose to study as opposed to self-reports of how they say they study because they may simply be unaware of what strategies they use and why they use them. Self-reports and behavioural data can both contribute to the study of metacognition and learning in future research (Son & Kornell, 2009). More work is also needed to clearly differentiate what is cognitive from what is metacognitive because many studies still show some lack of agreement (Hofer & Sinatra, 2010).
- The main difficulties that challenge researchers and practitioners emanate from a lack of comprehensive theory of metacognition, so that assessments can be standardised. There are still many different terms used for different

aspects of metacognition and not all theorists hold the idea that there is a unified concept of metacognition that will serve assessment needs at different ages or in different contexts. Different researchers investigate at different levels of analysis from overarching theories of conscious processes employed at a particular domain, such as reading, to micro analysis of specific monitoring or control strategies in a particular condition (Azevedo, 2009; Hofer & Sinatra, 2010). At present there is little in the way of classroom assessments of metacognition in science and across a range of subjects. The research studies that use metacognitive interventions to foster students' development of metacognitive knowledge, regulation and control processes tend to use pre- and post- intervention tests of cognitive skills. If they use metacognitive assessments these are either questionnaire-based or variations of tests/interviews. Research studies of metacognition in students often produce categories and lists of metacognitive behaviours grounded in those contexts and linked to theoretical frameworks of metacognition.

- There is need to devise assessment procedures that are more holistic and contextualised and give credit for thinking and monitoring thinking in formative manner rather than ticking off different itemised aspects of metacognition. It would be better to include instruction on theories of metacognition in teacher training and development and encourage teachers to develop good metacognitive skills themselves, which they can model for their students (Larkin, 2010). Assessment of metacognition would then become part of a teacher's judgement and normal classroom practice.
- Self-report instruments are often used without careful consideration of the nature and quality of these measures to uncover individual's learning behaviour or metacognitive capabilities. It is important to select an appropriate self-report instrument for a specific learning task. It is also important, that this specific learning task is representative of the tasks that can be generalised. Also, there is need to gain more knowledge about how measuring methods and self-report instruments in particular lead to responses and how they should be interpreted (Schellings & Van Hout-Wolters, 2011).
- Lastly, there is a need to carefully consider the nature of science content and processes when investigating metacognition in science learning settings.

There has been progress in investigating metacognition within the context of science education. Such progress is crucial in preparing science students for life in an information rich, rapidly changing and increasingly challenging world.

Chapter 3

METHODOLOGY

3.1 Introduction

This chapter is divided along broad sections starting with the research design and methods employed in this study (Section 3.2). The third section describes the metacognitive interventions which were conducted in this action research study (Section 3.3). The fourth section discusses the data sources and analysis of the quantitative and qualitative data collected in this study (Section 3.4), the fifth section outlines the quality criteria and research evaluation in this study (Section 3.5), and lastly the sixth section discusses the limitations to this study (Section 3.6).

3.2 Research Design and Methods Employed in this Study

3.2.1 Conceptual framework of this study

The purpose of this study was to conduct metacognitive interventions and investigate their effects on students' metacognitive capabilities, and achievement in science. The action research was conducted in three cycles. The interventions employed to enhance students' capabilities in the first cycle were: concept maps, collaborative activities, real life situations relating to topics covered and using focused outcomes as checklists for students to evaluate their understanding of the major concepts taught in a given topic. In the second cycle, the same interventions as in cycle one, were employed in addition to reflection journals and oral interviews in order to provide a deeper analysis of the metacognitive strategies employed. Lastly, in the third cycle the same interventions as in the second cycle were employed but the prompting questions in the reflection journals were more focused, and pre-post tests were employed to assess the students' achievement in science. Thus, in line with the above conceptual framework, the following research questions (RQ) were addressed:

RQ1. What was the effect of the interventions on the students' perceptions of their metacognitive strategies in science?

RQ2. What was the effect of the interventions on the students' perceptions of their metacognitive support in science?

RQ3. What was the effect of the metacognitive interventions on the students' achievement in science?

3.2.2 Participants

The action research was conducted at a low fee paying private high school located in the Northern Territory of Australia. The school motto is "Towards tomorrow" and the mission statement is justice, wisdom, courage, excellence, compassion, understanding, lifelong learners and Christian foundation. The school had 93 teaching staff and 11 support teachers. Most of the students were from middle-income families, with most of their parents in trade occupations.

The participants in the first cycle of this study were 35 Year 9 students, in the second cycle there were 48 students in Years 7 and 9 and in the third cycle there were 74 students in Years 7, 8 and 9.

In the first cycle, the participants included 17 girls and 18 boys. The students were of mixed ability but the majority were average-achieving students. This class had one student with a learning disability (Asperger's syndrome).

In the second cycle, the participants were 30 boys and 27 girls in Years 7 and 9 classes. The Year 7 class consisted of 23 students of mixed ability with 14 boys and 9 girls. The majority of the students in this class were average-achieving students. The average age in the Year 7 class was 12 years old. The Year 9 class consisted of 25 students of mixed ability with 13 boys and 12 girls. However, most of the students in this class were low-achieving students. The average age in the Year 9 class was 14 years old.

In the third cycle, there were 75 participants (36 boys and 39 girls) in Years 7, 8 and 9. The Year 7 class was a mixed ability class consisting of 26 students, comprising

13 girls and 13 boys. However, one boy had a learning disability (Autism). The majority of the students in this class were average-achieving students. The Year 8 class was an extension class (high-achieving students) consisting of 25 students. The Year 8 participants included 19 girls and 6 boys. Students were selected to this class using their achievements in literacy and numeracy tests (NAPLAN Test Results). The students with the highest grades in Year 8 in this school were selected to get into this class. The Year 9 class was a mixed ability class consisting of 24 students. The participants included 17 boys and 7 girls. The majority of the students in this class were low-achieving students. Three of the boys had learning disabilities (1 autistic, 1 partially deaf and 1 was mentally unstable due to brain tumour surgery).

3.2.3 Action research in this study

The action research approach was used in this study that investigated the effectiveness of a repertoire of interventions to enhance secondary students' metacognitive capabilities, and their achievement in science. Action research was the methodology employed because it brings about change in classroom practices while generating data for research at the same time (Williamson, 2002). Since the researcher conducted the research in the classes he taught science, this was the most suitable methodology to adopt.

In this action research, three cycles were conducted as shown in Table 3.01. The first cycle was conducted in 2009 for a period of 10 weeks (Term 3) with 35 Year 9 students. The metacognitive interventions conducted were provision of focused outcomes to students with a list of key concepts, collaborative activities and concept mapping. The first cycle also served as the pilot study. After reflecting on weaknesses and strengths of the first cycle, the second cycle was conducted in 2010 (semester 2) with a few modifications to the research. The number of participants was increased to 62. The participants were drawn from two different classes in Years 7 and 9 for the second cycle of the study. The metacognitive interventions conducted in the second cycle were the same as those in the first cycle, in addition to reflection journals and effective use of marking rubrics. The interventions were conducted over a period of 20 weeks with the perception that the longer the interventions are conducted the more significant their effect would be. After a period (one year) of reflection and rigorous analysis, which also included presentation of research findings at an international conference in Penang, Malaysia in November 2011, a third cycle was conducted. The interventions conducted in the third cycle were the same as those in the second cycle except that the prompting questions in the reflection journals were more specific and relevant to what the students were engaged in at the time in their science classes and students were given more time to discuss how they learned and approached science assignments and tests. The duration of the third cycle was 10 weeks, shorter than the second cycle, but more focused and intense. For example, students were given more time to record their learning experiences in reflection journals and the research ensured that every student recorded their reflections while the focused outcomes that had been taught were in front of them on their desks. Students were also regularly instructed to tick off the outcomes that had been taught in class so that they could monitor their learning.

It is also important to consider that each class had four science periods (one period = 50 minutes) a week. Each class had a double period, during which science experiments related to the current topic were conducted, and two single periods, during which theoretical lessons were conducted.

Table 3.01: Number of participants and duration of each cycle of the action research study.

Cycle	Year group (number of participants)	Length of interventions (year)
1	9 (N = 35)	10 weeks (2009)
2	7 and 9 (N = 53)	20 weeks (2010)
3	7, 8 and 9 (N = 75)	10 weeks (2012)

3.3 Metacognitive Interventions

The interventions conducted in the first cycle of this action research were: provision of focused outcomes, collaborative group work, concept maps and reading text skills. In the second cycle the same interventions were employed in addition to reflection journals and re-structuring of marking rubrics to clearly state the expectations and clear explanations to students on how to use marking rubrics to monitor their progress in an assignment. In the third cycle the interventions conducted were the same as in the second cycle except that the prompting questions in the reflection journals were more specific and relevant to what was going on in the classroom. Students were also given more collaborative activities in the classroom than in the second cycle.

3.3.1 Focused outcomes

Students were given clearly written focused outcomes at the beginning of every topic and were instructed to attach them in their workbooks at the start of every topic (road map) in all the action research cycles. Students were also given key words or concepts for each topic. The researcher always instructed the students to mark-off the outcomes covered after a lesson was conducted. Students were encouraged to use the focused outcomes as a checklist when preparing for a test and also to find the meanings of the keywords in the topic.

3.3.2 Collaborative group activities

Collaborative group activities were conducted in both the theoretical and practical (when doing experiments) lessons. Students were encouraged to discuss phenomena without writing anything down. During experiments students were instructed to take turns to set up the equipment and make observations in their experiments while discussing their inferences. Verbal thinking was encouraged during group discussions.

3.3.3 Concept maps

Concept maps were used at the end of each topic, in all the three cycles, to make connections between key concepts. Students were encouraged to use the keywords provided at the beginning of each topic to construct their concept maps. Students were reminded that there were many ways to construct concept maps and that this was a useful tool to summarise the major concepts in a topic and revise for a science test. However, after reflecting on the problems encountered by students in the construction of concept maps in the first and second cycles, the researcher reduced the number of concepts to be constructed to ten in the third cycle. In the third cycle, students were also given extensive practice to make connections between words in non-science areas that they were interested in, such as sports and school facilities. Students were allowed to select any ten concepts from the list and make connections between them. The best concept maps were also to be put up on the class notice board.

3.3.4 Reading texts

In all the three cycles, students were often given texts to read followed by questions to be answered. They were encouraged to skim through the text first followed by reading slowly and underlining or highlighting major concepts. In some instances student were given summary notes related to the text, with gaps to fill in. In the third cycle students were also asked to formulate questions while reading each text.

3.3.5 Reflection journals

In the second cycle, students were instructed to record their learning experiences in their reflection journals fortnightly except at the beginning of the term when little was covered. Students were instructed to record their reflections based on the focused outcomes that had been taught in the classroom. To assist the students to reflect the following guiding questions were provided: (1) What have you learnt easily and why? (2) What have you learnt with difficulty and why? (3) What have you not learnt properly and why? And (4) How do you plan to learn it? (as shown in Table 3.04) At the end of the second cycle students were also asked to reflect on whether they performed better in tests or assignments and give reasons for the difference in performance in the two types of assessments. In the third cycle, reflection journals were used from the beginning of the term and students regularly recorded their learning experiences every fortnight by following prompting questions. The prompting questions used in the third cycle were also more focused than those used in the second cycle, in relation to what was happening in the classroom during the week. For example, when students were given an assignment the reflection that week was only about that assignment or if they were to have a test the reflection that week was about the test. Throughout the second and third cycles, the researcher/teacher used the information from the reflection journals to re-adjust the teaching approach in order to enhance the students understanding of science.

3.3.6 Marking rubrics

In the second and third cycles, marking rubrics were formulated in a language that students could understand and given to students together with the assignment question(s). The major outcomes were clearly stated in the marking rubrics for theoretical research work and experiment reports. The criteria in the marking rubrics were clearly explained to students. Given the difficulty students experienced in designing experiments and writing practical reports, a lot of time was spent on explaining the experiment report marking rubrics to students. Students were encouraged to use the marking rubrics to monitor their progress when doing their assignments. They were also encouraged to break down their work and prepare a timeline that enabled them to complete their assignments at least two days before the due date. Students were advised against doing too much work in one sitting. In the third cycle, students were also instructed to highlight the key words on the marking rubric.

3.4 Assessing Metacognitive Capabilities

3.4.1 Metacognitive surveys

In this study, previously-developed metacognitive surveys (Cartwright-Hatton, Mather, Illingworth, Brocki, Harrington & Wells, 2002; Pintrich & De Groot 1990; Thomas, 2003) were used to elicit responses from participating students about their perceptions of their metacognitive strategies, and metacognitive support that they received in the classroom. The *Metacognitive Strategies Questionnaire (MStQ)* (Appendix A) consisted of three scales as shown in Table 3.02: (1) cognitive strategy use (CSU) with 13 items, (2) self-regulation (SR) with 9 items and (3) cognitive self-consciousness (CSC) with 6 items. The *Metacognitive Support Questionnaire (MSpQ)* (Appendix B) consisted of five scales as shown in Table 3.03: (1) metacognitive demand (MD) with 5 items, (2) student-student discourse (SSD) with

5 items, (3) student-teacher discourse (STD) with 5 items, (4) student voice (SV) with 5 items, and (5) teacher encouragement and support (TES) with 5 items. The scales means ranged from 1 to 5, with 1 for the most negative perception that represents ‘almost never’, 2 represents ‘seldom’, 3 represents ‘sometimes’, 4 represents ‘often’, and 5 for the most positive perception that represents ‘very often’.

Table 3.02: Description of scales and a sample item for each Scale on the *Metacognitive Strategies Questionnaire (MStQ)*

Scale name	Description	Sample item
Cognitive strategy use (CSU) a	Extent to which students use strategies to learn, remember and understand material.	In this science classroom I ask myself questions to make sure I know the material.
Self-regulation (SR) a	Extent to which students plan, monitor and modify their cognition during the learning process.	In this science classroom I try to put together the information from class and from the book when studying for a test.
Cognitive self-consciousness (CSC) b	Extent to which students monitor their thoughts during the learning process.	In this science classroom I am constantly aware of my thinking.

a – adapted from Pintrich and Groot, 1990

b – adapted from Cartwright-Hatton et al., 2002;

Table 3.03: Description of scales and a sample Item for each scale on the *Metacognitive Support Questionnaire (MSpQ)*

Scale name	Description	Sample item
Metacognitive demands (MD)	Extent to which students are asked to be aware of how they learn and how they can improve their science learning.	In this science classroom students are asked by their teacher to think about how they learn science.
Student-student discourse (SSD)	Extent to which students discuss their science learning processes with each other.	In this science classroom students discuss with each other about different ways of learning science.
Student-teacher discourse (STD)	Extent to which students discuss their science learning processes with their teacher.	In this science classroom students discuss with their teacher about how they can improve their learning of science.
Student voice (SV)	Extent to which students feel it is legitimate to question the teacher's pedagogical plans and methods.	In this science classroom it is OK for students to ask the teacher why they have to do a certain activity.
Teacher encouragement & support (TES)	Extent to which students are encouraged by the teacher to improve their science learning processes.	In this science classroom the teacher supports students who try to improve their science learning.

(All scales adapted from Thomas, 2003)

After the students had responded to the questionnaires, their responses were entered into a data base. The questionnaires were pre-coded. The validity of the data was checked by entering it twice and by comparing the two entries for accuracy. This was followed by the use of SPSS software to determine the mean, standard deviation, t-scores, effects size and alpha reliability of the instrument. The analyses conducted helped to answer the research questions about the students' perceptions of their metacognitive strategies and support before the interventions and the changes in students' metacognitive capabilities after the interventions.

3.4.2 Reflection journals

Reflection journals in this study were used to specifically gain a deeper understanding of students' self-regulation, a vital component of metacognition. Students recorded their reflections in their individual journals once a fortnight throughout the action research. Students of high and average achieving ability independently provided information in their journals whereas students of low achieving ability were given extensive support in order to provide significant reflections about their learning. The analyses of students' reflections were used to study the differences in the level of reflection and self-regulation in learning between low, average and high achieving students in Years 7, 9 and 11 in the second cycle.

Table 3.04: Guiding questions used in the reflection journals and the corresponding components of self-regulation

Component of self-regulation	Prompting questions
Cognitive strategy use (CSU)	How do you plan to learn material which you have not learnt properly?
Self-regulation (SR)	What did you learn easily and why? What did you learn with difficulty and why?
Cognitive self-consciousness (CSC)	How do you feel about this topic or assignment? Do you prefer assignments to tests?

3.4.3 Semi-structured interviews

In the first cycle of this study, semi-structured written interviews were used to interview students of varying abilities. A total of 12 students from Year 9 were interviewed. Students of high and average achieving levels provided information independently whereas the low achieving students were given extensive support. The interview questions were developed from the metacognitive surveys so that students could elaborate on their responses, which was not possible in the survey. Table 3.04 shows some of the semi-structured questions that were used in the metacognitive interviews, although a few variations were made in the oral interview conducted in the second cycle, depending on the year level of the students being interviewed.

After reflecting on the first cycle, in the second cycle of this study oral interviews were conducted in order to elicit adequate responses from students of all achieving levels. The interview questions used in the second cycle were also derived from the metacognitive surveys (convergent validity); however, some questions were about students' perceptions of their performance in science tests and assignments (self-regulation).

In the third cycle, the questions asked in the oral interviews were again derived from the metacognitive surveys. However, more questions were asked in each scale than were asked in the second and first cycles. This is because some of the students' responses in the second cycle were not clear enough for the researcher to make a valid judgement of what their perceptions within a given scale were. This was particularly a problem with the cognitive self-consciousness scale interview questions in the second cycle.

Table 3.05: Semi-structured metacognitive interview questions used in this study

Metacognitive strategies scale	Sample question
Self-regulation (SR)	When you are preparing for a test, do you usually try to put together notes from class or text books?
Cognitive Strategy Use (CSU)	How do you know that you remember material covered in class?
Cognitive Self-consciousness (CSC)	When you are solving a problem in a science class, are you aware of your thinking?

3.5 Data Analysis

The data collected were analysed and used to answer the three research questions that have already been stated in Section 3.2. Multiple methods, including quantitative and qualitative methods, were used in order to gain deeper understanding of the students' metacognitive capabilities in relation to their achievement in science.

3.5.1 What was the effect of the interventions on the students' perceptions of their metacognitive strategies in science?

In the first cycle, the data to address this research question were obtained from t-test values of the pre- and post- *Metacognitive Strategies Questionnaire (MStQ).* In the first cycle, the qualitative data were obtained from written interviews and analysed by using typologies (low, average and high achievers) and the same scales as those in the metacognitive survey shown in Table 3.02. Students' responses were recorded in a table under the appropriate scale (cognitive strategy use, self-regulation or cognitive self-consciousness) and later a structural analysis was conducted (searching for patterns).

In the second cycle, the data were again obtained from the *MStQ* and analysed in the same way as in the first cycle. The qualitative data to address this research question were obtained from oral interviews and reflection journals, and analysed in the same way as the interviews were analysed in the first cycle.

3.5.2 What was the effect of the interventions on the students' perceptions of their metacognitive support in science?

In all the three cycles the data to address this research question were obtained from the *MSpQ*. The significance of the differences in students' responses in the pre- and post-*MSpQ* was determined by analysing the differences in mean scores of students' responses to the *MSpQ*. The significance of the changes was analysed by using t-test scores (two-tailed).

3.5.3 What was the effect of the metacognitive interventions on the students' achievement in science?

In the first and third cycles the data to address this research question were obtained from the changes in students' scores in the pre- and post-tests. In the first cycle the Year 9 students' scores in a Light two-tier pre- and post-test (see appendix c) were analysed by using paired t-tests to assess the significance of the changes in the students' scores before and after the metacognitive interventions were conducted. However, in the second cycle the analysis of the changes in students' achievement in science was analysed by using the change in students' scores in the first and second semester examinations and assignments. This approach, in the second cycle, raised extensive statistical problems because the examinations and assignments that the students did before and after the interventions were different. After reflecting on the second cycle, the researcher reverted to two tier pre- and post-tests in the third cycle. The two tier pre-post tests conducted in the third cycle were: Year 7, Classification of living things (see appendix D); Year 8 , Geology (see appendix E); and Year 9, Ecology (see appendix F).

3.6 Quality Criteria and Research Evaluation

3.6.1 Internal validity

In this study, credibility was also addressed in terms of triangulation by using a number of data sources and methods that included metacognitive surveys, interviews with students and students' reflection journals. Peer examination took place through discussion with the associate supervisor and supervisor. This study involved sustained interventions and observations in three cycles, with duration of 10 weeks each for the first and third cycles, and duration of 20 weeks for the second cycle. This study also involved continual adjustment of teaching approaches in the second and third cycles, based on feedback from students' reflection journals (Williamson, 2002).

3.6.2 External validity

In the description of focus groups in this research, the researcher attempted to provide a thick description of the settings of the one year group (Year 9) in the first cycle , the two year groups (Years 7 and 9) in the second cycle and the three year groups (Years 7, 8 and 9) in the third cycle. The interventions conducted in the science lessons within these classes were also described in detail in Section 3.4. Similar interventions in this research were conducted in three cycles with different classes (Years 7, 8 and 9). This procedure was followed to investigate whether or not the effects of the interventions were similar across the different year groups of students and therefore whether valid generalisations could be made.

3.6.3 Reliability

Reliability was enhanced by the use of straightforward multiple-choice questions in the metacognitive questionnaires. The researcher ensured reliability in the interviews by being consistent all the time. Reliability was also helped by having multiple sources of data: metacognitive surveys, interviews and reflection journals. Research results can be unreliable if not guided by an explicit structure (Anderson, 2004). The researcher has outlined his position and theory behind this study in Chapter 1 and triangulation was discussed under internal validity.

3.6.4 Objectivity and confirmability

The extent to which data related to the objective criteria (reliability) was ascertained by the calculation of effect sizes. Effect size facilitates the interpretation of the substantive, as opposed to the statistical significance of a research result (Coolica, 2009). A small effect size (0.20) is an indication of a weak relationship between the variables, a medium effect size (0.50) is an indication of a moderate relationship and a large effect size (0.80) is an indication of a strong relationship between the variables (Cohen, 1988). In addition, the researcher has shown how data were converted into findings such that the findings are not simply part of the researcher's imagination (Anderson, 2004; Coolica, 2009).

3.7 Conclusion

This chapter dealt with the research methodology and justified the use of specific research techniques to answer each of the research questions. The chapter also described the characteristics of students in the classes participating in this study in order to provide the context in which the data were collected. Lastly, the limitations to the study in each of the three cycles have been discussed. The following chapter is devoted to the findings obtained after the implementation of the methodology explained above. The findings are presented in terms of each of the five research questions described in Section 3.2.

Chapter 4

RESULTS

4.1 Introduction

The previous chapter was primarily devoted to the methodology employed to answer the research questions. The instruments used to collect data, namely, questionnaires, interviews, reflection journals, research assignments, pre-post tests and protocols for analysing documents, within the context of the three research questions, were described.

The purpose of this chapter is to report on the findings as a result of the data analyses. Reporting in this chapter is divided into ten parts. Firstly, the reflections of the researcher on each of the three cycles in this action research (Section 4.2). The other parts of the chapter correspond to the three research questions (RQs) as indicated below:

RQ1: What was the effect of the interventions on the students' perceptions of their metacognitive strategies in science? (Section 4.3). The quantitative data analysis to address this research question is discussed in Section 4.4.The qualitative data analyses from interviews (Section 4.5) and from the students' reflection journals (Section 4.6) are also discussed.

RQ2: What was the effect of the interventions on students' perceptions of their metacognitive support in science? (Section 4.7). The quantitative data to address this research question is discussed in Section 4.8.

RQ3: What was the effect of the metacognitive interventions on the students' achievement in science? (Section 4.9). The quantitative data analyses from the pre-post science tests conducted in the three cycles are discussed in Section 4.9.

Lastly, the conclusions about the research findings are discussed in Section 4.10, and the conclusion of the chapter is discussed in Section 4.11.

4.2 Action Research Cycle-Reflection

The action research was conducted in three cycles. The interventions and data collection methods employed in the first cycle were reflected upon and modified or additions were made to enhance students' metacognitive capabilities in science. The research findings for each research question are presented in three major parts because the research was conducted in three cycles.

The instruments used to measure students' metacognitive capabilities in the first cycle were questionnaires, pre- and post-tests and written interviews. In the second cycle questionnaires were used but pre- and post-tests and written interviews were not used. The additional methods of data collection used in the second cycle were oral semi-structured interviews and reflection journals. Also, the first and second semester science examinations instead of pre-post topic tests were used to assess students' achievements in science. The reason for not using pre- and post-tests in the second cycle was because the items measured cognitive gains and not metacognition. Written interviews were not used in the second and third cycles because this method of data collection did not enable low achieving students to express their learning experiences clearly.

In the third cycle, the same interventions as those used in the second cycle were used with some modifications. Students were instructed to carry out reflections while referring to the focused outcomes that were given out to each student in the first science lesson of the term in order to minimise memory distortions. Samples of students' concept maps were also collected to analyse the differences in concept connections that were displayed by low, average and high achieving students. In the third cycle more questions were included in the interviews for each scale and the questions were closer in structure to those in the *Metacognitive Strategies Questionnaire (MStQ)*.

Questions on the *Metacognitive Support Questionnaire (MSpQ)* were not included because, firstly, the interviews would have been too long for the students to elicit meaningful responses, and secondly, the main aim of this study was to investigate the effect of metacognitive interventions on the students' metacognitive strategies, and their achievements in science. Also, in the third cycle the researcher reverted to the use of pre- and post-tests to measure students' achievement in science because of the statistical limitations involved with comparing examination and assignment results. For example t-tests could not be used in the second cycle to assess changes in students' achievement in science because the examinations and assignments before and after the interventions were different. And to be consistent with the first cycle, it was perceived that a similar method of measuring students' achievement in science be used. In the third cycle, processed questions were used in the pre-post-tests so that students were not assessed on declarative knowledge but procedural and conditional knowledge which require higher order thinking, and hence draw more on metacognition rather than cognition. A summary of the instruments and the interventions that were used in the three cycles is provided in Table 4.01.

Table 4.01 Summary of metacognitive assessment instruments and interventions used in the three cycles of this action research study

Cycle	Assessment instruments	Interventions
1	Questionnaires	Focused outcomes
	Pre- and post-tests	Collaborative activities
	Written interviews	
2	Questionnaires	Focused outcomes
		Keywords
	Oral and semi-structured interviews	Collaborative activities
	Reflection journals	Concept maps
		Reflection journals
3	Questionnaires	Focused outcomes
	Oral and semi-structured interviews	Keywords
	Reflection journals	Collaborative activities
		Concept maps
		Reflection journals

4.3 Response to Research Question 1: What was the effect of the interventions on the students' perceptions of their metacognitive strategies in science?

To investigate this research question, the *Metacognitive Strategies Questionnaire* (*MStQ*) was administered as a pre-test and a post-test to the students in the three cycles over three years. The students' responses to each of the three scales on the *MStQ* were coded and analysed by using SPSS software to calculate the means scores and the use of t-tests as described in Chapter 3. To examine Research Question 1, quantitative data from the instruments (Section 4.4) and qualitative data from the interviews (Section 4.5) and qualitative data from the students' reflection journals (Section 4.6) for each of the three cycles follow.

4.4 Metacognitive Strategies Questionnaire - Quantitative data

4.4.1 First cycle

At the beginning and end of the first cycle, in the second term of semester one in 2009, the *MStQ* was administered as a pre-test to 35 students in Year 9. Table 4.02 shows that the mean scores of all the scales in the pre-test of the *MStQ* were above 3. These results suggest a positive perception by students of their metacognitive strategies in science before the interventions in the first cycle. The scores indicated that the students' perceptions of their metacognitive strategies ranged between 'sometimes' (score of 3) and 'often' (score of 4).

At the beginning of the first cycle, when comparing the mean scores of the three scales of the *MStQ* pre-test, Table 4.02 shows that (1) the CSU scale mean was the highest (item mean score = 3.62), followed closely by (2) the CSC scale (mean score = 3.24) and then (3) the Self-Regulation scale with a relatively lower mean score of 3.01, indicative of a positive but rather lower perception of the students' self-regulation in science. These findings respectively suggest that most students (1) perceived that they often used various cognitive strategies when learning science, (2) sometimes monitored their thoughts when learning science and (3) sometimes engaged in planning, monitoring and evaluating their learning processes.

Table 4.02: Year 9 students' perceptions on the three scales of the *Metacognitive Strategies Questionnaire* in the first cycle (N = 35)

Scale	No. of Items	Mean		Standard Deviation		Difference		Alpha Reliability	
		Pre	Post	Pre	Post	t	ES	Pre	Post
CSU	13	3.62	3.45	0.52	0.43	1.32	0.35	0.68	0.65
SR	9	3.01	3.18	0.44	0.41	2.22**	0.39	0.43	0.61
CSC	6	3.24	3.64	0.80	0.78	2.43**	0.51	0.81	0.86

**p<0.01, ***p<0.001   ES – Effect Size

CSU = Cognitive Strategy Use, SR = Self-Regulation, CSC = Cognitive Self Consciousness

[Cohen (1988) has defined effect sizes as "small, *d* = 0.2," "medium, *d* = 0.5," and "large, *d* = 0.8"]

In the first cycle there were significant gains on all the scales of the *MStQ* except for Cognitive Strategy Use: [(Mean difference = 0.17, t(34) = 2.22] as shown in Table 4.02. This finding suggests that after the interventions there was an increase in the number of students who perceived that they engaged in planning, monitoring and evaluating their learning processes [Cognitive Self-Consciousness: (Mean difference = 0.40, t(34) = 2.43]. In addition, there was a significant increase in the number of students who perceived that they had monitored their thoughts during their learning processes in science [Cognitive Strategy Use: (Mean difference = - 0.17, t(34) = 1.32)]. The decrease in CSU suggests that fewer students employed cognitive strategies for memorisation, transformation, or elaboration after the interventions.

4.4.2 Second cycle

At the beginning of the second cycle in term 2 of the first semester in 2010 the *MStQ* was administered as a pre-test to 19 Year 7 and 20 Year 9 students. All the means of the three scales were above 3, as shown in Table 4.03, suggesting that the Year 7 students generally had positive perceptions of their metacognitive strategies at the beginning of the second cycle. However, the mean score of the Year 9 students' responses was below 3 in one of the scales, CSC, as shown in Table 4.04. This finding suggests that generally the Year 9 students' perceptions of their metacognitive strategies in this scale were lower than those of the Year 7s at the beginning of the second cycle.

There were no significant gains in any of the scales of the *MStQ* in the second cycle in both the Year 7 and 9 classes as shown Tables 4.03 and 4.04 respectively. There were only modest gains in all the scales for the Year 7 class with relatively small decreases in all the scales for the Year 9 class.

At the beginning of the second cycle in the Year 7 class, Table 4.03 shows that (1) the scale with the highest mean was CSU (mean score = 3.45), followed by (2) the CSC (mean score = 3.14), and then (3) the SRC scale with the lowest mean score of 3.03. These findings respectively suggest that most students perceived that they (1) sometimes used cognitive strategies to learn science, (2) sometimes monitored their thoughts when learning science, and (3) sometimes engaged in planning, monitoring and evaluating their learning in science. Overall, the Year 7 science students' perceptions were that their metacognitive strategies were at a sub-optimal level at the beginning of the second cycle.

Table 4.03: Year 7 students' perceptions on the three scales of the *Metacognitive Strategies Questionnaire* (N = 19)

Scales	No. of items	Mean		Standard deviation		Pre-post difference	Effect size (Cohen's d)
		Pre	Post	Pre	Post	t-value	
CSU	13	3.45	3.55	0.42	0.53	0.74	0.21
SR	9	3.03	3.15	0.37	0.38	1.01	0.32
CSC	6	3.14	3.54	0.53	0.73	1.97	0.63

CSU = Cognitive Strategy Use, SR = Self-Regulation, CSC = Cognitive Self Consciousness

In the Year 7 class the highest gain was for the CSC scale [Mean difference= 0.40, t(19) = 1.97] as shown in Table 4.03. This finding suggests that there was a small increase in the number of students who perceived that they monitored their thoughts when learning science. This was followed by a smaller increase in the SR scale [Mean difference = 0.12, t(19) = 1.01], suggesting that there was a small increase in the number of students who perceived that they engaged in planning, monitoring and evaluating of their learning in science. The smallest gain was in the CSU scale [Mean difference = 0.10, t(19) = 0.74], suggesting that there was an even smaller increase in the number of students who perceived that they used cognitive strategies to learn science.

As shown in Table 4.04, at the beginning of the second cycle in the Year 9 class (1) the scale with the highest mean was the CSU scale (mean score = 3.35), followed by (2) the SR scale (mean score = 3.04), and then (3) the CSC scale with the lowest mean score of 2.70. These findings respectively suggest that most of the students (1) sometimes used cognitive strategies to learn science, (2) perceived that they sometimes engaged in planning, monitoring and evaluating their learning processes in science, and (3) perceived that they sometimes monitored their thoughts when learning science. Overall, the data shows that the Year 9 students perceived that they did employ metacognitive strategies often. It is interesting to observe that at the beginning of the second cycle the scale with the highest mean value for both the Years 7 and 9 classes was the Cognitive Strategy Use (CSU).

Table 4.04 Year 9 students' perceptions on the three scales of the *Metacognitive Strategies Questionnaire* (N = 20)

Scales	No. of items	Mean		Standard deviation		Pre-post difference	Effect size (Cohen's d)
		Pre	Post	Pre	Post	t-value	
CSU	13	3.35	3.23	0.52	0.56	0.98	0.22
SR	9	3.04	2.90	0.68	0.39	0.90	0.25
CSC	6	2.70	2.60	1.05	1.00	0.47	0.10

CSU = Cognitive Strategy Use, SR = Self-Regulation, CSC = Cognitive Self Consciousness

Contrary to the intentions of the action research, in the Year 9 class there were small decreases on all the scales in the post-test of the *MStQ* as shown Table 4.04. The highest decrease was for the CSU scale [Mean difference = - 0.12, t(20) = 0.98]. This outcome suggests that there was a small decrease in the number of students who used cognitive strategies to learn science. This was followed by the SR scale [Mean difference = 0.16, t(20) = 0.90], probably due to a small decrease in the number of students who perceived that they engaged in planning, monitoring and evaluating their learning processes in science. The smallest decrease was for the CSC scale [Mean difference = 0.10, t(20) = 0.47], suggesting that the there was a very small decrease in the number of students who perceived that they had monitored their thoughts when learning science after the interventions.

Overall, according to the analysis of the quantitative data obtained from the *MStQ*, the interventions conducted in the second cycle did not significantly enhance students' perceptions of their metacognitive strategies in all the year groups.

The Cronbach's alpha reliability values for the three scales of the *MStQ* are summarised in Table 4.05.

Table 4.05: Cronbach's alpha reliability values for the three scales in the *Metacognitive Strategies Questionnaire* for Years 7 & 9 in the second cycle (N=39)

Scales	Cronbach's alpha reliability	
	Pre	Post
Cognitive Strategy Use (CSU)	0.73	0.78
Self-Regulation (SR)	0.67	0.20
Cognitive Self Consciousness (CSC)	0.82	0.90

According to Table 4.05 all the scales on the pre-test of the *MStQ* were acceptable (albeit the relatively small sample size) except for the SR scale in the post-test. This anomaly could have been probably due to students' uncertainty in reporting their metacognitive behaviour in the SR scale. The reliability values for classes, Years 9 and 7, in the second cycle were computed for the combined sample because of the small class sizes.

4.4.3 Third cycle

At the beginning of the third cycle, the *MStQ* was administered as a pre-test to 26 Year 7 students, 25 Year 8 students and 24 Year 9 students in term 2 of 2012. The responses were coded and analysed using SPSS software. The means scores of all the scales in the *MStQ* pre-test were above 3 for all the classes, as shown Tables 4.06, 4.07 and 4.08. This trend suggests that generally the students had positive perceptions of their metacognitive strategies at the beginning of the third cycle.

As shown in Table 4.06, at beginning of the third cycle in the Year 7 class (1) the CSU scale had the highest mean of 3.46, followed by the CSC scale with a mean score of 3.37, and then by (3) the SR scale with a mean score of 3.06. These findings respectively suggest that (1) most of the students perceived that they sometimes used cognitive strategies to learn science, (2) most of the students perceived that they sometimes monitored their thoughts when learning science, and (3) most of the students perceived that they sometimes engaged in planning, monitoring and evaluating their learning processes in science.

Table 4.06: Year 7 students' perceptions on the three scales of the *Metacognitive Strategies Questionnaire* (N = 26)

Scales	Number of items	Mean		Standard deviation		Pre-post difference	Effect size (Cohen's *d*)
		Pre	Post	Pre	Post	t-value	
CSU	13	3.46	3.31	0.50	0.36	1.36	0.34
SR	9	3.06	3.12	0.36	0.49	0.63	0.14
CSC	6	3.37	3.45	0.84	0.97	0.43	0.09

CSU = Cognitive Strategy Use, SR = Self-Regulation, CSC = Cognitive Self Consciousness

In the year 7 class there were no significant gains in the perceptions of students concerning their metacognitive strategies after the interventions. There were only modest gains in the mean scores of two scales, SR [Mean difference = 0.06, t(26) = 0.63] and CSC [Mean difference = 0.08, t(26) = 043] as shown Table 4.06. This trend suggests that there was a small increase in the number of students who perceived that they had engaged in planning, monitoring and evaluating of their learning processes in science, and monitored their thoughts when learning science. There was also a small decrease in the perceptions that the students often used cognitive strategies [Mean difference = - 0.15, t(26) = 1.36] in the learning of science. This may be attributed to the nature of assessments the students are given in the middle school that are predominantly research assignments as opposed to science tests that are referred to in the items on this scale.

Table 4.07 shows that at the beginning of the third cycle in the Year 8 class (1) the scale with the highest mean was the CSU of 3.75, followed closely by (2) the CSC scale with a mean score of 3.72, and then (3) the SR scale with the lowest mean score of 3.06. These findings respectively suggest that most students perceived that they (1) often used cognitive strategies to learn science, (2) often monitored their thoughts when learning science, and (3) sometimes engaged in planning, monitoring and evaluating their learning processes in science.

Table 4.07: Year 8 students' perceptions on the three scales of the *Metacognitive Strategies Questionnaire* (N = 25)

Scales	Number of items	Mean		Standard deviation		Pre-post difference	Effect size (Cohen's *d*)
		Pre	Post	Pre	Post	t-value	
CSU	13	3.75	3.81	0.38	0.40	0.89	0.15
SR	9	3.06	3.15	0.35	0.41	0.91	0.24
CSC	6	3.72	3.68	0.89	1.10	0.19	0.04

CSU = Cognitive Strategy Use, SR = Self-Regulation, CSC = Cognitive Self Consciousness

In the Year 8 class there were modest gains in the CSU scale mean [Mean difference = 0.06, t(24) = 0.89] and the SR scale mean [Mean difference = 0.09, t(24)= 0.91] as shown in Table 4.07. These findings suggest that there were small increases in the number of students who perceived that they had used cognitive strategies, and were engaged in planning, monitoring and evaluating their learning processes in science. There was a modest decrease in the CSC scale mean [Mean difference = - 0.04, t(25) = 0.19], suggesting that there was a decrease in the number of students who held the perception that they monitored their thoughts when learning science.

Table 4.08 shows that at the beginning of the third cycle in Year 9, (1) the scale with the highest mean was CSU (mean score = 3.34), then the (2) the CSC scale (mean score = 3.15), and followed closely by (3) the SR scale (mean score = 3.11). These findings respectively suggest that most students perceived that they (1) sometimes use cognitive strategies to learn science, (2) sometimes monitored their thoughts when learning science, and (3) sometimes engaged in planning, monitoring and evaluating their learning processes in science. At the beginning of the third cycle, in all the classes, the data showed that students had relatively high perceptions of their cognitive strategy use and their lowest perceptions in self-regulation.

Table 4.08: Year 9 students' perceptions on the three scales of the *Metacognitive Strategies Questionnaire* (N = 24)

Scales	Number of items	Mean		Standard deviation		Pre-post difference	Effect size (Cohen's *d*)
		Pre	Post	Pre	Post	t-value	
CSU	13	3.34	3.22	0.47	0.54	0.85	0.24
SR	9	3.11	3.04	0.39	0.44	0.57	0.17
CSC	6	3.15	3.19	0.79	0.90	0.17	0.05

CSU = Cognitive Strategy Use, SR = Self-Regulation, CSC = Cognitive Self Consciousness

The Year 9 class had the highest number of declines in the post-test means of the *MStQ* scales compared to the means in the pre-test . There was a modest gain in the CSC scale mean [Mean difference = 0.04, t(24)= 0.17] as shown in Table 4.08. This finding could imply that there was a relatively small increase in the number of students who perceived that they had monitored their thoughts when learning science. There were modest decreases in the CSU scale mean [Mean difference = - 0.12, t(24) = 0.85] and SR scale mean [Mean difference = - 0.07, t(24) = 0.57], suggesting a general decline in metacognitive strategies in the Year 9 class despite the metacognitive interventions conducted in the action research.

Overall, the gains in metacognitive strategies in the third cycle were modest. However, the declines in the perceptions of metacognitive strategies were relatively greatest in the Year 9 class. The year 9 class also generally had the lowest mean scores in the pre- and post-surveys. Expectedly, the Year 8 class that was an extension class with predominantly high achieving students had the highest metacognitive strategies mean scores.

As shown in Table 4.09, the Cronbach's alpha reliability values for two of the three scales of the *MStQ* in the pre-test and the post-test were all acceptable; the reliability values for the Self-Regulation scale were very low. Again, as in the second cycle, the reliability values were computed for the combined sample due to the small class sizes.

Table 4.09: Cronbach's alpha reliability values for the three scales in the *Metacognitive Strategies Questionnaire* for Years 7, 8 & 9 in the third cycle (N= 75)

Scales	Cronbach's alpha reliability	
	Pre	Post
Cognitive Strategy Use (CSU)	0.73	0.76
Self-Regulation (SR)	0.22	0.35
Cognitive Self Consciousness (CSC)	0.87	0.93

4.5 Qualitative Data Analysis – Interviews About Students' Metacognitive Strategies

Interviews relating to students' metacognitive strategies were conducted after implementation of the interventions. In the first cycle written interviews were used. As only a limited number of questions were asked, the responses were not as detailed as those in the second and third cycles in which responses were solicited using oral interviews. The third cycle interviews elicited the most detail because more questions were asked in each scale in order to gain a deeper understanding of the participants' perceptions of their metacognitive strategies. In all the cycles the participants were drawn from the low, average and high achieving sections of the classes in order to analyse the variations in students' metacognitive strategies in relation to their achievements in science.

4.5.1 First cycle

Cognitive strategy use

The perceptions elicited from the high performance students indicated that they studied their class notes, answered revision questions, and if they had textbooks they used them to supplement their notes or used the internet to do some research. The average and low achieving students' responses all indicated that they solely depended on the class notes, and used repetition and rote memorisation of facts when preparing for science tests. The following are examples of students' responses to the question: *Do you try to put together information from class and from the book when studying for a test?*

> Student 1 (high achieving): *It depends on whether I have a textbook with me when I'm studying; I usually go over the notes I have taken in class and do revision questions on them.*
>
> Students 3 (average achieving): *The way I prepare for a test is by reading my notes and then typing it up on my computer.*
>
> Student 4 (low achieving): *To help me in a test, I make up palm cards and try to remember the facts in my head.*

Self-regulation

The high and average achieving Year 9 students' responses were similar in terms of strategies employed in the learning process. Most of the high and average achieving students relied on classmates or family members to ask them questions in order to ensure they memorised material. However, the low achieving students were inconsistent in their effort to ensure that they remembered the material. Most of the low achieving students responded that they only sometimes tried to memorise. All the participants seemed to have a limited repertoire of cognitive strategies. The following are examples of students' responses to the question: *Do you ask yourself questions to make sure you know the material?*

> Student 1 (low achieving): *Yes sometimes but not usually.*
>
> Student 2 (average achieving): *Yes, I do ask make-up questions but I ask someone else to ask the questions.*
>
> Student 3 (high achieving): *I get friends to test me before the test.*

Cognitive self-consciousness

Contrary to the gains in the *MStQ*, students of all abilities responded that they were not always aware of their thinking during the learning the process. Both the average and high achieving students responded that they were sometimes aware of their thinking. The following are examples of students' responses to the question: *During science classes are you constantly aware of your thinking?*

> Student 1 (low achieving): *When I come to class I don't think about what topic we are learning in class.*
>
> Student 2 (average achieving): *Sometimes I am aware of my thinking but I mostly do it subconsciously.*
>
> Student 3 (high achieving): *Not always. If I'm trying hard to understand something I try to be aware of my thinking but otherwise I usually don't need to.*

4.5.2 Second cycle

The oral interviews in the second cycle elicited much more information about students' metacognitive strategies in terms of cognitive strategy use, self-regulation and cognitive self-consciousness compared to the written interviews in the first cycle, and other quantitative and qualitative methods of collecting data in the second cycle of this research. Low, average and high achieving students in Years 7 and 9 were able to express their learning experiences in detail. However, in some cases, especially in Year 9, some low achieving students claimed to have used more cognitive strategies than was observed in the science classes.

Cognitive strategy use

The Year 7 average and low achieving students' responses indicated that they often prepared for science tests a couple of days or the night before the test, whereas the high achieving students responded that they spent more time, about a week, preparing for their science tests. Most of the low achieving students also reported that they used only the notes provided by the teacher for their revision whereas the average and high achieving students' responses indicated that they obtained information from various sources such as textbooks, workbooks and worksheets. The following are examples of students' responses to the question: *How do you prepare for a test?*

> Student 1 (low achieving): *I get the notes from class and then a couple of days or the night before - it depends what's happening in my house - I study then.*
>
> Student 2 (average achieving): *Sometimes I will revise a few days before the test so that I don't have to do it later but sometimes I procrastinate a lot and I don't get it done until the night before. I use the notes that we took down during class, yeah.*
>
> Student 3 (high achieving): *I will study, like say if the test was on Friday, I would study, like, throughout the week. So like I would do some study on Monday, Tuesday, Wednesday, Thursday and I would just like use your notes and my notes and that sort of stuff, and I might use a textbook or look on the internet if I'm really confused or something.*

Generally, Year 9 participants in this interview at all levels of performance responded in a way that exhibited significant levels of cognitive strategy use. However, from the researcher's perspective, there was a discrepancy between what the low achieving students said in the interviews and what they actually did in the science classes. The high achieving students' responses also indicated that they had a well-organised structure to their study for tests or assignments and ensured that they implemented it whereas the low and average achieving students' responses suggested an organised structure but often did not implement it or followed it only when they were in a "good mood". The following are examples of students' responses to the question: *When preparing for a test, do you usually try to put together notes from class or information from a previous lesson?*

> Student 1 (low achieving): *I just look over all the notes that I have written down in class and just go over them a few times and then make up questions that would probably be on the test and try to answer them.*
>
> Student 2 (average achieving): *Well I go through my book and get all the handouts, which were given to us.*
>
> Student 3 (high achieving): *Not much, just the same as those guys.*

Self-regulation

Some of the Year 7 low achieving students responded that they went over the problem many times to try and understand it. In a situation where students have to solve complex problems, some of the low achieving students responded that they had to breakdown the task into manageable steps. The average and high achieving students all responded that it depended on the problem: if it was difficult, they broke it down into manageable steps but if it was easy they solved it all at once. Generally, all Year 7 participants in this interview responded in a way that indicated a reasonable level of self-regulation when solving complex problems, with the average and high achieving Year 7 students having similar and higher levels of self-regulation than their low achieving peers. The following are examples of students' responses to the question: *If you are solving a problem that involves more than one step, for example in science you have been asked to calculate for the density of an object, how do you go about it?*

> Student 1 (low achieving): *Well if there is an example, I would write that down and then I would write the question down after it, and then I would write little notes.*
>
> Student 2 (average achieving): *Yeah, like I'II probably do it all at once too because I don't think it is easier. If I don't understand I will ask a teacher or I would look back in the science book or other resource books.*
>
> Student 3 (high achieving): *Depending on how hard the question is but if it is easy I would just do it all at once. If it is harder I would break it down but I wouldn't write it down. I just break it down in my head step by step and then write down the result.*

The responses of the high and average achievers in Year 9 generally indicated the same level of self-regulation. Many of the high and average achievers reported the use of the rehearsal method of oral questioning whereas a significant number of the low achieving students responses indicated that they mostly relied on re-re-reading material (repetition) as a strategy to remember material. The following are examples of students' responses:

> Student 1 (low achieving): *I just keep going over my notes. Yeah, I'll ask my friend to, like, test me and to just help me.*
> Student 2 (average achieving): *I make my own questions or I get my parents or someone to make questions for me and then I answer them. If I get them wrong then I keep going over them to make sure that I get it right.*
> Student 3 (high achieving): *Yeah, well I usually test myself, so I usually - if we have a revision sheet or something - I would go over those questions or if not then I just go through my notes and then maybe get a family member to test me on them. So they just randomly go through my notes and just ask me any questions.*

Cognitive self-consciousness

Most of the Year 7 students' responses, at all levels of achievement, indicated that they were aware of their thinking when solving problems in science. The following are examples of students' responses to the question: *If you are reading material that is hard to understand, what do you do?*

> Student 1 (low achieving): *Well, if it was hard I would ask the teacher or someone next to me, and if still don't get it I would look in my book and see if there is another way to find out what that one is.*
> Student 2 (average achieving): *It's like 50/50. Sometimes I will just stare at it until it hits me or I will ask someone if they know how to do it. If I ask some and they do not know I will either give up or ask the teacher and see if he knows.*
> Student 3 (high achieving): *If I don't get it I would probably ask the teacher, and then if I still don't understand it I would probably - like if it is a worksheet or something and they had other questions on it - I would probably do other questions and see if that helped me understand the first one more, and then I would go back to it at the end of it, or ask the teacher or anyone else if they had any ideas from the classroom.*

Most of the Year 9 participants reported that they were not aware of their thinking when solving problems. The high achieving students seemed to indicate more awareness of their thinking than the low and average achieving students. A few participants, especially the high achieving students, and low achieving female students reported that they verbalised their thinking when solving problems. The following are examples of students' responses to the question: *When you are solving a problem in class, are you aware of your thinking? Do you monitor the way you are thinking about the problem*?

> Student 1 (low achieving): *I just usually do it absent-mindedly or sometimes I say it out loud because it kind of helps me.*
> Student 2 (average achieving): *I'm not quite sure actually. I don't really know how I'm thinking, like, to answer the question.*
> Student 3 (high achieving): *Well I'm not really aware of what I'm thinking. I know what I need to do in order to answer the question. Sometimes depending on the question, I verbalise it but I go through the steps one by one, so okay, step one; I have done that, now step two and so on and so forth.*

4.5.3 Third cycle

The third cycle involved more questions in each scale than the first and second cycles. This enabled the researcher to elicit more information about the 18 students' metacognitive strategies at the end of the third cycle. Two students from each level of achievement, low, average and high achievers were selected from Years, 8 and 9 to participate in this interview in the last week of the second term of 2012.

Cognitive strategy use

The Year 7 participants' responses generally indicated a significant level of cognitive strategy use. Most of the students responded that they often combined information from the class lessons and the textbook when preparing for science tests. Only two students, one low achieving and one average achieving, responded that they only used class notes. Almost all the students also responded that they tried to remember what the teacher had said so that they could get their homework right and make summaries of big ideas. One low achieving student responded that she does not make summaries and copies notes over and over to try and remember concepts or material. The following are examples of students' responses to the question: *When you are* *studying for a science test, do you try to put together information from class and from the book?*

> Student 1 (low achieving): *Yes, because it helps you study.*
>
> Student 2 (average achieving): *Sometimes. I mean, I ask dad and mum questions. They help, like, they give us information on it. Yeah, but, yeah, try to piece together.*
>
> Student 2 (high achieving): *Yes, but I also look in like the textbook and the internet.*

All the Year 8 students' responses indicated a significantly high level of cognitive strategy use. They all responded that they put together information from the class, textbooks and the internet when preparing for tests; they tried to remember what the teacher had said in class and took notes in their own words. Most of the Year 8 students also responded that they made summaries of the big ideas when reading from textbooks. The following is an example of a student's response:

> Student 1 (high achieving) *Yeah, I usually take notes during class and kind of put them in my own words so I can understand what I'm trying to say and then I take information from the book and my notes and try to compare them and get the best sort of answer, and I usually make palm cards too so I use them to memorise.*

The responses from the Year 9 high and average achieving students indicated a reasonably significant level of cognitive strategy use. Both high achieving students responded that they put together information from the class and the book when preparing for a science test, they tried to remember what the teacher had said in class so that they get their home work right, and were able to make connections of the material at hand with their prior knowledge. However, one of the Year 9 high achieving students said that she did not make summaries of the main ideas when studying science from a textbook. The responses of the average achieving students were similar to those of the high achieving students except that they both said that they did not often make connections with previous topics. One of the average achieving students also said that he did not make summaries of main ideas. The responses from the Year 9 low achieving students exhibited a lower level of cognitive strategy use compared to their high and average achieving peers. One of the low achieving students responded that she only used the classroom notes to study for science tests. Also, both low achieving students said that they did not make summaries of main ideas and they did not connect ideas from previous topics. The following are examples of students' responses:

> Student 1 (low achieving): *I mainly just look at notes that you have given us in class, from my book and then I try to remember what you have told us in class.*
>
> Student 2 (average achieving): *Yes, because that would be the stuff that would be in the test. Only if I am completely confused about something, I will look it up in textbooks or internet or ask the teacher.*
>
> Student 3 (high achieving): *Often yeah. I put together notes and then I try to remember what the teacher said in class too. I use textbooks if they are recommended.*

Self-regulation

All the high and average achieving Year 7 students' responses indicated significant levels of self-regulation. All the Year 7 participants in this interview responded that they asked themselves questions to make sure they remembered material and they did not give up easily when studying difficult material. Most of the participants also responded that they stopped once in a while to go over material when reading. All the high and average achieving students responded that they worked hard to get a good grade even when the topic was boring. However, both low achieving students responded that they did not put much effort in boring topics. The following are examples of students' responses to the question: *When you are studying material how do you ensure that you will remember what you are studying?*

> Student 1 (low achieving): *Well, yeah, I practice with mum and dad. I ask mum to ask questions and stuff like that.*
>
> Student 2 (average achieving): *Yeah, if I am reading something, yeah, I ask myself about the text in my head, just think about the answers, what it could be, yeah*.

> Student 3 (high achieving): *I will just quiz myself on it and, like, just keep on reading it until it sinks in and I can remember what the text is about.*

Most of the Year 8 students' responses indicated significant levels of self-regulation. They all responded that they asked themselves questions when preparing for a test. However, there were different approaches to this self-evaluation. Many of the Year 8 students said that they wrote down the questions and asked their family members to test them or use palm cards. All the Year 8 participants said that they did not give up when studying difficult material; they used various resources until they understood the material. Most of the students also responded that they worked hard to get a good grade even when the material was boring. However, two students said they did not put as much effort on boring topics or topics they did not like. It is worth mentioning that although this was an extension class, these two students' performance in science tests was average in most cases. The following is an example of a student's response:

> Student 1 (high achieving): *Sometimes, not always. I do the quiz thing and you know, test myself, but, and sometimes in class I tend to you know, ask myself questions, like how does that work and try to figure out in my head that way.*

The Year 9 high and average achievers responses exhibited a similar level of self-regulation. The students at all levels of achievement responded that they asked themselves questions when preparing for a test. All the high and average achievers admitted to working hard to get a good grade even when they did not like the topic. However, it is only the average achieving students who responded that they stop reading once in a while to go over what they have read. The two low achieving students responded that they did not put much effort in studying boring material; and that they gave up easily when studying difficult material. The following are examples of students' responses:

> Student 1 (low achieving): *Yes, I ask someone to ask the question to me (sic). My parents when they get home.*

> Student 2 (average achieving): *Yeah, I do just so it triggers key points in my mind and I try to remember. Sometimes I will ask my parents to ask me questions or I will just do it in my head. I do not usually write.*
>
> Student 3 (high achieving): *Yeah, I do that. I do that quite often. I always ask myself questions on what I am studying so I can answer them in my head or write the answers down.*

Cognitive self-consciousness

Almost all the Year 7 students responded that they were often aware of their thinking when preparing for a test and constantly monitored their thoughts. However, one high achieving Year 7 student responded that she did not always monitor her thoughts when solving a problem. Based on the researcher's observation, most of the students struggled to answer this question. Some of the students may have given responses which they thought were acceptable but not a true description of what goes on in their minds during the learning process. The following are examples of students' responses to the question: *When you are preparing for or during the science class are you constantly aware of your thinking?*

> Student 1 (low achieving): *Most of the time, yeah.*
>
> Student 2 (average achieving): *Yes I like thinking. Well, just thinking about the test, thinking what some of the questions might be, thinking about what I can do to get myself a better grade or be more prepared.*
>
> Student 3 (high achieving): *What do you mean... Well, yeah, I think over what I am thinking and ask myself is that question right or do I get the topic and everything, yeah.*

Like the Year 7 students, most of the Year 8 students in this interview (all high achievers) struggled to give responses to questions on cognitive self-consciousness. After explaining the questions, almost all the Year 8 participant students responded that they were aware of their thinking when solving problems and they monitored their thoughts during the learning process. However, one Year 8 student said that she was not aware of her thinking when studying and she did not monitor her thoughts during the learning process. It is again worth mentioning that this students' performance in science, though in an extension class, was average. The following are examples of a students' response:

> Student 1 (high achieving): *Yeah, like, I know what I am thinking and, you know, it comes naturally, like, you know - I think everybody knows what they are thinking most of the time like, otherwise you are not thinking and yeah, like.*
>
> Almost all the Year 9 students in this interview responded that they were aware of their thinking during the learning process in science, and that they constantly monitored their thoughts. However, one of the low achieving Year 9 students said that he did not monitor his thoughts during the learning process. The responses in this scale were the shortest and most students struggled to elaborate on their responses. The following are examples of students' responses:
>
> Student 1 (low achieving): *Yes. Just when I sit with my friend, he usually helps me a bit more. But when I am sitting with people I don't really know, it is hard to think.*
>
> Student 2 (average achieving): *Yes, because I do not want to get off track because I might miss important information.*
>
> Student 3 (high achieving): *Yes, I am. Sometimes I might notice when I go off and daydream. I try to get out of it so I can go back to listening. But it is difficult if the topic is not that interesting.*

4.6 Qualitative Data - Reflection Journals

4.6.1 First cycle

It is worth mentioning that in the first cycle the researcher did not use reflection journals as an intervention nor as a source of data. It was after the qualitative and quantitative data of the first cycle were analysed, and reflected upon, that the researcher decided to use reflection journals as an intervention and source of qualitative data in the second cycle. Reflection is a very important aspect of metacognition. It enhances students' ability to plan, monitor and evaluate their learning processes. It was an oversight that reflection journals were not used in the first cycle.

4.6.2 Second cycle

Cognitive strategy use

Most of the Year 7 reflection journals did not contain significant reflections on cognitive strategy use. Only a few high achieving students recorded reflections that would be categorised in this scale. There were no significant changes in the course of the action research in this category. The few reflections in this scale were about behaviour change, like *"I will pay more attention during class"*.

The Year 9 reflection journals, like the Year 7 journals, did not contain significant reflections on cognitive strategy use, and there were modest changes in this scale in most of the journals during the course of the research. Students' reflections on cognitive strategy use were mostly vague across all the levels of achievement in Year 9; many of them were unspecific such as, *"I will work harder" or "I will ask my teacher questions*". A few high achieving students reflected on the use of questioning techniques to remember phenomena. However, many reflection journals contained reflections of behaviour changes that would enhance achievement, such as, *"I will listen better and try to concentrate"*.

Self-regulation

Most of the Year 7 students' journals contained significant reflections that indicated self-regulation. They reflected on the concepts that they found easy and difficult to learn. The high and average achieving students' depth of reflection increased during the course of the action research, providing more details of the concepts they learnt with ease or difficulty. However, the low achieving students mostly wrote their reflections in general terms without going into specifics of the exact concepts they learnt or found difficult. In most cases the high and average achieving students' reflections contained reasons why they learnt concepts easily or with difficulty, unlike the low achieving students.

The Year 9 students' reflection journals also contained significant details of what they learnt easily or with difficulty, thus indicating a reasonable level of self-regulation. The amount of detail about what students learnt easily or with difficulty, and declarative knowledge of cognition, increased during the course of this action research. However, in most cases the students did not reflect on the reasons why they found some concepts easy or difficult to learn. Only the high achieving students' journals contained significant specific information about the reasons why they found some concepts easy or difficult. Also, in most cases students did not reflect on how they planned to improve their learning in depth. The plans lacked specific approaches to enhance achievement.

Cognitive self-consciousness

The Year 7 reflection journals did not contain much information about this scale across all the levels of achievement. The few reflections that were made in this scale were in reference to tests or assignments. Many students reflected that they found science tests stressful and assignments easier because they had more time. There were no significant changes to Year 7 students' reflections on cognitive self-consciousness during the course of the second cycle of the action research.

Like the Year 7 reflections, most of the Year 9 journals contained very little information that would be categorised in this scale. Most of the Year 9 students reflected that they felt under pressure or nervous when preparing for or doing science tests. Most of the Year 9 students' reflections indicated that they preferred assignments because they had more time to work on them. However, there were no significant changes to the Year 9 students' reflections on cognitive self-consciousness during the course of the second cycle.

In summary, the Year 7 and 9 reflection journals, in the second cycle, indicated significant increases in reflections on self-regulation, in terms of cognitive monitoring, particularly in declarative knowledge of their cognition. However, the changes in planning and evaluation of learning processes were modest. Also, most of the students rarely reflected on their cognitive strategy use and cognitive self-consciousness probably because they did not reflect on the reasons for variations in learning concepts and procedural and conditional knowledge of cognition, that would stimulate the appropriate cognitive strategies. However, there were relatively more, though modest, increases in reflections on cognitive strategy use and consciousness in Year 9 than in Year 7 during the course of the action research.

4.6.3 Third cycle

Cognitive strategy use

Most of the high and average achieving Year 7 students' journals contained increasingly detailed cognitive strategies that were used to complete science assignments and tests during the course of the action research. The students employed various strategies ranging from organisational strategies such as time management, rehearsal methods such as questioning and re-reading texts, closely following assignment criteria and the effective use of marking rubrics to complete assignments proficiently. Whereas the low achieving students' journals did not contain many reflections on cognitive strategy use apart from effort management like, "*I am going to study more on the topic*". In the low achieving students' journals there were no significant gains in cognitive strategy use reflections during the course of the research.

In the Year 8 class all the students were high achievers because this was an extension class. Most of the students' journals contained organisational strategies like creating a study routine and completing assignments early, as well as rehearsal and elaboration strategies like, re-reading work and using various sources of information. Many students also reflected on following the criteria of assignments closely and checking their performance against the marking rubrics. There were increases in the depth and details of reflection in terms of cognitive strategy use during the course of the research in the Year 8 class.

The reflections of the Year 9 high and low achieving students were of reasonable depth and detail right from the start of the cycle. However, there was not much difference in the reflections of the high and average achieving students in this scale in Year 9 throughout the action research. Most of the reflections of both the high and average achieving students were about organisation strategies such as effective use of time, following criteria more closely in assignments and breaking down the assignments into parts. Many of the high and average achieving students' journals also contained reflections concerned with rehearsal such re-reading notes and using their peers or family members to ask them questions. Most of the low achieving students' journals hardly contained any reflections in the category of cognitive strategy use apart from, in a few cases, organisational strategies such as effective use of time when doing assignments. However, there were no significant increases in detail or depth of the reflections in cognitive strategy use during the course of the research at all the levels of achievement in Year 9.

Self-regulation

Most of the Year 7 high achieving students' journals contained detailed planning, monitoring and evaluation of learning processes right from the start. The high achieving students clearly reflected on the concepts they found easy or difficult to learn with reasons for variations in the ease of learning. The average achieving students' journals contained plans but were not as detailed as the high achieving students. Cognitive monitoring in the average achievers' journals was generally similar to their high achieving counterparts, except that the average achieving boys in many cases did not reflect on reasons why they found some concepts difficult or easy. The journals of low achieving students contained significantly less details in planning, monitoring and evaluation. The reflections of the low achieving students were illegible in many cases, especially in the boys' journals. In both the high and average achieving students' journals there were increases in the details of reflections in terms of self-regulation, during the research whereas the low achieving students in most cases did not show any changes in the amount or depth of reflection.

In the Year 8 class most of the students' journals reflections were detailed from the start, especially that of the girls'. The boys' reflections on self-regulation increased later in the study. Most of the journals contained clearly stated goals and plans. Most of the students monitored their learning and gave reasons for finding phenomena easy or difficult. In many of the journals the students attributed their ease of learning to prior knowledge or interest in the topic at hand. Many of the reflections in this category contained control of effort such as, "*I will listen or concentrate harder*". There were a significant number of students who reflected on self-motivation in situations when they found a topic boring.

Half of the high achieving students in Year 9 recorded reflections on clear plans with specific approaches on how to achieve them. However, the average achieving students' plans were mostly clear but with quite general approaches on how to achieve them like, *"I will work harder"*. And most of the low achieving students' journals contained big goals with hardly any specific approaches on how to achieve them. Most of the high achieving students in Year 9 reflected in increasing detail and depth on cognitive monitoring during the course of the research, mentioning what they found easy or difficult to learn with reasons for variations in the ease of learning. The average achieving Year 9 students' reflections also increased in detail and depth in terms of cognitive monitoring during the research but often did not contain reasons for the variations in their ease of learning. The low achieving girls' journals contained more details in terms of cognitive monitoring than the low achieving boys' journals. There were no changes to the reflections in many of the boys' journals in terms of cognitive monitoring during the course of the research; many of them often contained short, illegible sentences. Most of the low achieving girls' journals contained increasing detail during the course of the research. The Year 9 journals at all levels of achievement contained a significant number of reflections on effort management such as listening to the teacher and putting more effort in classwork.

Cognitive self-consciousness

The high and average achieving Year 7 students' journals contained similar reflections in this category. Many reflected that they took pride in the outcome of assignments if they felt that they had done their best, and felt proud when they performed better than they thought. Also, many of the high achieving students' journals contained reflections that they found a topic interesting if it was new or different to what they had learnt before. However, many of the average achieving boys did not mention reasons for their feelings. In many cases the low achieving students had similar thoughts and feelings about their learning experiences as the high and average achievers but they did not reflect on the reasons for their thoughts. In all the levels of achievement in Year 7, there were no significant changes in the reflections in terms of cognitive self-consciousness throughout the research.

In the Year 8 class the least amount of reflections were recorded for this scale. A significant number of students reflected that they worried about an assignment when they had many other assignments in different subjects. Many students felt proud when they worked hard on an assignment and completed it on time. There were many students who reflected that they felt good about a topic if it was discussed at home or their parents were in a profession related to the topic. Lastly, many students reflected that they felt good to learn new topics about concepts they had not encountered before. However, there were no significant increases in reflections in this category during the course of the research.

The reflections of the Year 9 high and average achieving students in this category contained–much more detail than their low achieving counterparts. There was not much difference in the reflections of the high and average achieving students in terms of cognitive self-consciousness. Many of the high and average achieving students reflected that they felt good about a topic if they had prior knowledge or found the topic useful in real life. Many of the high and average achieving students' journals also contained reflections that they were proud of an assignment if they expected a good mark or had all the information to complete it effectively. However, many of the low achieving students expressed feelings of excitement or anxiety about a topic or assignment without giving reasons for these feelings. In all the Year 9 levels of achievement, the reflection journals did not contain significant changes in the reflections in this category.

4.7 Research Question 2: What was the effect of the interventions on the students' perceptions of their metacognitive support in science?

To investigate RQ2 (What was the effect of the interventions on the students' perceptions of their metacognitive support in science?), the *Metacognitive Support Questionnaire* (*MSpQ*) was administered as a pre-test and as a post-test to the students in three cycles over three years. To examine Research Question 2, quantitative data from the instruments (Section 4.8) for each of the three cycles follow.

4.8. Quantitative Data Analysis - *Metacognitive Support Questionnaire (MSpQ)*

4.8.1 First cycle

As indicated in Table 4.10, when comparing the pre-test mean scores of the five scales in the *MSpQ*, (1) the SV scale had the highest mean score of 3.90, (2) the TES scale had a mean score of 3.60, (3) the MD scale with a relatively low mean score of 2.61, (4) the STD scale with a relatively low mean score of 2.42, and (5) the SSD scale had the lowest mean score of 1.94. These findings respectively suggest that (1) most of the students perceived that they were often free to question their teacher's pedagogical methods and plans before the interventions were conducted, (2) the teacher often used the language of learning and encouraged students to improve their learning processes, (3) as a result of the low perception of students' metacognitive demands many students felt that they were seldom asked to be aware of how they learned and how they could improve their science learning prior to the interventions, (4) most students perceived that they seldom engaged in discussions about their science learning process with their teacher before the interventions, and (5) students perceived that they seldom discussed their science learning processes with each other. It may also be concluded that there were not enough collaborative or group activities in the science classes.

In the first cycle there were significant gains in all the scales on the *MSpQ* as shown in Table 4.10. The highest gain was in the MD scale mean [M = 0.81, t(34) = 7.87], suggesting that the largest significant increase in this cycle was in the number of students who held the perception that they were asked to be aware of how they learned science. This was followed by the STD scale mean [M = 0.73, t(34) = 4.06], suggesting that there was a significant increase in the number of students who perceived that they often engaged in discussions about their science learning process with the teacher. Though there were significant gains in the SSD scale mean [M = 0.38, t(34) = 3.10], it had the lowest pre- and post- mean scores. This finding suggests that most of the students still perceived after the interventions that they seldom discussed how they learned science with each other at the end of the first cycle. Overall, there were significant positive changes in the students' perceptions of the metacognitive support in their learning environment in science in the first cycle.

Table 4.10: Year 9 students' perceptions on the five scales of the *Metacognitive Support Questionnaire* (N = 35)

Scale	No. of Items	Mean		Standard deviation		Difference		Alpha Reliability	
		Pre	Post	Pre	Post	t	ES	Pre	Post
MD	5	2.61	3.42	0.75	0.66	7.87***	1.14	0.72	0.72
SSD	5	1.94	2.32	0.82	0.72	3.10**	0.49	0.87	0.83
STD	5	2.42	3.15	0.98	0.75	4.06***	0.84	0.91	0.87
SV	5	3.90	4.26	0.63	0.54	2.96**	0.61	0.66	0.45
TES	5	3.60	4.14	0.87	0.86	2.51**	0.62	0.82	0.93

MD = Metacognitive Demand, SSD = Student-Student Discourse, STD = Student-Teacher Discourse, SV = Student Voice, TES = Teacher Encouragement and Support (TES)

4.8.2 Second cycle

At the beginning of the second cycle, in the Year 7 class, as shown in Table 4.11, (1) the TES scale had the highest mean score of 4.15, (2) the SV scale had a mean item score of 4.06, (3) the STD scale had a mean score of 3.77, (4) the SSD scale had a mean score of 3.56, and (5) the MD scale had the lowest mean score of 2.81. These findings respectively suggest that most of the students perceived that (1) their science teacher often used the language of learning and encouraged them to improve their learning process, (2) they were often free to question their teacher's pedagogical methods and plans, (3) they often engaged in discussions about their learning process in science classes with the teacher, (4) they often had discussions with each other about the learning process in science, and (5) they were sometimes asked to be aware of how they learn and how they can improve their learning in science. Generally, all the scales in the metacognitive support questionnaire had high mean scores (above 3.50) at the beginning of the second cycle except for the MD scale. This trend suggests that generally most of the Year 7 students perceived that the learning environment supported the development of their metacognitive capabilities before the metacognitive interventions were conducted.

In the Year 7 class the only scale with significant gains was the MD scale mean [M = 0.62, t(19) =3.10] as shown Table 4.11, suggesting that after the interventions were conducted, there was a significant increase in the number of students who perceived that they were often asked to think about how they learned science.

Table 4.11: Year 7 students' perceptions on the five scales of the *Metacognitive Strategies Questionnaire* (N = 19)

Scales	No. of items	Mean		Standard deviation		Pre-post difference	ES (Cohen's *d*)
		Pre	Post	Pre	Post	t-value	
MD	5	2.81	3.43	0.67	0.67	**3.10	0.87
SSD	5	3.56	2.58	0.70	0.84	**4.40	1.27
STD	5	3.77	3.16	0.67	1.11	**6.73	0.67
SV	5	4.06	3.78	0.50	0.84	1.57	0.41
TES	5	4.15	4.08	0.52	0.92	0.26	0.09

**$p < 0.01$ ES – Effect size

MD = Metacognitive Demand, SSD = Student-Student Discourse, STD = Student-Teacher Discourse, SV = Student Voice, TES = Teacher Encouragement and Support (TES)

Contrary to the intentions of this action research there were significant decreases in the STD and SSD scale means. The STD scale mean had the most significant decrease [M = - 0.61, t(19) = 6.73], suggesting that there was a significant decrease in the number of students who perceived that the teacher discussed with students about their learning processes in science. This was followed by the SSD scale mean [M = - 0.98, t(19) = 4.40], suggesting that there was a significant decrease in the number of students who perceived that they discussed their learning processes with each other in science. There was a modest decrease in the SV scale mean [M = 0.28, t(19) =1.57] suggesting that there was a relatively small decrease in the number of students who perceived that they were free to question the teacher's pedagogy and lesson plans. The smallest change was in the TES scale mean [M = 0.07, t(19) =

0.26]. This finding suggests that there was a relatively small decrease in the number of students who perceived that the teacher used the language of science learning and encouraged students to improve their methods of learning science. Overall, contrary to the intentions of this action research, students' perceptions of their learning environment in terms of supporting metacognition were more negative after the interventions.

Table 4.12 shows that for the pre-test of the *MSpQ* in the Year 9 class, (1) the SV scale had the highest mean score of 3.76, (2) the TES scale had a mean score of 3.45, (3) the MD scale had a mean score of 3.16, (4) the STD scale had a mean score of 2.82, and (5) the SSD scale had the lowest mean of 2.09. These findings respectively suggest that most of the students (1) felt that they were often free to question their teacher's pedagogical methods at the beginning of the second cycle, (2) perceived that their science teacher often encouraged them to improve their learning processes in science, (3) felt that they were often asked to be aware of how they learned and how they could improve their science learning, (4) seldom engaged in discussions about their learning processes with the science teacher, and (5) perceived that they did not often discuss their science learning processes with each other. Generally, all the scales had high means except the SSD and STD at the beginning of the second cycle. These results suggest that the learning environment in the Year 9 science class reasonably supported the development of students' metacognitive capabilities in science before the interventions were conducted, except that students did not discuss enough with each other and with the teacher about how they could improve their learning in science.

In the Year 9 class only two scales had modest gains as shown Table 4.12. The highest gain was in the SV scale mean [M = 0.21, t(20) = 0.82], suggesting that there was a relatively small increase in the number of students who perceived that they were free to question the teacher's pedagogical methods. This was followed by the TES scale mean [M = 0.10, t(20) = 0.30], that suggests an even smaller increase in the number of students who perceived that their science teacher often encouraged them to improve their learning processes in science. The means of all the other scales had decreased. The most significant decrease was in the STD scale mean [M = 0.36, t(20) = 2.91], suggesting that there was a significant decrease in the number of students who perceived that they engaged in discussions about their science learning processes with their science teacher. This was followed by the MD scale mean [M = 0.14, t(20) = 0.51], which suggests that there was a small decrease in the number of students who perceived that they were asked to be aware of how they learned and could improve their understanding in science. The smallest decrease was in the SSD scale mean [M = 0.10, t(20) = 0.38], suggesting that there was an insignificant decease in the number of students who perceived that they engaged in discussions about their learning processes with each other in the science class.

Table 4.12: Year 9 students' perceptions on the five scales of the *Metacognitive Support Questionnaire* (N = 20)

Scales	No. of items	Mean		Standard deviation		Pre-post difference	ES (Cohen's *d*)
		Pre	Post	Pre	Post	t-value	
MD	5	3.16	3.02	0.66	1.04	0.51	0.16
SSD	5	2.09	1.99	0.72	0.92	0.38	0.12
STD	5	2.82	2.46	0.87	1.04	**2.91	0.38
SV	5	3.76	3.97	0.75	0.77	0.82	0.28
TES	5	3.45	3.55	0.98	1.10	0.30	0.10

**$p < 0.01$ ES – Effect size

MD = Metacognitive Demand, SSD = Student-Student Discourse, STD = Student-Teacher Discourse, SV = Student Voice, TES = Teacher Encouragement and Support (TES)

Overall, contrary to the intentions of the action research, most of the students in both Years 7 and 9 had more negative perceptions of the support in their learning environment in science to enhance their metacognitive capabilities as a result of the interventions. The possible causes of this will be discussed in detail in Chapter 5.

4.8.3 Third cycle

In the Year 7 class, at the beginning of the third cycle, as shown in Table 4.13, (1) the scale with the highest mean score was TES (mean score = 4.17), followed by (2) the SV scale with a mean score of 3.99, (3) the MD scale with a mean score of 3.48, (4) the STD scale with a mean score of 3.28, and (5) the SSD scale with the lowest mean score of 2.81. These findings respectively suggest that most of the students perceived that (1) their science teacher often used the language of learning and encouraged them to improve their learning process in science, (2) they were often free to question their science teacher's pedagogical methods and plans, (3) they were sometimes asked to be aware of how they learn and how they can improve their science learning, (4) they sometimes engaged in discussions about their science learning processes with their science teacher, and (5) they sometimes discussed their learning processes with each other in the science class. Except for SSD, most of the students' perceived the learning environment in the science classes to be reasonably supportive of the development of their metacognitive capabilities before the metacognitive interventions were conducted.

In the year 7 class there were modest gains in the means of three (STD, TES and MD) of the five scales and modest decreases in two scales as shown in Table 4.13. The highest gain was in the STD scale mean [M = 0.17, t(26) = 0.69], suggesting that there was a small increase in the number of students who perceived that they engaged in discussions with their teacher about their science learning processes. This was followed by the TES scale mean [M = 0.09, t(26) = 0.63], which suggests a small increase in the number of students who perceived that the science teacher encouraged them to improve their learning processes in science.

Table 4.13: Year 7 Students' perceptions on the five scales of the *Metacognitive Support Questionnaire* (N = 26)

Scales	No. of items	Mean		Standard deviation		Pre-post difference	ES (Cohen's *d*)
		Pre	Post	Pre	Post	t-value	
MD	5	3.48	3.57	0.80	0.64	0.43	0.12
SSD	5	2.81	2.74	0.95	1.09	0.34	0.07
STD	5	3.28	3.45	0.90	0.96	0.69	0.18
SV	5	3.99	3.98	0.66	0.57	0.05	0.02
TES	5	4.17	4.26	0.75	0.54	0.63	0.14

**$p < 0.01$ ES – Effect size

MD = Metacognitive Demand, SSD = Student-Student Discourse, STD = Student-Teacher Discourse, SV = Student Voice, TES = Teacher Encouragement and Support (TES)

The lowest gain was in the MD scale mean [0.09, t(26) = 0.43], suggesting an even smaller increase in the number of students who perceived that they were often asked to be aware of how they learned science. There were very small decreases in the SSD and SV scale means. The SSD scale mean score remained the lowest after the intervention which suggests that most of the students perceived that they did not sufficiently discuss their learning processes with each other. Instead, the SSD scale mean declined slightly further [M = - 0.03, t(26) = 034]. Whether this generally negative perception was caused by not giving students the opportunity to discuss learning processes in science or the students deliberately avoided such discussions could only be investigated by other means such as interviews. The modest decline in the SV scale mean [M = - 0.01, t(26) = 0.05] may have been due to the high mean score at the beginning of the cycle (pre-test mean score = 3.99).

At the beginning of the third cycle in the Year 8 class, as shown in Table 4.14, (1) the scale with the highest mean score was SV (mean score 4.28), followed by (2) the TES scale with a mean score of 4.17, (3) the MD scale with a mean score of 3.37, (4) the STD scale with a mean score of 3.34, and (5) the SSD scale with the lowest mean score of 3.03. These findings suggest that most of the students' perceived that (1) they were often free to question their teacher's pedagogical methods and plans, (2) the teacher often used the language of learning and encouraged the students to improve their learning processes in science, (3) they were sometimes asked to be aware of how they learn science and how they could improve, (4) they sometimes engaged in discussions about their learning processes with the science teacher, and (5) they sometimes discussed their science learning processes with each other. Overall, all the scales were high suggesting that most of the Year 8 students perceived that the learning environment in their science class was highly supportive of the development of their metacognitive capabilities before the interventions were conducted in the third cycle.

In the Year 8 class, four scales on the *MSpQ* had modest gains as shown in Table 4.14. The highest gain was in the MD scale mean [M = 0.36, t(26) = 2.04] suggesting that there was a small increase in the number of students who perceived that they were often asked to be aware of how they learnt science. The only modest decline in Year 8 was in the SV scale mean [M = - 0.21, t (26) = 1.54]. This small decrease in the number of students with the perception that they were free to question the science teacher's pedagogical methods and plans may also be attributed to a high mean score at the beginning of the cycle (pre-test mean score = 4.28).

Table 4.14: Year 8 students' perceptions on the five scales of the *Metacognitive Support Questionnaire* (N = 25)

Scales	No. of items	Mean		Standard deviation		Pre-post difference	ES (Cohen's *d*)
		Pre	Post	Pre	Post	t-value	
MD	5	3.37	3.73	0.74	0.68	2.04	0.51
SSD	5	3.03	3.28	0.71	0.93	1.00	0.30
STD	5	3.34	3.72	0.82	0.78	2.01	0.47
SV	5	4.28	4.07	0.46	0.46	1.54	0.46
TES	5	4.17	4.21	0.64	0.59	0.23	0.06

**$p < 0.01$ ES – Effect size

MD = Metacognitive Demand, SSD = Student-Student Discourse, STD = Student-Teacher Discourse, SV = Student Voice, TES = Teacher Encouragement and Support (TES)

As shown in Table 4.15, at the beginning of the third cycle in the Year 9 class, (1) the scale with the highest mean score was TES (mean score = 4.10), followed by (2) the SV scale with a mean score of 4.00, (3) the MD scale with a mean score of 3.55, (4) the STD scale with a mean score of 3.38, and (5) the SSD scale with the lowest mean score of 2.58. These findings respectively suggest that most of the students perceived that (1) their science teacher almost always used the language of learning and encouraged them to improve their learning process, (2 they were almost always free to question their teacher's pedagogical methods and plans, (3) they were often asked to be aware of how they learn and how they can improve their learning in science, (4) they often engaged in discussions about their science learning with the teacher, and (5) they seldom discussed their science learning processes with each other. Overall, most of the Year 9 students' perceptions suggest that the learning environment in their science class was highly supportive of the development of their metacognitive capabilities at the beginning of the third cycle, except that they did not discuss sufficiently with each other about how they learned science. All the

Cronbach's alpha reliability values of the scales in the *MSpQ were acceptable* as shown in Table 4.16.

In the Year 9 class all the scales on the *MSpQ* had modest gains as shown in Table 4.15. The relatively highest gain was in the TES scale mean [M = 0.34, t(24) = 1.77]. This finding suggests that there was a relatively small increase in the number of students who perceived that the science teacher encouraged the students to improve their learning processes in science. The modest gains in the SV and TES scale means may be attributed to the high mean scores before the interventions at the beginning of the cycle (pre-test mean scores of 4.00 and 4.10 respectively).

Table 4.15: Year 9 students' perceptions on the five scales of the *Metacognitive Support Questionnaire* (N = 24)

Scales	No. of items	Mean		Standard deviation		Pre-post difference	ES (Cohen's *d*)
		Pre	Post	Pre	Post	t-value	
MD	5	3.55	3.68	0.57	0.49	0.87	0.24
SSD	5	2.58	2.86	0.83	0.51	1.51	0.41
STD	5	3.38	3.54	0.74	0.46	0.89	0.26
SV	5	4.00	4.14	0.62	0.74	0.74	0.21
TES	5	4.10	4.44	0.72	0.54	1.77	0.53

**$p < 0.01$ ES – Effect size

MD = Metacognitive Demand, SSD = Student-Student Discourse, STD = Student-Teacher Discourse, SV = Student Voice, TES = Teacher Encouragement and Support (TES)

Overall, according to the third cycle quantitative data, there were relatively small gains in the students' perceptions of the metacognitive support in their learning environments in all the three science classes in this action research. The TES scale means (all above 4) and SV scale means (all above or close to 4) had the highest mean scores whereas the SSD scale had the lowest means in all the classes before and after the interventions.

4.9 Research Question 3: What was the effect of the metacognitive interventions on the students' achievement in science?

In response to RQ 3 (What was the effect of the metacognitive interventions on the students' achievement in science?), students' scores on different tests that were administered before (pre-test) and after (post-test) the interventions were compared. In the first cycle, data were from the Light test in Year 9; in the second cycle data were from different topic tests in Years 7 and 9; and in the third cycle, data were from different topic tests in Yeats 7, 8 and 9. The intention was that the metacognitive interventions could contribute to students' learning outcomes but other events such as increased students' interest could have contributed to any changes in achievement.

4.9.1 First cycle

The students were given the same test on light concepts (Appendix C) at the beginning and end of the topic (pre-post tests). The test consisted of 10 two-tier multiple-choice questions. The first tier of the questions required the students to choose the most appropriate answer to the question, and the second tier required the students to choose a reason for their choice of answer to the first tier. The data were coded and analysed by using SPPS software. A summary of the data collected is shown in Table 4.17.

Analysis of pre- and post-tests on light in the first cycle

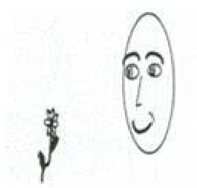
Overall, the students' performance in tier one was better than in the combined tiers as shown in Table 4.17 (except for Items 7 & 8 in the pre-test and for Item 8 in the post-test). There was also a general improvement in the post-test in both tiers. Students experienced greatest difficulty in providing scientific explanations for Items 3 (see Figure 4.01), 4, 6 and 7.

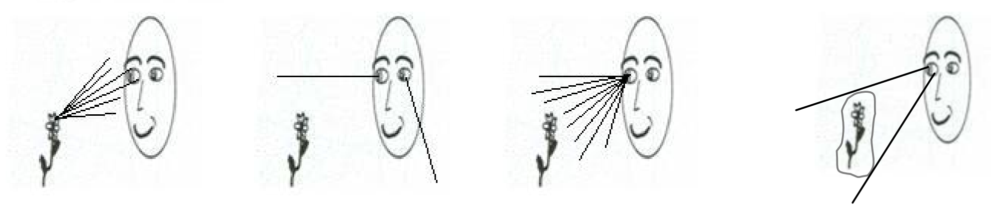
Table 4.16: Percentage of Year 9 students responding correctly to the first tier and both tiers of the items in the two-tier multiple-choice Light test (N = 35)

Item number	Pre-test		Post-test	
	First tier only	Both tiers	First tier only	Both tiers
1	88.6	71.4	85.7	68.6
2	82.9	54.3	97.1	62.9
3	42.9	22.9	82.9	40.0
4	48.6	31.4	91.4	40.0
5	88.6	40.0	100	71.4
6	60.0	31.4	74.3	57.1
7	37.1	37.1	77.1	74.3
8	60.0	60.0	85.7	85.7
9	85.7	55.2	94.3	42.9
10	85.7	68.6	97.1	82.9

Item 3

A boy sees a flower. How does he see the flower?





Also for both eyes and for more than one object point

Two lines indicate the range of vision

Also for both eyes

Also for both eyes

A B C D

The reason I chose my answer is because:

1 There are bundles of rays from the object, and so the boy can see.

2 Bundles of rays are coming out from the boy's eyes and so he is able to see the flower.

3 Light is not shown emanating from the light source, but is only present around the flower.

4 Light is shown emanating from the object and being received by the eye.

5 The object is located within the region of the boy's vision.

Figure 4.01: Example of Item 3 in the Light pre-post-test

Table 4.17 displays the results of paired samples t-tests analyses of the light pre- and post-tests with significant gains in the first tier: [Mean difference = 2.06, t(34) = 5.96, $p < 0.01$] and combined tiers: [Mean difference = 2.14, t(34) = 4.28, $p < 0.01$].

Table 4.17: Paired samples t-tests analyses of Year 9 pre- & post-tests on Light in the first cycle (N = 35)

Tier	Mean		SD		Difference (t-value)	Cronbach's alpha reliability	
	Pre	Post	Pre	Post		Pre	Post
1	6.80	8.86	1.78	1.68	**5.96	0.26	0.45
Combined tiers	4.20	6.34	1.92	2.87	**4.28	0.73	0.79

**p<0.01

Generally, the gains in correct responses to the Year 9 light pre- and post-tests, though significant in the first tier and combined tiers, were greater for the first tier than the combined tiers. The first tier items required students to select a correct answer from multiple-choice options whereas the second tier item required students to give a reason for their choice in the first tier. This finding suggests that, at the beginning of the first cycle, students generally had knowledge about the correct answers (declarative knowledge) but were in many cases unable to choose the correct scientific explanations of phenomena (procedural knowledge). Scientific explanations require the use of procedural knowledge; therefore this data analysis suggests that the students' procedural knowledge was not well developed before the metacognitive interventions. The participants were of mixed levels of achievement with the majority being of average or low achieving students; this could partially explain why the performance in the combined tiers was lower.

The first tiers of the pre- and post-tests were of low reliability (ranged from 0.26 and 0.45). This was probably due to the fact that students could easily memorise the correct answers in the pre-test, and correctly reproduced the answers in the post-test. Students' responses in the combined tiers of the pre- and post-tests showed more internal consistency (alpha reliability > 0.7); this was a rather surprising result considering that the sample size was small (N = 35). The low standard deviation values indicate that students' responses in most cases were similar.

4.9.2 Second cycle

The data in the second cycle were obtained from students' average scores in the first and second semester science tests and assignments. The topics in the Year 7 tests included laboratory skills, matter and cells whereas the topics in the Year 9 tests included the scientific method, environmental science, the periodic table and atoms. Students' performance in the science tests and assignments in semester one (before the interventions) and in semester two (after the interventions) were analysed by using SPSS software and the results are shown in Table 4.18.

Table 4.18: Analysis of Year 7 (N =19) and Year 9 (N= 20) students' average scores in science tests and assignments in 2010.

Assessment	Year	Semester	Mean	SD
Test	7	1	83.84	11.30
Assignment			70.05	16.77
Test	9		57.00	17.59
Assignment			66.60	12.10
Test	7	2	69.32	15.15
Assignment			73.00	14.69
Test	9		58.50	16.59
Assignment			73.40	16.31

When comparing students' achievement in science after the action research was conducted, Year 9 students' science assignment results improved by a larger percentage (average percentage score increase = 6.80%) in semester two than their science test results (average percentage score increase = 1.50%) as shown in Table 4.19. The data also shows that the students in Year 9 performed better in science assignments than in tests in both semesters one and two. The Year 7 students' performance in science assignments improved in semester two (average percentage score increase = 2.95%) whereas their achievement in science tests declined in semester two (average score decrease = 14.52%). The students in Year 7 performed better in science tests than in assignments in the first semester. The decline in the Year 7 science test results may be attributed to an increase in the knowledge and cognitive skills that were required to prepare for the science test in semester two.

Overall, in the second cycle of this action research, there were relatively bigger gains in students' science assignment mean scores but smaller gains or declines in the tests mean scores. The large standard deviations indicate that the students' achievement in both science assignments and tests, in semesters one and two, varied considerably. This variation could have been due to the students being of mixed levels of achieving ability. The better achievement in assignments is consistent with the information in the majority of the students' reflection journals in which they had reported that they found assignments easier than tests.

4.9.3 Third cycle

In the third cycle, students' achievement in science was assessed by using pre- and post-tests on major topics taught in term 2 of the first semester in 2012. The Years 7, 8 and 9 classes, taught by the researcher, were given pre-post tests at the beginning of the semester before the interventions and end of the term 2 after the interventions. The major topics taught in Years 7, 8 and 9 were on Classification of Living Things, Ecology and Geology, respectively.

Year 7 students' achievement in science

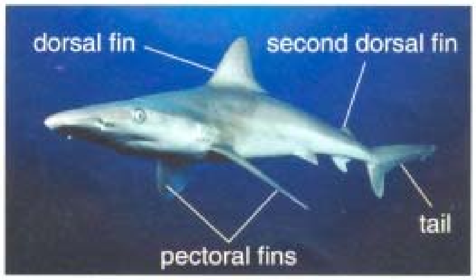
At the beginning and end of the third cycle, 26 students in Year 7, who were taught science by the researcher, were given a pre-test (before the interventions) and a post-test (after the interventions) on Classification of Living Things with 10 two-tier multiple-choice items (Appendix D). The first tier of the items required the students to choose the most appropriate answer to the question, while the second tier of the items required the students to select the most appropriate reason for their choice of answer in the first tier. The data were collected and analysed by using SPSS software. The mean scores for the first tier and combined tiers (tiers one and two) are shown in Table 4.19.

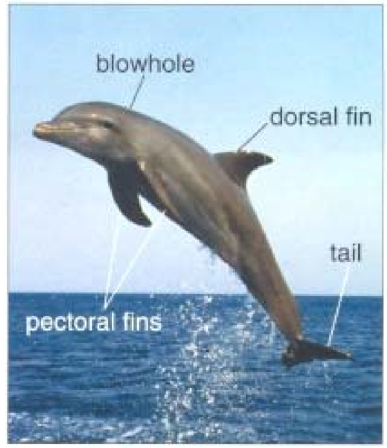
Table 4.19: Percentage of Year 7 students (cycle 3) answering the first tier and both tiers of the items correctly in the Classification of Living Things pre-test and post-test (N = 26)

	Pre-test		Post-test	
Item number	First tier only	Both tiers	First tier only	Both tiers
1	38.5	30.8	65.4	50.0
2	61.5	38.5	84.6	57.7
3	34.6	11.5	46.2	15.4
4	65.4	26.9	50.0	23.1
5	42.3	26.9	69.2	46.2
6	38.5	19.2	30.8	23.1
7	88.5	23.1	96.2	46.2
8	65.4	19.2	69.2	46.2
9	50.0	38.5	69.2	65.4
10	38.5	30.8	42.3	30.8

The Year 7 pre-post-tests average percentage scores in the first tiers were higher than the combined tier scores for all the items as shown in Table 4.19. This trend suggests that most students found it easier to remember the facts than to explain the choice of their answer. Examples of items (Item 1 & 4) in the Classification of Living Things test are shown in Figures 4.02 and 4.03).

Item 1: The photographs show a shark and a dolphin.





Which is the **least reliable** method of distinguishing between the shark and the dolphin shown?

A. orientation of the pectoral fins

B. orientation of the tail

C. presence of a blowhole

D. presence of a second dorsal fin

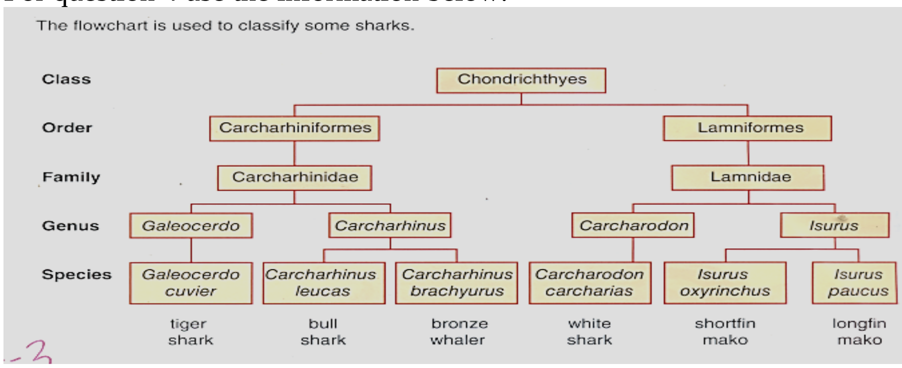
The reason for my choice of answer is:

1. The pectoral fins of the shark and dolphin all point in the same direction.
2. The pectoral fins of the shark and dolphin all have the same shape.
3. Both the shark and dolphin have a blowhole.
4. Both the shark and dolphin have dorsal fins.

Figure 4.02: Example of an item in the pre-post-test on Classification of Living Things

Item 4

For question 4 use the information below:



Dusky sharks have the scientific name Carcharhinus obscurus. To which genus do dusky sharks belong?

A. Carcharhinus

B. Carcharhinidae

C. Obscurus

D. Obscuridae

The reason for my choice of answer is:

1. Each family name starts in a similar way to the genus name.
2. Each family name ends in a similar way.
3. Each family is the same as the genus name except for the last three letters.
4. None of the above reasons is correct.

Figure 4.03: Example of an item in the pre-post-test on Classification of Living Things

Year 8 students' achievement in science

At the beginning and end of the third cycle, 25 students in Year 8, who were taught science by the researcher, were given a pre-test (before the interventions) and a post-test (after the interventions), respectively on Geology consisting of 10 two-tier multiple-choice items (Appendix E). The first tier of the items required the students to choose the most appropriate answer to the question, while the second tier of the items required the students to select the most appropriate reason for their choice in the first tier. The data were collected and analysed using SPSS software. The mean scores for the first tier and combined tiers (tiers one and two) are shown in Table 4.20.

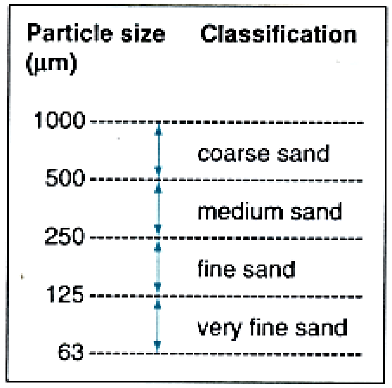
Table 4.20: Percentage of Year 8 students (cycle 3) correctly responding to the first tier and both tiers of the items in the Geology pre-test and post-test (N = 25)

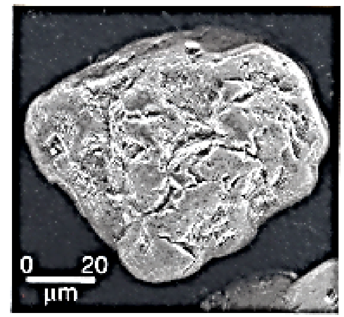
	Pre-test		Post-test	
Item number	First tier only	Both tiers	First tier only	Both tiers
1	72.0	72.0	84.0	80.0
2	76.0	48.0	76.0	60.0
3	68.0	56.0	64.0	56.0
4	68.0	52.0	80.0	80.0
5	88.0	48.0	96.0	56.0
6	92.0	88.0	88.0	84.0
7	88.0	80.0	96.0	84.0
8	16.0	12.0	16.0	16.0
9	84.0	48.0	92.0	88.0
10	80.0	76.0	84.0	80.0

For all but one item (Item 1) in the pre-test and two items (Items 4 & 8) in the post-test the frequency of correct responses in the first tier was higher than that in the combined tiers.

When considering the nature of the items in the Year 8 geology pre-post-tests, solving Item 1 (see Figure 4.04) would require declarative and procedural knowledge of the phenomenon, whereas Item 8 (see Figure 4.05), would require the use of procedural and conditional knowledge. Overall, consistent with the research literature, the Year 8 students made greater improvements in questions that required declarative and procedural knowledge, such as Item 1, than those that required the use of procedural and conditional knowledge, such as Item 8.

Item 1: The table shows the classification of sand grains by size. The scaled photograph shows a sand grain





The grain shown would be best classified as

A. Coarse sand
B. Medium sand
C. Fine sand
D. Very fine sand

The reason I chose my answer is because:

1. The grain has a length of approximately 800-1000 um.

2. The grain has a length of approximately 65 um.

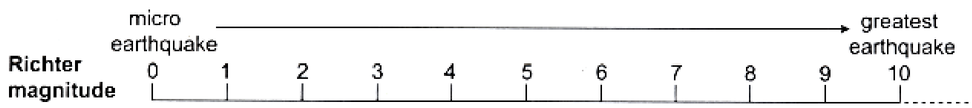
3. The grain has an area of approximately 800-1000 um.

4. The grain has a length of approximately 260 um.

Figure 4.04: Example of an item in the Geology pre-post-tests

Item 8

The Richter scale is used to describe the magnitude of earthquakes.



An increase of one in magnitude represents a tenfold increase in the distance the ground is displaced by the motion of an earthquake wave passing through an area. For example, magnitude 7 on the Richter scale indicates an earthquake with ground displacement 10 times larger than that produced by a magnitude 6 earthquake.

How many times further the ground would be displaced by a magnitude 6 earthquake than it would be by a magnitude 3 earthquake?

A. 3 times

B. 10 times

C. 30 times

D. 1 000 times

The reason for my choice of answer is because:

1. The difference in magnitude of displacement is calculated by only finding the difference in magnitude on the Richter scale.
2. The difference in magnitude of displacement is calculated by finding the difference in magnitude on the Richter scale, and then multiplying it by 10.
3. The difference in magnitude of displacement is calculated by finding the difference in magnitude on the Richter scale, and then raising it to the power of 10.
4. The difference in magnitude of displacement is calculated by raising 10 to the power of the difference in magnitude on the Richter scale.

Figure 4.05: Example of an item in the Geology pre-post-tests

Year 9 students' achievement in science

At the beginning and end of the third cycle, 24 students in Year 9, who were taught science by the researcher, were given a pre-test (before the interventions) and a post-test (after the interventions), respectively on Ecology consisting of 10 two-tier multiple-choice items (Appendix F). The first tier of the items required the students to choose the most appropriate answer to the question, while the second tier of the items required the students to select the most appropriate reason for their choice in the first tier. The data were collected and analysed using SPSS software. The mean scores for the first tier and combined tiers (tiers one and two) are shown in Table 4.21.

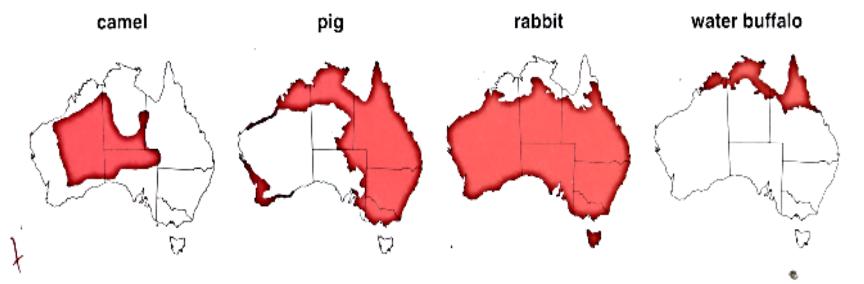
Table 4.21: Percentage of Year 9 students (cycle 3) correctly responding to the first tier and both tiers of the items in the Ecology pre-test and post-test (N = 24)

	Pre-test		Post-test	
Item number	First tier only	Both tiers	First tier only	Both tiers
1	8.3	0	16.7	8.3
2	66.7	58.3	91.7	91.7
3	87.5	83.3	95.8	91.7
4	91.7	62.5	95.8	79.2
5	91.7	70.8	100.0	70.8
6	100.0	91.7	95.8	95.8
7	95.8	75.0	83.3	66.7
8	75.0	70.8	75.0	70.8
9	75.0	62.5	83.3	70.8
10	25.0	8.3	45.8	20.8

Comparing the pre-post-test items, generally, the achievements in the first tiers were greater than in the combined tiers for all items in the pre-test and the post-test with the exception of two items in the post-test (Items 2 & 6) as shown in Table 4.22.

When considering the nature of the items in the Year 9 Ecology pre-post-tests, Item 5, shown in Figure 4.06, required only the use of declarative knowledge, hence the high percentage of students with the correct responses, whereas Item 10 required the use of declarative, procedural and conditional knowledge, hence the lower percentage of students with correct responses.

Item 5: The shaded areas on the maps show the distribution of some feral animals in Australia.



Which feral animal is distributed over the smallest area?

A. Camel

B. Pig

C. Rabbit

D. Water buffalo

The reason I chose my answer is because:

1. On the map this animal is only in central Australia.
2. On the map this animal is only along the northern coastline of Australia.
3. On the map this animal is only in north and Eastern Australia.
4. On the map this animal does not exist in Tasmania.

Figure 4.06: Example of an item in the Ecology pre-post-tests

Item 10:

The New South Wales Environment Protection Authority monitors air quality using a regional pollution index (RPI). The RPI for a particular pollutant is calculated by:

RPI = (Pollutant concentration ÷ pollutant standard level) x 50

Low = RPI between 0 and 24

Medium = RPI between 25 and 49

High = RPI 50 or higher

The standard level for the pollutant, nitrogen dioxide, is 0.12 parts per million (ppm) per hour. Scientists monitored the levels of nitrogen dioxide for one hour and determined the RPI to be 25.

What was the concentration (ppm per hour) of nitrogen dioxide?

A. 0.06

B. 0.24

C. 0.50

D. 0.60

The reason I chose my answer is because:

1. An RPI 85 means the pollution is less than 100%.
2. An RPI of 85 means the concentration of the pollutant is lower than normal.
3. An RPI of 85 means the pollutant concentration is significantly greater than that in the pollutant standard level.
4. The ratio of the pollutant concentration to pollutant standard level is 85:1.

Figure 4.07: Example of an item in the Ecology pre-post-tests

4.10 Conclusions about Research Findings

In summarising the findings of this study the following conclusions are discussed with respect to each of the research questions.

Research Question 1: What was the effect of the interventions on the students' perceptions of their metacognitive strategies in science?

The quantitative data from the *Metacognitive Strategies Questionnaire* (*MStQ*) have shown that at the beginning of all the three cycles prior to the interventions, the mean scores of all the three *MStQ* scales for all the classes involved in the study were generally above 3 (on a scale with a maximum of 5) with a few exceptions. In all the cycles the Cognitive Strategies Use (CSU) scale mean scores were the highest at the beginning of each cycle. This trend suggests that the majority of the participants generally had reasonably positive perceptions of their metacognitive strategies, especially cognitive strategy use, at the beginning of each of the three cycles in this study, prior to the interventions.

Although the quantitative data generally showed modest or no gains in the students' perceptions of their metacognitive strategies, except in the first cycle, the qualitative data from interviews and reflection journals generally indicated gains in the perceptions of the metacognitive strategies of the high and average achieving students. Generally, the girls' reflection journals contained more detail and depth at all levels of achievement in all the classes. It is also worth noting that in the second and third cycles, the Year 9 classes had the lowest mean scores in the *Metacognitive Strategies Questionnaire* (*MStQ*) scales.

Research Question 2: What was the effect of the interventions on students' perceptions of their metacognitive support in science?

In all the cycles, the means of all the five scales in the *Metacognitive Support Questionnaire* (*MSpQ*) were relatively high. The means of Students' Voice (SV) and Teacher Encouragement and Support (TES) scales were the highest at the beginning in all the cycles, while the mean of the Student-Student Discourse (SSD) scale was generally the lowest in all the cycles. This trend indicates that generally the students in all the three cycles had a positive perception of metacognitive support in their learning environment at the beginning of each cycle, prior to the interventions.

In the first cycle there were significant gains on all the scales of the *Metacognitive Support Questionnaire* (*MSpQ*) after the metacognitive interventions. However, there were no significant gains in the second and third cycles in students' perceptions of their metacognitive support. This could be partially attributed to the high mean scores on most of the scales at the start of the second and third cycles, leaving little room for further increases. Another reason could probably be because after the first cycle, the researcher adopted most of the metacognitive interventions in his daily teaching prior to the second and third cycles. This could have contributed to the high mean scores at the beginning of the second and third cycles prior to the interventions. The mean score on the SSD scale was generally the lowest before and after the interventions in all the three cycles. The possible causes of this will be discussed in detail in Chapter 5.

Research Question 3: What was the effect of the metacognitive interventions on the students' achievement in science?

Students' achievement (mean scores) in the pre- and post-tests were generally higher for the first tier of the two-tier multiple-choice items than for the combined tiers. This data suggest that students generally had difficulty in explaining scientific concepts even when they gave the correct answer to the first tier of the items. In other words they may have acquired the declarative knowledge but may have lacked the procedural and conditional knowledge about the phenomena concerned.

4.11 Conclusion

This chapter commenced by introducing the aims and research questions associated with this study in Section 4.1, followed by the 'Action research cycle-reflection' in Section 4.2. Subsequently, each of the three research questions was investigated in Sections 4.3 to 4.9, involving students' perceptions of their metacognitive strategies in science before the interventions, students' perceptions of their metacognitive support in science before the interventions, the effect of the interventions on the students' perceptions of their metacognitive strategies, the effect of the interventions on students' perceptions of their metacognitive support, and the effect of the metacognitive interventions on the students' science test results. Finally, the findings were summarised with respect to the three research questions in Section 4.10.

Chapter 5

FINDINGS, IMPLICATIONS, LIMITATIONS AND RECOMMENDATIONS

5.1 Overview of the Chapter

A major part of Chapter 5 includes a summary of the main findings arrived at in this study that have been discussed in Chapter 4 (Section 5.2). This section is followed by discussions of the implications of the study in relation to the research questions (Section 5.3), implications for research (section 5.4), implications for teaching (section 5.5), limitations of the study (section 5.6), recommendations (section 5.7) and the conclusion summarising this study (Section 5.8).

5.2 Main Findings

5.2.1 Findings from Research Question 1 (What was the effect of the interventions on the students' perceptions of their metacognitive strategies in science?)

Students' perceptions of their use of metacognitive strategies were solicited using the *Metacognitive Strategies Questionnaire (MStQ)*. At the beginning of each of the three cycles the Cognitive strategy use (CSU) scale displayed the highest mean score whereas that of the Self-regulation (SR) scale was the lowest in all the year levels. This indicates that prior to the implementation of each cycle most of the students, in all the year levels who participated in this research, perceived that they used cognitive strategies, such as memorisation, elaboration and organisation, more often than cognitive self-consciousness and self-regulation when learning science.

In all the three cycles in this study, students displayed reasonably satisfactory perceptions of their metacognitive strategies (mean score on scales above 3) before the interventions were conducted. However, in the second and third cycles, the Year 9 classes displayed the lowest perceptions on all the scales of the metacognitive strategies questionnaire in comparison to the Year 7 and 8 students. This could imply that in Year 9 students' perceptions of their metacognitive strategies had declined. This is consistent with the research finding that off-line methods do not show linear growth of metacogntive strategies between the age of 14-22 (Leutwyler, 2009).

Cognitive strategy use (CSU)

The quantitative data in the first cycle indicated a decrease in CSU whereas the qualitative data from interviews indicated that the high-achieving Year 9 students displayed high levels of CSU while the low and average achievers displayed low levels of CSU at the end of the first cycle.

In the second cycle, the quantitative data findings indicate that the Year 7 students achieved modest gains in CSU whereas the Year 9 students displayed a decrease in CSU. The qualitative data from the oral interviews indicated high levels of CSU among the average and high achieving Year 7 students, and in all the levels of achievement in the Year 9 class at the end of the second cycle. However, only reflection journals of the high achieving Years 7 and 9 students contained significant reflections on CSU. There were modest increases in the CSU reflections in both Year 7 and 9 during the second cycle in all the levels of achievement.

In the third cycle, both the Years 7 and 9 students displayed modest decreases in CSU, with the Year 9 students displaying the relatively largest decrease. The Year 8 class (extension class) achieved a modest gain in CSU. However, the qualitative data from interviews conducted at the end of the third cycle showed high levels of CSU in all levels of achievement in Years 7 and 8, and among the average and high achieving Year 9 students. As would be expected, based on the data from interviews, the high achieving students in Years 7 and 9 displayed slightly higher levels of CSU than the rest of the participants in the respective year groups. The Year 7 high and average achievers' journals contained increasingly detailed reflections on CSU throughout the third cycle. Although the Year 9 average and high achieving students' journals contained detailed reflections on CSU, there were no significant increases in this scale during the course of the third cycle. The Year 9 low achieving students' journals contained significantly less reflections on CSU. The Year 8 students' journals showed significant increases in reflections on CSU during the third cycle.

This is consistent with the research findings that higher levels of cognitive strategy use are associated with higher levels of achievement (Pintrich & De Groot, 1990).

Self-regulation (SR)

The quantitative data in the first cycle indicated significant gains in SR whereas the qualitative data obtained from interviews showed high levels of SR among the average and high achieving students in Year 9. The low achievers' responses reflected low levels of SR.

In the second cycle the quantitative data showed modest SR gains in Year 7 and a modest decrease in Year 9 whereas the qualitative data obtained from interviews showed high levels of SR among the average and high achieving students in Years 7 and 9. The low achieving students' responses to the interviews, in Years 7 and 9 also indicated reasonable levels of SR. The qualitative data obtained from the students' reflection journals in the second cycle showed increasing detail and depth of reflection on SR by the Year 7 high and average achieving students, and the high achieving Year 9 students. The reflections of the low achievers in Year 7 and average achievers in Year 9 also increased in depth and detail but lacked reasons for variations in learning.

In the third cycle, the quantitative data showed that there were modest gains in SR in Years 7 and 8 but a modest decrease in Year 9, whereas the qualitative data, obtained from interviews, indicated high levels of SR among the high and average achievers in Years 7 and 9. The interview responses also indicated reasonable levels of SR among the low achieving Year 7 participants. All the Year 8 participants' responses reflected high levels of SR. The qualitative data obtained from reflection journals demonstrated increasing levels of SR among the average and high achieving students in Year 7, and the high achieving students in Year 9. Although there was increasing depth and detail in the reflections of the Year 9 average achieving students, their journal entries often lacked reasons for variations in their learning. This is consistent with the research finding that higher levels of SR are associated with higher levels of achievement in tests or assignments (Pintrich & De Groot, 1990). The Year 8 journals contained significant details from the start, but the increases in their reflections were not significant. This stagnation of the students' self-reported use of metacognitive strategies could be attributed to a high “base level” above which no further metacognitive development occurs (Leutwyler, 2009). In all year levels and levels of achievement the girls provided more details in their reflection journals than the boys.

Cognitive self-consciousness (CSC)

In the first cycle the quantitative data indicated that there were significant gains in CSC in the Year 9 class whereas the qualitative data, obtained from the written interviews, showed that students’ levels of CSC were generally low at the end of the first cycle. However, the high and average achieving Year 9 students displayed relatively higher levels of CSC than their peers who were low achievers.

In the second cycle, the quantitative data indicated that there was a modest gain in CSC in Year7 and a modest decrease in CSC in the Year 9 class. However, the qualitative data, obtained from oral interviews at the end of the second cycle, showed high levels of CSC in the Year 7 class at all levels of achievement, and among the high achieving students in Year 9 class. The qualitative data obtained from the students’ reflection journals did not show significant gains in CSC in any of the levels of achievement in both Years 7 and 9. There were no significant changes in the CSC reflections in Years 7 and 9 from the beginning of the second cycle.

The quantitative data obtained in the third cycle showed modest gains in CSC in the Years 7 and 9 classes but a modest decrease for the Year 8 class. The qualitative data, obtained from oral interviews at the end of the third cycle, indicated high levels of CSC in all the levels of achievement among most of the Years 7, 8 and 9 participants. However, students struggled to give responses to questions in the CSC scale in the oral interviews. The reflection journals of the high and average achieving Years 7, 8 and 9 students contained more detail than their low achieving peers. Also, the low achieving Years 7 and 9 students often did not reflect on the reasons for the state of their CSC. Generally, the qualitative data obtained from the students’ reflection journals did not show significant gains in CSC in all the levels of achievement in Years 7, 8 and 9. This finding suggests that generally there were no significant increases in the students’ level of anxiety during the action research (Cartwright-Hatton et al., 2004).

5.2.2 *Findings from Research Question 2 (What was the effect of the interventions on students' perceptions of their metacognitive support in science?)*

Students' perceptions of the metacognitive support that they received were solicited using the *Metacognitive Support Questionnaire (MSpQ)*. The quantitative data research findings in this study show that the scales that generally had the highest mean scores (above 3.60) at the start of each of the three cycles were the Teacher encouragement & support (TES) and Student voice (SV) scales. These findings suggest that at the start of each cycle most of the students in all the year levels perceived that they were often free to question the teacher's pedagogy and they were often encouraged by the teacher to improve their learning processes in science. In all the three cycles the Student-student discourse (SSD) scale was generally the lowest at the start of each cycle, with the exception of Year 7 in the second cycle. This indicates that in all the three cycles most of the students perceived that they did not often engage in class discussions with each other about how they learned science. At the beginning of all the three cycles the students generally demonstrated high perceptions of their metacognitive support except that most of them believed that they did not often engage in classroom discussions with each other.

In the first cycle, there were significant gains in all the scales of the *Metacognitive Support Questionnaire* (*MSpQ*) that was administered to the Year 9 class. The highest gain was in Metacognitive demands (MD). However, although the gain in Student-student discourse (SSD) was significant, this scale had the lowest pre- and post- mean scores.

In the second cycle, the Year 7 class achieved only one significant gain and that was in MD. However, the Year 7 class experienced significant decreases in Student-teacher discourse (STD) and SSD. The Year 9 class did not display significant gains in any scale on the metacognitive questionnaire. However, the Year 9 class displayed a significant decrease in STD.

In the third cycle, there were no significant gains in Years 7, 8 and 9. However, there were high mean scores in the pre- and post- Teacher encouragement & support (TES) and Student voice (SV) scales. The SSD mean score was the lowest in the pre- and post- *Metacognitive Support Questionnaire*.

5.2.3 Findings from Research Question 3 (What was the effect of the metacognitive interventions on the students' achievement in science?):

In the first cycle, the gains were greater for the tier one items. Consistent with the literature, students' achievement was better in items that required only the use of declarative knowledge of concepts.

In the second cycle the Year 7 and 9 classes showed greater improvement in science assignments than science tests. Also, the performance was better in assignments in semesters one and two.

In the third cycle, all the Years 7 and 8 classes showed greater improvements in tier one items. Again, like the classes in the first cycle, students' improvements were greatest in the items that required only the use of declarative knowledge.

5.3 Implications

5.3.1 Implications for findings for Research Question 1 (What was the effect of the interventions on the students' perceptions of their metacognitive strategies in science?)

At the beginning, in each class in all the three cycles, generally most students' perceptions were highest in the CSU scale and lowest in the SR scale. If metacognitive questionnaires are administered at the beginning of a term or semester and analysed within the first days or week of the term or semester, such data could be used when designing teaching programmes so that activities that will enhance students' metacognitive strategies in major areas of weakness could be incorporated. For example, one of the effective ways to enhance self-regulation in a classroom is to engage the students in regular reflection activities. Reflection could be done verbally or in writing depending on the students' literacy levels and learning preferences.

Cognitive Strategy Use (CSU)

The quantitative data obtained from the *MStQ* did not indicate any significant gains in all the three cycles. However, the qualitative data obtained from interviews in all the three cycles, showed high levels of CSU among the high and average achieving students in all the year levels. The qualitative data obtained from the reflections did not show any significant gains in the second cycle. However, in the third cycle there were significant gains among the high and average achieving students in all the year levels except Year 9. It is important to mention that despite the lack of gains in cognitive self-consciousness (CSC) reflections in Year 9, the high and average achieving students' journals contained significantly detailed reflections on CSC. This finding suggests that generally in all the three cycles it is the average and high achieving students who gained from the metacognitive interventions. The lack of gains in quantitative data, therefore, could be attributed to the large proportion of low achieving students in most of the classes who in many cases could have contributed to decreases in their perceptions of cognitive strategy use. Classroom teachers need to find out the specific reasons for low CSU amongst low achieving students in order to design appropriate programmes to enhance their metacognitive strategies. The gains in the reflections on CSU in the third cycle could be attributed to the constant reminders to students to refer to the focused outcomes when recording their reflections in journals, and the use of prompting questions, specifically related to the task at hand, that could have stimulated their reflections on the use of appropriate metacognitive strategies. For example, students were given prompting questions such as "What have you done to ensure that you score an excellent grade in the assignment?" The reference to focused outcomes during reflections helps students to minimise memory distortions and also re-emphasises what students need to learn in a particular topic.

Self-regulation (SR)

According to the quantitative data obtained in all the three cycles in this study, there were no significant gains in self-regulation except in the first cycle. However, the qualitative data obtained from the interviews showed high levels of self-regulation among the high and average achieving students at the end of each of the three cycles. On the other hand, the qualitative data obtained from the reflection journals showed significant gains among the high and average students in Year 7 in the second and third cycles. However, only the high achieving students in Year 9 showed significant gains in their reflections on SR in the second and third cycles. The Year 8 class (extension class) showed significantly high levels of SR from the start of the third cycle, therefore there was not much room to achieve significant gains. The gain indicated by the quantitative data in the first cycle could have been partially due to the low start base, and the lack of gains in the second and third cycles could be partly attributed to the high start bases in all the year levels. The relatively lower gains in reflections in Year 9 could be partly due to the stage of development of the students (age 14 - 15) when students tend to pay more attention to the social aspects of their lives than to academic achievement. Since the majority of the students in the participating classes fall into the category of either average or low achieving students, it would be beneficial to investigate reasons why there was a decrease in reflections on SR amongst the average achieving students in Year 9. This would enable classroom teachers to design programmes that would motivate more Year 9 students to engage in SR in order to enhance their metacognitive capabilities. Probably, Year 9 students prefer to reflect verbally since the interviews with them elicited responses that showed SR among both high and average achieving Year 9 students. Generally, it was the high and average achieving students, except in Year 9, who benefited from the metacognitive interventions by improving their SR capabilities. There is need to design specific programmes to enhance self-regulation among low achieving students.

Cognitive Self-Consciousness (CSC)

The quantitative data in this study did not show any significant gains in cognitive self-consciousness (CSC) except in the first cycle. However, the qualitative data obtained from interviews showed low CSC in the first cycle. In the third cycle all the participants in the interviews in Year 7, 8 and 9 showed high levels of CSC. However, there were no significant gains in CSC reflections in the journals in both the second and third cycles. The gains in the first cycle were partly due to a low start base which could have made it easier for the effect of the interventions to make a significant change. The lack of significant gains in reflections on CSC could be due to the highly automated nature of cognitive self-consciousness, and therefore making it difficult for students to put their thoughts in writing. This is supported by the evidence that interviews elicited responses that indicated high levels of CSC among the students in the second and third cycles for all the Year levels. Teachers need to investigate the most suitable methods for students to express their thoughts about learning experiences as this could vary from student to student. In this research most students provided more responses about cognitive self-consciousness during interviews. The high and average students' journals contained more details of reflections on cognitive self-consciousness.

5.3.2 Implications for Findings for Research Question 2 (What was the effect of the interventions on students' perceptions of their metacognitive support in science?)

At the beginning, in each class in all the three cycles, generally most students' perceptions were highest in the TES and SV scales, and lowest in the SSD scale. Like in Research Question 1, this data could be obtained and analysed in the first days or week of the term or semester and used to design teaching programmes to provide a learning environment that the majority of the students perceive as conducive to the development of their metacognitive capabilities. For example, to enhance student-student discourse, more group activities in which students are given prompting questions on how they learn science could be conducted.

According to the quantitative data, the lack of significant gains in the students' perceptions of their metacognitive support could be misleading because many of the scales had generally high pre- and post- mean scores in the three cycles, therefore there was not much room to move up on the Likert scale (from 1 to 5). Despite the gains in the Student-student discourse (SSD) scale along with the other scales in the first cycle, the SSD scale consistently had the lowest or one of the lowest mean scores in the pre- and post- metacognitive support surveys in all the three cycles. This clearly indicated that most students perceived that they did not often discuss with each other how they learn science. Whether that meant that they were not given the opportunity to discuss or their discussions deviated from how they learn science to other conversations, could be investigated through oral interviews. Science teachers need to ensure that the students remain focused when asked to discuss how they learn science by giving them prompting questions to guide the discussions.

5.3.3 Implications for Findings for Research Question 3 (What was the effect of the metacognitive interventions on the students' achievement in science?)

The first and third cycles indicated that generally students performed better in tier one of the two-tier multiple-choice items than in the combined tiers that included a reason for their choice in the first tier. The gains in tier one items were also generally greater in both cycles. The research also showed that students performed better in responses to questions that required only the use of declarative knowledge, and poorly in questions that required the use of procedural and conditional knowledge. The research findings suggest that these students needed more practice at explaining scientific phenomena other than simply stating correct answers. Processed questions were used in the third cycle to eliminate the limitations in declarative knowledge of concepts, and elicit responses that predominantly require the use of metacognitive strategies. The use of processed questions in the pre- and post-tests in the science classroom will enable students to develop higher order thinking skills and metacognitive strategies that are applicable in new situations unlike the traditional content knowledge questions that require domain specific skills.

5.4 Implications

5.4.1 Implications for research

The findings of this study show a lack of convergent validity between the quantitative research instruments (questionnaires) and qualitative research instruments (interviews and reflection journals) that were used in this study. This implies that measuring students' metacognitive strategies still requires the use of multiple methods until a single reliable instrument is developed. According to Azevedo (2009), metacognitive processes may be automated and the exact nature of metacognitive judgements is still unclear. However, qualitative data from interviews and reflection journals would be required to gain a deeper understanding of individual students' metacognitive strategies. This finding suggests that generally there were no significant increases in the students' level of anxiety during the action research (Cartwright-Hatton et al., 2004). Qualitative data still remain the best source of information in small classes because for quantitative data to be reliable we require a large sample. Reflection journals would be classified as “semi-online” data sources since reflection is an integral part of metacognition. Students’ depth of reflection should have a correlation with their metacognitive strategies. According to Robson (2006), learners with metacognitive abilities are also reflective, and monitor and direct their own learning. The effective use of reflection journals would be greatly enhanced by the provision of focused outcomes to students so that they continually refer to them when reflecting in order to minimise memory distortions.

The use of processed questions in the pre-post tests to measure the effectiveness of metacognitive interventions in enhancing students’ achievement in science is an area that will require further investigation. It is important because it helps to eliminate the weakness of lack of content knowledge at the beginning of a topic. Processed questions also assess students on higher order thinking skills that draw more on metacognitive skills rather than on mere cognitive skills.

5.4.2 Implications for teaching

According to the qualitative data obtained from the reflection journals in this study, the metacognitive interventions conducted in this action research were effective in enhancing the metacognitive strategies of the students. Therefore, the combined application of the three major interventions of focused outcomes, reflection journals and concept maps to enhance students’ metacognitive capabilities would be beneficial in the science classroom if they are consistently used over a relatively long period (at least 10 weeks). However, there is a tendency for some students not to apply themselves sufficiently when engaged in some of the intervention tasks, such as concept maps and reflection journals, unless they are included in summative assessments.

The lack of gains in the perceptions of the low achieving students’ metacognitive strategies could be studied more deeply through individual students’ interviews because, quite often, the low achieving students have low literacy skills and therefore their reflection journals may not elicit their learning experiences or processes sufficiently. Metacognitive capability enhancing teaching programmes should be designed for the low achieving students based largely on their own perceived needs.

5.5 Limitations

In the first cycle there were some limitations to the study that precluded the ability to generalise the outcomes to larger populations. The first limitation is that the questions in which students' responses showed significant differences between the pre- and post-tests on Light are those that required declarative knowledge. These questions do not elicit responses that indicate development in metacognition. A second limitation was due to unforeseen interruptions to the school programme that involved the researcher and out of school obligations for jury duty. These interruptions resulted in a break in conducting the interventions that could have affected the momentum with which students were acquiring metacognitive skills. A third limitation is that some students with low literacy skills may not have been able to express their reasoning and perceptions clearly in the self-report instruments that required writing such as the pre-post tests and written interviews. This effect could have been significant because the Year 9 classes that participated in the first cycle of this action research were mixed ability classes with the majority of students being low achieving.

In the second cycle, the action research was conducted over a period of 20 weeks. This cycle was probably too long and needed to be analysed mid-cycle to inform the researcher of necessary changes to enhance the effectiveness of the interventions. Also, in the second cycle the data to study students' achievements in science was obtained for their scores in science examinations and assignments. These were difficult to compare because the examinations and assignments could have been of varying difficulty and therefore requiring different levels of cognitive skills.

The overall limitations of this study, including the third cycle, were that the author was unable to conduct two or more cycles in a row with exactly the same classes or students due to changes in the teaching time table of the researcher, and students being moved from one class to another. The second overall limitation was the lack of convergent validity of the instruments used to assess the students' metacognitive strategies. Whereas the metacognitive strategies questionnaires showed overall modest gains, the reflection journals showed significant gains among the high and average achieving students. The lack of reliable on-line research instruments in metacognition studies still remains a challenge (Azevedo, 2009; Veeman, 2011).

5.6 Recommendations

The analysis of students' metacognitive capabilities is enriched by the use of both quantitative and qualitative data. Quantitative data, obtained from metacognitive surveys, would be beneficial at the start of a science teaching programme to give the teacher a general impression of the students' metacognitive capabilities. This knowledge would enable the science teacher to design teaching programmes that would enhance the metacognitive capabilities of the majority of the students in particular classes.

Qualitative data should be collected at various stages of the teaching programme. The qualitative data, obtained through reflection journals and interviews, would help the science teacher to "zero in" on individual students. In other words qualitative data provide the "micro-analysis" whereas quantitative data provide the "macro-analysis" of the students' metacognitive capabilities.

Due to the highly automated nature of metacognition, the use of multiple methods (triangulation) in collecting data would help to increase the validity of the research findings. In this study the girls' reflections were deeper and more detailed than the boys' reflections in all the year levels and levels of achievement. This means that by using reflection journals to analyse students' metacognition, the data obtained may not be a true reflection of the boys' metacognitive capabilities.

The three interventions used together in this study – focused outcomes, reflection journals and concept maps – to enhance the students' metacognitive capabilities would be very useful in the science classroom especially if they were consistently used over a long period. In the middle school years keywords would help students to improve their spelling, and they are also useful when constructing concept maps during or at the end of the topic. The focused outcomes provide the "road map" to what students are expected to have learnt at the end of a topic. If the focused outcomes are spelled out clearly, some of the high achieving students may independently use the resources available to study ahead of the class. The reflection journals help to plan, monitor and evaluate progress in the students' learning processes. Reflection journals also provide feedback to the teacher on how the students are progressing. Concept maps make students aware of how much they have learnt or their areas of weakness. They also help the students to summarise and revise topics. Teachers may also use students' concept maps to gain an understanding of the areas where students need help.

The use of processed questions, instead of the traditional content knowledge questions, in the pre- and post-tests to assess students' achievement in science would help to eliminate the limitation of lack of content knowledge at the beginning of a topic. Processed questions in science assess students' higher order thinking skills that draw more on the students' metacognitive strategies in addition to their cognitive strategies. The regular use of processed questions in science tests would enhance the ability of students to apply scientific knowledge and solve problems in new and real life situations. In addition, with reference to the poor performance in the combined tiers of the items throughout this study, there is need to encourage students, in the middle school years, to explain scientific phenomena verbally and in writing other than simply stating "one word" or "short sentence" answers.

5.8 Conclusion

This action research showed differences in the findings about the students' perceptions of their metacognitive strategies, from the qualitative (i.e., interviews and reflection journals) and quantitative (i.e., questionnaires) data sources. The search for a reliable instrument to analyse students' metacognition in the classroom is an area that requires rigorous research if classroom teachers are to assess and design teaching programmes that will effectively develop students' use of metacognitive strategies in science. Although multiple methods increase the validity of the data, due to limited time in the classroom, teachers may not be able to effectively analyse multiple sources of data. Also, the use of multiple methods raises the question of how to judge which data have greater value (Schellings & Van Hout-Wolters, 2011).

Qualitative data findings in all the three cycles indicated gains among the high and average achieving students' perceptions of their metacognitive strategies. However, generally the low achieving students did not gain much from the metacognitive interventions. These findings are consistent with the literature that suggests that inefficient learners often do not use appropriate cognitive strategies to improve their achievement (Kolencik & Hillwig, 2011; Pintrich & Groot, 1990). This could have been a contributory factor to the modest or lack of gains in the students' perceptions of their metacognitive strategies according to the quantitative data findings. The lack of or decrease in perceptions of metacognitive strategies and support of a large proportion of low achieving students could have statistically cancelled out the gains of the average and high achieving students in the overall quantitative data findings.

Generally students improved in the first tier items of the pre- post-tests but the gains in the combined tiers were modest. Therefore, whereas students may give the correct answers (declarative knowledge) in science tests quite often they fail to explain why their answers are correct (procedural knowledge). This may become a bigger problem in senior secondary school science where large proportions of the science assessments require students to give explanations of scientific phenomena. In the third cycle of this research only processed questions were used because they draw more on metacognitive strategies instead of cognitive strategies. Therefore, they do not require a student to have read the content beforehand. The use of processed questions is an area that needs exploration, correlating the achievement in such assessments with data from more reliable quantitative metacognitive instruments.

If science educators are serious about creating a generation of life-long independent learners in science, where else would they start other than developing students' metacognitive strategies? However, reliable and easy-to-use metacognition assessment instruments in the science classroom need to be developed. New methods for assessing students' metacognitive strategies will require thorough examination in order to gain understanding of what these methods precisely measure (Veenman, 2011). This will lead to the development of "designer" teaching programmes that specifically address the metacognitive needs of particular science students in the secondary school classes.

To summarise, overall, the quantitative data suggest that there were no significant gains in the students' perceptions of their metacognitive strategies and support. However, the qualitative data from reflection journals suggests that the high and average achieving students demonstrated gains in metacognitive strategies. These results support the findings by Hofer and Sinatra (2010) that neither quantitative nor qualitative approaches reveal metacognitive strategies, but a combination of both is required.

The students' achievement in the two-tier tests was better in the first tier than in the combined tiers. This finding suggests that students had more declarative knowledge of phenomena than procedural or conditional knowledge.

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Appendix A: Metacognitive Strategies Questionnaire (*MStQ*)

Survey No: _____ Date: _______ Class: _________

Name:____

No.	Item	Almost always	Often	Sometime	Seldom	Never
In this science class I:						
1	Try to put together the information from class and from the book when studying for a test.					
2	Try to remember what the teacher has said in class so I can answer the homework correctly.					
3	It is hard for me to decide what the main ideas are in what I read.					
4	When I study I write important ideas in my own words.					
5	I always try to understand what the teacher is saying even if it does not make sense.					
6	When I study for a test I try to remember as many facts as I can.					
7	When studying, I copy my notes over again to help me remember material.					
8	When I study for a test I practice saying the important facts over and over to myself.					
9	I use what I have learned from old homework assignments and the textbook to do new assignments.					
10	When I am studying a topic, I try to make everything fit together.					
11	When I read material for this class, I say the words over and over to myself to help me remember.					
12	I outline the chapters in my book to help me study.					

No.	Item	Almost always	Often	Sometime	Seldom	Never
13	When reading I try to connect the things I am reading about with what I already know.					
When I study for this science class:						
14	I ask myself questions to make sure I know the material.					
15	I either give up or study only the easy parts when the work is hard.					
16	I work on practice exercises and answer end of chapter questions even when I don't have to.					
17	I keep working till I finish even when studying materials that are dull and uninteresting.					
18	Before I begin studying I think about the things I will need to do to learn.					
19	I often find I have been reading for class but don't know what it is all about.					
20	I find that when the teacher is talking I think of other things and I don't really listen to what is being said.					
21	When I am reading I stop once in a while and go over what I have read.					
22	I work hard to get a good grade even when I don't like a class.					
In preparing for and during this science class I:						
23	Am constantly aware of my thinking.					
24	Pay close attention to the way my mind works.					
25	Think a lot about my thoughts.					

No.	Item	Almost always	Often	Sometime	Seldom	Never
26	Constantly examine my thoughts.					
27	Monitor my thoughts.					
28	Am aware of the way my mind works when I am thinking through a problem.					

Appendix B: Metacognitive Support Questionnaire (*MSpQ*)

Survey No: _____ Date: _______ Class: _________

Name:____
__

No.	Item	Almost always	Often	Sometime	Seldom	Never
In this science class I am asked by the teacher:						
1	To think about how to learn science.					
2	To explain how I solve science problems.					
3	To think about my difficulties in learning science.					
4	To think about how I could become a better learner of science.					
5	To try new ways of learning science.					
In this science class I discuss with others:						
6	About how they learn science.					
7	About how they think when they learn science.					
8	About different ways of learning science.					
9	About how well they are learning science.					
10	How they can improve their learning of science.					
In this science class students discuss with the teacher about:						
11	How they learn science.					
12	How they think when they learn science.					
13	Different ways of learning science.					
14	How well they are learning science.					
15	How they can improve their learning of science.					
In this science class:						
16	It is alright for students to tell the teacher when they don't understand science.					
17	It is alright for students to ask the teacher why they have to do a certain activity.					
18	It is alright for students to suggest alternative science learning activities to those proposed by the teacher.					
19	It is alright for students to speak out about activities that are confusing.					
20	It is alright for students to speak out about anything that prevents them from learning.					
In this science class the teacher:						
21	Encourages students to try to improve the way they learn.					

No.	Item	Almost always	Often	Sometime	Seldom	Never
22	Encourages students to try different ways to learn science.					
23	Supports students who try to improve their science learning.					
24	Supports students who try new ways of learning science.					
25	Encourages students to talk with each other about how they learn science.					

Appendix C: Light two-tier multiple-choice test

NAME: ___________________________________ AGE: ________

Predicted mark ______________ out of 20

Instructions to Students

This diagnostic instrument consists of 10 items that evaluate your understanding of the propagation of light.

Each item has two parts: a multiple-choice response followed by a multiple-choice

reason.

For each item, you are asked to make the **most appropriate** choice (A, B, C, etc.) from the multiple-choice response section.

Then choose one of the reasons from the multiple-choice reason section (1, 2, 3, etc.) that best matches your answer to the first part.

If you do not agree with any of the given reasons, please write your reason in the space provided.

Remember it is important to provide a reason for selecting a particular response in each item.

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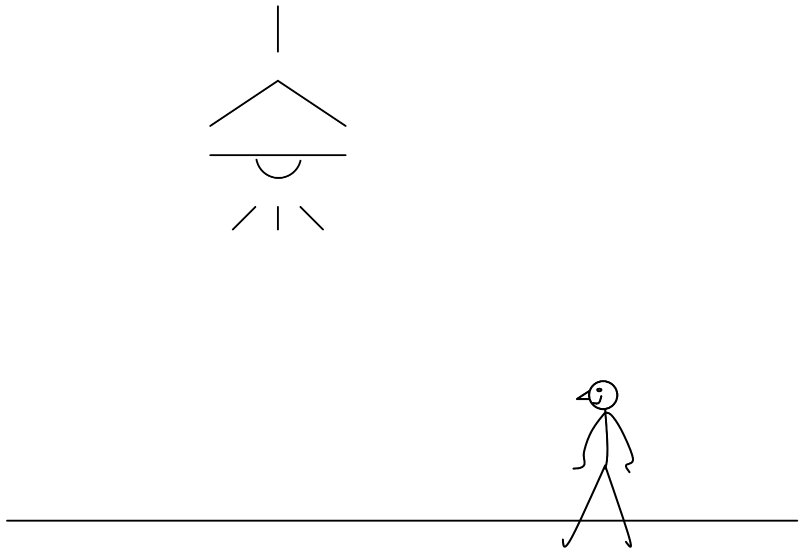
PROPAGATION OF LIGHT DIAGNOSTIC INSTRUMENT

Item 1



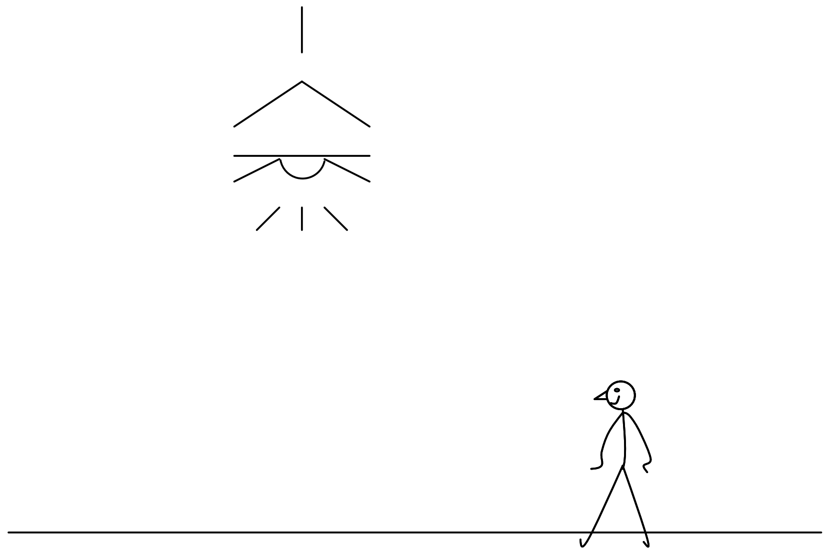
You have the light on during the day. The light from the bulb:

A. stays on the light bulb.
B. comes out about halfway towards you.
C. comes out as far as you are but no further.
D. comes out until it hits something.

The reason I chose my answer is because:

1. Light travels in all directions from the bulb.
2. Light does not travel at all during the day.
3. Light travels further at night than during the day.
4. Light travels about 1000 m during the day.
5. Light rays travel in a preferential way towards an object.

Item 2



You have the light on during the night. The light from the bulb:

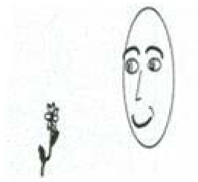
A. stays on the light bulb.
B. comes out about halfway towards you.
C. comes out as far as you are but no further.
D. comes out until it hits something.

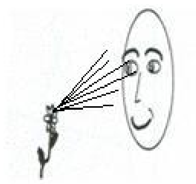
The reason I chose my answer is because:

1. Light travels in all directions from the bulb.
2. Light does not travel at all during the night.
3. Light travels further at night than during the day.
4. Light travels about 1000 m at night.
5. Light rays travel in a preferential way towards an object.

Item 3

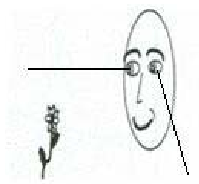
A boy sees a flower. How does he see the flower?





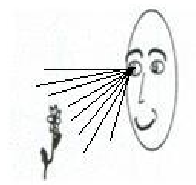
Also for both eyes and for more than one object point

A



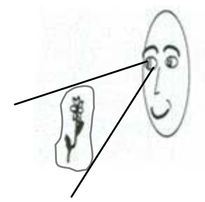
Two lines indicate the range of vision

B



Also for both eyes

C



Also for both eyes

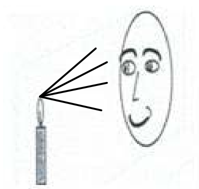
D

The reason I chose my answer is because:

1. There are bundles of rays from the object, and so the boy can see.
2. Bundles of rays are coming out from the boy's eyes and so he is able to see the flower.
3. Light is not shown emanating from the light source, but is only present around the flower.
4. Light is shown emanating from the object and being received by the eye.
5. The object is located within the region of the boy's vision.

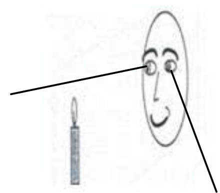
Item 4

The diagram shows a boy seeing the flame of a lit candle. Which of the following diagrams indicates how the boy is able to see the flame?



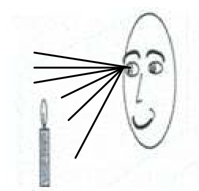
Also for both eyes and for more than one object point

A



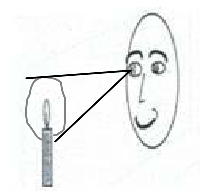
Two lines indicate the range of vision

B



Also for both eyes

C



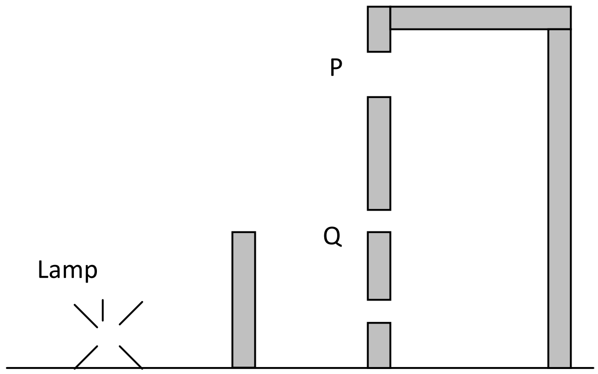
Also for both eyes

D

The reason I chose my answer is because:

1. There are bundles of rays from the object, and so the boy can see.
2. Bundles of rays are coming out from the boy's eyes and so he is able to see the candle flame.
3. Light is not shown emanating from the light source, but is only present around the candle flame.
4. Light is shown emanating from the object and being received by the eye.
5. The object is located within the region of the boy's vision.

Item 5



P, Q and R represent windows

The diagram shows a lamp and a room with windows P, Q and R. From which window can one see the lamp?

A. Window P B. Window Q C. Window R D. All (P, Q and R) E. None

The reason I chose my answer is because:

1. Light from the lamp would reach all points above the height of the obstructing wall.
2. Light would reach all windows by scattering or diffusion.
3. Light travels in straight lines in all directions from the lamp.
4. Light fills up the space in front of the wall.
5. Light is deflected around the wall forming a wide beam of light.

Item 6

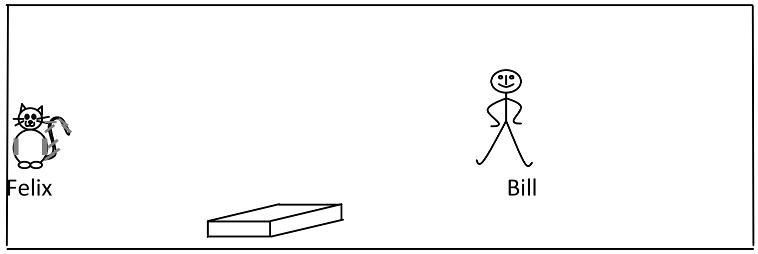
Which windows are illuminated by the light of the lamp in the figure above?

A. Window P B. Window Q C. Window R D. All (P, Q and R) E. None

The reason I chose my answer is because:

1. Light from the lamp would reach all points above the height of the obstructing wall.
2. Light would reach all windows by scattering or diffusion.
3. Light travels in straight lines in all directions from the lamp.
4. Light fills up the space in front of the wall.
5. Light is deflected around the wall forming a wide beam of light.

Item 7

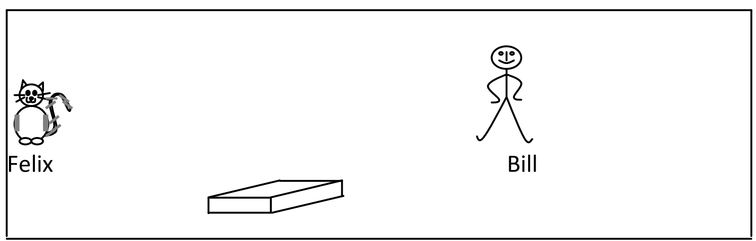


Felix the cat and Bill are in a completely dark room. There is no light in the room. Felix the cat would:

A. not be able to see at all.
B. just be able to see the box.
C. see the box quite clearly.

The reason I chose my answer is because:
1. Light has to be reflected from the book to the cat's eyes.
2. Cats can see in the dark.
3. The cat is able to see objects by looking at them.
4. The cat will be able to see in the dark after adjusting its eyes to the darkness.

Item 8

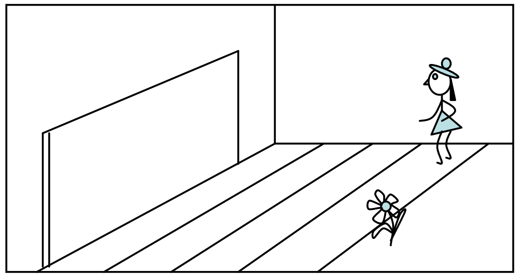


This item is just like item 7. The room is still completely dark.
Bill would:
A. not be able to see the box at all.
B. just be able to see the box.
C. see the box quite clearly.

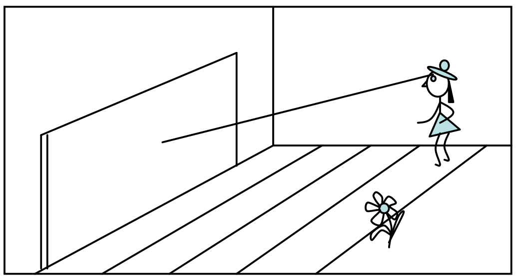
The reason I chose my answer is because:
1. We need light to be reflected to our eyes to be able to see in the dark.
2. People can just see in the dark.
3. We see by looking at objects.
4. We are able to see in the dark after our eyes have adjusted to the darkness.

Item 9

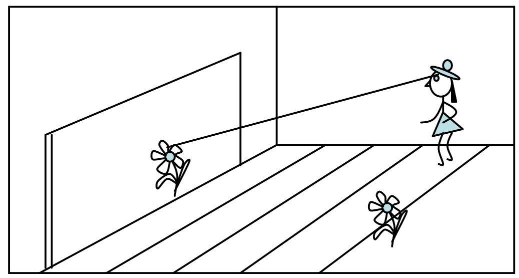
A girl is standing to one side away from a flower and is looking in the mirror. The girl says she can see the flower. Which of the diagrams below shows how she is able to see the flower?



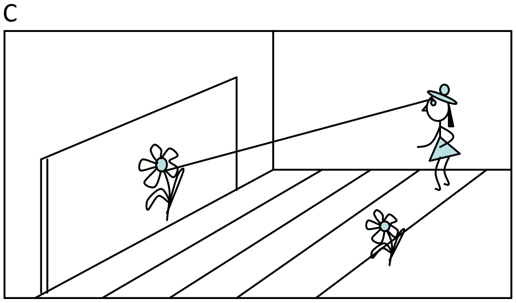
A



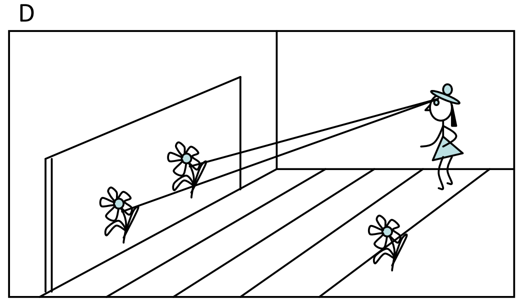
B



C



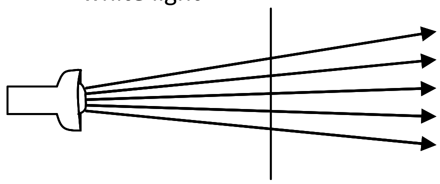
D



The reason I chose my answer is because:

1. The mirror reflects the rays from the flower and so the image of the flower is on the mirror.
2. The mirror reflects the rays from the flower in all directions and so the image of the flower can be in two places at once.
3. The image is located behind the mirror in the extended lines of reflected rays from the mirror to the eyes.
4. The mirror reflects the rays from the flower and so there is no image on the mirror.

Item 10



What colour would it appear when you shine white light through a piece of red glass?

A. White B. Red C. Pink D. Blue E. Black

The reason I chose my answer is because:

A. Light passing through the glass is painted red by the glass.
B. The red glass absorbs all the components of white light, except red light.
C. The colour through the glass appears as a mixture of white and red.
D. The red glass allows all the components of white light through except red light.
E. The red colour is purely a property of the red glass, not that of light itself.

Appendix D: Classification of Living Things two-tier multiple-choice test

NAME: ____________________________________ AGE: ________

Predicted mark ______________ out of 20

Instructions to Students

This diagnostic instrument consists of 10 items that evaluate your understanding of classification of living organisms.

Each item has two parts: a multiple-choice response followed by a multiple-choice

reason.

For each item, you are asked to make the **most appropriate** choice (A, B, C, etc.) from the multiple-choice response section.

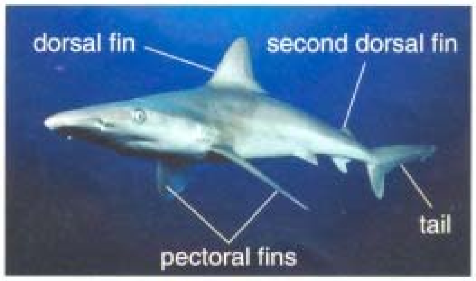
Then choose one of the reasons from the multiple-choice reason section (1, 2, 3, etc.) that best matches your answer to the first part.

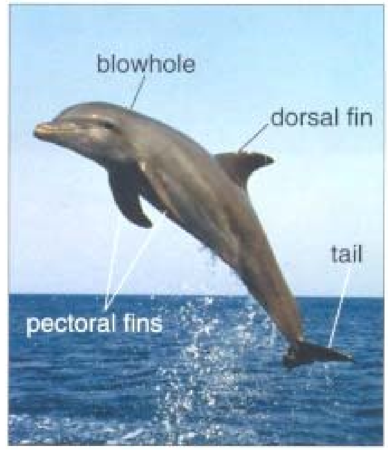
If you do not agree with any of the given reasons, please write your reason in the space provided.

Remember it is important to provide a reason for selecting a particular response in each item.

Question 1

The photographs show a shark and a dolphin.





Which is the **least reliable** method of distinguishing between the shark and the dolphin shown?

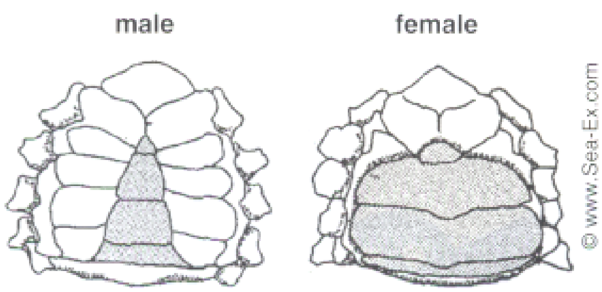
A) orientation of the pectoral fins
B) orientation of the tail
C) presence of a blowhole
D) presence of a second dorsal fin

The reason for my choice of answer is:

5 The pectoral fins of the shark and dolphin all point in the same direction.
6 The pectoral fins of the shark and dolphin all have the same shape.
7 Both the shark and dolphin have a blowhole.
8 Both the shark and dolphin have dorsal fins.

Question 2

The diagrams show the structure of the abdomen of male and female crabs.



Which photograph shows a male crab?

A)

© Laren Leonard

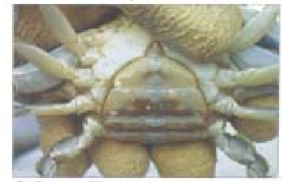
B)

© Fish Encyclopedia

C)

© Fish Encyclopedia

D)

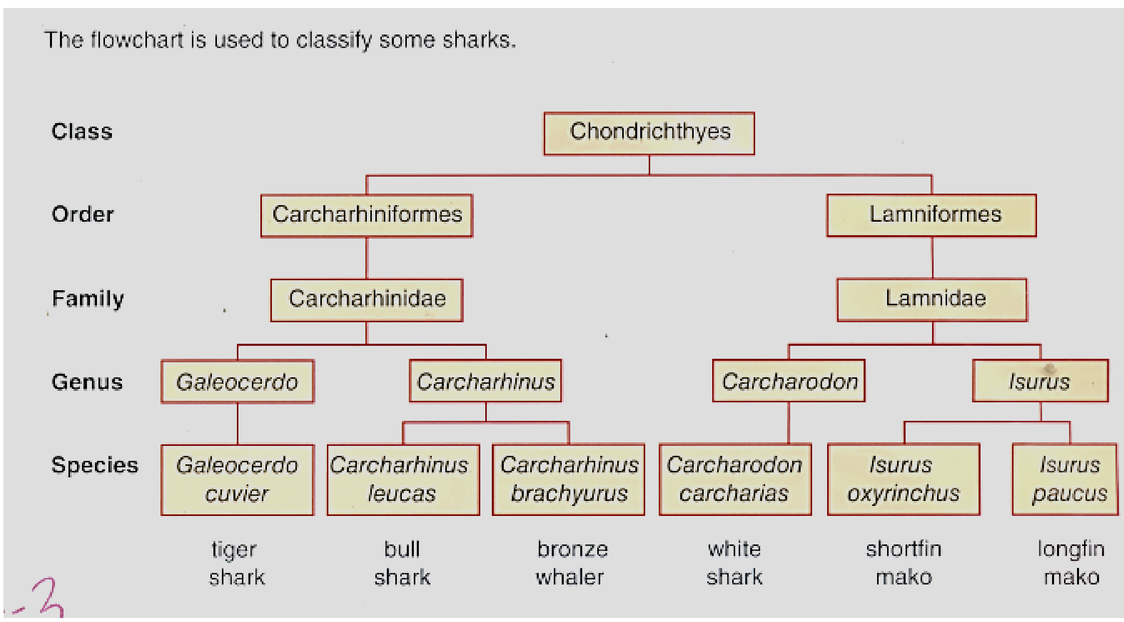


© Steve Zinski

The reason for my choice of answer is:

1. The male crab has a narrower abdomen than the female crab.
2. The female crab has a narrower abdomen than the male crab.
3. The female crab has sharper and longer mandibles.
4. The male crab has sharper and shorter mandibles.

For questions 3 and 4 use the information below.



Question 3

Hammerhead sharks belong to the genus *Sphyrna*. What is the most likely family name for hammerhead sharks?

A) Sphyrnidae
B) Sphyryniformes
C) Sphyrhinus
D) Sphyrithyes

The reason for my choice of answer is:

5 Each family name starts in a similar way to the genus name.
6 Each family name ends in a similar way.
7 Each family is the same as the genus name except for the last three letters.
8 None of the above reasons is correct.
9

Question 4

Dusky sharks have the scientific name **(species)** Carcharhinus obscurus. To which genus do dusky sharks belong?

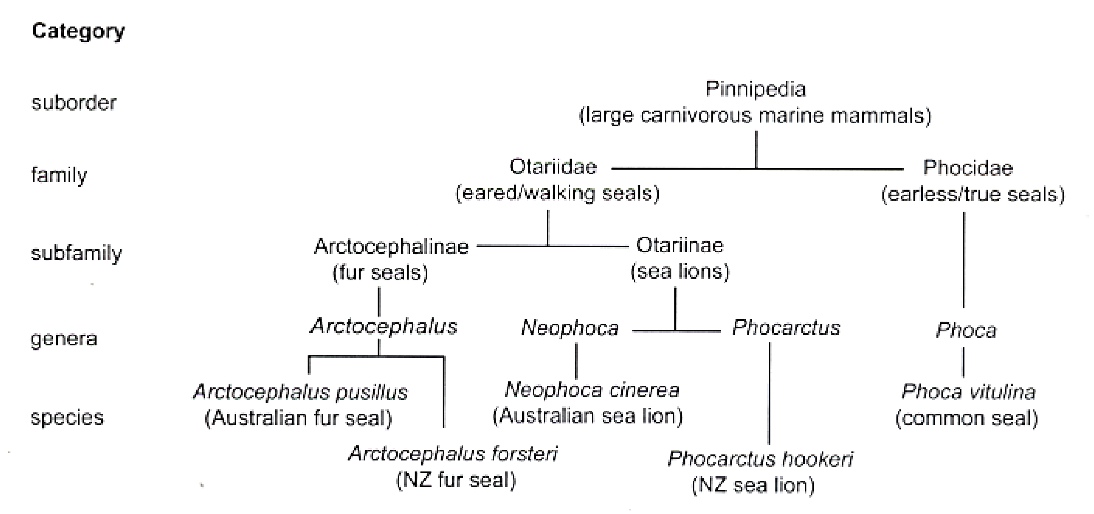
A) Carcharhinus
B) Carcharhinidae
C) Obscurus
D) Obscuridae

The reason for my choice of answer is:

1.The genus name is always the same as the family name.
2.The genus name is always the same as the last name of a specie.
3.The genus name is always the same as the first name of a specie.
4.The last three or two letters of the genus names are always the same.

Question 5

Scientific classification enables scientists to categorise plants and animals into groups (families, genera, and species) and to name them. The more categories two species have in common, the more closely they will be related. A particular animal or plant is known by its genus and species and by a common name.
The chart shows the classification of some large carnivorous marine mammals. Common names are given in brackets.



Which two animal species in the chart are most closely related?

A) Australian fur seals and common seals
B) Australian fur seals and NZ fur seals
C) Australian sea lions and NZ sea lions
D) Australian sea lions and Australian fur seals

The reason for my choice of answer is:

1. Animal species are more closely related if they belong to the same country.
2. Animal species are more closely related if they belong to the same genera.
3. Animal species are more closely related if the last part of their common names ends with the same letters.
4. Animal species are more closely related if they belong to the same family.

Question 6

Zac has a pet frog. He wants to find out more about frogs.

Which of the following hypotheses could Zac most easily test?

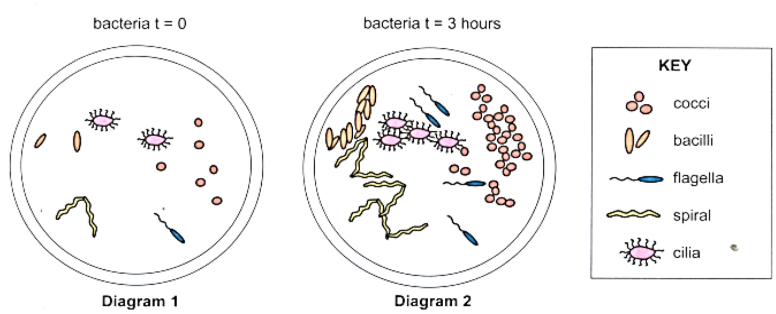
A) Frogs can taste their food better when it is warm
B) Frogs are more active in the light than in the dark
C) Frogs are more afraid of snakes when they are young
D) Frogs prefer to be fed at night rather than in the morning

The reason for my choice of answer is:

1. It is easy to measure amount of food eaten and change the temperature.
2. It is easy to measure the frogs' level of activity and change the amount of light.
3. You can easily measure the amount of food eaten and change the amount of light.
4. None of the above

Question 7

The diagrams represent samples of bacteria growing in a dish of nutrient. Diagram 2 shows the samples three hours after diagram 1.



Which type of bacterium is multiplying the fastest?
A) Cocci
B) Bacilli
C) Spiral
D) Cilia

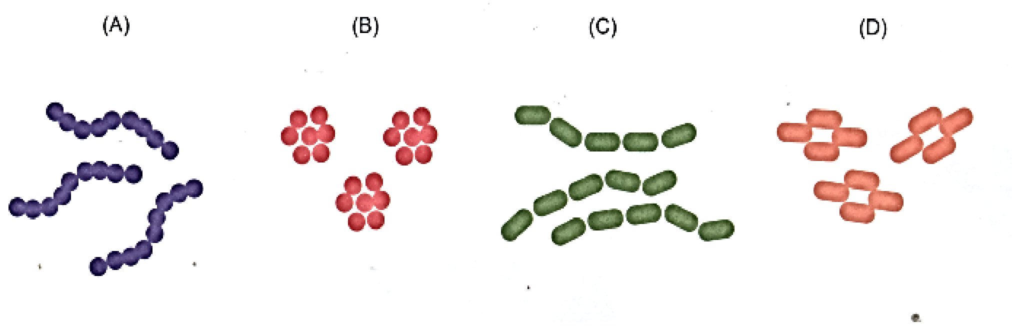
The reason for my choice of answer is:

1. The bacteria with largest population in diagram 2 is multiplying the fastest.
2. The bacteria with the greatest increase in size (individually) are multiplying the fastest.
3. The bacteria with the greatest increase in population are multiplying the fastest.
4. The longer or larger the bacteria the faster they multiply.

Question 8

Streptococcus bacteria are spherical in shape and form chains of colonies.

Which drawing represents colonies of *Streptococcus*?

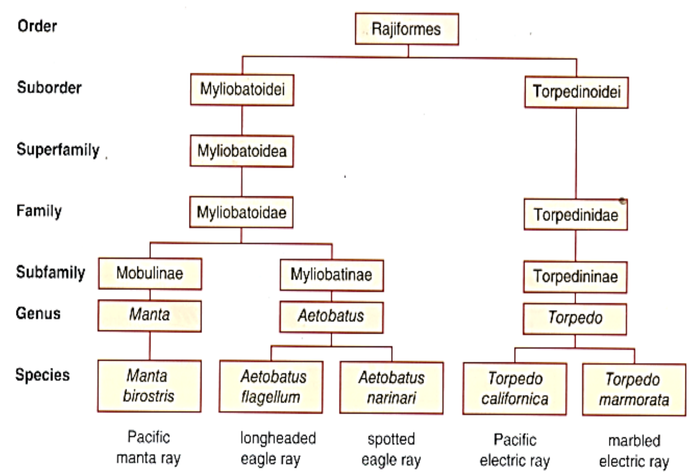


The reason for my choice of answer is because Streptococcus are:

1. In groups and joined together.
2. In groups but not joined together.
3. In groups and joined together sideways.
4. In groups and joined on all sides.

For questions 9 and 10 use the information below.

The flowchart is used to distinguish between some sea rays.



Question 9

Longheaded eagle rays are classified in the suborder

A) Myliobatinae
B) Myliobatoidae
C) Myliobatoidea
D) Myliobatoidei

The reason for my choice of answer is:

1. Suborder names are the same as family names.
2. Suborder names end in –idei
3. Suborder names end in-idea
4. Suborder names end in –idea

Question 10

Sawfish belong to the genus Pristis. What is the most likely family name for sawfish?

A) Pristidei
B) Pristidea
C) Pristidae
D) Pristidinae

The reason for my choice of answer is:

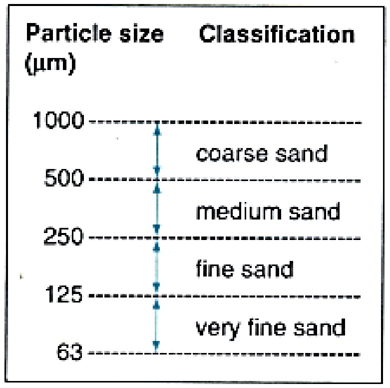
1. Family names end in –dei
2. Family names end in- dea
3. Family names end in-dae
4. Family names end in-nae

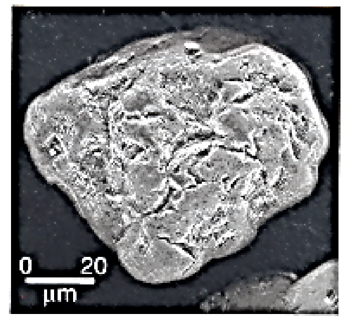
Appendix E: Geology two-tier multiple-choice test

NAME: ____________________________________ AGE: ________

Predicted mark ______________ out of 20

Question 1
The table shows the classification of sand grains by size. The scaled photograph shows a sand grain





The grain shown would be best classified as

A) Coarse sand
B) Medium sand
C) Fine sand
D) Very fine sand

The reason I chose my answer is:

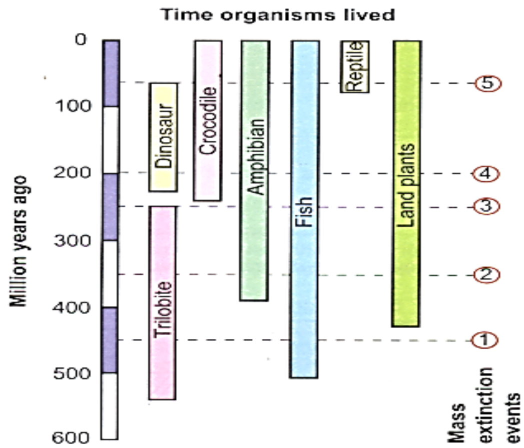
1 The grain has a length of approximately 800-1000 um
2 The grain has a length of approximately 65 um
3 The grain has an area of approximately 800-1000 um
4 The grain has a length of approximately 260 um

For questions 2 and 3 use the information below.

Extinction is the total disappearance from Earth of an animal or plant species.

Mass extinctions refer to the loss of a large number of species in a relatively short period of time. Mass extinctions occur at times when an event brings about rapid changes to Earth's environment.

The diagram shows a geological time scale, the time organisms lived, and the times at which five mass extinction events occurred.



Question 2

Which mass extinction event caused the extinction of the dinosaurs?

A) 1
B) 2
C) 4
D) 5

The reason I chose my answer is:

1. The event occurred approximately 50 million years ago after which dinosaurs became extinct.
2. The event occurred approximately 250 million years ago after which dinosaurs became extinct.
3. The event occurred 200 million years ago after which dinosaurs started to die in large numbers.
4. The event occurred approximately 50 million years ago after which dinosaurs started to die in large numbers.

Question 3

Trilobites are a group of extinct marine animals that were abundant in the oceans of the Earth during the Paleozoic era.

For approximately how long (millions of years) did trilobites live?

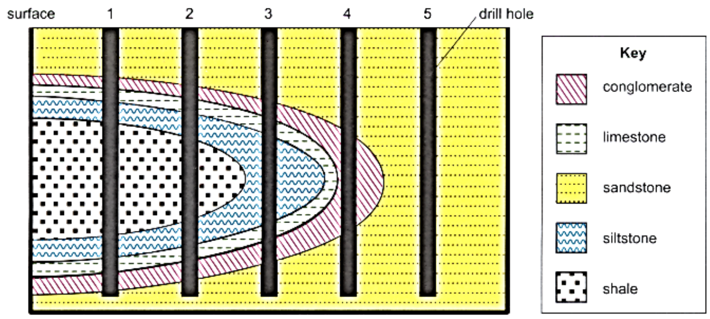
A) 540
B) 350
C) 290
D) 240

The reason I chose my answer is:

1. Trilobites lived from 540 to 250 million years ago.
2. Trilobites lived from 650 to 340 million years ago.
3. Trilobites lived from 640 t0 350 million years ago.
4. Trilobites lived from 550 to 200 million years ago.

Question 4

In a dry river bed, a geologist drilled through layers of rock as shown in the diagram below.



Why did the geologist drill more than one hole?

A) The geologist needed controls for his drill holes
B) There were too many rock types found in drill hole 1
C) The geologist wanted to ensure that all the samples collected contained sandstone.
D) The geologist wanted to ensure that he had a representative sample of the river bed.

The reason I chose my answer is:

1. Drilling holes in various parts enables the geologist to test the quality of the oil more accurately.
2. Drilling holes in various parts enables the geologist to the test the quality of the rocks more accurately.
3. Drilling more holes enables the geologist to collect more oil.
4. The geologist wanted to find out which was easiest to drill through.

Question 5

The photograph shows three different rocks.

The rocks are ordered from P to R.

What does the order show?

A) Increasing length
B) Increasing angularity
C) Increasing roundness
D) Increasing particle size

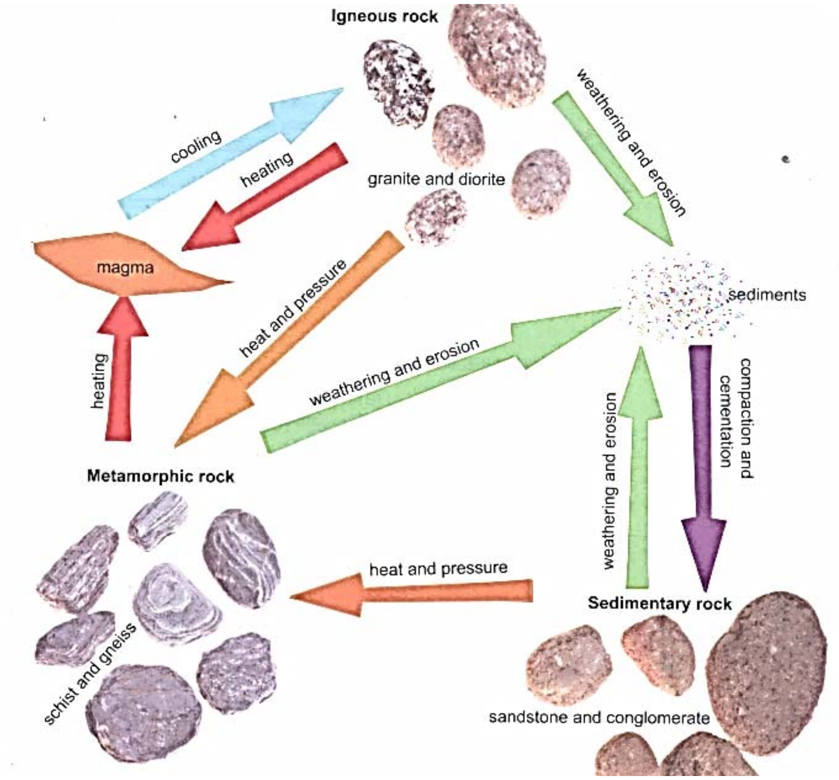
The reason I chose my answer is:

1. The rocks increase in sharpness on the edges from P to R.
2. The rocks increase in width from P to R
3. The rocks decrease in sharpness on the edges from P to R.
4. The surface of the rocks increases in smoothness from P to R.

For questions 6 and 7 use the information below.

There are three types of rocks: igneous, sedimentary and metamorphic.

The diagram shows the processes by which each type of rock is created and gives examples of each rock type.



Question 6

Metamorphic rock can become igneous rock through a process of

A) Heating only
B) Weathering and erosion
C) Heat and pressure
D) Heating and cooling

The reason for my choice of answer is:

1. Metamorphic rock changes to igneous through heat and pressure.
2. Metamorphic changes to igneous and vice versa through heating.
3. Any type of rock can be changed to igneous through heating and cooling only.
4. Metamorphic rock changes to igneous through heating followed by cooling.

Question 7

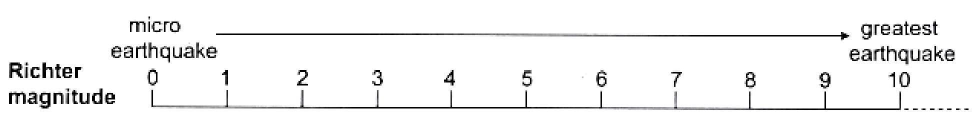
An example of sedimentary rock is

A) Schist
B) Granite
C) Magma
D) Conglomerate

The reason for my choice of answer is:
1. Sedimentary rocks form from this rock's sediments.
2. Sedimentary rocks are form this rock through heat and pressure.
3. This is a type of sedimentary rock.
4. All rocks are formed from magma.

Question 8

The Richter scale is used to describe the magnitude of earthquakes.



An increase of one in magnitude represents a tenfold increase in the distance the ground is displaced by the motion of an earthquake wave passing through an area. For example, magnitude 7 on the Richter scale indicates an earthquake with ground displacement 10 times larger than that produced by a magnitude 6 earthquake.

How many times further would the ground be displaced by a magnitude 6 earthquake than it would be by a magnitude 3 earthquake?

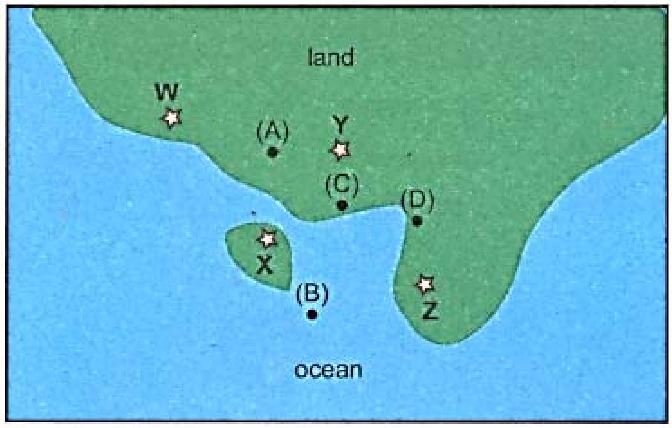
A) 3 times
B) 10 times
C) 30 times
D) 1 000 times

The reason for my choice of answer is:
1. The difference in magnitude of displacement is calculated by only finding the difference in magnitude on the Richter scale.
2. The difference in magnitude of displacement is calculated by finding the difference in magnitude on the Richter scale, and then multiply it by 10.
3. The difference in magnitude of displacement is calculated by finding the difference in magnitude on the Richter scale, and then raising it to the power of 10.
4. The difference in magnitude of displacement is calculated by raising 10 to the power of the difference in magnitude on the Richter scale

Question 9

The epicentre of an earthquake is the point on the surface of the Earth that is directly above the underground point where an earthquake originates. Scientists can calculate the distance to the epicentre of an earthquake using seismograms, but cannot determine the direction from which the wave came.

The map below shows four locations W, X, Y, Z. The table lists distances from four locations to an epicentre.



Seismogram location	W	X	Y	Z
Distance (km)	Not recorded	150	100	200

Where is the epicentre of this earthquake?

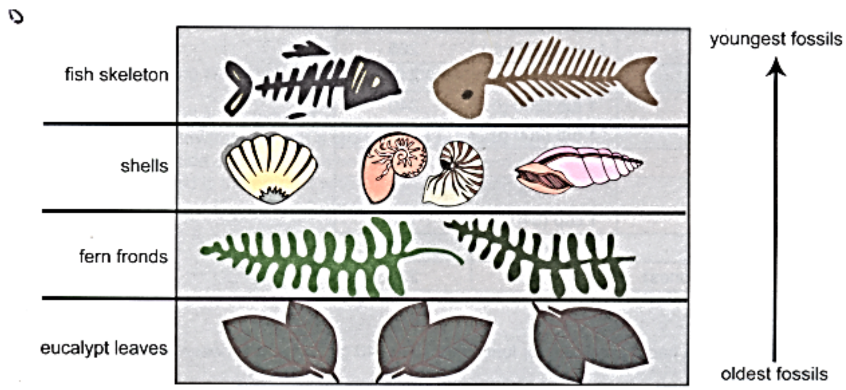
A) A B) B C) C D) D

The reason for my choice of answer is:

1. Z is twice the distance from this location compared to Y.
2. Y is twice the distance from this location compared to Z.
3. X, Y and Z are exactly the same distance from this location.
4. This location is the closest to X, Y and Z.

Question 10

The drawing shows some fossil layers that were uncovered.



Which of the following sequences could have produced the layers of fossils shown?

A) A river valley flooded and then dried out again.
B) Falling sea levels resulted in a forest replacing an ocean.
C) Drought caused a lake to dry out and become a grassland.
D) Rising sea levels meant a forest was flooded by the ocean.

The reason for my choice of answer is:

1. The fish died before all the other organisms.
2. The eucalyptus leaves and ferns were deposited first followed by shells and fish.
3. The trees in the forest absorbed all the water and then died.
4. There is no water in the fossil layers.

Appendix F: Ecology two-tier multiple-choice test

NAME: ____________________________________ AGE: ________

Predicted mark ______________ out of 20

<u>Instructions to Students</u>

This diagnostic instrument consists of 10 items that evaluate your understanding of ecology.

Each item has two parts: a <u>multiple-choice response</u> followed by a <u>multiple-choice reason.</u>

For each item, you are asked to make the **most appropriate** choice (A, B, C, etc.) from the <u>multiple-choice response</u> section.

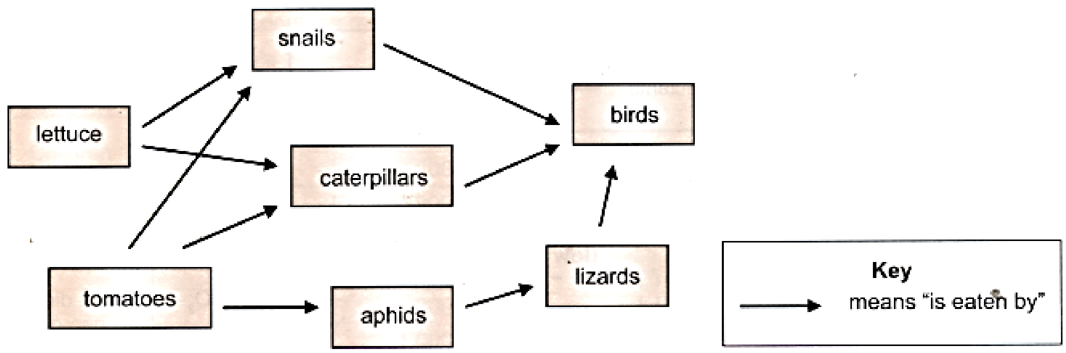
Then choose one of the reasons from the <u>multiple-choice reason</u> section (1, 2, 3, etc.) that best matches your answer to the first part.

If you do not agree with any of the given reasons, please write your reason in the space provided.

Remember it is important to provide a reason for selecting a particular response in each item.

For questions 1 and 2 use the information below.

Helen has a vegetable garden. The food web shows some of the plants and animals, and what the animals eat.



Question 1
Helen wants to reduce the number of snails in her garden.
She probably wants to do this because

A) The snails eat her plants.
B) The birds prefer caterpillars to snails.
C) The snails compete with caterpillars for food.
D) The birds eat more snails than caterpillars or lizards.

The reason I chose my answer is:

1. Snails eat a lot of lettuce compared to other organisms.
2. If the snail population is low the birds will eat more caterpillars.
3. It is easier to kill snails than caterpillars.
4. It is easier for birds to see snails from a distance.

Question 2
Helen does not want to use chemicals in her garden.
What would be the best thing for her to do to reduce the number of snails in her garden?

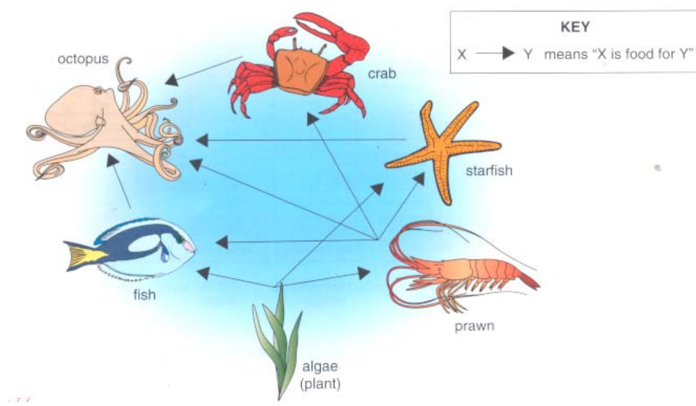
A) Grow fewer lettuce and more tomato plants.
B) Plant native trees to attract more birds to her garden.
C) Plant more tomatoes to increase the number of caterpillars.
D) Introduce an animal that eats lizards so the birds will eat more snails.

The reason I chose my answer is:

1. If there are less lettuces the snails will not have enough food and will die.
2. If the population of birds increases, more snails will be eaten by the birds.
3. If the population of caterpillars increases they will eat most of the lettuces and the snails will have less food to eat.
4. If the lizard population decreases the birds will eat more snails.

For questions 3 and 4 use the information below.

The diagram shows a rock pool food web.



Carnivores are animals that only eat animals.
Herbivores are animals that only eat plants.
Omnivores are animals that eat both plants and animals.

Question 3

Which option classifies the fish and the prawn correctly?

	Fish	**prawn**
A)	Carnivore	omnivore
B)	Carnivore	herbivore
C)	Omnivore	herbivore
D)	Omnivore	omnivore

The reason I chose my answer is:

1. Fish only eat plants and prawns only eat animals.
2. Fish eat both plants and animals whereas prawns only eat animals .
3. Fish only eat animals whereas prawns only eat plants.
4. Fish eat both plants and animals whereas prawns only eat plants.

Question 4

- A predator-prey interaction occurs when one animal is a food source for another animal.
- Two animal species are competitors if they eat the same food source.

What relationship occurs between octopus and prawn, and what relationship occurs between crab and fish?

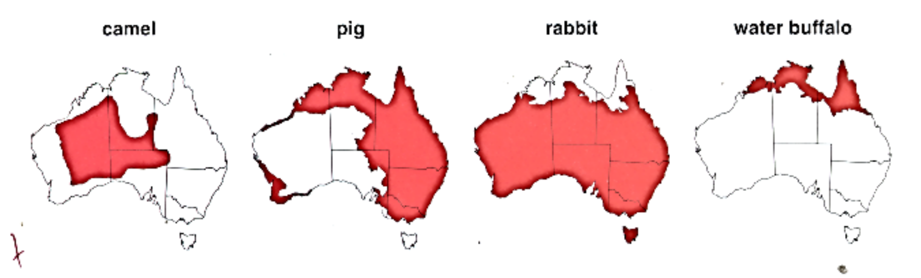
	Octopus and prawn	**crab and fish**
A)	Competitors	competitors
B)	Competitors	predator-prey
C)	Predator-prey	competitors
D)	Predator-prey	predator-prey

The reason I chose my answer is:

1. Octopuses and prawns eat the same food whereas fish eat crabs.
2. Octopuses eat prawns whereas crabs and fish eat the same food.
3. Fish and crabs are eaten by octopuses whereas fish eat prawns.
4. Prawns eat octopuses whereas crabs and fish eat the same food.

For questions 5 and 6 use the information below.

The shaded areas on the maps show the distribution of some feral animals in Australia.



Question 5

Which feral animal is distributed over the smallest area?

A) Camel
B) Pig
C) Rabbit
D) Water buffalo

The reason I chose my answer is because

1 On the map this animal is only in central Australia
2 On the map this animal is only along the northern coastline of Australia
3 On the map this animal is only in north and Eastern Australia.
4 On the map this animal does not exist in Tasmania

Question 6

The map below shows the location of Kakadu National Park in the Northern Territory.

Which feral animals are likely be found in Kakadu National Park?

A) Camels and pigs
B) Pigs and rabbits
C) Pigs and water buffalo
D) Rabbits and water buffalo

The reason I chose my answer is:

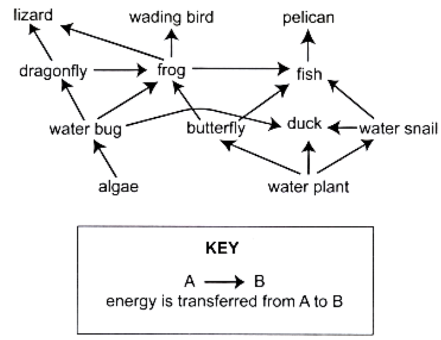
1. These animals are found in northern Australia
2. These animals are found in every part of Australia
3. These animals are found in central Australia
4. These animals move all over Australia

For questions 7 and 8 use the information below.

A food web shows how energy passes from one organism to another.

- A producer is an organism, usually a plant, which captures energy from the Sun through photosynthesis.
- A primary consumer is an animal that obtains energy by eating plants.
- A secondary consumer is an animal that obtains energy by eating primary consumers.

The diagram shows a food web in a wetlands ecosystem.



Question 7

Which organism is only a primary consumer?

A) Butterfly
B) Duck
C) Frog
D) Wading bird

The reason I chose my answer is:

1. This animal only eats one other organism.
2. This animals only eats animals.
3. This animal eats plants and animals.
4. This animal only eats plants.

Question 8

Which organism is both a primary and a secondary consumer in this ecosystem?

A) Butterfly
B) Duck
C) Frog
D) Wading bird

The reason I chose my answer is:

5. This animal only eats one organism.
6. This animal eats two types of animals.
7. This animal eats plants and animals.
8. This animal only eats plants.

For questions 9 and 10 use the information below.

The New South Wales Environment Protection Authority monitors air quality using a regional pollution index (RPI). The RPI for a particular pollutant is calculated by:

RPI = (Pollutant concentration ÷ pollutant standard level) x 50
Low = RPI between 0 and 24
Medium = RPI between 25 and 49
High = RPI 50 or higher

Question 9

Ozone is a pollutant. On a particular day, the RPI of ozone was 85.
Which of the following statements is correct?

A) The RPI for ozone was low for that day.
B) The RPI for ozone was medium for that day.
C) The concentration of ozone was less than the pollutant's standard level.
D) The concentration of ozone was more than the pollutant's standard level.

The reason I chose my answer is:

5. An RPI 85 means the pollution is less than 100%.
6. An RPI of 85 means the concentration of the pollutant is lower than normal.
7. An RPI of 85 means the pollutant concentration significantly greater than that in the pollutant standard level.
8. The ratio of the pollutant concentration to pollutant standard level is 85:1.

Question 10

The standard level for the pollutant, nitrogen dioxide, is 0.12 parts per million (ppm) per hour. Scientists monitored the levels of nitrogen dioxide for one hour and determined the RPI to be 25.

What was the concentration (ppm per hour) of nitrogen dioxide?

F) 0.06
G) 0.24
H) 0.50
I) 0.60

The reason I chose my answer is:

1. I calculated the pollutant concentration by multiplying the RPI by the pollutant standard level, and then divide by 50.
2. I calculated the pollutant concentration by dividing the RPI by the pollutant standard level, and then multiplying by 50.
3. I calculated the pollutant concentration by dividing the RPI by 50, and then added the standard level.
4. I calculated the pollutant concentration by dividing 50 by the RPI, and then multiplied by the standard level.

Appendix G: Northern Territory Science Curriculum-learning outcomes

NT Curriculum Framework

The updated Science Learning Area (2009) is organised into 5 strands. Each strand has a number of elements which are used to organise the indicators which provide the scope for planning and assessing learning within a Band level.

The Science as Inquiry strand should be integrated with the **concept strands** illustrating that all science knowledge is a result of an ongoing inquiry process. This integration facilitates rich and contextualised inquiry into each concept area. ‘Understanding and Acting on Personal and Social Issues’ within Science as Inquiry provides direction for teachers as to possible real world contexts by which learners can make sense of the ideas to be learnt.

.For example, students working towards Band 2 Life and Living and Science as Inquiry outcomes could care for stick insects and learn about insect life cycles through collaboratively planning, conducting and reporting on their own observations of insect life cycles. They may observe and measure the growth of stick insects, count and record egg production, observe insect behaviour and other changes such as skin shedding and synthesise and communicate their findings.

Strands	Elements
Science as Inquiry	**Understanding and Acting on Personal and Social Issues** recognise the contribution of science to many aspects of our daily life and consider how science may help us to address challenges of the future consider the ethical implications of new science applications **Investigating** **Planning investigations** generate ideas and plan investigations including experimental inquiry, field testing, modelling, simulations, secondary source research **Conducting investigations** conduct investigations and record data **Processing and analysing** process and interpret information and draw conclusions **Evaluating** reflect and evaluate on procedures, generate further ideas and communicate findings
Life and Living	**Interdependence of living things and their environment** living things respond to and interact with each other and their environment and are part of a dynamic and interdependent system **Structure and function** a relationship exists between the structure and function of organisms and this helps them to survive in their environment **Reproduction and change** all living things grow and change over time. Diversity of life is ensured through inheritance and evolution.
Natural and Processed Materials	**Structures, properties and uses** • different materials have different properties that can be explained by their substructure and different materials have different uses dependent on their properties

	Interactions and change • materials, their properties and their uses can be changed through physical and chemical changes
Earth and Beyond	**Earth's resources and sustainability** • the earth and our atmosphere provide resources which support life and these resources need to be used wisely to ensure a sustainable future **Earth in space** • processes within the earth our atmosphere and our place in the universe impact upon the way we live
Energy and Change	**Sources, patterns and uses** • there are different sources and uses of energy which have different consequences **Transfers and transformations** • energy can be transferred and transformed so that we can use it

Appendix H: Australian National Science Curriculum

AUSTRALIAN NATIONAL SCIENCE CURRICULUM

Content structure

The Australian Curriculum: Science has three interrelated strands: *Science Understanding, Science as a Human Endeavour* and *Science Inquiry Skills*.

Together, the three strands of the science curriculum provide students with understanding, knowledge and skills through which they can develop a scientific view of the world. Students are challenged to explore science, its concepts, nature and uses through clearly described inquiry processes.

Science Understanding

Science understanding is evident when a person selects and integrates appropriate science knowledge to explain and predict phenomena, and applies that knowledge to new situations. Science knowledge refers to facts, concepts, principles, laws, theories and models that have been established by scientists over time.

The *Science Understanding* strand comprises four sub-strands. The content is described by year level.

Biological sciences

The biological sciences sub-strand is concerned with understanding living things. The key concepts developed within this sub-strand are that: a diverse range of living things have evolved on Earth over hundreds of millions of years; living things are interdependent and interact with each other and their environment; and the form and features of living things are related to the functions that their body systems perform. Through this sub-strand, students investigate living things, including animals, plants, and micro-organisms, and their interdependence and interactions within ecosystems. They explore their life cycles, body systems, structural adaptations and behaviours, how these features aid survival, and how their characteristics are inherited from one generation to the next. Students are introduced to the cell as the basic unit of life and the processes that are central to its function.

Chemical sciences

The chemical sciences sub-strand is concerned with understanding the composition and behaviour of substances. The key concepts developed within this sub-strand are that: the chemical and physical properties of substances are determined by their structure at an atomic scale; and that substances change and new substances are produced by rearranging atoms through atomic interactions and energy transfer. In this sub-strand, students classify substances based on their properties, such as solids, liquids and gases, or their composition, such as elements, compounds and mixtures. They explore physical changes such as changes of state and dissolving, and investigate how chemical reactions result in the production of new substances. Students recognise that all substances consist of atoms which can combine to form molecules, and chemical reactions involve atoms being rearranged and recombined to form new substances. They explore the relationship between the way in which atoms are arranged and the properties of substances, and the effect of energy transfers on these arrangements.

Earth and space sciences

The Earth and space sciences sub-strand is concerned with Earth's dynamic structure and its place in the cosmos. The key concepts developed within this sub-strand are that: Earth is part of a solar system that is part of a larger universe; and Earth is subject to change within and on its surface, over a range of timescales as a result of natural processes and human use of resources. Through this sub-strand, students view Earth as part of a solar system, which is part of a galaxy, which is one of many in the universe and explore the immense scales associated with space. They explore how changes on Earth, such as day and night and the seasons relate to Earth's rotation and its orbit around the sun. Students investigate the processes that result in change to Earth's surface, recognising that Earth has evolved over 4.5 billion years and that the effect of some of these processes is only evident when viewed over extremely long timescales. They explore the ways in which humans use resources from the Earth and appreciate the influence of human activity on the surface of the Earth and the atmosphere.

Physical sciences

The physical sciences sub-strand is concerned with understanding the nature of forces and motion, and matter and energy. The two key concepts developed within this sub-strand are that: forces affect the behaviour of objects; and that energy can be transferred and transformed from one form to another. Through this sub-strand students gain an understanding of how an object's motion (direction, speed and acceleration) is influenced by a range of contact and non-contact forces such as friction, magnetism, gravity and electrostatic forces. They develop an understanding of the concept of energy and how energy transfer is associated with phenomena involving motion, heat, sound, light and electricity. They appreciate that concepts of force, motion, matter and energy apply to systems ranging in scale from atoms to the universe itself.

Science as a Human Endeavour

Through science, humans seek to improve their understanding and explanations of the natural world. Science involves the construction of explanations based on evidence and science knowledge can be changed as new evidence becomes available. Science influences society by posing, and responding to, social and ethical questions, and scientific research is itself influenced by the needs and priorities of society. This strand highlights the development of science as a unique way of knowing and doing, and the role of science in contemporary decision making and problem solving. It acknowledges that in making decisions about science practices and applications, ethical and social implications must be taken into account. This strand also recognises that science advances through the contributions of many different people from different cultures and that there are many rewarding science-based career paths.

The content in the *Science as a Human Endeavour* strand is described in two-year bands. There are two sub-strands of *Science as a Human Endeavour*. These are:

Nature and development of science: This sub-strand develops an appreciation of the unique nature of science and scientific knowledge, including how current knowledge has developed over time through the actions of many people.

Use and influence of science: This sub-strand explores how science knowledge and applications affect peoples' lives, including their work, and how science is influenced by society and can be used to inform decisions and actions.

Science Inquiry Skills

Science inquiry involves identifying and posing questions; planning, conducting and reflecting on investigations; processing, analysing and interpreting evidence; and communicating findings. This strand is concerned with evaluating claims, investigating ideas, solving problems, drawing valid conclusions and developing evidence-based arguments.

Science investigations are activities in which ideas, predictions or hypotheses are tested and conclusions are drawn in response to a question or problem. Investigations can involve a range of activities, including experimental testing, field work, locating and using information sources, conducting surveys, and using modelling and simulations. The choice of the approach taken will depend on the context and subject of the investigation.

In science investigations, collection and analysis of data and evidence play a major role. This can involve collecting or extracting information and reorganising data in the form of tables, graphs, flow charts, diagrams, prose, keys, spreadsheets and databases.

The content in the *Science Inquiry Skills* strand is described in two-year bands. There are five sub-strands of *Science Inquiry Skills*. These are:

Questioning and predicting: Identifying and constructing questions, proposing hypotheses and suggesting possible outcomes.

Planning and conducting: Making decisions regarding how to investigate or solve a problem and carrying out an investigation, including the collection of data.

Processing and analysing data and information: Representing data in meaningful and useful ways; identifying trends, patterns and relationships in data, and using this evidence to justify conclusions.

Evaluating: Considering the quality of available evidence and the merit or significance of a claim, proposition or conclusion with reference to that evidence.

Communicating: Conveying information or ideas to others through appropriate representations, text types and modes.

Relationship between the strands

In the practice of science, the three strands of *Science Understanding*, *Science as a Human Endeavour* and *Science Inquiry Skills* are closely integrated; the work of scientists reflects the nature and development of science, is built around scientific inquiry and seeks to respond to and influence society's needs. Students' experiences of school science should mirror and connect to this multifaceted view of science.

To achieve this, the three strands of the Australian Curriculum: Science should be taught in an integrated way. The content descriptions of the three strands have been written so that at each year this integration is possible. In the earlier years, the 'Nature and development of science' sub-strand within the *Science as a Human Endeavour* strand focuses on scientific inquiry. This enables students to make clear connections between the inquiry skills that they are learning and the work of scientists. As students progress through the curriculum they investigate how science understanding has developed, including considering some of the people and the stories behind these advances in science.

They will also recognise how this science understanding can be applied to their lives and the lives of others. As students develop a more sophisticated understanding of the knowledge and skills of science they are increasingly able to appreciate the role of science in society. The content of the *Science Understanding* strand will inform students' understanding of contemporary issues, such as climate change, use of resources, medical interventions, biodiversity and the origins of the universe. The importance of these areas of science can be emphasised through the content of the *Science as a Human Endeavour* strand, and students can be encouraged to view contemporary science critically through aspects of the *Science Inquiry Skills* strand, for example by analysing, evaluating and communicating.

Year level descriptions

Year level descriptions have three functions. Firstly, they emphasise the interrelated nature of the three strands, and the expectation that planning a science program will involve integration of content from across the strands. Secondly, they re-emphasise the overarching ideas as appropriate for that stage of schooling. Thirdly, they provide an overview of the content for the year level.

Content descriptions

The Australian Curriculum: Science includes content descriptions at each year level. These describe the knowledge, concepts, skills and processes that teachers are expected to teach and students are expected to learn. However, they do not prescribe approaches to teaching. While *Science Understanding* content is presented in year levels, when units of work are devised, attention should be given to the coverage of content from *Science Inquiry Skills* and *Science as a Human Endeavour* over the two-year band. The content descriptions ensure that learning is appropriately ordered and that unnecessary repetition is avoided. However, a concept or skill introduced at one year level may be revisited, strengthened and extended at later year levels as needed.

Content elaborations

Content elaborations are provided for Foundation to Year 10 to illustrate and exemplify content and assist teachers to develop a common understanding of the content descriptions. They are not intended to be comprehensive content points that all students need to be taught.

Appendix I: Examples of focused outcomes of topics covered in Year 7 in the third cycle

2012 Term 2 Year 7 Science Focused outcomes

Topic-classification of living organisms and feeding relationships (Taxonomy and Ecology)

At the end of this topic, the students should be able to:

- Describe the characteristics of living things.
- Differentiate between breathing and respiration
- Differentiate between excretion and elimination.
- Compare and contrast living and non-living things.
- Sort organisms in groups by using their natural characteristics
- Compare organisms by using their natural characteristics.
- Identify and classify living organisms by using tree diagrams and dichotomous keys.
- Classify plants and animals into kingdoms, phyla, order, family, genera and specie.
- Follow internationally accepted scientific convention to write scientific names of living organisms.
- Identify the different parts of a microscope and describe their uses.
- Prepare and mount a slide, and work out the magnification.
- Use a microscope to observe, draw and label small living organisms.
- Identify biotic and abiotic components in a given ecosystem.
- Describe and explain the interdependence of biotic and abiotic components of a given ecosystem.
- Use food chains and food webs to describe the feeding relationships between living organisms in an ecosystem.
- Identify the producers, primary consumers, secondary consumers, tertiary consumers and decomposers in a food web.
- Analyse the flow of energy within a food chain.

Appendix J: Example of focused outcomes of Year 8 topics in the third cycle

2012 Term 2 Year 8 Science focused outcomes

Topic-Dynamic Earth (Geology)

At the end of this topic students should be able to:

- Describe structure of a cross-section of the earth.
- Identify the different parts of the earth.
- Describe the structure and composition of the different parts of the earth.
- Explain how the different types of rocks are formed.
- Identify and classify the different types of rocks.
- Explain, and give examples which support, the plate tectonic theory.
- Explain how earthquakes, faulting and folding occur by using the plate tectonic theory.
- List the different types of fossil fuels
- Describe how fossil fuels were formed.
- Describe and explain the processes involved in refining crude oil.
- Name and gives uses of the different components of crude oil.
- Differentiate between renewable and non-renewable energy sources.
- Explain the environmental effects of excessive use of fossil fuels such as the greenhouse effect, acid rain and photochemical smog.
- List and describe alternative energy sources.
- Explain the advantages and disadvantages of using alternative energy sources such as wind power, nuclear power, hydro power, biogas etc
- Argue for or against the use of nuclear power.

Appendix K: Examples of focused outcomes in Year 9 topics covered in the third cycle

<u>2012 YEAR 9 TERM 2 SCIENCE TEACHING SEQUENCE</u>

TOPIC-ENVIRONMENTAL HEALTH

At the end of this topic students should be able to:

- Describe and compare the biotic and abiotic components of:
  Natural environments such as oceans, rainforests, deserts, grasslands etc
  Man made environments such as cities, dams, parks etc
  Virtual environments such on line, electronic games

- Define or describe the following terms: Ecosystem, habitat, food chains and food webs
- Explain and analyse the energy flow in a food chain
- Explain how biomagnification and bioaccumulation occur in a food chain
- State factors which affect our natural environment-water, temperature, air etc
- Describe and explain the effects of some environmental problems such as bushfires, floods, earthquakes, volcanoes eruption (Ice land), drought and cyclone (Comprehension on real life examples especially recent ones such as the volcanic eruptions in Ice Land, Cyclone in Indonesia, and tornadoes in America etc)

- Define pollution
- Describe the different types of pollution such as air pollution, water pollution and land pollution.
- Describe the causes and effects of salinity, soil erosion and eutrophication
- Make observations and assess the health of our local environment-rubbish, oil spills, Test pH, dissolved O_2, salinity, temperature
- Use the PH scale to analyse the acid-base nature of common household materials.
- Prepare and use an indicator (Red cabbage indicator).
- Design an experiment to find out the effect of pH on seed growth

- Rapid Creek Excursion-Carry out various test s on water and soil samples at three different points of Rapid Creek River. The tests include: PH, turbidity, salinity (electrical conductivity), temperature, phosphates, nitrates and oxygen.

- A field report (Rapid creek excursion report) to be written over a period of two weeks
- To effectively use a **marking rubric** as a guide when writing the field report
- Describe the structure of an atom and the properties of the sub-atomic particles (protons, electrons and neutrons)
- Explain the meaning of the terms atomic number, atomic mass (Mass number) and isotopes
- compare and identify elements, compounds and mixtures
- Explain the meaning of the term molecule and give examples of common molecules
- describe and analyse trends in the periodic table-Explain that elements in the periodic table are arranged in order of increasing atomic number.
- Predict the chemical and physical properties of elements in the same groups and periods.
- Use flame tests to identify elements.
- Appreciate the contribution Indigenous science has made to lives in modern Australia especially in medicine, tourism and environmental health

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APPENDIX A: Format of the Semi-Structured Interview with the CDD's Representative

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Curtin University

INTERVIEW FORMAT FOR THE INTENDED CURRICULUM

Part A- Personal background

1. What is your name?
2. What is your role in the CDD?

Part B- The Curriculum Development Division (CDD) intentions

1. How does the CDD intend the chemistry teachers to implement or manage the chemistry lessons? / Why?
2. How does the CDD intend the students to have their experiences after each of the chemistry lesson? / Why?
3. How does the CDD intend the students to have their achievements after each of the chemistry lesson? / Why?
4. How does the CDD intend the interactions between the teacher-students to take place during the chemistry lesson? / Why?
5. In what way do the CDD intentions have been informed to the chemistry teachers? / How well?

Part C- Chemistry Curriculum in Malaysian context

1. What does the Chemistry Curriculum actually refer to in the Malaysian education context? / What actually does the Chemistry Curriculum represent?
2. How important is the Chemistry Curriculum to chemistry teachers? / Why?
3. What is the basis of the development of the Malaysian Chemistry Curriculum?
4. Who was involved in the development of the Chemistry Curriculum?

APPENDIX B: Interview Transcript with the CDD's Representative

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CDD/MOE/16.02.2011

Interviewer: Ph.D. student from Science and Mathematics Education Centre, Curtin University, Perth, Australia.

Interviewee: Curriculum Officer responsible for the Chemistry Curriculum Form 4 and 5 in Curriculum Development Division, Ministry of Education, Malaysia.

Interview Setting: Interview conducted in interviewee's office located at Curriculum Development Division, Ministry of Education, Putrajaya, Malaysia. The interview was conducted at 3.00 PM on 16 February 2011 (Wednesday).

(Start of Interview)

Interviewer: How does the CDD intend the chemistry teachers to implement the chemistry lessons?

Interviewee: Teachers are encourage to employ a variety of approaches such as inquiry discovery, constructivism, contextual learning, mastery learning, science, technology and society or other approaches when planning for the lessons T & L (teaching and learning) methods. Teachers may use various methods such as experiments, discussions, simulations, projects, field trips and visits with the use of technology where applicable… In the curriculum, the teaching-learning methods suggested are stated under the column "Suggested Learning Activities."

Interviewer: How does the CDD intend the students to have their experiences after each of the chemistry lesson, for example in term of students' attitudes and perceptions towards the lesson?

Interviewee: After each chemistry lesson, it is expected that students will achieve the intended learning outcomes, be motivated with the student centred activities... have fun, excitement and accept the challenges involved through solving the tasks or problems given by the teachers or peers through good working etiquette. The activities must be seen as relevant to the student so that they are engaged in the activities and felt that they have learnt and achieved at least some knowledge and understanding of chemistry. The teachers must be able to provide opportunities for students to experience the chemistry concepts and principles in an articulated manner.

Interviewer: How does the CDD intend the students to have their achievements after each of the chemistry lesson?

Interviewee: During the lessons, the teacher will be giving good constructive questions, from low to high order thinking questions, to build the students' understanding on the scientific concepts or principles for the lesson. At the end of the lesson, teacher will give a task to the students as formative assessment in order to get feedback on the students' achievements for that lesson. The feedback will be used by the teacher to take improve the students' achievement.

Interviewer: How does the CDD intend the interactions between the teacher-students to take place during the chemistry lesson?

Interviewee: Encourage teachers to always plan students-centred lessons and most of the time the teacher act as the facilitator. Where possible the students decide the depth of the objectives and the type of activities involved.

Interviewer: Why emphasise student-centred learning?

Interviewee: To give students the opportunity to experience what they want to know and study… thus, giving the students the autonomy, confidence, interest and perseverance in what they are doing… and the real feeling of being a scientist, researcher or investigator.

Interviewer: In what way do the CDD intentions have been informed to the chemistry teachers?

Interviewee: The chemistry teachers have been informed through promotional events on curriculum, science and mathematics orientation courses in collaboration with MOE, State Education Department, or District Education Office, and in house training by senior teachers in their own schools

Interviewer: How well the CDD intentions have been informed to the chemistry teachers?

Interviewee: CDD monitoring shows that the impact is very little, since the courses were done through the cascading model causing the dilution factors in the training process.

Interviewer: What actually does the Chemistry Curriculum represent?

Interviewee: Chemistry curriculum specifications which represents the whole year study programs in secondary schools.

Interviewer: How important is the Chemistry Curriculum to chemistry teachers?

Interviewee: It is compulsory for teachers to adhere to the curriculum since the summative assessment will be based on the learning outcomes in the curriculum specifications by the Malaysian Assessment Syndicate at the end of the full course. Their achievements in this summative assessment may have high stakes for the students and the teachers too!

Interviewer: What is the basis of the development of the Malaysian Chemistry Curriculum?

Interviewee: The developments of Chemistry Curriculum are based on the National Philosophy of Education and National Science Education Philosophy.

Interviewer: Who was involved in the development of the Chemistry Curriculum?

Interviewee: MOE's curriculum officers, professional bodies, industries representatives, universities lecturers, expert teachers and experience teachers.

(End of Interview)

APPENDIX C: Questionnaire of Enacted Curriculum (QEC) – *Teacher Edition*

Curtin University

Science & Mathematics Education Centre (SMEC)

QUESTIONNAIRE OF ENACTED CURRICULUM

Teacher Edition
Chemistry
Acids & Bases Lessons

My name is Muhd Ibrahim Muhamad Damanhuri and currently am completing research for my Ph.D. at Curtin University in Perth, Western Australia. I am investigating the effectiveness of the acids-bases topic in the acids and bases lesson curriculum prepared by Curriculum Development Division (CDD), Malaysian Ministry of Education. This information can be used to assist Malaysian acids and bases lesson teachers like yourself in making acids and bases lesson lessons of the Form 4 acids and bases lesson curriculum more interesting and better understood. Your involvement in this research is entirely **voluntary**. You should be aware that you have the right to discontinue your participation at any time without affecting your personal or social life in any way. Your identity will be kept **confidential** and **anonymous** throughout this study.

If you have any inquiries regarding the procedures or require further information, do not hesitate to contact me at +614 5057 8984 or e-mail me at muhdibrahim83@gmail.com. Alternatively you can contact my supervisor Professor David Treagust at +618 9266 7924 or d.f.treagust@curtin.edu.au.

Your participation in this research is highly appreciated and valuable. Thank you very much!

(Note: Your personal information will be kept personal.)

Name:___________________________ School: _______________________

Email:___________________________ Phone: ________________________

Instructions for Teacher

For all questions about classroom practices, please refer only to activities in the acids and bases lesson class that you teach. If you teach more than one acids and bases lesson class, select the first class that you teach each week. If you teach a split class (i.e., the class is split into more than one group for acids and bases lesson instruction) select only one group to describe as the target class.

Please read each question and the possible responses carefully, and then mark your response by filling in the appropriate circle to indicate your response. A pen or pencil may be used to complete the survey.

SECTION A: CLASSROOM DESCRIPTION

1. How many different chemistry classes do you currently teach?

   ① ② ③ ④ ⑤
   (Number of classes taught)

2. How many students are in the target chemistry class?

   ① 10 or fewer
   ② 11 to 20
   ③ 21 to 30
   ④ 31 to 40
   ⑤ 41 or more

3. During a typical week, approximately how many hours will the target class spend in chemistry instruction?

   ① ② ③ ④ ⑤ ⑥
   (Number of instructional hours)

4. What is the average length of each class period for the target chemistry class?

   ① Not applicable
   ② 20 to 30 minutes
   ③ 31 to 40 minutes
   ④ 41 to 50 minutes
   ⑤ More than 50 minutes.

5. What is the achievement level of most of the students in the target chemistry class, compared to national norms?

   ① High achievement levels.
   ② Average achievement levels.
   ③ Low achievement levels.
   ④ Mixed achievement levels.

6.	What is the medium of instruction in the target chemistry class?	① English language	③ Mix of languages.		
		② Malay language	④ Others: ____________		

7.	How the students were place in the target chemistry class?	① Ability or prior achievement.	④ Parent request.
		② Limited English proficiency.	⑤ Student decision.
		③ Teacher recommendation.	⑥ No one factor more than another.

SECTION B: INSTRUCTIONAL ACTIVITIES IN ACIDS AND BASES LESSONS

How often do you do each of the following in your acids and bases instruction?	**Never** takes place	**Almost Never** takes place	**Sometimes** takes place	**Almost Always** takes place	**Always** takes place
1. Introduce content through formal presentations.	⓪	①	②	③	④
2. Pose open-ended questions.	⓪	①	②	③	④
3. Engage the whole class in discussions.	⓪	①	②	③	④
4. Require students to supply evidence to support their claims.	⓪	①	②	③	④
5. Ask students to explain concepts to one another.	⓪	①	②	③	④
6. Ask students to consider alternative explanations.	⓪	①	②	③	④

7. Help students see connections between acids and bases lesson with other disciplines.	⓪	①	②	③	④
8. Assign acids and bases lesson homework.	⓪	①	②	③	④

How often do students take part in the following acids and bases lesson activities?	**Never** takes place	**Almost Never** takes place	**Sometimes** takes place	**Almost Always** takes place	**Always** takes place
9. Listen and take notes during presentation by teacher.	⓪	①	②	③	④
10. Work in groups.	⓪	①	②	③	④
11. Read from a chemistry textbook in class.	⓪	①	②	③	④
12. Follow specific instructions in an activity or investigation.	⓪	①	②	③	④
13. Answer textbook or worksheet questions.	⓪	①	②	③	④
14. Record, represent, and/or analyse data.	⓪	①	②	③	④
15. Do hands-on/laboratory acids and bases lesson activities or investigation.	⓪	①	②	③	④
16. Collect data (other than laboratory activities).	⓪	①	②	③	④

17.	Use computers, calculators, or other educational technology to learn acids and bases.	⓪	①	②	③	④

When students in the target class are engaged in laboratory activities, investigations, or experiments as part of acids and bases instruction, how much of that time do they:		**Never** takes place	**Almost Never** takes place	**Sometimes** takes place	**Almost Always** takes place	**Always** takes place
18.	Make educated guesses, predictions, or hypotheses.	⓪	①	②	③	④
19.	Use acids and bases lesson equipment or measuring tools.	⓪	①	②	③	④
20.	Collect data.	⓪	①	②	③	④
21.	Analyse and interpret acids and bases data.	⓪	①	②	③	④
22.	Design their own investigation or experiment to solve a scientific question.	⓪	①	②	③	④

When students in the target class collect data or information about acids and bases lesson from books, magazines, computers, or other sources (other than laboratory activities), how much of that time do they:		**Never** takes place	**Almost Never** takes place	**Sometimes** takes place	**Almost Always** takes place	**Always** takes place
23.	Make a prediction based on the data.	⓪	①	②	③	④
24.	Analyse and interpret the information or data orally or in writing.	⓪	①	②	③	④

25.	Use of laboratory instruments connected to computer (e.g., Computer Based Lab).	⓪	①	②	③	④
26.	Display and analyse data.	⓪	①	②	③	④

SECTION C: PROFESSIONAL DEVELOPMENT ACTIVITIES IN CHEMISTRY

Did your professional development activities (e.g., in service training/ workshop/ course) refer to the following issues?		**None**	**Minor**	**Moderate**	**Major**
1.	State chemistry content standards (e.g., what they are and how they are used).	⓪	①	②	③
2.	Alignment of chemistry instruction to curriculum.	⓪	①	②	③
3.	In-depth study of chemistry or specific concepts within chemistry (e.g., acids and bases lesson).	⓪	①	②	③
4.	State or district chemistry assessment (e.g., preparing, understanding, or interpreting assessment data).	⓪	①	②	③
5.	Interpretation of assessment data for use in chemistry instruction.	⓪	①	②	③

SECTION D: TEACHER CHARACTERISTICS

1.	Please indicate your gender.	Female ①	Male ②			
		Less than 1 year	1 – 5 years	6 – 10 years	11 – 15 years	More than 15 years
2.	How many years have you taught acids and bases lesson prior to this year?	①	②	③	④	⑤
3.	How long have you been assigned to teach at your current school?	①	②	③	④	⑤
4.	What is the highest degree you hold?	Does not apply ①	Bachelor ②	Master ③	Ph.D. ④	Other ⑤

Questionnaire End.

Thank You!

APPENDIX D: Questionnaire of Enacted Curriculum (QEC) – *Student Edition*

Science & Mathematics Education Centre (SMEC)

QUESTIONNAIRE OF ENACTED CURRICULUM
SOAL SELIDIK PERLAKSANAAN KURIKULUM

Student Edition
Edisi Pelajar

Chemistry
Kimia

Acids & Bases Lessons
Pembelajaran Asid & Bes

My name is Muhd Ibrahim Muhamad Damanhuri and currently am completing research for my Ph.D. at Curtin University in Perth, Western Australia. I am investigating the effectiveness of the acids-bases topic in the Chemistry curriculum prepared by Curriculum Development Division (CDD), Malaysian Ministry of Education. Your views about lessons on acids-bases chemistry are important. This information can be used to assist Malaysian chemistry teachers in making chemistry lessons of the Form 4 Chemistry curriculum more interesting and better understood. Your involvement in this research is entirely **voluntary**. You should be aware that you have the right to discontinue your participation at any time without affecting your personal or social life in any way. Your **identity** will be kept **confidential** and **anonymous** throughout this study.

Nama saya ialah Muhd Ibrahim Muhamad Damanhuri dan kini sedang melengkapkapkan kajian bagi Ph.D. saya di Curtin University, Perth, Western Australia. Saya sedang menyiasat keberkesanan tajuk asid-bes daripada kurikulum kimia yang disediakan oleh Bahagian Pembangunan Kurikulum (BPK), Kementerian Pelajaran Malaysia. Pandangan anda dalam pembelajaran tajuk asid-bes ini adalah sangat penting. Maklumat tersebut boleh digunakan untuk membantu guru-guru kimia di Malaysia untuk menjadikan pembelajaran kimia bagi kurikulum kimia Tingkatan 4 lebih menarik dan lebih mudah difahami. Penyertaan anda dalam kajian ini adalah secara ***sukarela****. Perlu diingatkan di sini bahawa anda mempunyai hak untuk berhenti menyertai kajian ini pada bila-bila masa tanpa mengugat kehidupan peribadi atau sosial anda.* ***Identiti*** *anda akan* ***dirahsiakan*** *dan* ***dilindungi*** *sepanjang kajian ini.*

Your participation in this research is highly appreciated. Thank you!
Penyertaan anda dalam kajian ini amatlah dihargai. Terima kasih!

(Note: Your personal information will be kept personal.)
(Nota: Maklumat peribadi anda akan dirahsiakan)

Name/*Nama*:____________________________ Gender/*Jantina*: ________________

Form/*Tingkatan*:_____________ School/*Sekolah*: _____________________________

Instruction to student: This survey is **bilingual**. Please read each question and the possible responses carefully. **Mark** your response by filling in the appropriate **circle**. A pen or pencil may be used to complete the survey.
Arahan kepada pelajar: *Soal selidik ini adalah dalam* ***dwibahasa****. Sila baca setiap soalan dan pilihan respon yang diberikan dengan teliti.* ***Tandakan*** *pilihan anda dengan mengisi bahagian dalam* ***bulatan*** *yang berkenaan. Pen atau pensil boleh digunakan untuk melengkapkan soal selidik ini.*

SECTION A: CLASSROOM DESCRIPTION
SEKSYEN A: MAKLUMAT KELAS

1. What is your PMR science result?
Apakah keputusan sains PMR anda?

① A ② B ③ C ④ D ⑤ E

2. What is the medium of teaching and learning in your chemistry class?
Apakah medium pengajaran dan pembelajaran di dalam kelas kimia anda?

① English language *Bahasa Inggeris*
② Malay language *Bahasa Malaysia*
③ Mix of languages *Campuran bahasa*
④ Others: ______________ *Lain-lain:* ______________

SECTION B: INSTRUCTIONAL ACTIVITIES IN ACIDS AND BASES LESSONS
SEKSYEN B: AKTIVITI PENGAJARAN DALAM PELAJARAN ASID DAN BES

How often your chemistry teacher do each of the following in your acids and bases instruction? ***Berapa kerap guru kimia anda melakukan setiap aktiviti pengajaran asid dan bes berikut?***	**Never** takes place/ ***Tidak*** *berlaku*	**Almost Never** takes place/ ***Hampir*** *Tidak berlaku*	**Sometimes** takes place/ ***Kadang-kadang*** *berlaku*	**Almost Always** takes place/ ***Hampir Selalu*** *berlaku*	**Always** takes place/ ***Selalu*** *berlaku*
1. Teacher introduces content on the blackboard/whiteboard. *Guru memperkenalkan kandungan di atas papan hitam/papan putih.*	⓪	①	②	③	④

2.	Pose questions without a single answer. *Menanyakan soalan yang tidak hanya mempunyai satu jawapan sahaja.*	⓪	①	②	③	④
3.	Engage the whole class in discussions. *Melibatkan seluruh kelas di dalam perbincangan.*	⓪	①	②	③	④
4.	Require students to supply evidence to support their claims. *Memerlukan pelajar untuk menyediakan bukti bagi menyokong hujah mereka.*	⓪	①	②	③	④
5.	Ask students to explain concepts to one another. *Meminta pelajar untuk menerangkan konsep antara satu sama lain.*	⓪	①	②	③	④
6.	Ask students to consider alternative explanations. *Meminta pelajar menimbangkan penjelasan alternatif.*	⓪	①	②	③	④
7.	Help students see connections between acids and bases lesson with other disciplines. *Membantu pelajar membuat hubungan atara pelajaran asid dan bes dengan pelajaran lain.*	⓪	①	②	③	④
8.	Assign acids and bases lesson homework. *Menugaskan pelajaran asid dan bes sebagai kerja rumah.*	⓪	①	②	③	④

How often do you take part in the following acids and bases lesson activities? ***Berapa kerap anda turut serta dalam aktiviti pelajaran asid dan bes berikut?***	**Never** takes place/ ***Tidak** berlaku*	**Almost Never** takes place/ ***Hampir** Tidak berlaku*	**Sometimes** takes place/ ***Kadang-kadang** berlaku*	**Almost Always** takes place/ ***Hampir Selalu** berlaku*	**Always** takes place/ ***Selalu** berlaku*
9. Listen and take notes during presentation by teacher. *Mendengar dan mengambil nota semasa guru mengajar.*	⓪	①	②	③	④
10. Work in groups. *Bekerja di dalam kumpulan.*	⓪	①	②	③	④
11. Read about acids and bases from a chemistry textbook in class. *Membaca mengenai asid dan bes daripda buku teks kimia di dalam kelas.*	⓪	①	②	③	④
12. Follow specific instructions in an activity or investigation. *Mengikut arahan khusus di dalam suatu aktiviti atau penyiasatan.*	⓪	①	②	③	④
13. Answer textbook or worksheet questions. *Menjawab soalan-soalan buku teks atau lembaran kerja.*	⓪	①	②	③	④
14. Record, represent, and/or analyse data. *Merekod, mempersembahkan, dan/atau menganalisa data.*	⓪	①	②	③	④
15. Do hands-on/laboratory acids and bases lesson activities or investigation. *Melakukan aktiviti praktikal/aktiviti makmal atau penyiasatan bagi pelajaran asid dan bes.*	⓪	①	②	③	④

16. Collect data (other than laboratory activities). *Mengutip data (selain daripada aktiviti makmal).*	⓪	①	②	③	④
17. Use computers, calculators, or other educational technology to learn acids and bases. *Menggunakan komputer, kalkulator, atau teknologi pendidikan lain untuk mempelajari asid dan bes.*	⓪	①	②	③	④

When you are engaged in laboratory activities, investigations, or experiments as part of acids and bases lesson, how often of that activities do you: ***Apabila anda turut serta di dalam aktiviti makmal, penyiasatan, atau eksperimen dalam pelajaran asid dan bes, berapa kerap anda menjalankan aktiviti berikut:***	**Never** takes place/ ***Tidak** berlaku*	**Almost Never** takes place/ ***Hampir** Tidak berlaku*	**Sometimes** takes place/ ***Kadang-kadang** berlaku*	**Almost Always** takes place/ ***Hampir Selalu** berlaku*	**Always** takes place/ ***Selalu** berlaku*
18. Make educated guesses, predictions, or hypotheses. *Melakukan tekaan bijak, ramalan, atau hipotesis.*	⓪	①	②	③	④
19. Use acids and bases equipment or measuring tools. *Menggunakan kelengkapan atau alat sukatan asid dan bes.*	⓪	①	②	③	④
20. Collect data. *Mengutip data.*	⓪	①	②	③	④
21. Analyse and interpret acids and bases data. *Menganalisa dan menterjemahkan data asid dan bes.*	⓪	①	②	③	④
22. Design own investigation or experiment to solve a scientific question. *Mereka bentuk penyiasatan sendiri untuk menyelesaikan persoalan saintifik.*	⓪	①	②	③	④

When you are collecting data or information about acids and bases lesson from books, magazines, computers, or other sources (other than laboratory activities), how much of that time do you: ***Apabila anda mengutip data atau maklumat mengenai pelajaran asid dan bes daripada buku, majalah, komputer, atau daripada sumber lain (selain daripada aktiviti makmal), berapa banyak masa anda:***	**Never** takes place/ ***Tidak** berlaku*	**Almost Never** takes place/ ***Hampir** Tidak berlaku*	**Sometimes** takes place/ ***Kadang-kadang** berlaku*	**Almost Always** takes place/ ***Hampir Selalu** berlaku*	**Always** takes place/ ***Selalu** berlaku*
23. Make a prediction based on the data. *Membuat ramalan berdasarkan data.*	⓪	①	②	③	④
24. Analyse and interpret the information or data orally or in writing. *Menganalisa dan menterjemahkan maklumat atau data secara lisan atau bertulis.*	⓪	①	②	③	④
25. Use of laboratory instruments connected to computer (e.g., Computer Based Lab). *Menggunakan alatan makmal yang disambung kepada komputer (Contohnya, Makmal Berasaskan Komputer).*	⓪	①	②	③	④
26. Display and analyse data. *Mempamer dan menganalisa data.*	⓪	①	②	③	④

Questionnaire End.
Soal Selidik Tamat.

Thank You!
Terima Kasih!

APPENDIX E: Modified of the What Is Happening In This Class? (WIHIC) –

Actual Form

Curtin University

Science & Mathematics Education Centre (SMEC)

WHAT IS HAPPENING IN THIS CLASS?
APA YANG BERLAKU DALAM KELAS INI?

Actual Form
Borang Sebenar

Chemistry
Kimia

Acids & Bases Lessons
Pembelajaran Asid & Bes

My name is Muhd Ibrahim Muhamad Damanhuri and currently am completing research for my Ph.D. at Curtin University in Perth, Western Australia. I am investigating the effectiveness of the acids-bases topic in the Chemistry curriculum prepared by Curriculum Development Division (CDD), Malaysian Ministry of Education. Your views about lessons on acids-bases chemistry are important. This information can be used to assist Malaysian chemistry teachers in making chemistry lessons of the Form 4 Chemistry curriculum more interesting and better understood. Your involvement in this research is entirely **voluntary**. You should be aware that you have the right to discontinue your participation at any time without affecting your personal or social life in any way. Your **identity** will be kept **confidential** and **anonymous** throughout this study.

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Your participation in this research is highly appreciated. Thank you!
Penyertaan anda dalam kajian ini amatlah dihargai. Terima kasih!

(Note: Your personal information will be kept personal.)
(Nota: Maklumat peribadi anda akan dirahsiakan)

Name/*Nama*:____________________________ Gender/*Jantina*: ________________

Form/*Tingkatan*:_____________ School/*Sekolah*: _____________________________

Information for Students
Maklumat untuk Pelajar

1. This questionnaire is **bilingual**.
*Soal selidik ini adalah dalam **dwibahasa.***

2. This questionnaire consists of 41 items to describe your perceptions toward chemistry lesson practices. Decide **how often** for each of the practices takes place making use of the options provided. Draw a **circle** around the particular number of your choice to indicate your response.
*Soal selidik ini mengandungi 41 item bagi menggambarkan persepsi anda terhadap amalan pembelajaran kimia. Tentukan **berapa kerap** amalan tersebut berlaku menggunakan skala yang disediakan. **Bulatkan** pada nombor pilihan anda bagi menentukan respon anda.*

3. Answer **all** questions. **Thirty minutes** are allocated for this questionnaire.
*Jawab **semua** soalan. **Tiga puluh minit** diperuntukkan untuk soal selidik ini.*

4. Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements. There are no 'right' or 'wrong' answers. Your opinion is what is wanted.
Sesetengah pernyataan dalam soal selidik ini hampir sama dengan pernyataan yang lain. Jangan risau berkenaan ini. Berikan sahaja pendapat anda bagi semua pernyataan. Tiada jawapan 'betul' atau 'salah'. Hanya pendapat anda yang diperlukan.

Instruction: Decide **how often** for each of the practices takes place making use of the options below:
***Arahan:** Tentukan **berapa kerap** amalan tersebut berlaku menggunakan skala skala bawah:*

1	if the practice/*sekiranya amalan tersebut*	**Never** takes place/***Tidak** berlaku.*
2	if the practice/*sekiranya amalan tersebut*	**Almost Never** takes place/***Hampir Tidak** berlaku.*
3	if the practice/*sekiranya amalan tersebut*	**Sometimes** takes place/***Kadang-kadang** berlaku.*
4	if the practice/*sekiranya amalan tersebut*	**Almost Always** takes place/***Hampir Selalu** berlaku.*
5	if the practice/*sekiranya amalan tersebut*	**Always** takes place/***Selalu** berlaku.*

Draw a **circle** around the particular number of your choice to indicate your response.
***Bulatkan** pada nombor pilihan anda bagi menentukan respon anda*.

Items/*Item*		**Never** takes place/ ***Tidak*** *berlaku*	**Almost Never** takes place/ ***Hampir Tidak*** *berlaku*	**Sometimes** takes place/ ***Kadang-kadang*** *berlaku*	**Almost Always** takes place/ ***Hampir Selalu*** *berlaku*	**Always** takes place/ ***Selalu*** *berlaku*
1	The teacher takes a personal interest in me. *Guru memberi perhatian kepada saya.*	1	2	3	4	5
2	The teacher goes out of his/her way to help me. *Guru berusaha sedaya upaya untuk menolong saya.*	1	2	3	4	5
3	The teacher considers my feelings. *Guru mengambil kira perasaan saya.*	1	2	3	4	5
4	The teacher helps me when I have trouble with the work. *Guru menolong saya apabila saya menghadapi masalah dalam kerja saya*.	1	2	3	4	5
5	The teacher talks with me. *Guru bercakap-cakap dengan saya.*	1	2	3	4	5
6	The teacher is interested in my problems. *Guru berminat dengan masalah-masalah saya.*	1	2	3	4	5
7	The teacher moves about the class to talk with me. *Guru berusaha sedaya upaya untuk bercakap dengan saya.*	1	2	3	4	5
8	The teacher's questions help me to understand. *Soalan-soalan guru membantu saya untuk faham.*	1	2	3	4	5
9	I discuss ideas in class. *Saya berbincang idea-idea di dalam kelas.*	1	2	3	4	5
10	I give my opinion during class discussions. *Saya memberikan pendapat saya semasa perbincangan kelas.*	1	2	3	4	5
11	The teacher asks me questions. *Guru menyoal saya soalan.*	1	2	3	4	5
12	My ideas and suggestions are used during classroom discussions. *Idea–idea dan pendapat-pendapat saya digunakan semasa perbincangan kelas.*	1	2	3	4	5
13	I ask the teacher questions. *Saya bertanya soalan kepada guru.*	1	2	3	4	5

	Items/***Item***	**Never** takes place/ ***Tidak*** *berlaku*	**Almost Never** takes place/ ***Hampir Tidak*** *berlaku*	**Sometimes** takes place/ ***Kadang-kadang*** *berlaku*	**Almost Always** takes place/ ***Hampir Selalu*** *berlaku*	**Always** takes place/ ***Selalu*** *berlaku*
14	I explain my ideas to other students. *Saya menerangkan idea-idea saya kepada pelajar lain.*	1	2	3	4	5
15	Students discuss with me how to go about solving problems. *Pelajar-pelajar lain berbincang dengan saya untuk mencari penyelesaian sesuatu masalah.*	1	2	3	4	5
16	I am asked to explain how I solve problems. *Saya diminta untuk menerangkan bagaimana saya menyelesaikan masalah-masalah.*	1	2	3	4	5
17	I carry out investigations to test my ideas. *Saya mengendalikan penyiasatan untuk menguji idea-idea saya.*	1	2	3	4	5
18	I am asked to think about the evidence for statements. *Saya diminta berfikir untuk membuktikan sesuatu pernyataan.*	1	2	3	4	5
19	I carry out investigations to answer questions coming from discussions. *Saya menjalankan penyiasatan untuk menjawab soalan-soalan daripada perbincangan.*	1	2	3	4	5
20	I explain the meaning of statements, diagrams and graphs. *Saya menerangkan maksud pernyataan, gambarajah, dan graf.*	1	2	3	4	5
21	I carry out investigations to answer questions which puzzle me. *Saya menjalankan penyiasatan untuk menjawab soalan-soalan yang membinggungkan saya.*	1	2	3	4	5
22	I carry out investigations to answer the teacher's questions. *Saya menjalankan penyiasatan untuk menjawab soalan-soalan guru.*	1	2	3	4	5
23	I find out answers to questions by doing investigations. *Saya memperolehi sesuatu jawapan bagi soalan-soalan melalui penyiasatan.*	1	2	3	4	5

	Items/***Item***	**Never** takes place/ ***Tidak*** *berlaku*	**Almost Never** takes place/ ***Hampir Tidak*** *berlaku*	**Sometimes** takes place/ ***Kadang-kadang*** *berlaku*	**Almost Always** takes place/ ***Hampir Selalu*** *berlaku*	**Always** takes place/ ***Selalu*** *berlaku*
24	I solve problems by using information obtained from my own investigations. *Saya menyelesaikan masalah-masalah dengan menggunakan maklumat yang diperolehi daripada penyiasatan saya.*	1	2	3	4	5
25	I cooperate with other students when doing assignment work. *Saya berkerjasama dengan pelajar-pelajar lain apabila melakukan sesuatu tugasan.*	1	2	3	4	5
26	I share my books and resources with other students when doing assignments. *Saya berkongsi buku dan sumber-sumber lain dengan pelajar-pelajar lain semasa membuat tugasan.*	1	2	3	4	5
27	When I work in groups in this class, there is teamwork. *Semasa saya bekerja secara berkumpulan di dalam kelas, wujudnya kerjasama berpasukan.*	1	2	3	4	5
28	I work with other students on projects in this class. *Saya menjalankan tugas dengan pelajar lain bagi sesuatu projek di dalam kelas.*	1	2	3	4	5
29	I learn from other students in this class. *Saya belajar daripada pelajar-pelajar lain di dalam kelas ini.*	1	2	3	4	5
30	I work with other students in this class. *Saya melakukan tugas bersama-sama pelajar lain dalam kelas ini.*	1	2	3	4	5
31	I cooperate with other students on class activities. *Saya bekerjasama dengan pelajar-pelajar lain untuk menjalankan aktiviti-aktiviti kelas.*	1	2	3	4	5

	Items/***Item***	**Never** takes place/ ***Tidak*** *berlaku*	**Almost Never** takes place/ ***Hampir Tidak*** *berlaku*	**Sometimes** takes place/ ***Kadang-kadang*** *berlaku*	**Almost Always** takes place/ ***Hampir Selalu*** *berlaku*	**Always** takes place/ ***Selalu*** *berlaku*
32	Students work with me to achieve class goals. *Pelajar-pelajar lain melakukan tugas bersama saya bagi mencapai matlamat kelas.*	1	2	3	4	5
33	The teacher gives as much attention to my questions as to other students' questions. *Guru memberikan sepenuh perhatian kepada soalan-soalan saya sepertimana pelajar-pelajar lain.*	1	2	3	4	5
34	I get the same amount of help from the teacher as do other students. *Saya memperolehi bantuan yang sama daripada guru sepertimana pelajar-pelajar lain.*	1	2	3	4	5
35	I have the same amount of say in this class as other students. *Saya mempunyai peluang yang sama banyak untuk berkata-kata di dalam kelas ini.*	1	2	3	4	5
36	I am treated the same as other students in this class. *Saya dilayan sama seperti pelajar-pelajar lain dalam kelas ini.*	1	2	3	4	5
37	I receive the same encouragement from the teacher as other students do. *Saya mendapat galakan daripada guru sama seperti pelajar-pelajar lain.*	1	2	3	4	5
38	I get the same opportunity to contribute to class discussions as other students. *Saya dapat menyumbang kepada perbincangan kelas sama seperti pelajar-pelajar lain.*	1	2	3	4	5
39	My work receives as much praise as other students' work. *Kerja saya mendapat pujian sama seperti pelajar-pelajar lain.*	1	2	3	4	5

Items/***Item***		**Never** takes place/ ***Tidak*** *berlaku*	**Almost Never** takes place/ ***Hampir Tidak*** *berlaku*	**Sometimes** takes place/ ***Kadang-kadang*** *berlaku*	**Almost Always** takes place/ ***Hampir Selalu*** *berlaku*	**Always** takes place/ ***Selalu*** *berlaku*
40	I get the same opportunity to contribute to answer questions as other students. *Saya mendapat peluang menjawab soalan-soalan sama seperti pelajar-pelajar lain*.	1	2	3	4	5
41	If you read this item, please circle 5. *Sekiranya anda membaca item ini, sila bulatkan 5.*	1	2	3	4	5

Questionnaire End.
Soal Selidik Tamat.

Thank You!
Terima Kasih!

APPENDIX F: Modified of the What Is Happening In This Class? (WIHIC) –
Preferred Form

Curtin University

Science & Mathematics Education Centre (SMEC)

WHAT IS HAPPENING IN THIS CLASS?
APA YANG BERLAKU DALAM KELAS INI?

Preferred Form
Borang Harapan

Chemistry
Kimia

Acids & Bases Lessons
Pembelajaran Asid & Bes

My name is Muhd Ibrahim Muhamad Damanhuri and currently am completing research for my Ph.D. at Curtin University in Perth, Western Australia. I am investigating the effectiveness of the acids-bases topic in the Chemistry curriculum prepared by Curriculum Development Division (CDD), Malaysian Ministry of Education. Your views about lessons on acids-bases chemistry are important. This information can be used to assist Malaysian chemistry teachers in making chemistry lessons of the Form 4 Chemistry curriculum more interesting and better understood. Your involvement in this research is entirely **voluntary**. You should be aware that you have the right to discontinue your participation at any time without affecting your personal or social life in any way. Your **identity** will be kept **confidential** and **anonymous** throughout this study.

Nama saya ialah Muhd Ibrahim Muhamad Damanhuri dan kini sedang melengkapkapkan kajian bagi Ph.D. saya di Curtin University, Perth, Western Australia. Saya sedang menyiasat keberkesanan tajuk asid-bes daripada kurikulum kimia yang disediakan oleh Bahagian Pembangunan Kurikulum (BPK), Kementerian Pelajaran Malaysia. Pandangan anda dalam pembelajaran tajuk asid-bes ini adalah sangat penting. Maklumat tersebut boleh digunakan untuk membantu guru-guru kimia di Malaysia untuk menjadikan pembelajaran kimia bagi kurikulum kimia Tingkatan 4 lebih menarik dan lebih mudah difahami. Penyertaan anda dalam kajian ini adalah secara ***sukarela****. Perlu diingatkan di sini bahawa anda mempunyai hak untuk berhenti menyertai kajian ini pada bila-bila masa tanpa mengugat kehidupan peribadi atau sosial anda.* ***Identiti*** *anda akan* ***dirahsiakan*** *dan* ***dilindungi*** *sepanjang kajian ini.*

Your participation in this research is highly appreciated. Thank you!
Penyertaan anda dalam kajian ini amatlah dihargai. Terima kasih!

(Note: Your personal information will be kept personal.)
(Nota: Maklumat peribadi anda akan dirahsiakan)

Name/*Nama*:____________________________ Gender/*Jantina*: _________________

Form/*Tingkatan*:_____________ School/*Sekolah*: _____________________________

Information for Students
Maklumat untuk Pelajar

1. This questionnaire is **bilingual**.
   Soal selidik ini adalah dalam ***dwibahasa.***

2. This questionnaire consists of 41 items to describe your **preferred** perceptions toward chemistry lesson practices. Decide the **frequency** for each of the practices you **prefer** in terms of the scale provided. Draw a **circle** around the particular number of your choice to indicate your response.
   Soal selidik ini mengandungi 41 item bagi menggambarkan persepsi ***harapan*** *anda terhadap amalan pembelajaran kimia. Tentukan* ***kekerapan*** *amalan tersebut yang anda* ***harapkan*** *berlaku berdasarkan skala yang disediakan.* ***Bulatkan*** *pada nombor pilihan anda bagi menentukan respon anda.*

3. Answer **all** questions. **Thirty minutes** are allocated for this questionnaire.
   Jawab ***semua*** *soalan.* ***Tiga puluh minit*** *diperuntukkan untuk soal selidik ini.*

4. Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements. There are no 'right' or 'wrong' answers. Your opinion is what is wanted.
   Sesetengah pernyataan dalam soal selidik ini hampir sama dengan pernyataan yang lain. Jangan risau berkenaan ini. Berikan sahaja pendapat anda bagi semua pernyataan. Tiada jawapan 'betul' atau 'salah'. Hanya pendapat anda yang diperlukan.

Instruction: Decide the **frequency** for each of the practices you prefer in terms of the scale below:
Arahan: *Tentukan* ***kekerapan*** *amalan tersebut yang anda harapkan berlaku berdasarkan skala di bawah:*

1	if the practice/*sekiranya amalan tersebut*	**Never** takes place/***Tidak*** *berlaku.*
2	if the practice/*sekiranya amalan tersebut*	**Almost Never** takes place/***Hampir Tidak*** *berlaku.*
3	if the practice/*sekiranya amalan tersebut*	**Sometimes** takes place/***Kadang-kadang*** *berlaku.*
4	if the practice/*sekiranya amalan tersebut*	**Almost Always** takes place/***Hampir Selalu*** *berlaku.*
5	if the practice/*sekiranya amalan tersebut*	**Always** takes place/***Selalu*** *berlaku.*

Draw a **circle** around the particular number of your choice to indicate your response.
Bulatkan *pada nombor pilihan anda bagi menentukan respon anda*.

Items/*Item*		**Never** takes place/ ***Tidak** berlaku*	**Almost Never** takes place/ ***Hampir** Tidak berlaku*	**Sometimes** takes place/ ***Kadang-kadang** berlaku*	**Almost Always** takes place/ ***Hampir Selalu** berlaku*	**Always** takes place/ ***Selalu** berlaku*
1	The teacher will take a personal interest in me. *Guru akan memberi perhatian kepada saya.*	1	2	3	4	5
2	The teacher will go out of his/her way to help me. *Guru akan berusaha sedaya upaya untuk menolong saya.*	1	2	3	4	5
3	The teacher will consider my feelings. *Guru akan mengambil kira perasaan saya.*	1	2	3	4	5
4	The teacher will help me when I have trouble with the work. *Guru akan menolong saya apabila saya menghadapi masalah dalam kerja saya.*	1	2	3	4	5
5	The teacher will talk to me. *Guru akan bercakap-cakap dengan saya.*	1	2	3	4	5
6	The teacher will be interested in my problems. *Guru akan berminat dengan masalah-masalah saya.*	1	2	3	4	5
7	The teacher will move about the class to talk with me. *Guru akan berusaha sedaya upaya untuk bercakap dengan saya.*	1	2	3	4	5
8	The teacher's questions will help me to understand. *Soalan-soalan guru akan membantu saya untuk faham.*	1	2	3	4	5
9	I will discuss ideas in class. *Saya akan berbincang idea-idea di dalam kelas.*	1	2	3	4	5
10	I will give my opinion during class discussions. *Saya akan memberikan pendapat saya semasa perbincangan kelas.*	1	2	3	4	5
11	The teacher will ask me questions. *Guru akan menyoal saya soalan.*	1	2	3	4	5

	Items/*Item*	**Never** takes place/ ***Tidak** berlaku*	**Almost Never** takes place/ ***Hampir** Tidak berlaku*	**Sometimes** takes place/ ***Kadang-kadang** berlaku*	**Almost Always** takes place/ ***Hampir Selalu** berlaku*	**Always** takes place/ ***Selalu** berlaku*
12	My ideas and suggestions will be used during classroom discussions. *Idea–idea dan pendapat-pendapat saya akan digunakan semasa perbincangan kelas.*	1	2	3	4	5
13	I will ask the teacher questions. *Saya akan bertanya soalan kepada guru.*	1	2	3	4	5
14	I will explain my ideas to other students. *Saya akan menerangkan idea-idea saya kepada pelajar lain.*	1	2	3	4	5
15	Students will discuss with me how to go about solving problems. *Pelajar-pelajar lain akan berbincang dengan saya untuk mencari penyelesaian sesuatu masalah.*	1	2	3	4	5
16	I will be asked to explain how I solve problems. *Saya akan diminta untuk menerangkan bagaimana saya menyelesaikan masalah-masalah.*	1	2	3	4	5
17	I will carry out investigations to test my ideas. *Saya akan mengendalikan penyiasatan untuk menguji idea-idea saya.*	1	2	3	4	5
18	I will be asked to think about the evidence for statements. *Saya akan diminta berfikir untuk membuktikan sesuatu pernyataan.*	1	2	3	4	5
19	I will carry out investigations to answer questions coming from discussions. *Saya akan menjalankan penyiasatan untuk menjawab soalan-soalan daripada perbincangan.*	1	2	3	4	5
20	I will explain the meaning of statements, diagrams and graphs. *Saya akan menerangkan maksud pernyataan, gambarajah, dan graf.*	1	2	3	4	5

	Items/***Item***	**Never** takes place/ ***Tidak** berlaku*	**Almost Never** takes place/ ***Hampir** Tidak berlaku*	**Sometimes** takes place/ ***Kadang-kadang** berlaku*	**Almost Always** takes place/ ***Hampir Selalu** berlaku*	**Always** takes place/ ***Selalu** berlaku*
21	I will carry out investigations to answer questions which puzzle me. *Saya akan menjalankan penyiasatan untuk menjawab soalan-soalan yang membinggungkan saya.*	1	2	3	4	5
22	I will carry out investigations to answer the teacher's questions. *Saya akan menjalankan penyiasatan untuk menjawab soalan-soalan guru.*	1	2	3	4	5
23	I will find out answers to questions by doing investigations. *Saya akan memperolehi sesuatu jawapan bagi soalan-soalan melalui penyiasatan.*	1	2	3	4	5
24	I will solve problems by using information obtained from my own investigations. *Saya akan menyelesaikan masalah-masalah dengan menggunakan maklumat yang diperolehi daripada penyiasatan saya.*	1	2	3	4	5
25	I will cooperate with other students when doing assignment work. *Saya akan berkerjasama dengan pelajar-pelajar lain apabila melakukan sesuatu tugasan.*	1	2	3	4	5
26	I will share my books and resources with other students when doing assignments. *Saya akan berkongsi buku dan sumber-sumber lain dengan pelajar-pelajar lain semasa membuat tugasan.*	1	2	3	4	5
27	When I work in groups in this class, there will be teamwork. *Semasa saya bekerja secara berkumpulan di dalam kelas, akan wujudnya kerjasama berpasukan.*	1	2	3	4	5
28	I will work with other students on projects in this class. *Saya akan menjalankan tugas dengan pelajar lain bagi sesuatu projek di dalam kelas.*	1	2	3	4	5

Items/*Item*		**Never** takes place/ ***Tidak*** *berlaku*	**Almost Never** takes place/ ***Hampir*** *Tidak berlaku*	**Sometimes** takes place/ ***Kadang-kadang*** *berlaku*	**Almost Always** takes place/ ***Hampir Selalu*** *berlaku*	**Always** takes place/ ***Selalu*** *berlaku*
29	I will learn from other students in this class. *Saya akan belajar daripada pelajar-pelajar lain di dalam kelas ini.*	1	2	3	4	5
30	I will work with other students in this class. *Saya akan melakukan tugas bersama-sama pelajar lain dalam kelas ini.*	1	2	3	4	5
31	I will cooperate with other students on class activities. *Saya akan bekerjasama dengan pelajar-pelajar lain untuk menjalankan aktiviti-aktiviti kelas.*	1	2	3	4	5
32	Students will work with me to achieve class goals. *Pelajar-pelajar lain akan melakukan tugas bersama saya bagi mencapai matlamat kelas.*	1	2	3	4	5
33	The teacher will give as much attention to my questions as to other students' questions. *Guru akan memberikan sepenuh perhatian kepada soalan-soalan saya sepertimana pelajar-pelajar lain.*	1	2	3	4	5
34	I will get the same amount of help from the teacher as do other students. *Saya akan memperolehi bantuan yang sama daripada guru sepertimana pelajar-pelajar lain.*	1	2	3	4	5
35	I will have the same amount of say in this class as other students. *Saya akan mempunyai peluang yang sama banyak untuk berkata-kata di dalam kelas ini.*	1	2	3	4	5
36	I will be treated the same as other students in this class. *Saya akan dilayan sama seperti pelajar-pelajar lain dalam kelas ini.*	1	2	3	4	5

Items/*Item*		**Never** takes place/ ***Tidak*** *berlaku*	**Almost Never** takes place/ ***Hampir*** *Tidak berlaku*	**Sometimes** takes place/ ***Kadang-kadang*** *berlaku*	**Almost Always** takes place/ ***Hampir Selalu*** *berlaku*	**Always** takes place/ ***Selalu*** *berlaku*
37	I will receive the same encouragement from the teacher as other students do. *Saya akan mendapat galakan daripada guru sama seperti pelajar-pelajar lain.*	1	2	3	4	5
38	I will get the same opportunity to contribute to class discussions as other students. *Saya akan dapat menyumbang kepada perbincangan kelas sama seperti pelajar-pelajar lain.*	1	2	3	4	5
39	My work will receive as much praise as other students' work. *Kerja saya akan mendapat pujian sama seperti pelajar-pelajar lain.*	1	2	3	4	5
40	I will get the same opportunity to contribute to answer questions as other students. *Saya akan mendapat peluang menjawab soalan-soalan sama seperti pelajar-pelajar lain.*	1	2	3	4	5
41	If you read this item, please circle 5. *Sekiranya anda membaca item ini, sila bulatkan 5.*	1	2	3	4	5

Questionnaire End.
Soal Selidik Tamat.

Thank You!
Terima Kasih!

APPENDIX G: Modified of the Attitude Towards Chemistry Lessons Scales (ATCLS) – *Actual Form*

Curtin University

Science & Mathematics Education Centre (SMEC)

ATTITUDES TOWARD CHEMISTRY LESSONS SCALES
SKALA SIKAP TERHADAP PEMBELAJARAN KIMIA

Actual Form
Borang Sebenar

Chemistry
Kimia

Acids & Bases Lessons
Pembelajaran Asid & Bes

My name is Muhd Ibrahim Muhamad Damanhuri and currently am completing research for my Ph.D. at Curtin University in Perth, Western Australia. I am investigating the effectiveness of the acids-bases topic in the Chemistry curriculum prepared by Curriculum Development Division (CDD), Malaysian Ministry of Education. Your views about lessons on acids-bases chemistry are important. This information can be used to assist Malaysian chemistry teachers in making chemistry lessons of the Form 4 Chemistry curriculum more interesting and better understood. Your involvement in this research is entirely **voluntary**. You should be aware that you have the right to discontinue your participation at any time without affecting your personal or social life in any way. Your **identity** will be kept **confidential** and **anonymous** throughout this study.

Nama saya ialah Muhd Ibrahim Muhamad Damanhuri dan kini sedang melengkapkapkan kajian bagi Ph.D. saya di Curtin University, Perth, Western Australia. Saya sedang menyiasat keberkesanan tajuk asid-bes daripada kurikulum kimia yang disediakan oleh Bahagian Pembangunan Kurikulum (BPK), Kementerian Pelajaran Malaysia. Pandangan anda dalam pembelajaran tajuk asid-bes ini adalah sangat penting. Maklumat tersebut boleh digunakan untuk membantu guru-guru kimia di Malaysia untuk menjadikan pembelajaran kimia bagi kurikulum kimia Tingkatan 4 lebih menarik dan lebih mudah difahami. Penyertaan anda dalam kajian ini adalah secara ***sukarela****. Perlu diingatkan di sini bahawa anda mempunyai hak untuk berhenti menyertai kajian ini pada bila-bila masa tanpa mengugat kehidupan peribadi atau sosial anda.* ***Identiti*** *anda akan* ***dirahsiakan*** *dan* ***dilindungi*** *sepanjang kajian ini.*

Your participation in this research is highly appreciated. Thank you!
Penyertaan anda dalam kajian ini amatlah dihargai. Terima kasih!

(Note: Your personal information will be kept personal.)
(Nota: Maklumat peribadi anda akan dirahsiakan)

Name/*Nama*:____________________________ Gender/*Jantina*: ________________

Form/*Tingkatan*:_____________ School/*Sekolah*: _____________________________

Information for Students
Maklumat untuk Pelajar

1. This questionnaire is **bilingual**.
   *Soal selidik ini adalah dalam **dwibahasa.***

2. This questionnaire consists of 12 items to describe your attitudes toward acids-bases chemistry lessons. Decide your level of **agreement** for each of the statements given in terms of the scale provided. Draw a **circle** around the particular number of your choice to indicate your response.
   *Soal selidik ini mengandungi 12 item bagi menggambarkan sikap anda terhadap pembelajaran asid-bes kimia. Tentukan tahap **persetujuan** anda bagi setiap pernyataan diberikan berdasarkan skala yang disediakan. **Bulatkan** pada nombor pilihan anda bagi menentukan respon anda.*

3. Answer **all** questions. **Fifteen minutes** are allocated for this questionnaire.
   *Jawab **semua** soalan. **Lima belas minit** diperuntukkan untuk soal selidik ini.*

4. Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements. There are no 'right' or 'wrong' answers. Your opinion is what is wanted.
   Sesetengah pernyataan dalam soal selidik ini hampir sama dengan pernyataan yang lain. Jangan risau berkenaan ini. Berikan sahaja pendapat anda bagi semua pernyataan. Tiada jawapan 'betul' atau 'salah'. Hanya pendapat anda yang diperlukan.

Instruction: Decide your level of **agreement** for each of the statements given in terms of the scale below:
Arahan: *Tentukan tahap **persetujuan** anda bagi setiap pernyataan diberikan berdasarkan skala dibawah:*

1	if you/*sekiranya anda*	Strongly Disagree/*Sangat Tidak Setuju*
2	if you/*sekiranya anda*	Disagree/*Tidak Setuju*
3	if you are/*sekiranya anda*	Not Sure/*Tidak Pasti*
4	if you/*sekiranya anda*	Agree/ *Setuju*
5	if you/*sekiranya anda*	Strongly Agree/*Sangat Setuju*

Draw a **circle** around the particular number of your choice to indicate your response.
Bulatkan *pada nombor pilihan anda bagi menentukan respon anda.*

	Items/*Item*	**Strongly Disagree/** ***Sangat Tidak Setuju***	**Disagree/** ***Tidak Setuju***	**Not Sure/** ***Tidak Pasti***	**Agree/** ***Setuju***	**Strongly Agree/** ***Sangat Setuju***
1	I like acids-bases chemistry more than any other chemistry topic. *Saya suka asid-bes kimia melebihi topik-topik kimia yang lain.*	1	2	3	4	5
2	Acids-bases chemistry lessons are interesting. *Pelajaran asid-bes kimia adalah menarik.*	1	2	3	4	5
3	Acids-bases chemistry is useful for solving everyday problems. *Asid-bes kimia berguna untuk menyelesaikan masalah seharian.*	1	2	3	4	5
4	Acids-bases chemistry is one of my favourite topics. *Asid-bes kimia adalah salah satu topik kegemaran saya.*	1	2	3	4	5
5	I am willing to spend more time reading acids-bases chemistry books. *Saya sanggup meluangkan lebih masa membaca buku-buku asid-bes kimia.*	1	2	3	4	5
6	I like to do acids-bases chemistry experiments. *Saya suka melakukan eksperimen-eksperimen asid-bes kimia.*	1	2	3	4	5
7	When I am working in the acids-bases chemistry lab, I feel I am doing something important. *Apabila saya bekerja di dalam makmal asid-bes kimia, saya merasakan sedang melakukan sesuatu yang penting.*	1	2	3	4	5
8	People must understand acids-bases chemistry because it affect their lives. *Manusia perlu memahami asid-bes kimia kerana ia mempengaruhi kehidupan mereka.*	1	2	3	4	5
9	I like trying to solve new problems in acids-bases chemistry. *Saya gemar menyelesaikan masalah-masalah baru dalam pelajaran asid-bes kimia.*	1	2	3	4	5
10	Doing acids-bases chemistry experiments in school is fun. *Menjalankan eksperimen-eksperimen asid-bes kimia di sekolah adalah menyeronokkan.*	1	2	3	4	5

	Items/*Item*	**Strongly Disagree/** ***Sangat Tidak Setuju***	**Disagree/** ***Tidak Setuju***	**Not Sure/** ***Tidak Pasti***	**Agree/** ***Setuju***	**Strongly Agree/** ***Sangat Setuju***
11	Acids-bases chemistry is one of the most important topics for people to study. *Asid-bes kimia adalah salah satu topik yang amat penting bagi manusia untuk dipelajari.*	1	2	3	4	5
12	If I had a chance, I would do a project on acids-bases chemistry. *Sekiranya diberi peluang, saya akan menjalankan projek asid-bes kimia.*	1	2	3	4	5

Questionnaire End.
Soal Selidik Tamat.

Thank You!
Terima Kasih!

APPENDIX H: Modified of the Attitude Towards Chemistry Lessons Scales (ATCLS) – *Preferred Form*

Curtin University

Science & Mathematics Education Centre (SMEC)

ATTITUDES TOWARD CHEMISTRY LESSONS SCALES

SKALA SIKAP TERHADAP PEMBELAJARAN KIMIA

Preferred Form

Borang Harapan

Chemistry

Kimia

Acids & Bases Lessons

Pembelajaran Asid & Bes

My name is Muhd Ibrahim Muhamad Damanhuri and currently am completing research for my Ph.D. at Curtin University in Perth, Western Australia. I am investigating the effectiveness of the acids-bases topic in the Chemistry curriculum prepared by Curriculum Development Division (CDD), Malaysian Ministry of Education. Your views about lessons on acids-bases chemistry are important. This information can be used to assist Malaysian chemistry teachers in making chemistry lessons of the Form 4 Chemistry curriculum more interesting and better understood. Your involvement in this research is entirely **voluntary**. You should be aware that you have the right to discontinue your participation at any time without affecting your personal or social life in any way. Your **identity** will be kept **confidential** and **anonymous** throughout this study.

Nama saya ialah Muhd Ibrahim Muhamad Damanhuri dan kini sedang melengkapkapkan kajian bagi Ph.D. saya di Curtin University, Perth, Western Australia. Saya sedang menyiasat keberkesanan tajuk asid-bes daripada kurikulum kimia yang disediakan oleh Bahagian Pembangunan Kurikulum (BPK), Kementerian Pelajaran Malaysia. Pandangan anda dalam pembelajaran tajuk asid-bes ini adalah sangat penting. Maklumat tersebut boleh digunakan untuk membantu guru-guru kimia di Malaysia untuk menjadikan pembelajaran kimia bagi kurikulum kimia Tingkatan 4 lebih menarik dan lebih mudah difahami. Penyertaan anda dalam kajian ini adalah secara ***sukarela****. Perlu diingatkan di sini bahawa anda mempunyai hak untuk berhenti menyertai kajian ini pada bila-bila masa tanpa mengugat kehidupan peribadi atau sosial anda.* ***Identiti*** *anda akan* ***dirahsiakan*** *dan* ***dilindungi*** *sepanjang kajian ini.*

Your participation in this research is highly appreciated. Thank you!

Penyertaan anda dalam kajian ini amatlah dihargai. Terima kasih!

(Note: Your personal information will be kept personal.)

(Nota: Maklumat peribadi anda akan dirahsiakan)

Name/*Nama*:___________________________ Gender/*Jantina*: ________________

Form/*Tingkatan*:_____________ School/*Sekolah*: ____________________________

Information for Students
Maklumat untuk Pelajar

1. This questionnaire is **bilingual**.
   Soal selidik ini adalah dalam ***dwibahasa.***

2. This questionnaire consists of 12 items to describe your **preferred** attitudes toward acids-bases chemistry lessons. Decide your level of **agreement** for each of the attitudes you **prefer** in terms of the scale provided. Draw a **circle** around the particular number of your choice to indicate your response.
   Soal selidik ini mengandungi 12 item bagi menggambarkan sikap ***harapan*** *anda terhadap pembelajaran asid-bes kimia. Tentukan tahap* ***persetujuan*** *anda bagi setiap sikap yang anda* ***harapkan*** *berlaku berdasarkan skala yang disediakan.* ***Bulatkan*** *pada nombor pilihan anda bagi menentukan respon anda.*

3. Answer **all** questions. **Fifteen minutes** are allocated for this questionnaire.
   Jawab ***semua*** *soalan.* ***Lima belas minit*** *diperuntukkan untuk soal selidik ini.*

4. Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements. There are no 'right' or 'wrong' answers. Your opinion is what is wanted.
   Sesetengah pernyataan dalam soal selidik ini hampir sama dengan pernyataan yang lain. Jangan risau berkenaan ini. Berikan sahaja pendapat anda bagi semua pernyataan. Tiada jawapan 'betul' atau 'salah'. Hanya pendapat anda yang diperlukan.

Instruction: Decide your level of **agreement** for each of the attitudes you prefer in terms of the scale below:
Arahan: *Tentukan tahap* ***persetujuan*** *anda bagi setiap sikap yang anda harapkan berlaku berdasarkan skala dibawah:*

1	if you/*sekiranya anda*	Strongly Disagree/*Sangat Tidak Setuju*
2	if you/*sekiranya anda*	Disagree/*Tidak Setuju*
3	if you are/*sekiranya anda*	Not Sure/*Tidak Pasti*
4	if you/*sekiranya anda*	Agree/*Setuju*
5	if you/*sekiranya anda*	Strongly Agree/*Sangat Setuju*

Draw a **circle** around the particular number of your choice to indicate your response.
Bulatkan *pada nombor pilihan anda bagi menentukan respon anda*.

	Items/**Item**	**Strongly Disagree/** ***Sangat Tidak Setuju***	**Disagree/** ***Tidak Setuju***	**Not Sure/** ***Tidak Pasti***	**Agree/** ***Setuju***	**Strongly Agree/** ***Sangat Setuju***
1	I prefer acids-bases chemistry more than any other chemistry topic. *Saya berkecenderung terhadap asid-bes kimia melebihi topik-topik kimia yang lain.*	1	2	3	4	5
2	Acids-bases chemistry lessons will surely be interesting. *Pelajaran asid-bes kimia pasti akan menarik.*	1	2	3	4	5
3	Acids-bases chemistry will be useful for solving everyday problems. *Asid-bes kimia akan berguna untuk menyelesaikan masalah seharian.*	1	2	3	4	5
4	Acids-bases chemistry will be one of my favourite topics. *Asid-bes kimia akan menjadi salah satu topik kegemaran saya.*	1	2	3	4	5
5	I would be inclined to spend more time reading acids-bases chemistry books. *Saya akan cenderung untuk meluangkan lebih masa membaca buku-buku asid-bes kimia.*	1	2	3	4	5
6	I would prefer to do acids-bases chemistry experiments. *Saya berharap akan dapat melakukan eksperimen-eksperimen asid-bes kimia.*	1	2	3	4	5
7	When I am working in the acids-bases chemistry lab, I will feel to be doing something important. *Apabila saya bekerja di dalam makmal asid-bes kimia, saya akan merasakan sedang melakukan sesuatu yang penting.*	1	2	3	4	5
8	People must understand acids-bases chemistry because it will affect their lives. *Manusia perlu memahami asid-bes kimia kerana ia akan mempengaruhi kehidupan mereka.*	1	2	3	4	5
9	I would like solving new problems in acids-bases chemistry. *Saya akan gemar menyelesaikan masalah-masalah baru dalam pelajaran asid-bes kimia.*	1	2	3	4	5

	Items/Item	**Strongly Disagree/** *Sangat Tidak Setuju*	**Disagree/** *Tidak Setuju*	**Not Sure/** *Tidak Pasti*	**Agree/** *Setuju*	**Strongly Agree/** *Sangat Setuju*
10	Doing acids-bases chemistry experiments in school will be fun. *Menjalankan eksperimen-eksperimen asid-bes kimia di sekolah akan menyeronokkan.*	1	2	3	4	5
11	Acids-bases chemistry will be one of the most important topics for people to study. *Asid-bes kimia akan menjadi salah satu topik yang amat penting bagi manusia untuk dipelajari.*	1	2	3	4	5
12	If I had a chance, I will do a project on acids-bases chemistry. *Sekiranya diberi peluang, saya akan menjalankan projek asid-bes kimia.*	1	2	3	4	5

Questionnaire End.
Soal Selidik Tamat.

Thank You!
Terima Kasih!

APPENDIX I: Acids-Bases Achievement Test (ABCAT) – *Create Multiple-Choice Items with Free Responses of the Initial Version (English)*

ACIDS AND BASES CHEMISTRY ACHIEVEMENT TEST

Name: ______________________ School: _____________________

Class: ____________ Date: ___________

Instructions to Students:

This paper consists of 8 items that evaluate your understanding of several properties of acids and bases.

Each of the items in this paper consists of two parts.

In the first part of each item, circle one of the responses, A, B, C, D, etc., to indicate what you consider to be the most appropriate answer.

In the second part, suggest your reason for selecting the particular response.

Remember it is important to provide a reason for selecting a particular answer in each item.

Do not forget to record your name and other details on this page.

Note to the teacher:

Please collate your students' answer scripts and mail them to the address below.

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Mobile: +61450578984 / +60194401808

1. Two common substances that have the formulas HCl and CH_4 both contain the element hydrogen. Yet, only HCl has acidic properties while CH_4 does not.

    A. True*
    B. False

    The reason for my answer is:

    ____

    ____

    ____

2. What is a property of citrus fruits like oranges and lemons?

    A. Acidic*
    B. Basic
    C. Neutral

    The reason for my answer is:

    ____

    ____

    ____

3. Some brands of 'effervescent' Vitamin C tablets contain sodium bicarbonate, tartaric acid and citric acid. When added to water, the tablets…

    A. cause the temperature of the water to rise.
    B. produce vigorous fizzing.*
    C. break up into small pieces and dissolve.
    D. produce a white precipitate.

    The reason for my answer is:

    ____

    ____

    ____

4. Baking soda (sodium bicarbonate) added to dough when baking bread causes the bread to rise.

   A. True*
   B. False

   The reason for my answer is:

   ____

   ____

   ____

5. After a kettle is used to boil water over a long period of time, the inside of the kettle becomes coated with 'scales' (consisting of calcium carbonate). What could you use to remove this coating?

   A. An aqueous solution of baking soda.
   B. Lemon juice diluted with water.*
   C. An aqueous solution of sodium hydroxide.

   The reason for my answer is:

   ____

   ____

   ____

6. If soil has a pH value of less than 7, it is not likely to support the healthy growth of grass. What chemical would you add to the soil to promote the growth of grass?

   A. Common salt
   B. Vinegar
   C. Lime (calcium oxide)*
   D. Caustic soda

   The reason for my answer is:

   ____

   ____

   ____

7. When pieces of chopped red cabbage are boiled with water and the resulting mixture is filtered, a purple solution is obtained. This purple solution can be used to distinguish between...

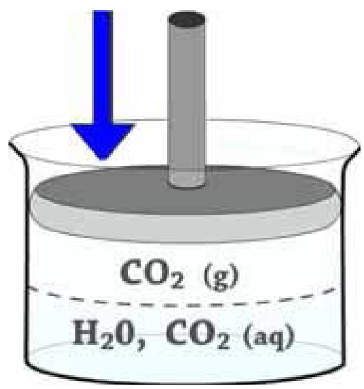
   A. lemonade and lime juice.
   B. lemonade and tap water.*
   C. rain water and mineral water.

   The reason for my answer is:

   ____

   ____

   ____

8. 

   A certain number of moles of carbon dioxide (CO_2) and 100mL of pure water containing dissolved carbon dioxide are placed in an enclosed container with an attached piston at a temperature of 25°C. When the piston is pushed down, the pH value of solution will.....

   A. increase.
   B. decrease.*
   C. remain unchanged.

   The reason for my answer is:

   ____

   ____

   ____

@->--- THANK YOU ---<-@

APPENDIX J: Acids-Bases Achievement Test (ABCAT) – *Create Multiple-Choice Items with Free Responses of the Initial Version (Malay)*

UJIAN PENCAPAIAN ASID DAN BES KIMIA

Nama: ________________________ Sekolah: _______________________

Kelas: ______________ Tarikh: _____________

Arahan kepada pelajar:

Kertas ini mengandungi 8 item yang menilai pemahaman anda mengenai beberapa sifat-sifat asid dan bes.

Setiap item di dalam kertas ini mengandungi dua bahagian.

Pada bahagian pertama setiap item, bulatkan salah satu respon, A, B, C, D, atau sebagainya bagi jawapan yang anda rasakan paling sesuai.

Dalam bahagian kedua, cadangkan sebab anda memilih jawapan tersebut.

Perlu diingatkan bahawa adalah penting untuk menyediakan sebab pemilihan sesuatu jawapan bagi setiap item.

Jangan lupa untuk merekodkan nama anda dan maklumat lain pada muka surat ini.

Arahan kepada guru:

Sila kumpulkan skrip jawapan pelajar anda dan poskan kepada alamat di bawah.

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1. Dua bahan biasa ditemui yang berformula HCl dan CH_4 mengandungi unsur hidrogen. Walaubagaimanapun, hanya HCl mempunyai sifat-sifat asid tetapi CH_4 tidak.

   A. Betul*
   B. Salah

   Sebab bagi jawapan saya adalah:

   ____

   ____

   ____

2. Apakah sifat buah-buahan sitrus seperti oren dan lemon?

   A. Berasid*
   B. Berbes
   C. Neutral

   Sebab bagi jawapan saya adalah:

   ____

   ____

   ____

3. Sesetengah jenama tablet Vitamin C yang berbuih mengandungi sodium bikarbonat, asid tartarik dan asid sitrik. Apabila dicampur ke dalam air, tablet tersebut...

   A. menyebabkan suhu air meningkat.
   B. mengasilkan bunyi desis yang kuat.*
   C. berpecah menjadi butiran-butiran kecil dan larut.
   D. menghasilkan mendakan putih.

   Sebab bagi jawapan saya adalah:

   ____

   ____

   ____

4. Soda penaik (sodium bikarbonat) yang ditambah kepada doh semasa pembuatan roti akan menyebabkan roti meningkat.

   A. Betul*
   B. Salah

   Sebab bagi jawapan saya adalah:

   ____

   ____

   ____

5. Selepas cerek air digunakan untuk suatu tempoh masa yang lama, keadaan di dalam cerek tersebut akan disaluti ‘saduran’ (terdiri daripada kalsium karbonat). Apakah yang akan anda gunakan untuk menyingkirkan saduran tersebut?

   A. Larutan akues soda penaik.
   B. Jus lemon dicairkan dengan air.*
   C. Larutan akues sodium hidroksida.

   Sebab bagi jawapan saya adalah:

   ____

   ____

   ____

6. Jika tanah mempunyai nilai pH kurang daripada 7, ia dikatakan tidak menyokong pertumbuhan rumput yang sihat. Apakah bahan kimia yang boleh anda tambahkan kepada tanah tersebut untuk menggalakkan pertumbuhan rumput?

   A. Garam biasa
   B. Cuka
   C. Kapur (kalsium oksida)*
   D. Soda kaustik

   Sebab bagi jawapan saya adalah:

   ____

   ____

   ____

7. Apabila cebisan potongan kubis merah dididihkan dengan air dan hasil campurannya ditapis, suatu larutan ungu akan diperolehi. Larutan ungu tersebut boleh digunakan untuk membezakan antara...

   A. lemonade dan jus limau.
   B. lemonade dan air pili.*
   C. air hujan dan air mineral.

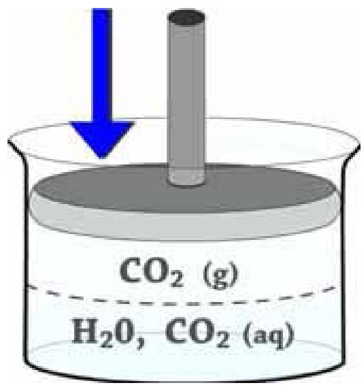
   Sebab bagi jawapan saya adalah:

   ____

   ____

   ____

8.



   Sebilangan mol tertentu karbon dioksida (CO_2) dan 100mL air tulen yang mengandungi karbon dioksida terlarut dimasukkan ke dalam satu bekas tertutup yang disambung ke sebuah piston pada suhu 25°C. Apabila piston itu ditekan, nilai pH larutan akan…..

   A. meningkat.
   B. berkurangan.*
   C. tidak berubah.

   Sebab bagi jawapan saya adalah:

   ____

   ____

   ____

@->--- TERIMA KASIH ---<-@

APPENDIX K: Acids-Bases Achievement Test (ABCAT) – *Pilot Test of the Initial Version (English)*

ACIDS AND BASES CHEMISTRY ACHIEVEMENT TEST

Name: ______________________ School: _____________________

Class: ____________ Date: ___________

Instructions to Students:

This paper consists of 11 items that evaluate your understanding of several properties of acids and bases. Each item has two parts: a multiple-choice response followed by a multiple-choice reason. For each item, you are asked to make the most appropriate choice from the multiple-choice response section and circle your answer A, B, C, etc. Then choose one of the reasons from the multiple-choice reason section that best matches your answer to the first part and circle your answer 1, 2, 3, etc. If you do not agree with any of the given reasons, please write your reason in the space provided.

Remember it is important to answer both parts of each item.

Do not forget to record your name and other details on this page.

Note to the teacher:

Please collate your students' answer scripts and mail them to the address below.

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1. Two common substances that have the formulas HCl and CH_4 both contain the element hydrogen. Yet, only HCl has acidic properties while CH_4 does not.

   A. True*
   B. False

   The reason for my answer is:

   1. Only HCl dissolves in water to produce H^+ ions.
   2. CH_4 completely ionised to produce more H^+ ions in water than HCl.
   3. Any substance that contains H atom in the molecular formula is acidic.
   4. Only HCl completely ionised to produce H^+ ions in water.*
   5. *Other reason:*

   ____

   ____

2. What is a property of citrus fruits like oranges and lemons?

   A. Acidic*
   B. Basic
   C. Neutral

   The reason for my answer is:

   1. Citrus fruits have pH value less than 7.*
   2. Citrus fruits have harmful and poisonous properties.
   3. Citrus fruits have pH values greater than 7.
   4. *Other reason:*

   ____

   ____

3. Some brands of 'effervescent' Vitamin C tablets contain sodium bicarbonate, tartaric acid and citric acid. When added to water, the tablets…

   A. cause the temperature of the water to rise.
   B. produce vigorous fizzing.*
   C. break up into small pieces and dissolve.
   D. produce a white precipitate.

   The reason for my answer is:
   1. H^+ ions are produced when the acids ionise in water.
   2. The sodium bicarbonate completely reacts with the acids to produce a neutral salt and water.
   3. CO_2 gas is produced when the acids react with the sodium bicarbonate.*

4. The sodium element in sodium bicarbonate is highly reactive in water.
5. *Other reason:*

   ____

   ____

4. Baking soda (sodium bicarbonate) added to dough when baking bread causes the bread to rise.

   A. True*
   B. False

   The reason for my answer is:

   1. OH^- ions are produced when sodium bicarbonate reacts with water in the dough.
   2. H^+ ions are produced when sodium bicarbonate reacts with water in the dough.
   3. The sodium bicarbonate decomposes when heated to produce CO_2 gas.*
   4. *Other reason:*

      ____

      ____

5. After a kettle is used to boil water over a long period of time, the inside of the kettle becomes coated with 'scales' (consisting of calcium carbonate). What could you use to remove this coating?

   A. An aqueous solution of baking soda.
   B. Lemon juice diluted with water.*
   C. An aqueous solution of sodium hydroxide.

   The reason for my answer is:

   1. The calcium carbonate coating completely reacts with the acidic solution to produce a neutral salt and water.
   2. The calcium carbonate coating dissolves by reacting with the alkaline solution.
   3. The calcium carbonate coating dissolves by reacting with the acidic solution.*
   4. *Other reason:*

      ____

      ____

6. If soil has a pH value of less than 7, it is not likely to support the healthy growth of grass. What chemical would you add to the soil to promote the growth of grass?

   A. Common salt
   B. Vinegar
   C. Lime (calcium oxide)*
   D. Caustic soda

   The reason for my answer is:

   1. The basic substance neutralises the acidic soils.*
   2. The basic substance reduces the soil acidity to pH value greater than 7.
   3. The acidic substance changes the pH of soil closer to the ideal pH.
   4. *Other reason:*

   ____

   ____

7. When pieces of chopped red cabbage are boiled with water and the resulting mixture is filtered, a purple solution is obtained. This purple solution can be used to distinguish between...

   A. lemonade and lime juice.
   B. lemonade and tap water.*
   C. rain water and mineral water.

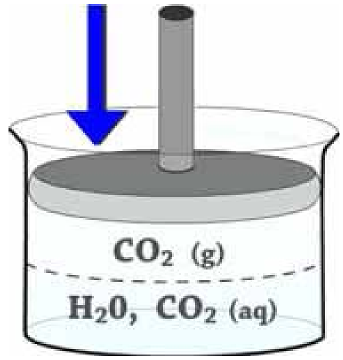
   The reason for my answer is:

   1. The purple cabbage solution can be used to distinguish between the acidic and neutral solutions.
   2. The purple cabbage solution can be used to distinguish between the acidic and alkaline solutions.*
   3. The purple cabbage solution is a phenolphthalein indicator.
   4. *Other reason:*

   ____

   ____

8.



A certain number of moles of carbon dioxide (CO_2) and 100mL of pure water containing dissolved carbon dioxide are placed in an enclosed container with an attached piston at a temperature of 25°C. When the piston is pushed down, the pH value of solution will.....

A. increase.
B. decrease.*
C. remain unchanged.

The reason for my answer is:

1. The CO_2 gas molecules contain acidic properties.
2. The CO_2 gas molecules do not dissolve in water.
3. The water contains a high concentration of H^+ ions.
4. The concentration of CO_2 in water increases producing more acidic solution.*
5. *Other reason:*

____

____

9. Aqueous solutions of potassium hydroxide as well as ammonia are both weak alkalis.

A. True
B. False*

The reason for my answer is:

1. Aqueous potassium hydroxide is completely ionised in water, while aqueous ammonia is only partially ionised.*
2. Potassium hydroxide and ammonia are only partially ionised in water.
3. Aqueous ammonia, NH_3, is not an alkali because it does not contain OH^- ions in its formula.
4. Potassium hydroxide and ammonia ionise completely in water.
5. *Other reason:*

____

____

10. Concentrated solutions of acids and alkalis are also strongly acidic and alkaline.

A. True
B. False*

The reason for my answer is:

1. The solutions contain high concentrations of H^+ or OH^- ions.
2. The solutions may or may not be highly ionised in aqueous solution.*
3. Relatively large amounts of the substances are dissolved in water.
4. *Other reason:*

____

____

11. Soaps and detergents as well as household cleaners for floors, ovens and glass windows contain weakly alkaline chemicals like sodium hydroxide and ammonia, but not acids.

A. True*
B. False

The reason for my answer is:

1. Alkalis are soapy and so are able to wash away stains.
2. Acids are more corrosive than alkalis and so are more effective in removing stains.
3. Alkalis dissolve grease present in dirt more readily than acids.*
4. Acids are able to neutralise alkali stains present in dirt.
5. *Other reason:*

____

____

@->--- THANK YOU ---<-@

APPENDIX L: Acids-Bases Achievement Test (ABCAT) – ***Pilot Test of the Initial Version (Malay)***

UJIAN PENCAPAIAN ASID DAN BES KIMIA

Nama: ______________________ Sekolah: _____________________

Kelas: _____________ Tarikh: ____________

Arahan kepada pelajar:

Kertas ini mengandungi 11 item yang menilai pemahaman anda mengenai beberapa sifat-sifat asid dan bes. Setiap item terdiri daripada dua bahagian: respon pelbagai pilihan diikuti sebab pelbagai pilihan. Bagi setiap item, anda dikehendaki membuat pilihan yang paling sesuai pada bahagian respon pelbagai pilihan dengan membulatkan jawapan anda samada A, B, C, atau sebagainya. Anda kemudiannya dikehendaki memilih salah satu sebab di bahagian sebab pelbagai pilihan yang sepadan dengan jawapan anda di bahagian pertama dan bulatkan jawapan anda samada 1, 2, 3, atau sebagainya. Sekiranya anda tidak bersetuju dengan mana-mana sebab yang diberikan, anda diminta untuk menulis sebab anda di ruang yang disediakan.

Anda diingatkan untuk menjawab kedua-dua bahagian pada setiap item.

Jangan lupa untuk merekodkan nama anda dan maklumat lain pada muka surat ini.

Arahan kepada guru:

Sila kumpulkan skrip jawapan pelajar anda dan poskan kepada alamat di bawah.

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Mobile: +61450578984 / +60194401808

1. Dua bahan biasa ditemui yang berformula HCl dan CH_4 mengandungi unsur hydrogen. Walaubagaimanapun, hanya HCl mempunyai sifat-sifat asid tetapi CH_4 tidak.

   A. Betul*
   B. Salah

   Sebab bagi jawapan saya adalah:

   1. Hanya HCl larut dalam air untuk menghasilkan ion-ion H^+.
   2. CH_4 mengalami ionisasi lengkap menghasilkan lebih banyak ion-ion H^+ di dalam air berbanding HCl.
   3. Sebarang bahan yang mengandungi atom H di dalam formula molekulnya adalah berasid.
   4. Hanya HCl yang mengalami ionisasi lengkap di dalam air untuk menghasilkan ion-ion H^+.*
   5. *Sebab lain:*
      ____

      ____

2. Apakah sifat buah-buahan sitrus seperti oren dan lemon?

   A. Berasid*
   B. Berbes
   C. Neutral

   Sebab bagi jawapan saya adalah:

   1. Buah-buahan sitrus mempunyai nilai pH kurang daripada 7.*
   2. Buah-buahan sitrus memiliki ciri-ciri berbahaya dan beracun.
   3. Buah-buahan sitrus mempunyai nilai pH lebih daripada 7.
   4. *Sebab lain:*
      ____

      ____

3. Sesetengah jenama tablet Vitamin C yang berbuih mengandungi sodium bikarbonat, asid tartarik dan asid sitrik. Apabila dicampur ke dalam air, tablet tersebut...

   A. menyebabkan suhu air meningkat.
   B. mengasilkan bunyi desis yang kuat.*
   C. berpecah menjadi butiran-butiran kecil dan larut.
   D. menghasilkan mendakan putih.

Sebab bagi jawapan saya adalah:

1. Ion-ion H^+ dihasilkan apabila asid-asid tersebut mengalami ionisasi di dalam air.
2. Sodium bikarbonat bertindakbalas lengkap dengan asid-asid tersebut menghasilkan garam neutral dan air.
3. Gas CO_2 dibebaskan apabila asid-asid tersebut bertindakbalas dengan sodium bikarbonat.*
4. Elemen sodium yang terdapat di dalam sodium bikarbonat adalah sangat reaktif di dalam air.
5. *Sebab lain:*

   ____

   ____

4. Soda penaik (sodium bikarbonat) yang ditambah kepada doh semasa pembuatan roti akan menyebabkan roti meningkat.

   A. Betul*
   B. Salah

   Sebab bagi jawapan saya adalah:

   1. Ion-ion OH^- dibebaskan apabila sodium bikarbonat bertindakbalas dengan air yang terdapat di dalam doh.
   2. Ion-ion H^+ dibebaskan apabila sodium bikarbonat bertindakbalas dengan air yang terdapat dalam doh.
   3. Sodium bikarbonat terurai apabila dipanaskan menghasilkan gas CO_2.*
   4. *Sebab lain:*

      ____

      ____

5. Selepas cerek air digunakan untuk suatu tempoh masa yang lama, keadaan di dalam cerek tersebut akan disaluti ‘saduran’ (terdiri daripada kalsium karbonat). Apakah yang akan anda gunakan untuk menyingkirkan saduran tersebut?

   A. Larutan akues soda penaik.
   B. Jus lemon dicairkan dengan air.*
   C. Larutan akues sodium hidroksida.

   Sebab bagi jawapan saya adalah:

   1. Saduran kalsium karbonat bertindakbalas lengkap dengan larutan berasid tersebut untuk menghasilkan garam neutral dan air.
   2. Saduran kalsium karbonat larut apabila bertindakbalas dengan larutan beralkali tersebut.

3. Saduran kalsium karbonat larut apabila bertindakbalas dengan larutan berasid tersebut.*
4. *Sebab lain:*

   ____

   ____

6. Jika tanah mempunyai nilai pH kurang daripada 7, ia dikatakan tidak menyokong pertumbuhan rumput yang sihat. Apakah bahan kimia yang boleh anda tambahkan kepada tanah tersebut untuk menggalakkan pertumbuhan rumput?

   A. Garam biasa
   B. Cuka
   C. Kapur (kalsium oksida)*
   D. Soda kaustik

   Sebab bagi jawapan saya adalah:

   1. Bahan berbes tersebut dapat meneutralkan keasidan tanah.*
   2. Bahan berbes tersebut mengurangkan keasidan tanah sehingga nilai pH melebihi 7.
   3. Bahan berasid tersebut menukarkan pH tanah mendekati nilai pH yang ideal.
   4. *Sebab lain:*

      ____

      ____

7. Apabila cebisan potongan kubis merah dididihkan dengan air dan hasil campurannya ditapis, suatu larutan ungu akan diperolehi. Larutan ungu tersebut boleh digunakan untuk membezakan antara...

   A. lemonade dan jus limau.
   B. lemonade dan air pili.*
   C. air hujan dan air mineral.

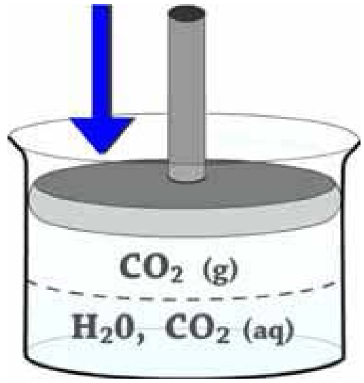
   Sebab bagi jawapan saya adalah:

   1. Larutan ungu kobis boleh digunakan untuk membezakan antara larutan berasid dan larutan neutral.
   2. Larutan ungu kobis boleh digunakan untuk membezakan antara larutan berasid dan larutan beralkali.*
   3. Larutan ungu kobis ialah penunjuk *phenolphtalein*.
   4. *Sebab lain:*

      ____

      ____

8.



Sebilangan mol tertentu karbon dioksida (CO_2) dan 100mL air tulen yang mengandungi karbon dioksida terlarut dimasukkan ke dalam satu bekas tertutup yang disambung ke sebuah piston pada suhu 25°C. Apabila piston itu ditekan, nilai pH larutan akan…..

A. meningkat.
B. berkurangan.*
C. tidak berubah.

Sebab bagi jawapan saya adalah:

1. Molekul-molekul gas CO_2 ini memiliki sifat-sifat berasid.
2. Molekul-molekul gas CO_2 ini tidak larut dalam air.
3. Air tersebut mengandungi kepekatan ion-ion H^+ yang tinggi.
4. Kepekatan CO_2 dalam air meningkat menghasilkan lebih banyak larutan berasid.*
5. *Sebab lain:*

   ____

   ____

9. Kedua-dua larutan akues kalium hidroksida dan juga amonia adalah alkali lemah.

A. Betul
B. Salah*

Sebab bagi jawapan saya adalah:

1. Akues kalium hikdroksida mengalami ionisasi lengkap di dalam air, manakala akues amonia hanya mengalami ionisasi separa.*
2. Kalium hidroksida dan amonia hanya mengalami ionisasi separa di dalam air.
3. Akues amonia, NH_3, adalah bukan alkali kerana ia tidak mengandungi ion-ion OH^- di dalam formulanya.
4. Kalium hidroksida dan amonia mengalami ionisasi lengkap di dalam air.

5. *Sebab lain:*

    ____

    ____

10. Larutan asid dan alkali pekat adalah juga asid dan alkali kuat.

    A. Betul
    B. Salah*

    Sebab bagi jawapan saya adalah:

    1. Larutan-larutan tersebut mengandungi kepekatan ion-ion H^+ atau OH^- yang tinggi.
    2. Larutan-larutan tersebut mungkin atau mungkin tidak mengalami ionisasi lengkap di dalam larutan akues.*
    3. Secara relatifnya, sebahagian besar bahan-bahan tersebut larut di dalam air.
    4. *Sebab lain:*

       ____

       ____

11. Sabun, deterjen, dan juga bahan-bahan pembersih rumah untuk lantai, oven, dan cermin tingkap mengandungi bahan kimia alkali lemah seperti sodium hidroksida dan amonia, tetapi bukan asid.

    A. Betul*
    B. Salah

    Sebab bagi jawapan saya adalah:

    1. Sifat alkali seperti sabun membolehkan kotoran dibersihkan.
    2. Asid adalah lebih korosif berbanding alkali yang mana lebih efektif menanggalkan kotoran.
    3. Alkali dapat melarutkan gris pada kotoran lebih mudah berbanding asid.*
    4. Asid dapat meneutralkan kotoran yang bersifat alkali.
    5. *Sebab lain:*

       ____

       ____

@->--- TERIMA KASIH ---<-@

APPENDIX M: Acids-Bases Achievement Test (ABCAT) – *Create Multiple-Choice Items with Free Responses of the Amended Version (Bilingual)*

Curtin University

Science & Mathematics Education Centre (SMEC)

ACIDS-BASES CHEMISTRY ACHIEVEMENT TEST
UJIAN PENCAPAIAN ASID-BES KIMIA

Chemistry
Kimia

Acids & Bases Lessons
Pembelajaran Asid & Bes

My name is Muhd Ibrahim Muhamad Damanhuri and currently am completing research for my Ph.D. at Curtin University in Perth, Western Australia. I am investigating the effectiveness of the acids-bases topic in the Chemistry curriculum prepared by Curriculum Development Division (CDD), Malaysian Ministry of Education. Your views about lessons on acids-bases chemistry are important. This information can be used to assist Malaysian chemistry teachers in making chemistry lessons of the Form 4 Chemistry curriculum more interesting and better understood. Your involvement in this research is entirely **voluntary**. You should be aware that you have the right to discontinue your participation at any time without affecting your personal or social life in any way. Your **identity** will be kept **confidential** and **anonymous** throughout this study.

Nama saya ialah Muhd Ibrahim Muhamad Damanhuri dan kini sedang melengkapkapkan kajian bagi Ph.D. saya di Curtin University, Perth, Western Australia. Saya sedang menyiasat keberkesanan tajuk asid-bes daripada kurikulum kimia yang disediakan oleh Bahagian Pembangunan Kurikulum (BPK), Kementerian Pelajaran Malaysia. Pandangan anda dalam pembelajaran tajuk asid-bes ini adalah sangat penting. Maklumat tersebut boleh digunakan untuk membantu guru-guru kimia di Malaysia untuk menjadikan pembelajaran kimia bagi kurikulum kimia Tingkatan 4 lebih menarik dan lebih mudah difahami. Penyertaan anda dalam kajian ini adalah secara ***sukarela****. Perlu diingatkan di sini bahawa anda mempunyai hak untuk berhenti menyertai kajian ini pada bila-bila masa tanpa mengugat kehidupan peribadi atau sosial anda.* ***Identiti*** *anda akan* ***dirahsiakan*** *dan* ***dilindungi*** *sepanjang kajian ini.*

Your participation in this research is highly appreciated. Thank you!
Penyertaan anda dalam kajian ini amatlah dihargai. Terima kasih!

(Note: Your personal information will be kept personal.)
(Nota: Maklumat peribadi anda akan dirahsiakan)

Name/*Nama*:____________________________ Gender/*Jantina*: _________________

Form/*Tingkatan*:______________ School/*Sekolah*: ______________________________

Section A
Seksyen A

Instruction: Each item in this section consists of four alternative responses A, B, C and D. For each item, choose one answer only and **circle** your answer in this test booklet.
Arahan: *Setiap item di dalam seksyen ini mengandungi empat pilihan jawapan, iaitu A, B, C dan D. Bagi setiap soalan, pilih satu jawapan sahaja dan* ***bulatkan*** *jawapan anda dalam kertas ujian ini.*

1. An acid displays its properties when it…..
Suatu asid menunjukkan sifat-sifatnya apabila ia…..

   A. ionises in water to produce H^+ ions.*
   mengion dalam air menghasilkan ion-ion H^+.

   B. ionises in propane to produce H^+ ions.
   mengion dalam propana menghasilkan ion-ion H^+.

   C. ionises in water to produce OH^- ions.
   mengion dalam air menghasilkan ion-ion OH^-.

   D. ionises in propane to produce OH^- ions.
   mengion dalam propana menghasilkan ion-ion OH^-.

2. Which of the following statements is correct about the pH of a solution?
Yang mana antara pernyataan berikut benar mengenai skala pH?

   A. A solution that has pH value less than 7 is an alkaline solution.
   Larutan yang mempunyai nilai pH kurang daripada 7 adalah larutan beralkali.

   B. A solution that has pH value more than 7 is an acidic solution.
   Larutan yang mempunyai nilai pH lebih daripada 7 adalah larutan berasid.

   C. A solution that has pH value equal to 7 is a neutral solution.*
   Larutan yang mempunyai nilai pH bersamaan 7 adalah larutan neutral.

   D. A solution that has pH value equal to 7 is an alkaline solution.
   Larutan yang mempunyai nilai pH bersamaan 7 adalah larutan beralkali.

3. Which of the following equations correctly describes the relationship between concentration (g dm^{-3}) and molarity (mol dm^{-3})?
Yang mana antara persamaan berikut adalah betul menggambarkan hubungan di antara kepekatan (g dm^{-3}) dan kemolaran (mol dm^{-3})?

A. $\text{Molarity (mol dm}^{-3}) = \dfrac{\text{Concentration (g dm}^{-3})}{\text{Molar mass (g mol}^{-1})}$ *
$\text{Kemolaran (mol dm}^{-3}) = \dfrac{\text{Kepekatan (g dm}^{-3})}{\text{Jisim molar (g mol}^{-1})}$

B. $\text{Molarity (mol dm}^{-3}) = \dfrac{\text{Molar mass (g mol}^{-1})}{\text{Concentration (g dm}^{-3})}$
$\text{Kemolaran (mol dm}^{-3}) = \dfrac{\text{Jisim molar (g mol}^{-1})}{\text{Kepekatan (g dm}^{-3})}$

C. $\text{Concentration (g dm}^{-3}) = \dfrac{\text{Molarity (mol dm}^{-3})}{\text{Molar mass (g mol}^{-1})}$
$\text{Kepekatan (g dm}^{-3}) = \dfrac{\text{Kemolaran (mol dm}^{-3})}{\text{Jisim molar (g mol}^{-1})}$

D. $\text{Concentration (g dm}^{-3}) = \dfrac{\text{Molar mass (g mol}^{-1})}{\text{Molarity (mol dm}^{-3})}$
$\text{Kepekatan (g dm}^{-3}) = \dfrac{\text{Jisim molar (g mol}^{-1})}{\text{Kemolaran (mol dm}^{-3})}$

4. Which of the following solutions has the lowest pH value?
Yang mana antara larutan berikut mempunyai nilai pH paling rendah?

A. 20 cm^3 of 2.0 mol dm^{-3} sulphuric acid.
20 cm^3 asid sulfurik 2.0 mol dm^{-3}.

B. 20 cm^3 of 3.0 mol dm^{-3} sulphuric acid.*
20 cm^3 asid sulfurik 3.0 mol dm^{-3}.

C. 50 cm^3 of 2.0 mol dm^{-3} sulphuric acid.
50 cm^3 asid sulfurik 2.0 mol dm^{-3}.

D. 100 cm^3 of 2.0 mol dm^{-3} sulphuric acid.
100 cm^3 asid sulfurik 2.0 mol dm^{-3}.

5. Distilled water is added to 50 cm^3 of 2 mol dm^{-3} potassium hydroxide solution to produce 250 cm^3 of potassium hydroxide solution. What is the concentration of the potassium hydroxide solution produced?
Air suling ditambahkan kepada 50 cm^3 larutan kalium hidroksida 2 mol dm^{-3} untuk menghasilkan 250 cm^3 larutan kalium hidroksida. Apakah kepekatan larutan kalium hidroksida yang dihasilkan?

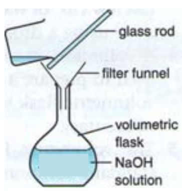
A. 0.3 mol dm^{-3}.

B. 0.4 mol dm^{-3}.*

C. 0.5 mol dm^{-3}.

D. 0.6 mol dm^{-3}.

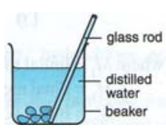
6. The diagrams below, **not** necessarily in the correct order, show five steps involved in the preparation of a standard solution of sodium hydroxide, NaOH.
*Gambarajah di bawah **tidak** semestinya disusun dalam turutan yang betul menunjukkan lima langkah yang terlibat dalam penyediaan suatu larutan piawai sodium hidroksida, NaOH.*

I. 

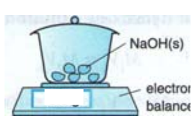
The aqueous NaOH solution is transferred to a volumetric flask.
Larutan NaOH akues dipindahkan ke dalam kelalang isipadu.

II. 

Distilled water is added up to the graduation mark.
Air suling ditambahkan sehingga ke penanda aras.

III. 

NaOH solid is dissolved using distilled water.
Pepejal NaOH dilarutkan menggunakan air suling.

IV. 

NaOH solid is weighed.
Pepejal NaOH ditimbang.

V. 
The NaOH solution is shaken.
Larutan NaOH digoncang.

Which of the following is the correct order of steps in the preparation of a standard solution of sodium hydroxide, NaOH?
Yang mana antara berikut adalah turutan langkah yang betul dalam penyediaan larutan piawai sodium hidroksida, NaOH?

A. I, III, IV, II, V.

B. III, V, I, II, IV.

C. IV, III, I, II, V.*

D. II, I, III, V, IV.

7. Which of the following is **not** a step in the procedure to prepare a solution with a specified concentration using the dilution method?
*Yang manakah antara berikut **bukan** merupakan langkah penyediaan larutan dengan kepekatan tertentu menggunakan kaedah pencairan?*

A. Distilled water is added to the volumetric flask until the graduation mark.
Air suling ditambahkan ke dalam kelalang isipadu sehingga ke penanda aras.

B. A few drops of universal indicator solution are added into the volumetric flask.*
Beberapa titis larutan penunjuk semesta ditambahkan ke dalam kelalang isipadu.

C. The volume of stock solution required is calculated.
Isipadu larutan stok yang diperlukan dikira.

D. The required volume of stock solution is transferred into the volumetric flask using a pipette.
Isipadu larutan stok yang diperlukan dipindahkan ke dalam kelalang isipadu menggunakan pipet.

8. Which of the following apparatus might **not** be needed for a titration experiment?
*Yang manakah antara radas berikut mungkin **tidak** diperlukan dalam eksperimen pentitratan?*

A. Pipette.
Pipet.

B. White tile.
Jubin putih.

C. Retort stand.
Kaki retot.

D. Test tube.*
Tabung uji.

9. Which of the following equations most accurately describes the neutralisation reaction between the acid, HA, and magnesium hydroxide?
Yang mana antara persamaan berikut paling tepat menggambarkan tindakbalas peneutralan di antara asid, HA, dan magnesium hidroksida?

A. $Mg(OH)_2 + HA \rightarrow MgA_2 + H_2O$

B. $Mg(OH)_2 + 2HA \rightarrow MgA_2 + 2H_2O$*

C. $MgA_2 + H_2O \rightarrow Mg(OH)_2 + HA$

D. $MgA_2 + 2H_2O \rightarrow Mg(OH)_2 + 2HA$

10. A group of chemistry students carried out an experiment in the school laboratory to determine the concentration of a hydrochloric acid solution by titration. In order to do that, they added a few drops of phenolphthalein indicator solution into 25 cm^3 of 1.5 mol dm^{-3} sodium hydroxide solution. The alkali solution was then titrated with the acid solution. The average volume of the hydrochloric acid solution used for this experiment was found to be 28.15 cm^3. What is the concentration of the hydrochloric acid solution used in this experiment?
Sekumpulan pelajar kimia telah menjalankan suatu eksperimen di makmal sekolah untuk menentukan kepekatan suatu larutan asid hidroklorik melalui pentitratan. Untuk itu, mereka telah menambahkan beberapa titis larutan penunjuk phenolphthalein ke dalam 25 cm^3 larutan sodium hidroksida 1.5 mol dm^{-3}. Larutan alkali itu kemudiannya telah dititratkan dengan larutan asid tersebut. Isipadu purata bagi larutan asid hidroklorik yang digunakan dalam ekperimen ini didapati sebanyak 28.15 cm^3. Apakah kepekatan larutan asid hidroklorik yang digunakan dalam eksperimen ini?

A. 2.35 mol dm^{-3}.

B. 2.30 mol dm^{-3}.

C. 1.82 mol dm^{-3}.

D. 1.33 mol dm^{-3}.*

11. When a standard solution of specific concentration is diluted, the concentration of the solution will _____, while the number of moles of solute present will be _____.
Apabila suatu larutan piawai berkepekatan tertentu dicairkan, kepekatan larutan tersebut akan _____, manakala bilangan mol bahan terlarut yang hadir akan _____.

A. increase; decrease
bertambah; berkurang

B. increase; constant
bertambah; tetap sama

C. decrease; constant*
berkurang; tetap sama

D. decrease; decrease
berkurang; berkurang

12. Aqueous potassium hydroxide reacts with _____ to produce a salt and water.
Kalium hidroksida akues boleh mengalami tindakbalas dengan _____ untuk menghasilkan garam dan air.

A. Glacial acetic acid.
Asid asetik glasial.

B. Aqueous sodium chloride.
Sodium klorida akues.

C. Dilute nitric acid.*
Asid nitrik cair.

D. Aqueous magnesium hydroxide.
Magnesium hikdrosida akues.

Section B
Seksyen B

This **test** consists of 11 items. Each item in this section has two parts. In the first part of each item, **circle** one of the responses, A, B, C, D, etc., to indicate what you consider to be the most appropriate answer. In the second part, **suggest** your reason for selecting the particular response in the space provided.
__Ujian__ ini mengandungi 11 item. Setiap item di dalam seksyen ini mengandungi dua bahagian. Pada bahagian pertama setiap item, __bulatkan__ salah satu jawapan, A, B, C, D, atau sebagainya bagi pertimbangan jawapan anda yang paling sesuai. Dalam bahagian kedua, __cadangkan__ sebab memilih jawapan tersebut di ruang yang disediakan.

1. Chemical X shows the following properties:
Bahan kimia X menunjukkan ciri-ciri berikut:

- ✓ Tastes bitter and feels soapy.
Berasa pahit dan licin.
- ✓ Turns red litmus paper blue.
Menukarkan kertas litmus merah kepada biru.
- ✓ Reacts with an acid to produce a salt and water.
Bertindakbalas dengan asid untuk menghasilkan garam dan air.
- ✓ Produces ammonia gas when heated with an ammonium salt.
Menghasilkan gas ammonia apabila dipanaskan dengan garam ammonium.
- ✓ Reacts with an aqueous salt solution to produce a metal hydroxide.
Bertindakbalas dengan larutan garam akues untuk menghasilkan logam hidroksida.

Which of the following is most probably chemical X?
Yang mana antara berikut paling berkemungkinan bahan kimia X?

A. Dry ammonia gas.
Gas ammonia kering.

B. Sodium hydroxide dissolved in propane.
Sodium hidroksida larut dalam propana.

C. Glacial acetic acid.
Asid asetik glasial.

D. Aqueous calcium hydroxide.*
Kalsium hidroksida akues.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

____

____

____

2. The table shows the pH value of four aqueous solutions, P, Q, R, and S.
Jadual di bawah menunjukkan nilai pH bagi empat larutan, P, Q, R, dan S.

Solution/*Larutan*	P	Q	R	S
pH value/*Nilai pH*	13	7	3	9

Which of the following solutions will react with calcium carbonate to produce carbon dioxide gas?
Yang manakah antara larutan tersebut akan bertindakbalas dengan kalsium karbonat untuk menghasilkan gas karbon dioksida?

A. P

B. Q

C. R*

D. S

The reason for my answer is:
Sebab bagi jawapan saya adalah:

____

____

____

3. When methyl orange indicator in a titration experiment turns yellow, this indicates the reaction between acid solution and alkali solution has reached its end point.
Apabila penunjuk metil oren dalam suatu eksperimen pentitratan bertukar ke warna kuning, ini menunjukkan tindakbalas antara larutan asid dan larutan alkali telah mencapai takat akhir.

A. True.
Betul.

B. False.*
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

4. What is the main apparatus that is used in the preparation of a standard solution?
Apakah radas utama yang digunakan dalam penyediaan suatu larutan piawai?

A. Volumetric flask*
Kelalang isipadu.

B. Beaker
Bikar.

C. Measuring cylinder
Silinder penyukat.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

5. Both sulphuric acid and ethanoic acid are strong acids.
Kedua-dua asid sulfurik dan asid etanoik adalah asid kuat.

A. True.
Betul.

B. False.*
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

6. Two common substances that have the formulas HCl and CH_4 both contain the element hydrogen. However, only HCl has acidic properties while CH_4 does **not**.
*Dua bahan yang biasa ditemui mempunyai formula HCl dan CH_4 yang mana kedua-duanya mengandungi unsur hidrogen. Walaubagaimanapun, hanya HCl menunjukkan sifat-sifat asid tetapi CH_4 **tidak**.*

A. True.*
Betul.

B. False.
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

____

____

____

7. What is a property of citrus fruits like oranges and lemons?
Apakah sifat buah-buahan sitrus seperti oren dan lemon?

A. Acidic.*
Berasid.

B. Basic.
Berbes.

C. Neutral.
Neutral.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

____

____

____

8. Soaps and detergents as well as household cleaners for floors, ovens and glass windows contain alkaline chemicals like sodium hydroxide and ammonia, but **not** acids.
Sabun, deterjen, dan juga bahan-bahan pembersih rumah untuk lantai, oven, dan cermin tingkap mengandungi bahan kimia alkali seperti sodium hidroksida dan amonia, tetapi ***bukan*** *asid.*

A. True.*
Betul.

B. False.
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Alkalis are soapy and so are able to wash away stains.
Sifat alkali yang licin membolehkan kotoran dibersihkan.

2. Acids are more corrosive than alkalis and so are more effective in removing stains.
Asid adalah lebih korosif berbanding alkali yang mana lebih efektif menanggalkan kotoran.

3. Alkalis dissolve grease and oils present in dirt more readily than acids.*
Alkali dapat melarutkan gris dan minyak yang hadir dalam kotoran lebih mudah berbanding asid.

4. Acids are able to neutralise alkalis present in dirt.
Asid dapat meneutralkan alkali yang hadir dalam kotoran.

5. Other reason:
Sebab lain:

____

____

9. If soil is too acidic, it is not likely to support the healthy growth of grass. What chemical would you add to the soil to promote the growth of grass?
Jika tanah terlalu berasid, ia dikatakan tidak menyokong pertumbuhan rumput yang sihat. Apakah bahan kimia yang boleh anda tambahkan kepada tanah tersebut untuk menggalakkan pertumbuhan rumput?

A. Common salt.
Garam biasa.

B. Vinegar.
Cuka.

C. Lime (calcium oxide).*
Kapur (kalsium oksida).

D. Caustic soda.
Soda kaustik.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

____

____

____

10. Aqueous solutions of potassium hydroxide as well as ammonia are both weak alkalis.
Kedua-dua larutan akues kalium hidroksida dan juga amonia adalah alkali lemah.

A. True.
Betul.

B. False.*
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Aqueous potassium hydroxide is completely ionised in water, while aqueous ammonia is only partially ionised.*
Kalium hikdroksida akues mengalami ionisasi lengkap di dalam air, manakala ammonia akues hanya mengalami ionisasi separa.

2. Potassium hydroxide and ammonia are only partially ionised in water.
Kalium hidroksida dan amonia hanya mengalami ionisasi separa di dalam air.

3. Aqueous ammonia, NH_3, is not an alkali because it does not contain OH^- ions in its formula.
Amonia akues, NH_3, adalah bukan alkali kerana ia tidak mengandungi ion-ion OH^- di dalam formulanya.

4. Potassium hydroxide and ammonia ionise completely in water.
Kalium hidroksida dan amonia mengalami ionisasi lengkap di dalam air.

5. Other reason:
Sebab lain:

____

____

11. Concentrated solutions of acids and alkalis are also strongly acidic and alkaline.
Larutan asid dan alkali pekat adalah juga asid dan alkali kuat.

A. True.
Betul.

B. False.*
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. The solutions contain high concentrations of H^+ or OH^- ions.
Larutan-larutan tersebut mengandungi kepekatan ion-ion H^+ atau OH^- yang tinggi.

2. The solutions may or may not be highly ionised in aqueous solution.*
Larutan-larutan tersebut mungkin atau mungkin tidak mengalami ionisasi lengkap di dalam larutan akues.

3. Relatively large amounts of the substances are dissolved in water.
Secara relatifnya, sebahagian besar bahan-bahan tersebut larut di dalam air.

4. Other reason:
Sebab lain:

____

____

Test End.
Ujian Tamat.

Thank You!
Terima Kasih!

APPENDIX N: Acids-Bases Achievement Test (ABCAT) – ***Developing Second Tiers Distracters of the Amended Version (Bilingual)***

Name/*Nama*:__________________________________ Gender/*Jantina*:____________

Form/*Tingkatan*:___________ School/*Sekolah*:_______________ Email/*Emel*:_______

This **test** consists of 11 items. Each item in this section has two parts. In the first part of each item, **circle** one of the responses, A, B, C, D, etc., to indicate what you consider to be the most appropriate answer. In the second part, **suggest** your reason for selecting the particular response in the space provided.
Ujian *ini mengandungi 11 item. Setiap item di dalam seksyen ini mengandungi dua bahagian. Pada bahagian pertama setiap item,* ***bulatkan*** *salah satu jawapan, A, B, C, D, atau sebagainya bagi pertimbangan jawapan anda yang paling sesuai. Dalam bahagian kedua,* ***cadangkan*** *sebab memilih jawapan tersebut di ruang yang disediakan.*

1. Chemical X shows the following properties:
Bahan kimia X menunjukkan ciri-ciri berikut:

- ✓ Tastes bitter and feels soapy.
Berasa pahit dan licin.

- ✓ Turns red litmus paper blue.
Menukarkan kertas litmus merah kepada biru.

- ✓ Reacts with an acid to produce a salt and water.
Bertindakbalas dengan asid untuk menghasilkan garam dan air.

- ✓ Produces ammonia gas when heated with an ammonium salt.
Menghasilkan gas ammonia apabila dipanaskan dengan garam ammonium.

- ✓ Reacts with an aqueous salt solution to produce a metal hydroxide.
Bertindakbalas dengan larutan garam akues untuk menghasilkan logam hidroksida.

Which of the following is most probably chemical X?
Yang mana antara berikut paling berkemungkinan bahan kimia X?

A. Dry ammonia gas.
Gas ammonia kering.

B. Sodium hydroxide dissolved in propane.
Sodium hidroksida larut dalam propana.

C. Glacial acetic acid.
Asid asetik glasial.

D. Aqueous calcium hydroxide.*
Kalsium hidroksida akues.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

____

____

____

2. The table shows the pH value of four aqueous solutions, P, Q, R, and S.
Jadual di bawah menunjukkan nilai pH bagi empat larutan, P, Q, R, dan S.

Solution/*Larutan*	P	Q	R	S
pH value/*Nilai pH*	13	7	3	9

Which of the following solutions will react with calcium carbonate to produce carbon dioxide gas?
Yang manakah antara larutan tersebut akan bertindakbalas dengan kalsium karbonat untuk menghasilkan gas karbon dioksida?

A. P

B. Q

C. R*

D. S

The reason for my answer is:
Sebab bagi jawapan saya adalah:

____

____

____

3. When methyl orange indicator in a titration experiment turns yellow, this indicates the reaction between acid solution and alkali solution has reached its end point.
Apabila penunjuk metil oren dalam suatu eksperimen pentitratan bertukar ke warna kuning, ini menunjukkan tindakbalas antara larutan asid dan larutan alkali telah mencapai takat akhir.

A. True.
Betul.

B. False.*
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

____

____

____

4. What is the main apparatus that is used in the preparation of a standard solution?
Apakah radas utama yang digunakan dalam penyediaan suatu larutan piawai?

   A. Volumetric flask*
   Kelalang isipadu.

   B. Beaker
   Bikar.

   C. Measuring cylinder
   Silinder penyukat.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

____

____

____

5. Both sulphuric acid and ethanoic acid are strong acids.
Kedua-dua asid sulfurik dan asid etanoik adalah asid kuat.

   A. True.
   Betul.

   B. False.*
   Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

____

____

____

6. Two common substances that have the formulas HCl and CH_4 both contain the element hydrogen. However, only HCl has acidic properties while CH_4 does **not**.
Dua bahan yang biasa ditemui mempunyai formula HCl dan CH_4 yang mana kedua-duanya mengandungi unsur hidrogen. Walaubagaimanapun, hanya HCl menunjukkan sifat-sifat asid tetapi CH_4 ***tidak****.*

   A. True.*
   Betul.

   B. False.
   Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

____

____

____

7. What is a property of citrus fruits like oranges and lemons?
Apakah sifat buah-buahan sitrus seperti oren dan lemon?

   A. Acidic.*
   Berasid.

   B. Basic.
   Berbes.

   C. Neutral.
   Neutral.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

____

____

____

8. Soaps and detergents as well as household cleaners for floors, ovens and glass windows contain alkaline chemicals like sodium hydroxide and ammonia, but **not** acids.
*Sabun, deterjen, dan juga bahan-bahan pembersih rumah untuk lantai, oven, dan cermin tingkap mengandungi bahan kimia alkali seperti sodium hidroksida dan amonia, tetapi **bukan** asid.*

A. True.*
Betul.

B. False.
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Alkalis are soapy and so are able to wash away stains.
Sifat alkali yang licin membolehkan kotoran dibersihkan.

2. Acids are more corrosive than alkalis and so are more effective in removing stains.
Asid adalah lebih korosif berbanding alkali yang mana lebih efektif menanggalkan kotoran.

3. Alkalis dissolve grease and oils present in dirt more readily than acids.*
Alkali dapat melarutkan gris dan minyak yang hadir dalam kotoran lebih mudah berbanding asid.

4. Acids are able to neutralise alkalis present in dirt.
Asid dapat meneutralkan alkali yang hadir dalam kotoran.

5. Other reason:
Sebab lain:

____

____

9. If soil is too acidic, it is not likely to support the healthy growth of grass. What chemical would you add to the soil to promote the growth of grass?
Jika tanah terlalu berasid, ia dikatakan tidak menyokong pertumbuhan rumput yang sihat. Apakah bahan kimia yang boleh anda tambahkan kepada tanah tersebut untuk menggalakkan pertumbuhan rumput?

A. Common salt.
Garam biasa.

B. Vinegar.
Cuka.

C. Lime (calcium oxide).*
Kapur (kalsium oksida).

D. Caustic soda.
Soda kaustik.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

____

____

____

10. Aqueous solutions of potassium hydroxide as well as ammonia are both weak alkalis.
Kedua-dua larutan akues kalium hidroksida dan juga amonia adalah alkali lemah.

A. True.
Betul.

B. False.*
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Aqueous potassium hydroxide is completely ionised in water, while aqueous ammonia is only partially ionised.*
Kalium hikdroksida akues mengalami ionisasi lengkap di dalam air, manakala ammonia akues hanya mengalami ionisasi separa.

2. Potassium hydroxide and ammonia are only partially ionised in water.
Kalium hidroksida dan amonia hanya mengalami ionisasi separa di dalam air.

3. Aqueous ammonia, NH_3, is not an alkali because it does not contain OH^- ions in its formula.
Amonia akues, NH_3, adalah bukan alkali kerana ia tidak mengandungi ion-ion OH^- di dalam formulanya.

4. Potassium hydroxide and ammonia ionise completely in water.
Kalium hidroksida dan amonia mengalami ionisasi lengkap di dalam air.

5. Other reason:
Sebab lain:

____

____

11. Concentrated solutions of acids and alkalis are also strongly acidic and alkaline.
Larutan asid dan alkali pekat adalah juga asid dan alkali kuat.

A. True.
Betul.

B. False.*
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. The solutions contain high concentrations of H^+ or OH^- ions.
Larutan-larutan tersebut mengandungi kepekatan ion-ion H^+ atau OH^- yang tinggi.

2. The solutions may or may not be highly ionised in aqueous solution.*
Larutan-larutan tersebut mungkin atau mungkin tidak mengalami ionisasi lengkap di dalam larutan akues.

3. Relatively large amounts of the substances are dissolved in water.
Secara relatifnya, sebahagian besar bahan-bahan tersebut larut di dalam air.

4. Other reason:
Sebab lain:

____

____

Items End.
Item Tamat.

Thank You!
Terima Kasih!

APPENDIX O: Acids-Bases Achievement Test (ABCAT) – *Pilot Test of the Amended Version (Bilingual)*

Science & Mathematics Education Centre (SMEC)

ACIDS-BASES CHEMISTRY ACHIEVEMENT TEST
UJIAN PENCAPAIAN ASID-BES KIMIA

Pilot-Test
Ujian Rintis

Chemistry
Kimia

Acids & Bases Lessons
Pembelajaran Asid & Bes

My name is Muhd Ibrahim Muhamad Damanhuri and currently am completing research for my Ph.D. at Curtin University in Perth, Western Australia. I am investigating the effectiveness of the acids-bases topic in the Chemistry curriculum prepared by Curriculum Development Division (CDD), Malaysian Ministry of Education. Your views about lessons on acids-bases chemistry are important. This information can be used to assist Malaysian chemistry teachers in making chemistry lessons of the Form 4 Chemistry curriculum more interesting and better understood. Your involvement in this research is entirely **voluntary**. You should be aware that you have the right to discontinue your participation at any time without affecting your personal or social life in any way. Your **identity** will be kept **confidential** and **anonymous** throughout this study.

Nama saya ialah Muhd Ibrahim Muhamad Damanhuri dan kini sedang melengkapkapkan kajian bagi Ph.D. saya di Curtin University, Perth, Western Australia. Saya sedang menyiasat keberkesanan tajuk asid-bes daripada kurikulum kimia yang disediakan oleh Bahagian Pembangunan Kurikulum (BPK), Kementerian Pelajaran Malaysia. Pandangan anda dalam pembelajaran tajuk asid-bes ini adalah sangat penting. Maklumat tersebut boleh digunakan untuk membantu guru-guru kimia di Malaysia untuk menjadikan pembelajaran kimia bagi kurikulum kimia Tingkatan 4 lebih menarik dan lebih mudah difahami. Penyertaan anda dalam kajian ini adalah secara ***sukarela****. Perlu diingatkan di sini bahawa anda mempunyai hak untuk berhenti menyertai kajian ini pada bila-bila masa tanpa mengugat kehidupan peribadi atau sosial anda.* ***Identiti*** *anda akan* ***dirahsiakan*** *dan* ***dilindungi*** *sepanjang kajian ini.*

Your participation in this research is highly appreciated. Thank you!
Penyertaan anda dalam kajian ini amatlah dihargai. Terima kasih!

(Note: Your personal information will be kept personal.)
(Nota: Maklumat peribadi anda akan dirahsiakan)

Name/*Nama*:____________________________ Gender/*Jantina*: ________________

Form/*Tingkatan*:______________ School/*Sekolah*: _____________________________

Information for Students

Maklumat untuk Pelajar

1. This test is **bilingual**.
   *Ujian ini adalah dalam **dwibahasa**.*

2. The test is composed of two sections, Section A and Section B.
   Ujian ini terdiri daripada dua seksyen, Seksyen A dan Seksyen B.

   (a) **Section A** consists of 12 items. Each item in this section consists of four alternative responses A, B, C and D. For each item, choose one answer only and **circle** your answer in this test booklet.
   ***Seksyen A** mengandungi 12 item. Setiap item di dalam seksyen ini mengandungi empat pilihan jawapan, iaitu A, B, C dan D. Bagi setiap soalan, pilih satu jawapan sahaja dan **bulatkan** jawapan anda dalam kertas ujian ini.*

   (b) **Section B** consists of 11 items. Each item of this section has two parts, a multiple-choice content response followed by a multiple-choice reason response. For each item, choose your most appropriate response from the first part and **circle** your answer A, B, C, etc. Then choose one of the reasons from the second part that best matches your answer to the first part and **circle** your answer 1, 2, 3, etc. If you do **not** agree with any of the given reasons, please write your reason in the space provided.
   ***Seksyen B** mengandungi 10 item. Setiap item daripada seksyen ini terdiri daripada dua bahagian, kandugan respon aneka pilihan diikuti sebab aneka pilihan. Bagi setiap item, buat pilihan yang sesuai daripada bahagian pertama dan **bulatkan** jawapan anda samada A, B, C, atau sebagainya. Kemudian pilih salah satu sebab di bahagian kedua yang sepadan dengan jawapan anda di bahagian pertama dan **bulatkan** jawapan anda samada 1, 2, 3, atau sebagainya. Sekiranya anda **tidak** bersetuju dengan mana-mana sebab yang diberikan, sila tulis sebab anda di ruang yang disediakan.*

3. Answer **all** questions. **Forty-five minutes** are allocated for this test.
   *Jawab **semua** soalan. **Empat puluh lima minit** diperuntukkan untuk ujian ini.*

Section A

Seksyen A

Instruction: Each item in this section consists of four alternative responses A, B, C and D. For each item, choose one answer only and **circle** your answer in this test booklet.
Arahan: *Setiap item di dalam seksyen ini mengandungi empat pilihan jawapan, iaitu A, B, C dan D. Bagi setiap soalan, pilih satu jawapan sahaja dan* **bulatkan** *jawapan anda dalam kertas ujian ini.*

1. An acid displays its properties when it…..
   Suatu asid menunjukkan sifat-sifatnya apabila ia…..

   A. ionises in water to produce H^+ ions.*
   mengion dalam air menghasilkan ion-ion H^+.

   B. ionises in propane to produce H^+ ions.
   mengion dalam propana menghasilkan ion-ion H^+.

   C. ionises in water to produce OH^- ions.
   mengion dalam air menghasilkan ion-ion OH^-.

   D. ionises in propane to produce OH^- ions.
   mengion dalam propana menghasilkan ion-ion OH^-.

2. Which of the following statements is correct about the pH of a solution?
   Yang mana antara pernyataan berikut benar mengenai skala pH?

   A. A solution that has pH value less than 7 is an alkaline solution.
   Larutan yang mempunyai nilai pH kurang daripada 7 adalah larutan beralkali.

   B. A solution that has pH value more than 7 is an acidic solution.
   Larutan yang mempunyai nilai pH lebih daripada 7 adalah larutan berasid.

   C. A solution that has pH value equal to 7 is a neutral solution.*
   Larutan yang mempunyai nilai pH bersamaan 7 adalah larutan neutral.

   D. A solution that has pH value equal to 7 is an alkaline solution.
   Larutan yang mempunyai nilai pH bersamaan 7 adalah larutan beralkali.

3. Which of the following equations correctly describes the relationship between concentration (g dm^{-3}) and molarity (mol dm^{-3})?
Yang mana antara persamaan berikut adalah betul menggambarkan hubungan di antara kepekatan (g dm^{-3}) dan kemolaran (mol dm^{-3})?

A. $$\text{Molarity (mol dm}^{-3}) = \frac{\text{Concentration (g dm}^{-3})}{\text{Molar mass (g mol}^{-1})}$$ *
$$\text{Kemolaran (mol dm}^{-3}) = \frac{\text{Kepekatan (g dm}^{-3})}{\text{Jisim molar (g mol}^{-1})}$$

B. $$\text{Molarity (mol dm}^{-3}) = \frac{\text{Molar mass (g mol}^{-1})}{\text{Concentration (g dm}^{-3})}$$
$$\text{Kemolaran (mol dm}^{-3}) = \frac{\text{Jisim molar (g mol}^{-1})}{\text{Kepekatan (g dm}^{-3})}$$

C. $$\text{Concentration (g dm}^{-3}) = \frac{\text{Molarity (mol dm}^{-3})}{\text{Molar mass (g mol}^{-1})}$$
$$\text{Kepekatan (g dm}^{-3}) = \frac{\text{Kemolaran (mol dm}^{-3})}{\text{Jisim molar (g mol}^{-1})}$$

D. $$\text{Concentration (g dm}^{-3}) = \frac{\text{Molar mass (g mol}^{-1})}{\text{Molarity (mol dm}^{-3})}$$
$$\text{Kepekatan (g dm}^{-3}) = \frac{\text{Jisim molar (g mol}^{-1})}{\text{Kemolaran (mol dm}^{-3})}$$

4. Which of the following solutions has the lowest pH value?
Yang mana antara larutan berikut mempunyai nilai pH paling rendah?

A. 20 cm^3 of 2.0 mol dm^{-3} sulphuric acid.
20 cm^3 asid sulfurik 2.0 mol dm^{-3}.

B. 20 cm^3 of 3.0 mol dm^{-3} sulphuric acid.*
20 cm^3 asid sulfurik 3.0 mol dm^{-3}.

C. 50 cm^3 of 2.0 mol dm^{-3} sulphuric acid.
50 cm^3 asid sulfurik 2.0 mol dm^{-3}.

D. 100 cm^3 of 2.0 mol dm^{-3} sulphuric acid.
100 cm^3 asid sulfurik 2.0 mol dm^{-3}.

5. Distilled water is added to 50 cm^3 of 2 mol dm^{-3} potassium hydroxide solution to produce 250 cm^3 of potassium hydroxide solution. What is the concentration of the potassium hydroxide solution produced?
Air suling ditambahkan kepada 50 cm^3 larutan kalium hidroksida 2 mol dm^{-3} untuk menghasilkan 250 cm^3 larutan kalium hidroksida. Apakah kepekatan larutan kalium hidroksida yang dihasilkan?

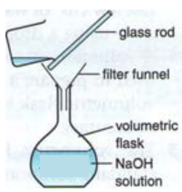
A. 0.3 mol dm^{-3}.

B. 0.4 mol dm^{-3}.*

C. 0.5 mol dm^{-3}.

D. 0.6 mol dm^{-3}.

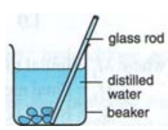
6. The diagrams below, **not** necessarily in the correct order, show five steps involved in the preparation of a standard solution of sodium hydroxide, NaOH.
*Gambarajah di bawah **tidak** semestinya disusun dalam turutan yang betul menunjukkan lima langkah yang terlibat dalam penyediaan suatu larutan piawai sodium hidroksida, NaOH.*

I. 

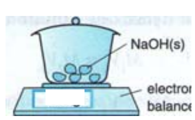
The aqueous NaOH solution is transferred to a volumetric flask.
Larutan NaOH akues dipindahkan ke dalam kelalang isipadu.

II. 

Distilled water is added up to the graduation mark.
Air suling ditambahkan sehingga ke penanda aras.

III. 

NaOH solid is dissolved using distilled water.
Pepejal NaOH dilarutkan menggunakan air suling.

IV. 

NaOH solid is weighed.
Pepejal NaOH ditimbang.

V. 
The NaOH solution is shaken.
Larutan NaOH digoncang.

Which of the following is the correct order of steps in the preparation of a standard solution of sodium hydroxide, NaOH?
Yang mana antara berikut adalah turutan langkah yang betul dalam penyediaan larutan piawai sodium hidroksida, NaOH?

A. I, III, IV, II, V.

B. III, V, I, II, IV.

C. IV, III, I, II, V.*

D. II, I, III, V, IV.

7. Which of the following is **not** a step in the procedure to prepare a solution with a specified concentration using the dilution method?
Yang manakah antara berikut ***bukan*** *merupakan langkah penyediaan larutan dengan kepekatan tertentu menggunakan kaedah pencairan?*

A. Distilled water is added to the volumetric flask until the graduation mark.
Air suling ditambahkan ke dalam kelalang isipadu sehingga ke penanda aras.

B. A few drops of universal indicator solution are added into the volumetric flask.*
Beberapa titis larutan penunjuk semesta ditambahkan ke dalam kelalang isipadu.

C. The volume of stock solution required is calculated.
Isipadu larutan stok yang diperlukan dikira.

D. The required volume of stock solution is transferred into the volumetric flask using a pipette.
Isipadu larutan stok yang diperlukan dipindahkan ke dalam kelalang isipadu menggunakan pipet.

8. Which of the following apparatus might **not** be needed for a titration experiment?
Yang manakah antara radas berikut mungkin ***tidak*** *diperlukan dalam eksperimen pentitratan?*

A. Pipette.
Pipet.

B. White tile.
Jubin putih.

C. Retort stand.
Kaki retot.

D. Test tube.*
Tabung uji.

9. Which of the following equations most accurately describes the neutralisation reaction between the acid, HA, and magnesium hydroxide?
Yang mana antara persamaan berikut paling tepat menggambarkan tindakbalas peneutralan di antara asid, HA, dan magnesium hidroksida?

A. $Mg(OH)_2 + HA \rightarrow MgA_2 + H_2O$

B. $Mg(OH)_2 + 2HA \rightarrow MgA_2 + 2H_2O$*

C. $MgA_2 + H_2O \rightarrow Mg(OH)_2 + HA$

D. $MgA_2 + 2H_2O \rightarrow Mg(OH)_2 + 2HA$

10. A group of chemistry students carried out an experiment in the school laboratory to determine the concentration of a hydrochloric acid solution by titration. In order to do that, they added a few drops of phenolphthalein indicator solution into 25 cm^3 of 1.5 mol dm^{-3} sodium hydroxide solution. The alkali solution was then titrated with the acid solution. The average volume of the hydrochloric acid solution used for this experiment was found to be 28.15 cm^3. What is the concentration of the hydrochloric acid solution used in this experiment?
Sekumpulan pelajar kimia telah menjalankan suatu eksperimen di makmal sekolah untuk menentukan kepekatan suatu larutan asid hidroklorik melalui pentitratan. Untuk itu, mereka telah menambahkan beberapa titis larutan penunjuk phenolphthalein ke dalam 25 cm^3 larutan sodium hidroksida 1.5 mol dm^{-3}. Larutan alkali itu kemudiannya telah dititratkan dengan larutan asid tersebut. Isipadu purata bagi larutan asid hidroklorik yang digunakan dalam ekperimen ini didapati sebanyak 28.15 cm^3. Apakah kepekatan larutan asid hidroklorik yang digunakan dalam eksperimen ini?

A. 2.35 mol dm^{-3}.

B. 2.30 mol dm^{-3}.

C. 1.82 mol dm^{-3}.

D. 1.33 mol dm^{-3}.*

11. When a standard solution of specific concentration is diluted, the concentration of the solution will _____, while the number of moles of solute present will be _____.
Apabila suatu larutan piawai berkepekatan tertentu dicairkan, kepekatan larutan tersebut akan _____, manakala bilangan mol bahan terlarut yang hadir akan _____.

A. increase; decrease
bertambah; berkurang

B. increase; constant
bertambah; tetap sama

C. decrease; constant*
berkurang; tetap sama

D. decrease; decrease
berkurang; berkurang

12. Aqueous potassium hydroxide reacts with _____ to produce a salt and water.
Kalium hidroksida akues boleh mengalami tindakbalas dengan _____ untuk menghasilkan garam dan air.

A. Glacial acetic acid.
Asid asetik glasial.

B. Aqueous sodium chloride.
Sodium klorida akues.

C. Dilute nitric acid.*
Asid nitrik cair.

D. Aqueous magnesium hydroxide.
Magnesium hikdrosida akues.

Section B
Seksyen B

Instruction: Each item of this section has two parts, a multiple-choice content response followed by a multiple-choice reason response. For each item, choose your most appropriate response from the first part and **circle** your answer A, B, C, etc. Then choose one of the reasons from the second part that best matches your answer to the first part and **circle** your answer 1, 2, 3, etc. If you do **not** agree with any of the given reasons, please write your reason in the space provided.
Arahan: *Setiap item daripada seksyen ini terdiri daripada dua bahagian, kandugan respon aneka pilihan diikuti sebab aneka pilihan. Bagi setiap item, buat pilihan yang sesuai daripada bahagian pertama dan* ***bulatkan*** *jawapan anda samada A, B, C, atau sebagainya. Kemudian pilih salah satu sebab di bahagian kedua yang sepadan dengan jawapan anda di bahagian pertama dan* ***bulatkan*** *jawapan anda samada 1, 2, 3, atau sebagainya. Sekiranya anda* ***tidak*** *bersetuju dengan mana-mana sebab yang diberikan, sila tulis sebab anda di ruang yang disediakan.*

1. Chemical X shows the following properties:
Bahan kimia X menunjukkan ciri-ciri berikut:

- ✓ Tastes bitter and feels soapy.
Berasa pahit dan licin.
- ✓ Turns red litmus paper blue.
Menukarkan kertas litmus merah kepada biru.
- ✓ Reacts with an acid to produce a salt and water.
Bertindakbalas dengan asid untuk menghasilkan garam dan air.
- ✓ Produces ammonia gas when heated with an ammonium salt.
Menghasilkan gas ammonia apabila dipanaskan dengan garam ammonium.
- ✓ Reacts with an aqueous salt solution to produce a metal hydroxide.
Bertindakbalas dengan larutan garam akues untuk menghasilkan logam hidroksida.

Which of the following is most probably chemical X?
Yang mana antara berikut paling berkemungkinan bahan kimia X?

A. Dry ammonia gas.
Gas ammonia kering.

B. Sodium hydroxide dissolved in propane.
Sodium hidroksida larut dalam propana.

C. Glacial acetic acid.
Asid asetik glasial.

D. Aqueous calcium hydroxide.*
Kalsium hidroksida akues.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Chemical X could ionise in water to produce H^+ ions.
   Bahan kimia X boleh mengion di dalam air untuk menghasilkan ion-ion H^+.

2. Chemical X could ionise in water to produce OH^- ions.*
   Bahan kimia X boleh mengion di dalam air untuk menghasilkan ion-ion OH^-.

3. Chemical X could ionise to produce OH^- ions in the absence of water.
   Bahan kimia X boleh mengion untuk menghasilkan ion-ion OH^- tanpa kehadiran air.

4. Chemical X is soluble in water.
   Bahan kimia X larut di dalam air.

5. Other reason:
   Sebab lain:

   ____

   ____

2. The table shows the pH value of four aqueous solutions, P, Q, R, and S.
   Jadual di bawah menunjukkan nilai pH bagi empat larutan, P, Q, R, dan S.

Solution/*Larutan*	P	Q	R	S
pH value/*Nilai pH*	13	7	3	9

Which of the following solutions will react with calcium carbonate to produce carbon dioxide gas?
Yang manakah antara larutan tersebut akan bertindakbalas dengan kalsium karbonat untuk menghasilkan gas karbon dioksida?

A. P

B. Q

C. R*

D. S

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. The solution contains a higher concentration of OH^- ions than H^+ ions.
   Larutan tersebut mengandungi kepekatan ion-ion OH^- yang lebih tinggi berbanding ion-ion H^+.

2. The solution contains a higher concentration of H^+ ions than OH^- ions.*
   Larutan tersebut mengandungi kepekatan ion-ion H^+ yang lebih tinggi berbanding ion-ion OH^-.

3. The solution contains equal concentrations of H^+ and OH^- ions.
   Larutan tersebut mengandungi kepekatan ion-ion H^+ dan ion-ion OH^- yang sama.

4. Other reason:
   Sebab lain:

   ____

   ____

3. When methyl orange indicator in a titration experiment turns yellow, this indicates the reaction between acid solution and alkali solution has reached its end point.
   Apabila penunjuk metil oren dalam suatu eksperimen pentitratan bertukar ke warna kuning, ini menunjukkan tindakbalas antara larutan asid dan larutan alkali telah mencapai takat akhir.

   A. True.
   Betul.

   B. False.*
   Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Methyl orange turns yellow because neutralisation has occurred.
   Metil oren bertukar ke warna kuning kerana peneutralan telah berlaku.

2. Methyl orange turns yellow because water and a salt are present in the solution.
   Metil oren bertukar ke warna kuning kerana terdapat kehadiran air dan garam dalam larutan tersebut.

3. Methyl orange turns yellow because there is an excess of alkali in the solution.*
   Metil oren bertukar ke warna kuning kerana terdapat lebihan alkali dalam larutan tersebut.

4. Methyl orange turns yellow because there is an excess of acid in the solution.
Metil oren bertukar ke warna kuning kerana terdapat lebihan asid dalam larutan tersebut.

5. Other reason:
Sebab lain:

____

____

4. What is the main apparatus that is used in the preparation of a standard solution?
Apakah radas utama yang digunakan dalam penyediaan suatu larutan piawai?

A. Volumetric flask*
Kelalang isipadu.

B. Beaker
Bikar.

C. Measuring cylinder
Silinder penyukat.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. It is easier to dissolve the solute by shaking.
Ia memudahkan bahan terlarut melarut dengan menggoncang.

2. It prevents the solution from splashing out.
Ia dapat mengelakkan larutan tersebut daripada terpercik keluar.

3. It can measure a fixed volume of solution more accurately.*
Ia dapat menyukat isipadu tetap larutan dengan lebih tepat.

4. Other reason:
Sebab lain:

____

____

5. Both sulphuric acid and ethanoic acid are strong acids.
Kedua-dua asid sulfurik dan asid etanoik adalah asid kuat.

A. True.
Betul.

B. False.*
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Sulfuric acid ionises completely in water to produce H^+ ions, while ethanoic acid ionises partially in water to produce H^+ ions.*
Asid sulfurik mengion lengkap di dalam air untuk menghasilkan ion-ion H^+, manakala asid etanoik mengion separa di dalam air untuk menghasilkan ion-ion H^+.

2. Ethanoic acid ionises completely in water to produce H^+ ions, while sulfuric acid ionises partially in water to produce H^+.
Asid etanoik mengion lengkap di dalam air untuk menghasilkan ion-ion H^+, manakala asid sulfurik mengion separa di dalam air untuk menghasilkan ion-ion H^+.

3. Both acids ionise completely in water to produce H^+ ions.
Kedua-dua asid tersebut mengion lengkap di dalam air untuk menghasilkan ion-ion H^+.

4. Both acids ionise partially in water to produce H^+ ions.
Kedua-dua asid tersebut mengion separa di dalam air untuk menghasilkan ion-ion H^+.

5. Other reason:
Sebab lain:

____

____

6. Two common substances that have the formulas HCl and CH_4 both contain the element hydrogen. However, only HCl has acidic properties while CH_4 does **not**.
*Dua bahan yang biasa ditemui mempunyai formula HCl dan CH_4 yang mana kedua-duanya mengandungi unsur hidrogen. Walaubagaimanapun, hanya HCl menunjukkan sifat-sifat asid tetapi CH_4 **tidak**.*

A. True.*
Betul.

B. False.
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. CH_4 completely ionises to produce more H^+ ions in water than HCl.
   CH_4 mengalami ionisasi lengkap menghasilkan lebih banyak ion-ion H^+ di dalam air berbanding HCl.

2. Any substance that contains H atom in the molecular formula is acidic.
   Sebarang bahan yang mengandungi atom H di dalam formula molekulnya adalah berasid.

3. Only HCl ionises to produce H^+ ions in water.*
   Hanya HCl yang mengalami ionisasi di dalam air untuk menghasilkan ion-ion H^+.

4. Other reason:
   Sebab lain:

   ____

   ____

7. What is a property of citrus fruits like oranges and lemons?
   Apakah sifat buah-buahan sitrus seperti oren dan lemon?

   A. Acidic.*
   Berasid.

   B. Basic.
   Berbes.

   C. Neutral.
   Neutral.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Citrus fruits have pH value less than 7.*
   Buah-buahan sitrus mempunyai nilai pH kurang daripada 7.

2. Citrus fruits have pH values greater than 7.
   Buah-buahan sitrus mempunyai nilai pH lebih daripada 7.

3. Citrus fruits have pH values equal to 7.
   Buah-buahan sitrus mempunyai nilai pH bersamaan 7.

4. Other reason:
   Sebab lain:

   ____

   ____

8. Soaps and detergents as well as household cleaners for floors, ovens and glass windows contain alkaline chemicals like sodium hydroxide and ammonia, but **not** acids.
   Sabun, deterjen, dan juga bahan-bahan pembersih rumah untuk lantai, oven, dan cermin tingkap mengandungi bahan kimia alkali seperti sodium hidroksida dan amonia, tetapi ***bukan*** *asid.*

   A. True.*
   Betul.

   B. False.
   Salah.

   The reason for my answer is:
   Sebab bagi jawapan saya adalah:

   1. Alkalis are soapy and so are able to wash away stains.
      Sifat alkali yang licin membolehkan kotoran dibersihkan.

   2. Acids are more corrosive than alkalis and so are more effective in removing stains.
      Asid adalah lebih korosif berbanding alkali yang mana lebih efektif menanggalkan kotoran.

   3. Alkalis dissolve grease and oils present in dirt more readily than acids.*
      Alkali dapat melarutkan gris dan minyak yang hadir dalam kotoran lebih mudah berbanding asid.

   4. Acids are able to neutralise alkalis present in dirt.
      Asid dapat meneutralkan alkali yang hadir dalam kotoran.

   5. Other reason:
      Sebab lain:

      ____

      ____

9. If soil is too acidic, it is not likely to support the healthy growth of grass. What chemical would you add to the soil to promote the growth of grass?
Jika tanah terlalu berasid, ia dikatakan tidak menyokong pertumbuhan rumput yang sihat. Apakah bahan kimia yang boleh anda tambahkan kepada tanah tersebut untuk menggalakkan pertumbuhan rumput?

A. Common salt.
Garam biasa.

B. Vinegar.
Cuka.

C. Lime (calcium oxide).*
Kapur (kalsium oksida).

D. Caustic soda.
Soda kaustik.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. The basic substance neutralises the acidic soils.*
Bahan berbes tersebut dapat meneutralkan keasidan tanah.

2. The basic substance changes the soil acidity to a pH value greater than 7.
Bahan berbes tersebut mengurangkan keasidan tanah sehingga nilai pH melebihi 7.

3. The acidic substance changes the pH of soil closer to the ideal pH.
Bahan berasid tersebut menukarkan pH tanah mendekati nilai pH yang ideal.

4. Other reason:
Sebab lain:

____

____

10. Aqueous solutions of potassium hydroxide as well as ammonia are both weak alkalis.
Kedua-dua larutan akues kalium hidroksida dan juga amonia adalah alkali lemah.

A. True.
Betul.

B. False.*
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Aqueous potassium hydroxide is completely ionised in water, while aqueous ammonia is only partially ionised.*
   Kalium hikdroksida akues mengalami ionisasi lengkap di dalam air, manakala ammonia akues hanya mengalami ionisasi separa.

2. Potassium hydroxide and ammonia are only partially ionised in water.
   Kalium hidroksida dan amonia hanya mengalami ionisasi separa di dalam air.

3. Aqueous ammonia, NH_3, is not an alkali because it does not contain OH^- ions in its formula.
   Amonia akues, NH_3, adalah bukan alkali kerana ia tidak mengandungi ion-ion OH^- di dalam formulanya.

4. Potassium hydroxide and ammonia ionise completely in water.
   Kalium hidroksida dan amonia mengalami ionisasi lengkap di dalam air.

5. Other reason:
   Sebab lain:

   ____

   ____

11. Concentrated solutions of acids and alkalis are also strongly acidic and alkaline.
    Larutan asid dan alkali pekat adalah juga asid dan alkali kuat.

    A. True.
       Betul.

    B. False.*
       Salah.

    The reason for my answer is:
    Sebab bagi jawapan saya adalah:

    1. The solutions contain high concentrations of H^+ or OH^- ions.
       Larutan-larutan tersebut mengandungi kepekatan ion-ion H^+ atau OH^- yang tinggi.

    2. The solutions may or may not be highly ionised in aqueous solution.*
       Larutan-larutan tersebut mungkin atau mungkin tidak mengalami ionisasi lengkap di dalam larutan akues.

    3. Relatively large amounts of the substances are dissolved in water.
       Secara relatifnya, sebahagian besar bahan-bahan tersebut larut di dalam air.

4. Other reason:
Sebab lain:

____

____

Test End.
Ujian Tamat.

Thank You!
Terima Kasih!

APPENDIX P: Acids-Bases Achievement Test (ABCAT) – ***Pre-Test of the Amended Version*** **(*Bilingual)***

Curtin University

Science & Mathematics Education Centre (SMEC)

ACIDS-BASES CHEMISTRY ACHIEVEMENT TEST
UJIAN PENCAPAIAN ASID-BES KIMIA

Pre-Test
Ujian Pra

Chemistry
Kimia

Acids & Bases Lessons
Pembelajaran Asid & Bes

My name is Muhd Ibrahim Muhamad Damanhuri and currently am completing research for my Ph.D. at Curtin University in Perth, Western Australia. I am investigating the effectiveness of the acids-bases topic in the Chemistry curriculum prepared by Curriculum Development Division (CDD), Malaysian Ministry of Education. Your views about lessons on acids-bases chemistry are important. This information can be used to assist Malaysian chemistry teachers in making chemistry lessons of the Form 4 Chemistry curriculum more interesting and better understood. Your involvement in this research is entirely **voluntary**. You should be aware that you have the right to discontinue your participation at any time without affecting your personal or social life in any way. Your **identity** will be kept **confidential** and **anonymous** throughout this study.

*Nama saya ialah Muhd Ibrahim Muhamad Damanhuri dan kini sedang melengkapkapkan kajian bagi Ph.D. saya di Curtin University, Perth, Western Australia. Saya sedang menyiasat keberkesanan tajuk asid-bes daripada kurikulum kimia yang disediakan oleh Bahagian Pembangunan Kurikulum (BPK), Kementerian Pelajaran Malaysia. Pandangan anda dalam pembelajaran tajuk asid-bes ini adalah sangat penting. Maklumat tersebut boleh digunakan untuk membantu guru-guru kimia di Malaysia untuk menjadikan pembelajaran kimia bagi kurikulum kimia Tingkatan 4 lebih menarik dan lebih mudah difahami. Penyertaan anda dalam kajian ini adalah secara **sukarela**. Perlu diingatkan di sini bahawa anda mempunyai hak untuk berhenti menyertai kajian ini pada bila-bila masa tanpa mengugat kehidupan peribadi atau sosial anda. **Identiti** anda akan **dirahsiakan** dan **dilindungi** sepanjang kajian ini.*

Your participation in this research is highly appreciated. Thank you!
Penyertaan anda dalam kajian ini amatlah dihargai. Terima kasih!

(Note: Your personal information will be kept personal.)
(Nota: Maklumat peribadi anda akan dirahsiakan)

Name/*Nama*:____________________________ Gender/*Jantina*: ________________

Form/*Tingkatan*:_____________ School/*Sekolah*: _____________________________

Information for Students
Maklumat untuk Pelajar

1. This test is **bilingual**.
   *Ujian ini adalah dalam **dwibahasa**.*

2. The test is composed of two sections, Section A and Section B.
   Ujian ini terdiri daripada dua seksyen, Seksyen A dan Seksyen B.

   (a) **Section A** consists of 12 items. Each item in this section consists of four alternative responses A, B, C and D. For each item, choose one answer only and **circle** your answer in this test booklet.
   ***Seksyen A** mengandungi 12 item. Setiap item di dalam seksyen ini mengandungi empat pilihan jawapan, iaitu A, B, C dan D. Bagi setiap soalan, pilih satu jawapan sahaja dan **bulatkan** jawapan anda dalam kertas ujian ini.*

   (b) **Section B** consists of 10 items. Each item of this section has two parts, a multiple-choice content response followed by a multiple-choice reason response. For each item, choose your most appropriate response from the first part and **circle** your answer A, B, C, etc. Then choose one of the reasons from the second part that best matches your answer to the first part and **circle** your answer 1, 2, 3, etc. If you do **not** agree with any of the given reasons, please write your reason in the space provided.
   ***Seksyen B** mengandungi 10 item. Setiap item daripada seksyen ini terdiri daripada dua bahagian, kandugan respon aneka pilihan diikuti sebab aneka pilihan. Bagi setiap item, buat pilihan yang sesuai daripada bahagian pertama dan **bulatkan** jawapan anda samada A, B, C, atau sebagainya. Kemudian pilih salah satu sebab di bahagian kedua yang sepadan dengan jawapan anda di bahagian pertama dan **bulatkan** jawapan anda samada 1, 2, 3, atau sebagainya. Sekiranya anda **tidak** bersetuju dengan mana-mana sebab yang diberikan, sila tulis sebab anda di ruang yang disediakan.*

3. Answer **all** questions. **Forty-five minutes** are allocated for this test.
   *Jawab **semua** soalan. **Empat puluh lima minit** diperuntukkan untuk ujian ini.*

Section A
Seksyen A

Instruction: Each item in this section consists of four alternative responses A, B, C and D. For each item, choose one answer only and **circle** your answer in this test booklet.
Arahan: *Setiap item di dalam seksyen ini mengandungi empat pilihan jawapan, iaitu A, B, C dan D. Bagi setiap soalan, pilih satu jawapan sahaja dan* ***bulatkan*** *jawapan anda dalam kertas ujian ini.*

1. Aqueous potassium hydroxide reacts with _____ to produce a salt and water.
Kalium hidroksida akues boleh mengalami tindakbalas dengan _____ untuk menghasilkan garam dan air.

    A. Glacial acetic acid.
    Asid asetik glasial.

    B. Aqueous sodium chloride.
    Sodium klorida akues.

    C. Dilute nitric acid.*
    Asid nitrik cair.

    D. Aqueous magnesium hydroxide.
    Magnesium hikdrosida akues.

[1 mark/Understanding/LO5/Post:A12]

2. A group of chemistry students carried out an experiment in the school laboratory to determine the concentration of a hydrochloric acid solution by titration. In order to do that, they added a few drops of phenolphthalein indicator solution into 25 cm^3 of 1.5 mol dm^{-3} sodium hydroxide solution. The alkali solution was then titrated with the acid solution. The average volume of the hydrochloric acid solution used for this experiment was found to be 28.15 cm^3. What is the concentration of the hydrochloric acid solution used in this experiment?
Sekumpulan pelajar kimia telah menjalankan suatu eksperimen di makmal sekolah untuk menentukan kepekatan suatu larutan asid hidroklorik melalui pentitratan. Untuk itu, mereka telah menambahkan beberapa titis larutan penunjuk phenolphthalein ke dalam 25 cm^3 larutan sodium hidroksida 1.5 mol dm^{-3}. Larutan alkali itu kemudiannya telah dititratkan dengan larutan asid tersebut. Isipadu purata bagi larutan asid hidroklorik yang digunakan dalam ekperimen ini didapati sebanyak 28.15 cm^3. Apakah kepekatan larutan asid hidroklorik yang digunakan dalam eksperimen ini?

    A. 2.35 mol dm^{-3}.

    B. 2.30 mol dm^{-3}.

    C. 1.82 mol dm^{-3}.

    D. 1.33 mol dm^{-3}.*

[1 marks/Analysing/LO26/Post:A10]

3. Which of the following apparatus might **not** be needed for a titration experiment?
*Yang manakah antara radas berikut mungkin **tidak** diperlukan dalam eksperimen pentitratan?*

A. Pipette.
Pipet.

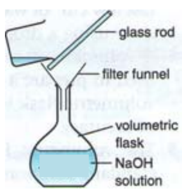
B. White tile.
Jubin putih.

C. Retort stand.
Kaki retot.

D. Test tube.*
Tabung uji.

[1 mark/Remembering/LO24/Post:A8]

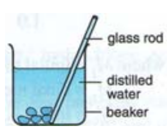
4. The diagrams below, **not** necessarily in the correct order, show five steps involved in the preparation of a standard solution of sodium hydroxide, NaOH.
*Gambarajah di bawah **tidak** semestinya disusun dalam turutan yang betul menunjukkan lima langkah yang terlibat dalam penyediaan suatu larutan piawai sodium hidroksida, NaOH.*

I. 

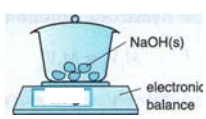
The aqueous NaOH solution is transferred to a volumetric flask.
Larutan NaOH akues dipindahkan ke dalam kelalang isipadu.

II. 

Distilled water is added up to the graduation mark.
Air suling ditambahkan sehingga ke penanda aras.

III. 

NaOH solid is dissolved using distilled water.
Pepejal NaOH dilarutkan menggunakan air suling.

IV. 

NaOH solid is weighed.
Pepejal NaOH ditimbang.

V. 
The NaOH solution is shaken.
Larutan NaOH digoncang.

Which of the following is the correct order of steps in the preparation of a standard solution of sodium hydroxide, NaOH?
Yang mana antara berikut adalah turutan langkah yang betul dalam penyediaan larutan piawai sodium hidroksida, NaOH?

A. I, III, IV, II, V.

B. III, V, I, II, IV.

C. IV, III, I, II, V.*

D. II, I, III, V, IV.

[1 mark/Applying/LO17/Post:A6]

5. Which of the following solutions has the lowest pH value?
Yang mana antara larutan berikut mempunyai nilai pH paling rendah?

A. 20 cm^3 of 2.0 mol dm^{-3} sulphuric acid.
20 cm^3 asid sulfurik 2.0 mol $dm^{-3.}$

B. 20 cm^3 of 3.0 mol dm^{-3} sulphuric acid.*
20 cm^3 asid sulfurik 3.0 mol dm^{-3}.

C. 50 cm^3 of 2.0 mol dm^{-3} sulphuric acid.
50 cm^3 asid sulfurik 2.0 mol dm^{-3}.

D. 100 cm^3 of 2.0 mol dm^{-3} sulphuric acid.
100 cm^3 asid sulfurik 2.0 mol dm^{-3}.

[1 mark/Analysing/LO19/Post:A4]

6. Which of the following statements is correct about the pH of a solution?
Yang mana antara pernyataan berikut benar mengenai skala pH?

A. A solution that has pH value less than 7 is an alkaline solution.
Larutan yang mempunyai nilai pH kurang daripada 7 adalah larutan beralkali.

B. A solution that has pH value more than 7 is an acidic solution.
Larutan yang mempunyai nilai pH lebih daripada 7 adalah larutan berasid.

C. A solution that has pH value equal to 7 is a neutral solution.*
Larutan yang mempunyai nilai pH bersamaan 7 adalah larutan neutral.

D. A solution that has pH value equal to 7 is an alkaline solution.
Larutan yang mempunyai nilai pH bersamaan 7 adalah larutan beralkali.

[1 mark/Remembering/LO7/Post:A2]

7. Which of the following equations correctly describes the relationship between concentration (g dm^{-3}) and molarity (mol dm^{-3})?
Yang mana antara persamaan berikut adalah betul menggambarkan hubungan di antara kepekatan (g dm^{-3}) dan kemolaran (mol dm^{-3})?

A. $\text{Molarity (mol dm}^{-3}) = \dfrac{\text{Concentration (g dm}^{-3})}{\text{Molar mass (g mol}^{-1})}$ *
Kemolaran (mol dm^{-3}) = $\dfrac{\text{Kepekatan (g dm}^{-3})}{\text{Jisim molar (g mol}^{-1})}$

B. $\text{Molarity (mol dm}^{-3}) = \dfrac{\text{Molar mass (g mol}^{-1})}{\text{Concentration (g dm}^{-3})}$
Kemolaran (mol dm^{-3}) = $\dfrac{\text{Jisim molar (g mol}^{-1})}{\text{Kepekatan (g dm}^{-3})}$

C. $\text{Concentration (g dm}^{-3}) = \dfrac{\text{Molarity (mol dm}^{-3})}{\text{Molar mass (g mol}^{-1})}$
Kepekatan (g dm^{-3}) = $\dfrac{\text{Kemolaran (mol dm}^{-3})}{\text{Jisim molar (g mol}^{-1})}$

D. $\text{Concentration (g dm}^{-3}) = \dfrac{\text{Molar mass (g mol}^{-1})}{\text{Molarity (mol dm}^{-3})}$
Kepekatan (g dm^{-3}) = $\dfrac{\text{Jisim molar (g mol}^{-1})}{\text{Kemolaran (mol dm}^{-3})}$

[1 mark/Remembering/LO15/Post:A3]

8. Distilled water is added to 50 cm^3 of 2 mol dm^{-3} potassium hydroxide solution to produce 250 cm^3 of potassium hydroxide solution. What is the concentration of the potassium hydroxide solution produced?
Air suling ditambahkan kepada 50 cm^3 larutan kalium hidroksida 2 mol dm^{-3} untuk menghasilkan 250 cm^3 larutan kalium hidroksida. Apakah kepekatan larutan kalium hidroksida yang dihasilkan?

A. 0.3 mol dm^{-3}.

B. 0.4 mol dm^{-3}.*

C. 0.5 mol dm^{-3}.

D. 0.6 mol dm^{-3}.

[1 mark/Analysing/LO20/Post:A5]

9. Which of the following is **not** a step in the procedure to prepare a solution with a specified concentration using the dilution method?
*Yang manakah antara berikut **bukan** merupakan langkah penyediaan larutan dengan kepekatan tertentu menggunakan kaedah pencairan?*

A. Distilled water is added to the volumetric flask until the graduation mark.
Air suling ditambahkan ke dalam kelalang isipadu sehingga ke penanda aras.

B. A few drops of universal indicator solution are added into the volumetric flask.*
Beberapa titis larutan penunjuk semesta ditambahkan ke dalam kelalang isipadu.

C. The volume of stock solution required is calculated.
Isipadu larutan stok yang diperlukan dikira.

D. The required volume of stock solution is transferred into the volumetric flask using a pipette.
Isipadu larutan stok yang diperlukan dipindahkan ke dalam kelalang isipadu menggunakan pipet.

[1 mark/Understanding/LO18/Post:A7]

10. Which of the following equations most accurately describes the neutralisation reaction between the acid, HA, and magnesium hydroxide?
Yang mana antara persamaan berikut paling tepat menggambarkan tindakbalas peneutralan di antara asid, HA, dan magnesium hidroksida?

A. $Mg(OH)_2 + HA \rightarrow MgA_2 + H_2O$

B. $Mg(OH)_2 + 2HA \rightarrow MgA_2 + 2H_2O$*

C. $MgA_2 + H_2O \rightarrow Mg(OH)_2 + HA$

D. $MgA_2 + 2H_2O \rightarrow Mg(OH)_2 + 2HA$

[1 mark/Understanding/LO23/Post:A9]

11. When a standard solution of specific concentration is diluted, the concentration of the solution will _____, while the number of moles of solute present will be _____.
Apabila suatu larutan piawai berkepekatan tertentu dicairkan, kepekatan larutan tersebut akan _____, manakala bilangan mol bahan terlarut yang hadir akan _____.

A. increase; decrease
bertambah; berkurang

B. increase; constant
bertambah; tetap sama

C. decrease; constant*
berkurang; tetap sama

D. decrease; decrease
berkurang; berkurang

[1 mark/Understanding/LO16/Post:A11]

12. An acid displays its properties when it…..
Suatu asid menunjukkan sifat-sifatnya apabila ia…..

A. ionises in water to produce H^+ ions.*
mengion dalam air menghasilkan ion-ion H^+.

B. ionises in propane to produce H^+ ions.
mengion dalam propana menghasilkan ion-ion H^+.

C. ionises in water to produce OH^- ions.
mengion dalam air menghasilkan ion-ion OH^-.

D. ionises in propane to produce OH^- ions.
mengion dalam propana menghasilkan ion-ion OH^-.

[1 mark/Remembering/LO3/Post:A1]

Section B
Seksyen B

Instruction: Each item of this section has two parts, a multiple-choice content response followed by a multiple-choice reason response. For each item, choose your most appropriate response from the first part and **circle** your answer A, B, C, etc. Then choose one of the reasons from the second part that best matches your answer to the first part and **circle** your answer 1, 2, 3, etc. If you do **not** agree with any of the given reasons, please write your reason in the space provided.
Arahan: *Setiap item daripada seksyen ini terdiri daripada dua bahagian, kandugan respon aneka pilihan diikuti sebab aneka pilihan. Bagi setiap item, buat pilihan yang sesuai daripada bahagian pertama dan* ***bulatkan*** *jawapan anda samada A, B, C, atau sebagainya. Kemudian pilih salah satu sebab di bahagian kedua yang sepadan dengan jawapan anda di bahagian pertama dan* ***bulatkan*** *jawapan anda samada 1, 2, 3, atau sebagainya. Sekiranya anda* ***tidak*** *bersetuju dengan mana-mana sebab yang diberikan, sila tulis sebab anda di ruang yang disediakan.*

1. Aqueous solutions of potassium hydroxide as well as ammonia are both weak alkalis.
Kedua-dua larutan akues kalium hidroksida dan juga amonia adalah alkali lemah.

A. True.
Betul.

B. False.*
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Aqueous potassium hydroxide is completely ionised in water, while aqueous ammonia is only partially ionised.*
Kalium hikdroksida akues mengalami ionisasi lengkap di dalam air, manakala ammonia akues hanya mengalami ionisasi separa.

2. Potassium hydroxide and ammonia are only partially ionised in water.
Kalium hidroksida dan amonia hanya mengalami ionisasi separa di dalam air.

3. Aqueous ammonia, NH_3, is not an alkali because it does not contain OH^- ions in its formula.
Amonia akues, NH_3, adalah bukan alkali kerana ia tidak mengandungi ion-ion OH^- di dalam formulanya.

4. Potassium hydroxide and ammonia ionise completely in water.
Kalium hidroksida dan amonia mengalami ionisasi lengkap di dalam air.

5. Other reason:
Sebab lain:

____

____

[1 mark/Analysing/ LO11/Post:B10]

2. Soaps and detergents as well as household cleaners for floors, ovens and glass windows contain alkaline chemicals like sodium hydroxide and ammonia, but **not** acids.
Sabun, deterjen, dan juga bahan-bahan pembersih rumah untuk lantai, oven, dan cermin tingkap mengandungi bahan kimia alkali seperti sodium hidroksida dan amonia, tetapi ***bukan*** *asid.*

A. True.*
Betul.

B. False.
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Alkalis are soapy and so are able to wash away stains.
Sifat alkali yang licin membolehkan kotoran dibersihkan.

2. Acids are more corrosive than alkalis and so are more effective in removing stains.
Asid adalah lebih korosif berbanding alkali yang mana lebih efektif menanggalkan kotoran.

3. Alkalis dissolve grease and oils present in dirt more readily than acids.*
Alkali dapat melarutkan gris dan minyak yang hadir dalam kotoran lebih mudah berbanding asid.

4. Acids are able to neutralise alkalis present in dirt.
Asid dapat meneutralkan alkali yang hadir dalam kotoran.

5. Other reason:
Sebab lain:

____

____

[1 mark/Applying/LO2/Post:B8]

3. Two common substances that have the formulas HCl and CH_4 both contain the element hydrogen. However, only HCl has acidic properties while CH_4 does **not**.
Dua bahan yang biasa ditemui mempunyai formula HCl dan CH_4 yang mana kedua-duanya mengandungi unsur hidrogen. Walaubagaimanapun, hanya HCl menunjukkan sifat-sifat asid tetapi CH_4 ***tidak****.*

A. True.*
Betul.

B. False.
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. CH_4 completely ionises to produce more H^+ ions in water than HCl.
CH_4 mengalami ionisasi lengkap menghasilkan lebih banyak ion-ion H^+ di dalam air berbanding HCl.

2. Any substance that contains H atom in the molecular formula is acidic.
Sebarang bahan yang mengandungi atom H di dalam formula molekulnya adalah berasid.

3. Only HCl ionises to produce H^+ ions in water.*
Hanya HCl yang mengalami ionisasi di dalam air untuk menghasilkan ion-ion H^+.

4. Other reason:
Sebab lain:

____

____

[1 mark/Understanding/LO1/Post:B6]

4. What is the main apparatus that is used in the preparation of a standard solution?
Apakah radas utama yang digunakan dalam penyediaan suatu larutan piawai?

A. Volumetric flask*
Kelalang isipadu.

B. Beaker
Bikar.

C. Measuring cylinder
Silinder penyukat.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. It is easier to dissolve the solute by shaking.
   Ia memudahkan bahan terlarut melarut dengan menggoncang.

2. It prevents the solution from splashing out.
   Ia dapat mengelakkan larutan tersebut daripada terpercik keluar.

3. It can measure a fixed volume of solution more accurately.*
   Ia dapat menyukat isipadu tetap larutan dengan lebih tepat.

4. Other reason:
   Sebab lain:

   ____

   ____

[1 mark/Applying/ LO17/Post:B4]

5. The table shows the pH value of four aqueous solutions, P, Q, R, and S.
Jadual di bawah menunjukkan nilai pH bagi empat larutan, P, Q, R, dan S.

Solution/*Larutan*	P	Q	R	S
pH value/*Nilai pH*	13	7	3	9

Which of the following solutions will react with calcium carbonate to produce carbon dioxide gas?
Yang manakah antara larutan tersebut akan bertindakbalas dengan kalsium karbonat untuk menghasilkan gas karbon dioksida?

A. P

B. Q

C. R*

D. S

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. The solution contains a higher concentration of OH^- ions than H^+ ions.
   Larutan tersebut mengandungi kepekatan ion-ion OH^- yang lebih tinggi berbanding ion-ion H^+.

2. The solution contains a higher concentration of H^+ ions than OH^- ions.*
Larutan tersebut mengandungi kepekatan ion-ion H^+ yang lebih tinggi berbanding ion-ion OH^-.

3. The solution contains equal concentrations of H^+ and OH^- ions.
Larutan tersebut mengandungi kepekatan ion-ion H^+ dan ion-ion OH^- yang sama.

4. Other reason:
Sebab lain:

____

____

[1 mark/Understanding/LO5/Post:B2]

6. When methyl orange indicator in a titration experiment turns yellow, this indicates the reaction between acid solution and alkali solution has reached its end point.
Apabila penunjuk metil oren dalam suatu eksperimen pentitratan bertukar ke warna kuning, ini menunjukkan tindakbalas antara larutan asid dan larutan alkali telah mencapai takat akhir.

A. True.
Betul.

B. False.*
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Methyl orange turns yellow because neutralisation has occurred.
Metil oren bertukar ke warna kuning kerana peneutralan telah berlaku.

2. Methyl orange turns yellow because water and a salt are present in the solution.
Metil oren bertukar ke warna kuning kerana terdapat kehadiran air dan garam dalam larutan tersebut.

3. Methyl orange turns yellow because there is an excess of alkali in the solution.*
Metil oren bertukar ke warna kuning kerana terdapat lebihan alkali dalam larutan tersebut.

4. Methyl orange turns yellow because there is an excess of acid in the solution.
Metil oren bertukar ke warna kuning kerana terdapat lebihan asid dalam larutan tersebut.

5. Other reason:
Sebab lain:

____

____

[1 mark/Understanding/LO25/Post:B3]

7. Both sulphuric acid and ethanoic acid are strong acids.
Kedua-dua asid sulfurik dan asid etanoik adalah asid kuat.

A. True.
Betul.

B. False.*
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Sulfuric acid ionises completely in water to produce H^+ ions, while ethanoic acid ionises partially in water to produce H^+ ions.*
Asid sulfurik mengion lengkap di dalam air untuk menghasilkan ion-ion H^+, manakala asid etanoik mengion separa di dalam air untuk menghasilkan ion-ion H^+.

2. Ethanoic acid ionises completely in water to produce H^+ ions, while sulfuric acid ionises partially in water to produce H^+.
Asid etanoik mengion lengkap di dalam air untuk menghasilkan ion-ion H^+, manakala asid sulfurik mengion separa di dalam air untuk menghasilkan ion-ion H^+.

3. Both acids ionise completely in water to produce H^+ ions.
Kedua-dua asid tersebut mengion lengkap di dalam air untuk menghasilkan ion-ion H^+.

4. Both acids ionise partially in water to produce H^+ ions.
Kedua-dua asid tersebut mengion separa di dalam air untuk menghasilkan ion-ion H^+.

5. Other reason:
Sebab lain:

____

____

[1 mark/Analysing/ LO10/Post:B5]

8. What is a property of citrus fruits like oranges and lemons?
Apakah sifat buah-buahan sitrus seperti oren dan lemon?

A. Acidic.*
Berasid.

B. Basic.
Berbes.

C. Neutral.
Neutral.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Citrus fruits have pH value less than 7.*
Buah-buahan sitrus mempunyai nilai pH kurang daripada 7.

2. Citrus fruits have pH values greater than 7.
Buah-buahan sitrus mempunyai nilai pH lebih daripada 7.

3. Citrus fruits have pH values equal to 7.
Buah-buahan sitrus mempunyai nilai pH bersamaan 7.

4. Other reason:
Sebab lain:

____

____

[1 mark/Understanding/LO7/Post:B7]

9. If soil is too acidic, it is not likely to support the healthy growth of grass. What chemical would you add to the soil to promote the growth of grass?
Jika tanah terlalu berasid, ia dikatakan tidak menyokong pertumbuhan rumput yang sihat. Apakah bahan kimia yang boleh anda tambahkan kepada tanah tersebut untuk menggalakkan pertumbuhan rumput?

A. Common salt.
Garam biasa.

B. Vinegar.
Cuka.

C. Lime (calcium oxide).*
Kapur (kalsium oksida).

D. Caustic soda.
Soda kaustik.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. The basic substance neutralises the acidic soils.*
   Bahan berbes tersebut dapat meneutralkan keasidan tanah.

2. The basic substance changes the soil acidity to a pH value greater than 7.
   Bahan berbes tersebut mengurangkan keasidan tanah sehingga nilai pH melebihi 7.

3. The acidic substance changes the pH of soil closer to the ideal pH.
   Bahan berasid tersebut menukarkan pH tanah mendekati nilai pH yang ideal.

4. Other reason:
   Sebab lain:

   ____

   ____

[1 mark/Applying/LO22/Post:B9]

10. Chemical X shows the following properties:
Bahan kimia X menunjukkan ciri-ciri berikut:

✓ Tastes bitter and feels soapy.
Berasa pahit dan licin.

✓ Turns red litmus paper blue.
Menukarkan kertas litmus merah kepada biru.

✓ Reacts with an acid to produce a salt and water.
Bertindakbalas dengan asid untuk menghasilkan garam dan air.

✓ Produces ammonia gas when heated with an ammonium salt.
Menghasilkan gas ammonia apabila dipanaskan dengan garam ammonium.

✓ Reacts with an aqueous salt solution to produce a metal hydroxide.
Bertindakbalas dengan larutan garam akues untuk menghasilkan logam hidroksida.

Which of the following is most probably chemical X?
Yang mana antara berikut paling berkemungkinan bahan kimia X?

A. Dry ammonia gas.
Gas ammonia kering.

B. Sodium hydroxide dissolved in propane.
Sodium hidroksida larut dalam propana.

C. Glacial acetic acid.
Asid asetik glasial.

D. Aqueous calcium hydroxide.*
Kalsium hidroksida akues.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Chemical X could ionise in water to produce H^+ ions.
Bahan kimia X boleh mengion di dalam air untuk menghasilkan ion-ion H^+.

2. Chemical X could ionise in water to produce OH^- ions.*
Bahan kimia X boleh mengion di dalam air untuk menghasilkan ion-ion OH^-.

3. Chemical X could ionise to produce OH^- ions in the absence of water.
Bahan kimia X boleh mengion untuk menghasilkan ion-ion OH^- tanpa kehadiran air.

4. Chemical X is soluble in water.
Bahan kimia X larut di dalam air.

5. Other reason:
Sebab lain:

____

____

[1 mark/Understanding/LO4/Post:B1]

Test End.
Ujian Tamat.

Thank You!
Terima Kasih!

APPENDIX Q: Acids-Bases Achievement Test (ABCAT) – ***Post-Test of the Amended Version (Bilingual)***

Curtin University

Science & Mathematics Education Centre (SMEC)

ACIDS-BASES CHEMISTRY ACHIEVEMENT TEST

UJIAN PENCAPAIAN ASID-BES KIMIA

Post-Test

Ujian Pos

Chemistry

Kimia

Acids & Bases Lessons

Pembelajaran Asid & Bes

My name is Muhd Ibrahim Muhamad Damanhuri and currently am completing research for my Ph.D. at Curtin University in Perth, Western Australia. I am investigating the effectiveness of the acids-bases topic in the Chemistry curriculum prepared by Curriculum Development Division (CDD), Malaysian Ministry of Education. Your views about lessons on acids-bases chemistry are important. This information can be used to assist Malaysian chemistry teachers in making chemistry lessons of the Form 4 Chemistry curriculum more interesting and better understood. Your involvement in this research is entirely **voluntary**. You should be aware that you have the right to discontinue your participation at any time without affecting your personal or social life in any way. Your **identity** will be kept **confidential** and **anonymous** throughout this study.

Nama saya ialah Muhd Ibrahim Muhamad Damanhuri dan kini sedang melengkapkapkan kajian bagi Ph.D. saya di Curtin University, Perth, Western Australia. Saya sedang menyiasat keberkesanan tajuk asid-bes daripada kurikulum kimia yang disediakan oleh Bahagian Pembangunan Kurikulum (BPK), Kementerian Pelajaran Malaysia. Pandangan anda dalam pembelajaran tajuk asid-bes ini adalah sangat penting. Maklumat tersebut boleh digunakan untuk membantu guru-guru kimia di Malaysia untuk menjadikan pembelajaran kimia bagi kurikulum kimia Tingkatan 4 lebih menarik dan lebih mudah difahami. Penyertaan anda dalam kajian ini adalah secara ***sukarela****. Perlu diingatkan di sini bahawa anda mempunyai hak untuk berhenti menyertai kajian ini pada bila-bila masa tanpa mengugat kehidupan peribadi atau sosial anda.* ***Identiti*** *anda akan* ***dirahsiakan*** *dan* ***dilindungi*** *sepanjang kajian ini.*

Your participation in this research is highly appreciated. Thank you!

Penyertaan anda dalam kajian ini amatlah dihargai. Terima kasih!

(Note: Your personal information will be kept personal.)

(Nota: Maklumat peribadi anda akan dirahsiakan)

Name/*Nama*:____________________________ Gender/*Jantina*: ________________

Form/*Tingkatan*:_____________ School/*Sekolah*: _____________________________

Information for Students
Maklumat untuk Pelajar

4. This test is **bilingual**.
   *Ujian ini adalah dalam **dwibahasa**.*

5. The test is composed of two sections, Section A and Section B.
   Ujian ini terdiri daripada dua seksyen, Seksyen A dan Seksyen B.

   (c) **Section A** consists of 12 items. Each item in this section consists of four alternative responses A, B, C and D. For each item, choose one answer only and **circle** your answer in this test booklet.
   ***Seksyen A** mengandungi 12 item. Setiap item di dalam seksyen ini mengandungi empat pilihan jawapan, iaitu A, B, C dan D. Bagi setiap soalan, pilih satu jawapan sahaja dan **bulatkan** jawapan anda dalam kertas ujian ini.*

   (d) **Section B** consists of 10 items. Each item of this section has two parts, a multiple-choice content response followed by a multiple-choice reason response. For each item, choose your most appropriate response from the first part and **circle** your answer A, B, C, etc. Then choose one of the reasons from the second part that best matches your answer to the first part and **circle** your answer 1, 2, 3, etc. If you do **not** agree with any of the given reasons, please write your reason in the space provided.
   ***Seksyen B** mengandungi 10 item. Setiap item daripada seksyen ini terdiri daripada dua bahagian, kandugan respon aneka pilihan diikuti sebab aneka pilihan. Bagi setiap item, buat pilihan yang sesuai daripada bahagian pertama dan **bulatkan** jawapan anda samada A, B, C, atau sebagainya. Kemudian pilih salah satu sebab di bahagian kedua yang sepadan dengan jawapan anda di bahagian pertama dan **bulatkan** jawapan anda samada 1, 2, 3, atau sebagainya. Sekiranya anda **tidak** bersetuju dengan mana-mana sebab yang diberikan, sila tulis sebab anda di ruang yang disediakan.*

6. Answer **all** questions. **Forty-five minutes** are allocated for this test.
   *Jawab **semua** soalan. **Empat puluh lima minit** diperuntukkan untuk ujian ini.*

Section A
Seksyen A

Instruction: Each item in this section consists of four alternative responses A, B, C and D. For each item, choose one answer only and **circle** your answer in this test booklet.
Arahan: *Setiap item di dalam seksyen ini mengandungi empat pilihan jawapan, iaitu A, B, C dan D. Bagi setiap soalan, pilih satu jawapan sahaja dan* ***bulatkan*** *jawapan anda dalam kertas ujian ini.*

1. An acid displays its properties when it…..
Suatu asid menunjukkan sifat-sifatnya apabila ia…..

A. ionises in water to produce H^+ ions.*
mengion dalam air menghasilkan ion-ion H^+.

B. ionises in propane to produce H^+ ions.
mengion dalam propana menghasilkan ion-ion H^+.

C. ionises in water to produce OH^- ions.
mengion dalam air menghasilkan ion-ion OH^-.

D. ionises in propane to produce OH^- ions.
mengion dalam propana menghasilkan ion-ion OH^-.

[1 mark/Remembering/LO3/Pre:A12]

2. Which of the following statements is correct about the pH of a solution?
Yang mana antara pernyataan berikut benar mengenai skala pH?

A. A solution that has pH value less than 7 is an alkaline solution.
Larutan yang mempunyai nilai pH kurang daripada 7 adalah larutan beralkali.

B. A solution that has pH value more than 7 is an acidic solution.
Larutan yang mempunyai nilai pH lebih daripada 7 adalah larutan berasid.

C. A solution that has pH value equal to 7 is a neutral solution.*
Larutan yang mempunyai nilai pH bersamaan 7 adalah larutan neutral.

D. A solution that has pH value equal to 7 is an alkaline solution.
Larutan yang mempunyai nilai pH bersamaan 7 adalah larutan beralkali.

[1 mark/Remembering/LO7/Pre:A6]

3. Which of the following equations correctly describes the relationship between concentration (g dm^{-3}) and molarity (mol dm^{-3})?
Yang mana antara persamaan berikut adalah betul menggambarkan hubungan di antara kepekatan (g dm^{-3}) dan kemolaran (mol dm^{-3})?

A. $\text{Molarity (mol dm}^{-3}) = \dfrac{\text{Concentration (g dm}^{-3})}{\text{Molar mass (g mol}^{-1})}$ *
$\text{Kemolaran (mol dm}^{-3}) = \dfrac{\text{Kepekatan (g dm}^{-3})}{\text{Jisim molar (g mol}^{-1})}$

B. $\text{Molarity (mol dm}^{-3}) = \dfrac{\text{Molar mass (g mol}^{-1})}{\text{Concentration (g dm}^{-3})}$
$\text{Kemolaran (mol dm}^{-3}) = \dfrac{\text{Jisim molar (g mol}^{-1})}{\text{Kepekatan (g dm}^{-3})}$

C. $\text{Concentration (g dm}^{-3}) = \dfrac{\text{Molarity (mol dm}^{-3})}{\text{Molar mass (g mol}^{-1})}$
$\text{Kepekatan (g dm}^{-3}) = \dfrac{\text{Kemolaran (mol dm}^{-3})}{\text{Jisim molar (g mol}^{-1})}$

D. $\text{Concentration (g dm}^{-3}) = \dfrac{\text{Molar mass (g mol}^{-1})}{\text{Molarity (mol dm}^{-3})}$
$\text{Kepekatan (g dm}^{-3}) = \dfrac{\text{Jisim molar (g mol}^{-1})}{\text{Kemolaran (mol dm}^{-3})}$

[1 mark/Remembering/LO15/Pre:A7]

4. Which of the following solutions has the lowest pH value?
Yang mana antara larutan berikut mempunyai nilai pH paling rendah?

A. 20 cm^3 of 2.0 mol dm^{-3} sulphuric acid.
20 cm^3 asid sulfurik 2.0 mol dm^{-3}.

B. 20 cm^3 of 3.0 mol dm^{-3} sulphuric acid.*
20 cm^3 asid sulfurik 3.0 mol dm^{-3}.

C. 50 cm^3 of 2.0 mol dm^{-3} sulphuric acid.
50 cm^3 asid sulfurik 2.0 mol dm^{-3}.

D. 100 cm^3 of 2.0 mol dm^{-3} sulphuric acid.
100 cm^3 asid sulfurik 2.0 mol dm^{-3}.

[1 mark/Analysing/LO19/Pre:A5]

5. Distilled water is added to 50 cm^3 of 2 mol dm^{-3} potassium hydroxide solution to produce 250 cm^3 of potassium hydroxide solution. What is the concentration of the potassium hydroxide solution produced?
Air suling ditambahkan kepada 50 cm^3 larutan kalium hidroksida 2 mol dm^{-3} untuk menghasilkan 250 cm^3 larutan kalium hidroksida. Apakah kepekatan larutan kalium hidroksida yang dihasilkan?

A. 0.3 mol dm^{-3}.

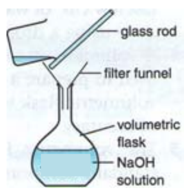
B. 0.4 mol dm^{-3}.*

C. 0.5 mol dm^{-3}.

D. 0.6 mol dm^{-3}.

[1 mark/Analysing/LO20/Pre:A8]

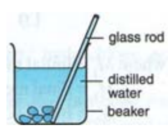
6. The diagrams below, **not** necessarily in the correct order, show five steps involved in the preparation of a standard solution of sodium hydroxide, NaOH.
*Gambarajah di bawah **tidak** semestinya disusun dalam turutan yang betul menunjukkan lima langkah yang terlibat dalam penyediaan suatu larutan piawai sodium hidroksida, NaOH.*

I. 

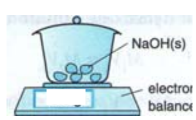
The aqueous NaOH solution is transferred to a volumetric flask.
Larutan NaOH akues dipindahkan ke dalam kelalang isipadu.

II. 

Distilled water is added up to the graduation mark.
Air suling ditambahkan sehingga ke penanda aras.

III. 

NaOH solid is dissolved using distilled water.
Pepejal NaOH dilarutkan menggunakan air suling.

IV. 

NaOH solid is weighed.
Pepejal NaOH ditimbang.

V. 
The NaOH solution is shaken.
Larutan NaOH digoncang.

Which of the following is the correct order of steps in the preparation of a standard solution of sodium hydroxide, NaOH?
Yang mana antara berikut adalah turutan langkah yang betul dalam penyediaan larutan piawai sodium hidroksida, NaOH?

A. I, III, IV, II, V.

B. III, V, I, II, IV.

C. IV, III, I, II, V.*

D. II, I, III, V, IV.

[1 mark/Applying/LO17/Pre:A4]

7. Which of the following is **not** a step in the procedure to prepare a solution with a specified concentration using the dilution method?
Yang manakah antara berikut ***bukan*** *merupakan langkah penyediaan larutan dengan kepekatan tertentu menggunakan kaedah pencairan?*

A. Distilled water is added to the volumetric flask until the graduation mark.
Air suling ditambahkan ke dalam kelalang isipadu sehingga ke penanda aras.

B. A few drops of universal indicator solution are added into the volumetric flask.*
Beberapa titis larutan penunjuk semesta ditambahkan ke dalam kelalang isipadu.

C. The volume of stock solution required is calculated.
Isipadu larutan stok yang diperlukan dikira.

D. The required volume of stock solution is transferred into the volumetric flask using a pipette.
Isipadu larutan stok yang diperlukan dipindahkan ke dalam kelalang isipadu menggunakan pipet.

[1 mark/Understanding/LO18/Pre:A9]

8. Which of the following apparatus might **not** be needed for a titration experiment?
Yang manakah antara radas berikut mungkin ***tidak*** *diperlukan dalam eksperimen pentitratan?*

A. Pipette.
Pipet.

B. White tile.
Jubin putih.

C. Retort stand.
Kaki retot.

D. Test tube.*
Tabung uji.

[1 mark/Remembering/LO24/Pre:A3]

9. Which of the following equations most accurately describes the neutralisation reaction between the acid, HA, and magnesium hydroxide?
Yang mana antara persamaan berikut paling tepat menggambarkan tindakbalas peneutralan di antara asid, HA, dan magnesium hidroksida?

A. $Mg(OH)_2 + HA \rightarrow MgA_2 + H_2O$

B. $Mg(OH)_2 + 2HA \rightarrow MgA_2 + 2H_2O$*

C. $MgA_2 + H_2O \rightarrow Mg(OH)_2 + HA$

D. $MgA_2 + 2H_2O \rightarrow Mg(OH)_2 + 2HA$

[1 mark/Understanding/LO23/Pre:A10]

10. A group of chemistry students carried out an experiment in the school laboratory to determine the concentration of a hydrochloric acid solution by titration. In order to do that, they added a few drops of phenolphthalein indicator solution into 25 cm^3 of 1.5 mol dm^{-3} sodium hydroxide solution. The alkali solution was then titrated with the acid solution. The average volume of the hydrochloric acid solution used for this experiment was found to be 28.15 cm^3. What is the concentration of the hydrochloric acid solution used in this experiment?
Sekumpulan pelajar kimia telah menjalankan suatu eksperimen di makmal sekolah untuk menentukan kepekatan suatu larutan asid hidroklorik melalui pentitratan. Untuk itu, mereka telah menambahkan beberapa titis larutan penunjuk phenolphthalein ke dalam 25 cm^3 larutan sodium hidroksida 1.5 mol dm^{-3}. Larutan alkali itu kemudiannya telah dititratkan dengan larutan asid tersebut. Isipadu purata bagi larutan asid hidroklorik yang digunakan dalam ekperimen ini didapati sebanyak 28.15 cm^3. Apakah kepekatan larutan asid hidroklorik yang digunakan dalam eksperimen ini?

A. 2.35 mol dm^{-3}.

B. 2.30 mol dm^{-3}.

C. 1.82 mol dm^{-3}.

D. 1.33 mol dm^{-3}.*

[1 marks/Analysing/LO26/Pre:A2]

11. When a standard solution of specific concentration is diluted, the concentration of the solution will _____, while the number of moles of solute present will be _____.
Apabila suatu larutan piawai berkepekatan tertentu dicairkan, kepekatan larutan tersebut akan _____, manakala bilangan mol bahan terlarut yang hadir akan _____.

A. increase; decrease
bertambah; berkurang

B. increase; constant
bertambah; tetap sama

C. decrease; constant*
berkurang; tetap sama

D. decrease; decrease
berkurang; berkurang

[1 mark/Understanding/LO16/Pre:A11]

12. Aqueous potassium hydroxide reacts with _____ to produce a salt and water.
Kalium hidroksida akues boleh mengalami tindakbalas dengan _____ untuk menghasilkan garam dan air.

A. Glacial acetic acid.
Asid asetik glasial.

B. Aqueous sodium chloride.
Sodium klorida akues.

C. Dilute nitric acid.*
Asid nitrik cair.

D. Aqueous magnesium hydroxide.
Magnesium hikdrosida akues.

[1 mark/Understanding/LO5/Pre:A1]

Section B
Seksyen B

Instruction: Each item of this section has two parts, a multiple-choice content response followed by a multiple-choice reason response. For each item, choose your most appropriate response from the first part and **circle** your answer A, B, C, etc. Then choose one of the reasons from the second part that best matches your answer to the first part and **circle** your answer 1, 2, 3, etc. If you do **not** agree with any of the given reasons, please write your reason in the space provided.
Arahan: *Setiap item daripada seksyen ini terdiri daripada dua bahagian, kandungan respon aneka pilihan diikuti sebab aneka pilihan. Bagi setiap item, buat pilihan yang sesuai daripada bahagian pertama dan* ***bulatkan*** *jawapan anda samada A, B, C, atau sebagainya. Kemudian pilih salah satu sebab di bahagian kedua yang sepadan dengan jawapan anda di bahagian pertama dan* ***bulatkan*** *jawapan anda samada 1, 2, 3, atau sebagainya. Sekiranya anda* ***tidak*** *bersetuju dengan mana-mana sebab yang diberikan, sila tulis sebab anda di ruang yang disediakan.*

1. Chemical X shows the following properties:
Bahan kimia X menunjukkan ciri-ciri berikut:

✓ Tastes bitter and feels soapy.
Berasa pahit dan licin.

✓ Turns red litmus paper blue.
Menukarkan kertas litmus merah kepada biru.

✓ Reacts with an acid to produce a salt and water.
Bertindakbalas dengan asid untuk menghasilkan garam dan air.

✓ Produces ammonia gas when heated with an ammonium salt.
Menghasilkan gas ammonia apabila dipanaskan dengan garam ammonium.

✓ Reacts with an aqueous salt solution to produce a metal hydroxide.
Bertindakbalas dengan larutan garam akues untuk menghasilkan logam hidroksida.

Which of the following is most probably chemical X?
Yang mana antara berikut paling berkemungkinan bahan kimia X?

A. Dry ammonia gas.
Gas ammonia kering.

B. Sodium hydroxide dissolved in propane.
Sodium hidroksida larut dalam propana.

C. Glacial acetic acid.
Asid asetik glasial.

D. Aqueous calcium hydroxide.*
Kalsium hidroksida akues.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Chemical X could ionise in water to produce H^+ ions.
   Bahan kimia X boleh mengion di dalam air untuk menghasilkan ion-ion H^+.

2. Chemical X could ionise in water to produce OH^- ions.*
   Bahan kimia X boleh mengion di dalam air untuk menghasilkan ion-ion OH^-.

3. Chemical X could ionise to produce OH^- ions in the absence of water.
   Bahan kimia X boleh mengion untuk menghasilkan ion-ion OH^- tanpa kehadiran air.

4. Chemical X is soluble in water.
   Bahan kimia X larut di dalam air.

5. Other reason:
   Sebab lain:

   ____

   ____

[1 mark/Understanding/LO4/Pre:B10]

2. The table shows the pH value of four aqueous solutions, P, Q, R, and S.
   Jadual di bawah menunjukkan nilai pH bagi empat larutan, P, Q, R, dan S.

Solution/*Larutan*	P	Q	R	S
pH value/*Nilai pH*	13	7	3	9

Which of the following solutions will react with calcium carbonate to produce carbon dioxide gas?
Yang manakah antara larutan tersebut akan bertindakbalas dengan kalsium karbonat untuk menghasilkan gas karbon dioksida?

A. P

B. Q

C. R*

D. S

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. The solution contains a higher concentration of OH^- ions than H^+ ions.
   Larutan tersebut mengandungi kepekatan ion-ion OH^- yang lebih tinggi berbanding ion-ion H^+.

2. The solution contains a higher concentration of H^+ ions than OH^- ions.*
   Larutan tersebut mengandungi kepekatan ion-ion H^+ yang lebih tinggi berbanding ion-ion OH^-.

3. The solution contains equal concentrations of H^+ and OH^- ions.
   Larutan tersebut mengandungi kepekatan ion-ion H^+ dan ion-ion OH^- yang sama.

4. Other reason:
   Sebab lain:

   ____

   ____

[1 mark/Understanding/LO5/Pre:B5]

3. When methyl orange indicator in a titration experiment turns yellow, this indicates the reaction between acid solution and alkali solution has reached its end point.
   Apabila penunjuk metil oren dalam suatu eksperimen pentitratan bertukar ke warna kuning, ini menunjukkan tindakbalas antara larutan asid dan larutan alkali telah mencapai takat akhir.

   A. True.
   Betul.

   B. False.*
   Salah.

   The reason for my answer is:
   Sebab bagi jawapan saya adalah:

   1. Methyl orange turns yellow because neutralisation has occurred.
      Metil oren bertukar ke warna kuning kerana peneutralan telah berlaku.

   2. Methyl orange turns yellow because water and a salt are present in the solution.
      Metil oren bertukar ke warna kuning kerana terdapat kehadiran air dan garam dalam larutan tersebut.

   3. Methyl orange turns yellow because there is an excess of alkali in the solution.*
      Metil oren bertukar ke warna kuning kerana terdapat lebihan alkali dalam larutan tersebut.

4. Methyl orange turns yellow because there is an excess of acid in the solution.
Metil oren bertukar ke warna kuning kerana terdapat lebihan asid dalam larutan tersebut.

5. Other reason:
Sebab lain:

____

____

[1 mark/Understanding/LO25/Pre:B6]

4. What is the main apparatus that is used in the preparation of a standard solution?
Apakah radas utama yang digunakan dalam penyediaan suatu larutan piawai?

A. Volumetric flask*
Kelalang isipadu.

B. Beaker
Bikar.

C. Measuring cylinder
Silinder penyukat.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. It is easier to dissolve the solute by shaking.
Ia memudahkan bahan terlarut melarut dengan menggoncang.

2. It prevents the solution from splashing out.
Ia dapat mengelakkan larutan tersebut daripada terpercik keluar.

3. It can measure a fixed volume of solution more accurately.*
Ia dapat menyukat isipadu tetap larutan dengan lebih tepat.

4. Other reason:
Sebab lain:

____

____

[1 mark/Applying/ LO17/Pre:B4]

5. Both sulphuric acid and ethanoic acid are strong acids.
Kedua-dua asid sulfurik dan asid etanoik adalah asid kuat.

   A. True.
   Betul.

   B. False.*
   Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Sulfuric acid ionises completely in water to produce H^+ ions, while ethanoic acid ionises partially in water to produce H^+ ions.*
   Asid sulfurik mengion lengkap di dalam air untuk menghasilkan ion-ion H^+, manakala asid etanoik mengion separa di dalam air untuk menghasilkan ion-ion H^+.

2. Ethanoic acid ionises completely in water to produce H^+ ions, while sulfuric acid ionises partially in water to produce H^+.
   Asid etanoik mengion lengkap di dalam air untuk menghasilkan ion-ion H^+, manakala asid sulfurik mengion separa di dalam air untuk menghasilkan ion-ion H^+.

3. Both acids ionise completely in water to produce H^+ ions.
   Kedua-dua asid tersebut mengion lengkap di dalam air untuk menghasilkan ion-ion H^+.

4. Both acids ionise partially in water to produce H^+ ions.
   Kedua-dua asid tersebut mengion separa di dalam air untuk menghasilkan ion-ion H^+.

5. Other reason:
   Sebab lain:

   ____

   ____

[1 mark/Analysing/ LO10/Pre:B7]

6. Two common substances that have the formulas HCl and CH_4 both contain the element hydrogen. However, only HCl has acidic properties while CH_4 does **not**.
Dua bahan yang biasa ditemui mempunyai formula HCl dan CH_4 yang mana kedua-duanya mengandungi unsur hidrogen. Walaubagaimanapun, hanya HCl menunjukkan sifat-sifat asid tetapi CH_4 ***tidak****.*

   A. True.*
   Betul.

   B. False.
   Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. CH_4 completely ionises to produce more H^+ ions in water than HCl.
   CH_4 mengalami ionisasi lengkap menghasilkan lebih banyak ion-ion H^+ di dalam air berbanding HCl.

2. Any substance that contains H atom in the molecular formula is acidic.
   Sebarang bahan yang mengandungi atom H di dalam formula molekulnya adalah berasid.

3. Only HCl ionises to produce H^+ ions in water.*
   Hanya HCl yang mengalami ionisasi di dalam air untuk menghasilkan ion-ion H^+.

4. Other reason:
   Sebab lain:

   ____

   ____

[1 mark/Understanding/LO1/Pre:B3]

7. What is a property of citrus fruits like oranges and lemons?
   Apakah sifat buah-buahan sitrus seperti oren dan lemon?

   A. Acidic.*
      Berasid.

   B. Basic.
      Berbes.

   C. Neutral.
      Neutral.

   The reason for my answer is:
   Sebab bagi jawapan saya adalah:

   1. Citrus fruits have pH value less than 7.*
      Buah-buahan sitrus mempunyai nilai pH kurang daripada 7.

   2. Citrus fruits have pH values greater than 7.
      Buah-buahan sitrus mempunyai nilai pH lebih daripada 7.

   3. Citrus fruits have pH values equal to 7.
      Buah-buahan sitrus mempunyai nilai pH bersamaan 7.

4. Other reason:
Sebab lain:

____

____

[1 mark/Understanding/LO7/Pre:B8]

8. Soaps and detergents as well as household cleaners for floors, ovens and glass windows contain alkaline chemicals like sodium hydroxide and ammonia, but **not** acids.
Sabun, deterjen, dan juga bahan-bahan pembersih rumah untuk lantai, oven, dan cermin tingkap mengandungi bahan kimia alkali seperti sodium hidroksida dan amonia, tetapi ***bukan*** *asid.*

A. True.*
Betul.

B. False.
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Alkalis are soapy and so are able to wash away stains.
Sifat alkali yang licin membolehkan kotoran dibersihkan.

2. Acids are more corrosive than alkalis and so are more effective in removing stains.
Asid adalah lebih korosif berbanding alkali yang mana lebih efektif menanggalkan kotoran.

3. Alkalis dissolve grease and oils present in dirt more readily than acids.*
Alkali dapat melarutkan gris dan minyak yang hadir dalam kotoran lebih mudah berbanding asid.

4. Acids are able to neutralise alkalis present in dirt.
Asid dapat meneutralkan alkali yang hadir dalam kotoran.

5. Other reason:
Sebab lain:

____

____

[1 mark/Applying/LO2/Pre:B2]

9. If soil is too acidic, it is not likely to support the healthy growth of grass. What chemical would you add to the soil to promote the growth of grass?
Jika tanah terlalu berasid, ia dikatakan tidak menyokong pertumbuhan rumput yang sihat. Apakah bahan kimia yang boleh anda tambahkan kepada tanah tersebut untuk menggalakkan pertumbuhan rumput?

A. Common salt.
Garam biasa.

B. Vinegar.
Cuka.

C. Lime (calcium oxide).*
Kapur (kalsium oksida).

D. Caustic soda.
Soda kaustik.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. The basic substance neutralises the acidic soils.*
Bahan berbes tersebut dapat meneutralkan keasidan tanah.

2. The basic substance changes the soil acidity to a pH value greater than 7.
Bahan berbes tersebut mengurangkan keasidan tanah sehingga nilai pH melebihi 7.

3. The acidic substance changes the pH of soil closer to the ideal pH.
Bahan berasid tersebut menukarkan pH tanah mendekati nilai pH yang ideal.

4. Other reason:
Sebab lain:

____

____

[1 mark/Applying/LO22/Pre:B9]

10. Aqueous solutions of potassium hydroxide as well as ammonia are both weak alkalis.
Kedua-dua larutan akues kalium hidroksida dan juga amonia adalah alkali lemah.

A. True.
Betul.

B. False.*
Salah.

The reason for my answer is:
Sebab bagi jawapan saya adalah:

1. Aqueous potassium hydroxide is completely ionised in water, while aqueous ammonia is only partially ionised.*
Kalium hikdroksida akues mengalami ionisasi lengkap di dalam air, manakala ammonia akues hanya mengalami ionisasi separa.

2. Potassium hydroxide and ammonia are only partially ionised in water.
Kalium hidroksida dan amonia hanya mengalami ionisasi separa di dalam air.

3. Aqueous ammonia, NH_3, is not an alkali because it does not contain OH^- ions in its formula.
Amonia akues, NH_3, adalah bukan alkali kerana ia tidak mengandungi ion-ion OH^- di dalam formulanya.

4. Potassium hydroxide and ammonia ionise completely in water.
Kalium hidroksida dan amonia mengalami ionisasi lengkap di dalam air.

5. Other reason:
Sebab lain:

____

____

[1 mark/Analysing/ LO11/Pre:B1]

Test End.
Ujian Tamat.

Thank You!
Terima Kasih!

APPENDIX R: Result of the Factor Analysis of the Student Edition of the QEC

Pattern Matrix[a]

	Component			
	1	2	3	4
AL_B19	.775			
MC_B20	.687			
LA_B12	.623			
TT_B9	.539			
LA_B10	.515			
AI_B21	.513		-.405	
LA_B15	.508			.332
MC_B18	.491		-.381	
CI_B6		.765		
CI_B4		.654		
CI_B5		.627		
CI_B7		.613		
CI_B2		.587		-.312
CI_B3		.575		
TT_B8		.531		
TT_B1		.486		
AI_B26			-.748	
AI_B23			-.695	
MC_B22			-.673	
AL_B25			-.657	
AI_B24			-.622	
TT_B13				.623
TT_B11				.610
AL_B16			-.366	.492
LA_B14	.437			.447
AL_B17				.301

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

a. Rotation converged in 16 iterations.