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An Action Research in Science: Providing Metacognitive Support to Year 9 Students

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ABSTRACT
An action research study was designed to evaluate the effectiveness of providing metacognitive support to enhance Year 9 students' metacognitive capabilities in order to better understand science concepts related to light, environmental health, ecosystems, genetics, ecology, atoms and the Periodic Table. The study was conducted over three years involving 35, 20 and 24 students in each year. The interventions included providing students with clearly stated focused outcomes about the relevant science concepts, engaging in collaborative group work, reading scientific texts and using concept mapping techniques. The data to evaluate the effectiveness of the metacognitive interventions were obtained from pre- and posttest results of the *Metacognitive Support Questionnaire* (*MSpQ*). The results showed gains in the *MSpQ*.

KEYWORDS
Action research; metacognition; metacognitve support; science concepts

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Introduction

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 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.

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The term metacognition gained significant recognition in the 1970s from the early work of Flavell who 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), selfregulated 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 and 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 selfregulation, 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, 2006; Zohar & David, 2009).

Theoretical Framework

Action research is usually carried out in cycles as shown in Figure 1, 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.

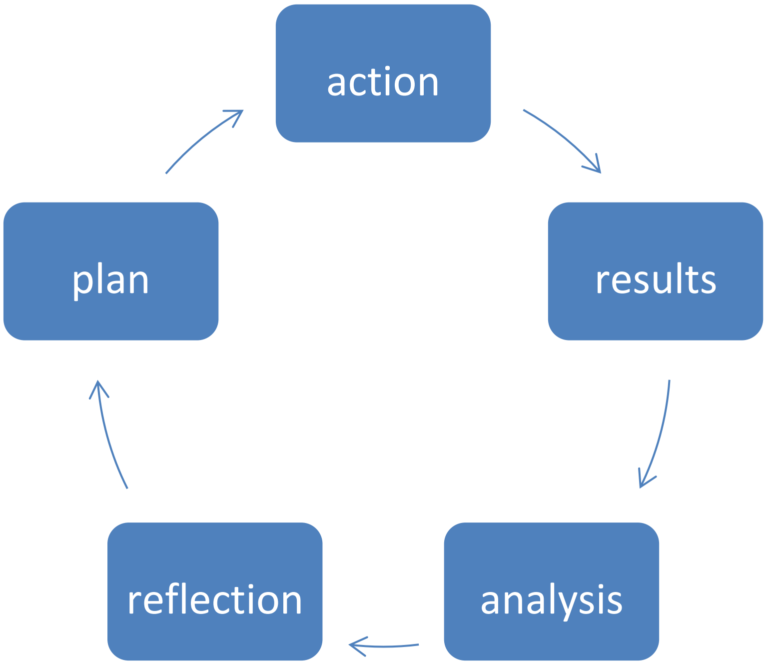

Figure 1. Example of an action research cycle

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 miniexperiments in practice. In each cycle, the result indicates whether or not what was intended workedor if it needs to be changed (Coolican, 2009; Williamson, 2002).

Strengths and Weaknesses of Action Research

Action research as its 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 practicelocational, 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.

Action research has a deliberate agenda; the task of the researcher is not to be an ideologue 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).

Students' Metacognitive Capabilities

The conceptual framework for the investigation of the effectiveness of a repertoire of interventions to enhance students' metacognitive capabilities and their achievements in science has its roots in cognitive psychology. In this study, the metacognitive interventions employed have been derived from two metacognitive models: the metacognitive model of self-regulated learning of Pintrich (2000) and the socio-cognitive model of self-regulated learning espoused by Zimmerman and Schunk (2001). According to Pintrich (2000), self-regulated learning, as a component of metacognition, is an active, constructive process whereby students set goals for their learning and then attempt to monitor, regulate and control their cognition, motivation and behaviour guided and constrained by the goals and features in their learning environment. According to Zimmerman and Schunk (2001), metacognitive learning involves the use of numerous self-regulatory processes such as planning, knowledge activation, metacognitive monitoring and regulation and reflection (Azevedo, 2009).

The focus of this research was on the enhancement of students' metacognitive capabilities, in order to improve their understanding of science concepts, by providing a repertoire of metacognitive support.

Metacognitive Support

According to Thomas (2003, 2006), the characteristics of a metacognitively oriented learning environment involves 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 study conducted by Thomas (2006), 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' achievement 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 just about learning the social skills of working together. 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 study conducted by Thomas (2003, 2006), 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 or elaborate on 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, 2006). 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 it is legitimate to question the teacher's pedagogical plans and methods. According to research findings by

Thomas (2006), 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 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, 2006). 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, 2006).

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 goals that emphasize deep understanding of important subject-matter content, (2) the use of scaffolds to support the students, (3) frequent opportunities for formative self-assessment, revision, and reflection, and (4) social organisations that promote collaboration and a striving for high standards (Greene, Costa & Dellinger, 2011; Hacker, Dunlosky & Graser, 1998).

Classroom factors which limit metacognitive development include: (1) predetermined syllabus, (2) long established expectations for appropriate student participation, (3) lesson development, and (4) classroom management (Greene, Costa & Dellinger, 2011). Furthermore, it is often impossible to know how students are progressing metacognitively because most academic assessments are designed to assess cognitive rather than metacognitive processing. Even the available instruments for assessing students' metacognitive strategies give inconsistent results. Research studies by Leutwyler (2009) showed no overall development in students' self-reported metacognitive strategy use in high school whereas studies by Veenman et al (2004) showed a linear increase in the use of metacognitive strategies between the ages of 14 and 22. Veenman and Spans (2005) used on-line methods such as observation and think-aloud for assessing the use of metacogntive strategies whereas studies conducted by Leutwyler (2009) used data obtained from self-report instruments 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.

Purpose of Study and Research Questions

The purpose of this action research was to study the effects of progressively implementing metacognitive strategies during instruction in science. Based on feedback received in each cycle, improvements were made in subsequent cycles. The following main research question was addressed to achieve the purpose of this study:

How do Year 9 students' perceive the metacognitive support that was provided during instruction over three years in an action research study?

Methodology

Research Design and Sample

The research design that was used to conduct this study was an action research study (Cohen, Manion & Morrison, 2011). The study investigated the effectiveness of a repertoire of interventions to enhance Year 9 students' metacognitive capabilities in order to facilitate their understanding of science concepts in various topics. The sample consisted of 35 students in the first year, 20 students in the second year and 24 students in the third year.

Instructional Program

In order to enhance the students' metacognitive capabilities, several interventions were incorporated during classroom instruction like providing students with focused outcomes, organising collaborative activities and enhancing skills in reading scientific text and concept mapping. The interventions were conducted over 10 weeks totalling 33.3 hours of curriculum time in the first cycle, 20 weeks in the second cycle totalling 66 hours and 10 weeks in the third cycle totalling 33.3 hours. (see Figure 1).

The first cycle was conducted over a period of 10 weeks as shown in Figure 2. The interventions included skills on reading scientific text, monitoring the learning by checking against the outline of the focused outcomes periodically, and engaging in collaborative activities in the science classroom.

The second cycle was conducted over a period of 20 weeks as shown in Figure 3. The reason the first author spent 20 weeks on the second cycle was because it was felt that the longer the interventions are conducted the more significant the changes in students' metacognitive capabilities would be. The metacogntive interventions were similar to those conducted in the first cycle with the addition of reflection journals. However, although students entered their learning experiences in reflection journals, the qualitative data collected in the second cycle has not been used in this research paper because the emphasis is on quantitative data about how students perceived the metacognitive support that they received in the science classroom.

Week	Metacognitive interventions

1	Pre-metacognitive strategies support survey conducted. Key words and focused outcomes on light were provided to students and an explanation made that students will be expected to tick off topics as they get covered. Topic – Light Focussed outcomes: • Illustrate that light travels in straight lines and give various everyday examples. • Desugn an experiment which shows that light is a form of energy. • Define the terms reflection and refraction. • Draw ray diagrams to describe how a parallel beam of light is reflected from smooth and rough surfaces. • Describe how light is reflected by a plane mirror and curved mirrors (convex and concave mirrors). • Label the incident, normal and reflected rays on a plane mirror. • Label the focal point and the focal length on a ray diagram showing how a parallel beam of light is refracted by convex and convex lenses. • Design experiments to measure the focal length of convex and concave lenses. • Describe how white light is split by a triangular prism. • Explain how a raibow is formed. • Draw and label a cross-section of the human eye. • Explain the functions of the following prts of the human eye: cornea, lens, retina, optic nerve and iris.
2	Collaborative group work (3 students per group) - conducted a practical investigation about the properties of light. Students were expected to discuss their observations in groups.
3.	Reading a text on refraction of light. Students were instructed to skim through the text first and then read the text slowly while highlighting the main ideas. Students ticked off focused out comes covered in the first two weeks.
4	Students brainstormed concepts on light energy. Prompting questions about students' prior knowledge on light were provided and students discussed them in groups.
5	Students ticked off focused outcomes covered in weeks 3 and 4. Students collaboratively conducted experiments on properties of light and discussed their observations in groups.
6	Students read a text on speed and wavelength of the visible region of the electro-magnetic spectrum in relation to other parts of the electromagnetic spectrum and answered questions. They were instructed to first skim through the text then read slowly as they highlighted the main points.
7	Week interrupted by teacher being on jury duty.
8	Students ticked off outcomes covered in weeks 5 and 6. Students used the key words given at the beginning of the topic to construct cocept maps in groups of three.
9	Students ticked off outcomes covered in week 8. Students discussed and shared information displayed in concept maps.
10	Post-metacognitive strategy support in the science classroom survey conducted

Figure 2. Outline of classroom instruction in the first cycle

Week	Metacognitive interventions

1	Pre-metacognitive strategies support survey conducted. Focused outcomes and key words on environmental health and the periodic table provided to students and an explanation made that students will be expected to tick off topics as they were covered. Topic - Ecosystems Focused outcomes: • Distinguish between the biotic and abiotic components of an ecosystem. • Define the terms ecosystem, habitat, autotrophs and heterotrophs. • Draw a food web and a food chain, given a list of living organisms in a particular ecosystem. • Analyse and explain the energy flow in a food chain when given a set of data about the energy available at a given trophic level. • Explain how biomagnification and bioaccumulation occur in a food chain. • Describe and explain how some abiotic factors (water, temperature and air) affect a given ecosystem. • Describe and explain the effects of some environmental problems such as bushfires, floods, earthquakes, volcanoes eruption (Iceland), drought and cyclone (Comprehension on real life examples especially recent ones such as the volcanic eruptions in Iceland, cyclone in Indonesia, and tornadoes in America, etc.). • Define pollution. • Describe and explain the effects of different types of pollution such as air pollution, water pollution and land pollution. • Explain 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 some common indicators (such as litmus paper and methyl orange) to measure pH of various household chemicals and 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. • Conduct an investigation to test the water quality of Rapid Creek by carrying out various tests on water and soil samples at three different points of Rapid Creek. The tests include: pH, turbidity, salinity (electrical conductivity), temperature, phosphates, nitrates and oxygen. • Write a practical report (Rapid Creek excursion report). • Effectively use a marking rubric as a guide when writing a practical report. • Account for the contribution indigenous science has made to lives in modern Australia especially in medicine, tourism and environmental health. Topic- Genetics Focused outcomes: • Brain storm prior knowledge about cells and specialised cells. • Compare and contrast sexual and asexual reproduction (sexual reproduction requires gametes, gametes have half the chromosome number compared to other normal body cells - somatic cells - and variation). • Describe Mendel's theories. Characteristics are passed from generation to generation. Each characteristic is controlled by two factors. At fertilisation one factor is contributed by each parent. Each factor can be dominant or recessive.

	• State four factors that led to the success of Mendel's experiments (large sample sizes, pea plants, scientific method and the mathematics of probability). • Define the following terms: genotype, phenotype, alleles, recessive, dominant, co-dominant, heterozygous and homozygous. • Carry out simple monohybrid calculations using punnet squares to predict the genotypes and phenotypes of offspring (F1 generation). • Compare mitosis and meiosis i.e., type of cells in which process occurs, number of chromosomes in daughter cells compared to parent cells. Use the terms diploid number and haploid number. The importance of having haploid number in gametes. • Describe the role of breeding programs for specific characteristics in pets and agriculture. • Describe what is involved in genetic counselling. • List four groups of people who could use a genetic counselling service and give a reason for each group to use this service. • Critically analyse the importance of having a genetic counselling service. • State four genetic diseases for which individuals may have genetic counselling and describe each of these diseases (research work). • Define ethics. • Give specific examples of what ethical considerations need to be taken when designing science experiments involving animals (to use the movies "Nutty professor" and "Animal pharm").
2	Collaborative group work (3 students per group) to collect data for an investigation about the concentration of various minerals, pH, temperature and turbidity of water in a local river. Students are expected to discus their observations in groups.
3	Read a text on water quality. Students instructed to first skim through then read slowly while highlighting or underlining the main points. Use samples of water collected to conduct tests in the laboratory about various aspects of water quality: concentration of minerals such nitrates (NO_3^{-}), phosphates (PO_4^{3-}). Students encouraged to work collaboratively by allocating roles to each member of the group, and discuss their observations together.
4	Students ticked off focused outcomes covered in week 1, 2 and 3. Students entered their learning experiences in reflection journals by responding to the prompting questions provided. Teacher explained to students how to use a marking a rubric to monitor their progress when writing a practical report.
5	Students constructed concept maps in groups of three by using at least 10 of the key words provided at the beginning of the topic. Formative test on focused outcomes covered in environmental health conducted.
6	Students ticked off focused outcomes covered in weeks 4 and 5. Students' learning experiences about the focused outcomes covered in weeks 4 and 5 entered in their reflection journals. Students are given an explicit explanation of the marking rubric which is used to assess their practical assignment.
7	Students use the practical assignment marking rubric to monitor their progress while writing the practical report.
8	Students use the marking rubric to self-assess their practical report.
9	Students entered their learning experiences in reflection journal.

10	Revision Formative test
11	Students recall prior knowledge on cells, cell structure and specialised cells. Focused outcomes on new topic, genetics, given to students.
12	Students instructed to skim through a text on Gregor Mendel's work then read slowly while highlighting or underlining the main points.
13	Students use punnet squares to predict offsring genotypes and phenotypes.
14	Students ticked off focused outcomes covered in weeks 11-13. Reflection journal entry of learning experiences in weeks 11-13.
15	Students used acronyms to recall the sequence of stages in mitosis.
16	Students ticked off focused outcomes covered in weeks 14-15. Students entered their learning experiences of focused outcomes covered in weeks 14-15 in their reflection journals.
17	Students wrote a practical report of their findings when they extracted DNA from kiwi fruit with an emphasis on evaluation of the experimental procedures in the discussion section of the report.
18	Revision Students used the key words given at the beginning of the topic to construct concept maps in groups of three. Formative test on genetics.
19	Students entered their learning experiences about focused outcomes covered in weeks 16-18 in their reflection journals. Students individually constructed concept maps using most of the key words given out at the beginning of the topic.
20	Post-metacognitive strategies support survey conducted. Revision Semester examination

Figure 3. Outline of Year 9 science classroom instruction in the second cycle

After reflecting on the difficulties encountered due to the length of the second cycle (20 weeks), the first author reverted to conducting the action research over a period of 10 weeks in the third cycle. The students felt that participation in the action research was taking time away from their summative assessments, and therefore were reluctant to participate in activities like entering reflection journals or constructing concept maps because they did not contribute directly to their report card grades.

In the third cycle the same interventions as those conducted in the second cycle were employed, as shown in Figure 4, except that the prompting questions in the reflection journals were more focused. For example, unlike in the previous cycles, students were asked to reflect on aspects like how they conducted practical activities and the difficulties they encountered when writing practical reports or preparing for science tests or examinations. The focused outcomes covered in the third cycle were also similar to those in the first 10 weeks of the second cycle in addition to the topic on atoms and the periodic table.

In all the three cycles of this action research similar interventions were employed and modifications made after reflecting on each cycle as shown in Figure 5. However, qualitative data from the concept maps and reflection journals have not been included in this research paper.

Week	Metacognitive interventions

1	Pre-metacognitive strategies support survey conducted. Topic – Ecology Focused outcomes: Focused outcomes on ecology provided to students and an explanation made that students will be expected to tick off topics as they get covered. • Distinguished between the biotic and abiotic components of an ecosystem. • Defined the terms ecosystem, habitat, autotrophs and heterotrophs. • Drew a food web and a food chain, given a list of living organisms in a particular ecosystem. • Analysed and explained the energy flow in a food chain when given a set of data about the energy available at a given trophic level. • Explained how biomagnification and bioaccumulation occur in a food chain. • Described and explained how some abiotic factors (water, temperature and air) affect a given ecosystem. • Described and explained the effects of some environmental problems such as bushfires, floods, earthquakes, volcanoes eruption (Iceland), drought and cyclone (Comprehension on real life examples especially recent ones such as the volcanic eruptions in Iceland, cyclone in Indonesia, and tornadoes in America, etc.). • Define pollution. • Describe and explaine the effects of different types of pollution such as air pollution, water pollution and land pollution. • Explain the causes and effects of salinity, soil erosion and eutrophication. • Make observations and assess the health of our local environment - effect of rubbish, oil spills; test pH, dissolved O_2, salinity, temperature. • Use some common indicators (such as litmus paper and methyl orange) to measure pH of various household chemicals and 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. • Conduct an investigation to test the water quality of Rapid Creek by carrying out various tests on water and soil samples at three different points of Rapid Creek. The tests include: pH, turbidity, salinity (electrical conductivity), temperature, phosphates, nitrates and oxygen. • Write a practical report (Rapid creek excursion report). • To effectively use a marking rubric as a guide when writing a practical report. • Account for the contribution indigenous science has made to lives in modern Australia especially in medicine, tourism and environmental health • 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 • Predict the chemical and physical properties of elements in the same groups and periods. • Use flame tests to identify elements.
2	Collaborative group work (3 students per group) to construct food chains.
3.	Read slowly and highlight main ideas in a text about a given ecosystem and feeding relationships.
4	Students tick off focused outcomes covered in week 1,2 and 3

	Enter learning experiences in reflection journal by referring to focused otcomes covered in weeks 1,2 and 3
5	Read slowly and highlight main ideas in a scientific text on water quality 6
	Students tick off focused outcomes covered in weeks 4 and 5. Enter learning experiences in a reflection journal about their learning experiences by referring to the focused outcomes covered in weeks 4 and 5.
7	Individually construct concept maps using atleast 10 of the key words provided at the beginning of the topic
8	Students tick off focused outcomes covered in weeks 6 and 7 Enter learning experiences in a reflection journal about their learning experiences by referring to the focused outcomes covered in weeks 7 and 8.
9	Construct concept maps individually, using all or most of the key words provided at the beginning of the topic.
10	Post-test on metacognitive strategies support conducted

Figure 4. Outline of Year 9 science classroom instruction in the third cycle

Cycle no.	Metacognitive support strategies
1.	Concept maps, collaborative activities, real life situations relating to topics covered and using focused outcomes.
2.	The same interventions as in cycle one in addition to reflection journals.
3.	More focused prompting questions in the reflection journals.

Figure 5. A summary of the metacognitive support strategies in each of the three cycles in this study

Measuring Metacognitive Capabilities

In order to assess students' metacognitive capabilities, the authors used a metacognitive survey at the beginning (pre-metacognitive survey) and at the end (post-metacognitive survey) of instruction in each cycle. The survey questionnaire was used to ascertain students' perceptions of the metacognitive support that they had received during the lessons. Referred to as the *Metacognitive Support Questionnaire* (*MSpQ*), the questionnaire consisted of 20 items in five scales – Student-Student Discourse (SSD), Student-Teacher Discourse (STD), Student Voice (SV), Metacognitive Demand (MD). and Teacher Encouragement and Support (TES). The items in the scales were scored using a Likert-type scale ranging from 1 to 5 to represent students' perceptions, with 1 representing 'almost never', 2 for 'seldom', 3 for 'sometimes', 4 for 'often', and 5 for 'very often'. The questionnaire was administered as a pretest before commencement of the study and again as a posttest at the end of the interventions in each cycle. Students were given 50 minutes to respond to the questionnaire. The questionnaire is found in the Appendix.

Data Analyses Procedures

After the students had responded to the *MSpQ*, their responses were entered into an Excel data file. SPSS software (version 20) was then used to analyse the Cronbach's alpha reliabilities, the means and the standard deviations of the scales in the questionnaire. Comparisons between the pretest and posttest results were made using a paired samples t-test analysis and by computing effect sizes.

Results

The results of the analyses of students' responses to the *MSpQ* in each cycle are summarised in Tables 1, 2 and 3.

Table 1. Analyses of responses to the *Metacognitive Support Questionnaire* (*MSpQ*) in cycle 1 (N = 34)

Scales	No. of items	Cronbach's alpha reliability		Means		Standard deviation		t-value	Effect size
		Pre	Post	Pre	Post	Pre	Post		
Student-Student Discourse (SSD)	5	0.87	0.83	1.94	2.32	0.82	0.72	3.10**	0.49
Student-Teacher Discourse (STD)	5	0.91	0.87	2.42	3.15	0.98	0.75	4.06**	0.84
Student Voice (SV)	5	0.66	0.45	3.90	4.26	0.63	0.54	2.96**	0.61
Metacognitive Demands (MD)	5	0.72	0.72	2.61	3.42	0.75	0.66	7.87**	1.14
Teacher Encouragement and Support (TES)	5	0.82	0.93	3.60	4.14	0.87	0.86	2.51**	0.62

***p* < 0.01; ES - effect size

Note: Cohen (1988) has defined the effect size as being small when *d* = 0.2, medium when *d* = 0.5 and large when *d* = 0.8.

Table 2. Analyses of responses to the *Metacognitive Support Questionnaire* (*MSpQ*) in cycle 2 (N = 20)

Scales	No. of items	Mean		Standard deviation		Pre-post difference t-value	ES (Cohen's d)
		Pre	Post	Pre	Post		
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
MD	5	3.16	3.02	0.66	1.04	0.51	0.16
TES	5	3.45	3.55	0.98	1.10	0.30	0.10

***p* < 0.01; ES - effect size

Table 3. Analyses of responses to the *Metacognitive Support Questionnaire* (*MSpQ*) in cycle3 (N = 24)

Scales	No. of items	Mean		Standard deviation		Pre-post difference t-value	ES (Cohen's d)
		Pre	Post	Pre	Post		
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

MD	5	3.55	3.68	0.57	0.49	0.87	0.24
TES	5	4.10	4.44	0.72	0.54	1.77	0.53

$^{**}p < 0.01$; ES - effect size

Discussion of Results

When comparing the mean scores of the four scales of the *MSQ* in cycle 1 as shown in Table 1, two scales had high initial scores - Student Voice (mean = 3.90) and Teacher Encouragement and Support (mean = 3.60). The other two scales - Student-Teacher Discourse (mean = 2.42) and Student-Student Discourse (mean = 1.94), with lower pretest means suggest that students did not often engage in discussions with their teacher nor with each other in collaborative or group activities in the science classroom before the interventions. Following the interventions, students' mean scores on all four scales increased and these differences were statistically significant suggesting that the students perceived that they received metacognitive support during the interventions. Three of the scales had acceptable Cronbach's alpha values.

Table 2 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 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 2. 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.

As shown in Table 3, 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 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 learned and how they ~~can~~ could 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 1.

In the Year 9 class all the scales on the *MSpQ* had modest gains as shown in Table 3. 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).

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. 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 before and after the interventions.

In cylces 2 and 3, there were no major gains in the pre-post means of the scales of the *MSpQ*. This change was not surprising as in both these cycles instruction was during the second or third terms. As a result, the first author had begun teaching from the beginning of the year using using the metacognitive strategies involved. Hence, by the time the study was conducted in the second or third term, students were already familiar with the metacognitive staregies that were used in the studies, resulting in limited or no change in the means of the different scales.

Conclusions

In all the three cycles, the means of all the five scales in the *Metacognitive Support Questionnaire* (*MSpQ*) were relatively high at the beginning. 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 StudentStudent 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.

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. 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 9 class displayed a significant decrease in STD. In the third cycle, there were no significant gains in Years 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*.

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. However, according to a research conducted by Thomas (2003, 2006a), student-student discussions are more often related to content and less to metacognitive strategies. Therefore, students need to be given frequent opportunities to interact in the classroom in order to practice their metacognitive strategies (Larkin, 2006). In addition, 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.

With respect to the main research question of this study (How do Year 9 students' perceive the metacognitive support that was provided during instruction over three years in an action research study?) it may be concluded that at the beginning, in all the three cycles, generally most students' perceptions were highest in the TES and SV scales, and lowest in the SSD scale. 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.

Limitations

There were several limitations to the study that precluded the ability to generalise the outcomes to larger populations. In the first cycle, the first limitation was due to unforeseen interruptions to the school programme that involved the researcher being out of school 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 second limitation is that some students with low literacy skills may not have been able to read and understand the self-report instruments. 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.

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. Another 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).

Another major limitation was the choice of time for implementing the metacognitive interventions. It would have been more appropriate to begin the study with the first topic in the second and third cycles.

Recommendations

Based on the findings of this study, it is suggested that reliable and easy-touse 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 programs that specifically address the metacognitive needs of particular science students in the secondary school science classes.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix

Metacognitive Support Questionnaire *(MSpQ)*

Survey No: _____ Date: _______ Class: _________

Name:____

No.	Item	Almost always	Often	Sometimes	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.					
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.					