The Effects of Self-Regulated Learning Training on Students' Metacognition and Achievement in Chemistry

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Abstract

Self-regulated learning strategies are critical for students to be able to learn abstract subjects successfully and meaningfully. This article reports on an empirical investigation of the effectiveness of self-regulatory training on secondary school students' metacognition and achievement in chemistry. A total of 60 students aged 14-15 were randomly assigned into either the experimental group or the control group. Participants in the experimental group completed four self-regulated learning (SRL) exercises based on Zimmerman's (2002) cyclical model. Data were collected using pre and post self-regulated learning questionnaire (SRLQ), and pre and post reaction rates knowledge test (RRKT). Additional qualitative data were collected through classroom observation and interviews. Quantitative data were analysed using sample independent t-test while thematic analysis was used for the qualitative data. The results revealed that there were significant differences between the two groups in terms of SRL skills, i.e. students in the experimental group scored higher on post-SRLQ. Regarding students' achievement in chemistry, a slightly greater improvement was found for the students with SRL training than those in the control group. The findings suggested that training in SRL improves students' achievement in chemistry and therefore should be included in secondary science classrooms.

Introduction

In science, technology, engineering and mathematics (STEM)-related subjects, students' self-regulation and motivation have been two of the most frequently studied topics in recent years (Lindstrøm & Sharma, 2010; Johnson & Sinatra, 2013; Fortus & Vedder-Weiss, 2014). These studies show that students' self-regulation and motivational beliefs are among the most important factors that influence science learning. Students' lack of motivation towards science subjects such as chemistry continues to be a problem in developing countries (Edomwonyi & Avaa, 2011; Kihwele, 2014). For a developing country like Nigeria to attain technological advancement, there is a need to motivate secondary school students' interest in learning science. Edomwonyi and Avaa (2011), noted that technological advancement will play an important role in elevating Nigeria from being a developing country to a developed country. Nigerian education policy emphasises the importance of science teaching and learning within the curriculum; this involves teaching chemistry right from senior secondary 1 (SS1) to SS3 (Federal Ministry of Education, 2007). The national curriculum aimed at developing students' interest in STEM subjects, acquiring basic skills, theoretical and practical knowledge in STEM, and developing a reasonable level of competence in information computer and technology (ICT) application, in order to engender entrepreneurial skills (National Policy on Education, 2008). The development of students' interest in STEM learning has always been recognised to be of great importance to enable them to make decisions wisely and to perform efficiently in the STEM subjects.

One explanation for why these students struggle academically in science subjects may be due to the lack of SRL strategies. Self-regulated learning from the social cognitive theorists' perspectives refers to a process where learners proactively initiate and sustain cognitive, affective and behavioural strategies in order to attain academic goals (Ramdass & Zimmerman, 2011). Moreover, self-regulated learners are regarded as active learners who are capable of managing their own learning in different contexts. Self-regulated learning is an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and learning preferences in the context of those goals (Ramdass & Zimmerman, 2011).

Inquiry-based learning is an approach to teaching and learning that places students' questions, ideas and observations at the centre of the learning experience. Teachers play an active role throughout the process by establishing a culture where ideas are respectfully challenged, tested, redefined and viewed as improvable, moving students from a position of wondering to a position of enacted understanding and further questioning (Scardamalia, 2002). Inquiry-based learning is a student centred approach that encourages students to draw on prior knowledge and experience in exploring their inquiries (Scardamalia, 2002). However, to effectively engage students in an inquiry-based learning environment, they must become responsible for their learning and actively participate in the processes of constructing knowledge and making meaning (Mergendoller, Markham, Ravitz, & Larmer, 2006). In order for the potential of student-centred, inquiry-based approaches to be realised, students must make the shift to their new role as active learners and develop SRL skills. Students who are self-regulated learners will be able to set goals, plan a course of action, select appropriate strategies, self-monitor, and self-evaluate their learning processes in inquiry-based learning environment. According to theorists, SRL is a developmental skill that is dependent upon the individual as well as characteristics of the environment (Zimmerman, 2000). This means that students may be at differing levels of ability to self-regulate when they are introduced to inquiry-based learning, and that they can improve in the way they self-regulate over time.

Previous studies have shown that SRL can help in enhancing achievement and assists students in learning how to control their learning environment (Montalvo & Torres, 2004; Bail, Zhang, & Tachiyama, 2008). However, very little research has examined the impact of SRL on students in the context of chemical reaction. Self-regulated learning strategies in chemistry include group learning, self-monitoring, feedback as well as the use of standardised diaries to stimulate self-reflection (Avezedo & Cromley, 2004; Kramarski & Gutman, 2006; Schmitz & Perels, 2011). In all these studies, direct instruction was seen as an effective means of enhancing students' SRL.

The relationship between SRL strategies and students' academic performance in chemistry is worth investigating, given that students who are interested in STEM-related courses at the university level are expected to have at least credit (50%) in chemistry. Students at this stage therefore need to analytically examine their learning contexts, identify relevant learning targets as well as the appropriate strategy they should employ, appraise the effectiveness of the adopted strategies in attaining their learning objectives as well as their emerging understanding of the topic under consideration. They also need to modify their plans, goals, strategies, and effort in relation to the learning context (Ramdass & Zimmerman, 2011).

Research findings revealed that learners might encounter problems in self-regulating their own learning processes under the given learning conditions (Shapiro & Niederhauser, 2004; Lajoie & Azevedo 2006). This consequently hinders their goals of improving their academic performance when learning challenging chemical concepts. One possible solution to students' difficulty in regulating their own learning is to investigate the impact of SRL training on their metacognition and achievement in chemistry. In the training intervention, cognitive and metacognitive strategies are explicitly explained to students prior to the lessons and students were prompted to apply these strategies to their learning.

Therefore, the purpose of the study being reported in this article was to investigate the effects of SRL training on SS1 students' achievement in chemistry. Additionally, because metacognition is a foundational construct of SRL, we assessed students' perceptions of their use of metacognition as one of the outcomes of this study. Metacognition involves knowledge and deliberate monitoring of one's cognitive processes inherent within the SRL phases of planning, task performance, and self-evaluation. It also entails time management strategies (Hacker, 1998).

In this study, we expected SRL training to improve students' metacognition which in turn leads to increase in students' academic achievement. More specifically, the research questions that guided the study were as follows: (1) Does training in SRL affect the academic performance of the students? (2) Does training in SRL affect the cognitive and metacognition strategies of SS1 students?

Social Cognitive Theory of Self-regulation

This study is based on Bandura's social cognitive theory of self-regulation as it relates to metacognition. Bandura's social cognitive theory states that human behaviour is regulated by interplay of self-generated and external sources of influence (Bandura, 1991). It highlights how personal, behavioural, and environmental factors affect students' thoughts when faced with instructional choices during teaching and learning processes. Social cognitive theory of SRL reveals three types of interaction taking place during learning. The first interaction is between a person and behaviour and it involves the influences of a person's thoughts and actions. The second interaction is between a person and the environment in which human beliefs and cognitive competencies are developed and modified by social influences and structures within the environment. The last one is between the environment and behaviour in which a person's behaviour determines the aspects of his or her environment and in turn their behaviour is modified by that environment.

Zimmerman (2002) found that students are not just being controlled by external factors but rather, they possess self-directed capabilities to influence their own behavioural responses in a learning environment. This means that students have the ability to control their activities by applying cognitive, meta-cognitive, and behavioural learning strategies when given learning tasks. In addition, Schunk (2001) explains that students' efforts to self-regulate during learning are not determined merely by personal processes such as cognition or affective issues, but rather, these processes are assumed to be influenced by environmental and behavioural events in a reciprocal manner. Bandura (1991) shares a similar view that SRL occurs to the degree that students can use personal processes to strategically regulate his or her behaviour and the immediate learning environment. Based on the adaptation of Bandura's theory to this context, it was assumed that students who received SRL training are required to analyse the learning situation, set meaningful learning goals, and determine which strategies are effective as well as evaluating their emerging understanding of the topic under consideration. The study presented in this article examined SRL from the social cognitive perspective in which SRL training in chemistry learning is assumed to influence the students' metacognitive processes and their academic achievement in chemistry.

Self-regulated Learning

Self-regulated learning refers to strategic metacognitive behaviour, motivation, and cognition aimed toward a learning target. It is a process in which individuals organise and manage their thoughts, emotions and behaviour, as well as their learning environment, in order to attain the set learning goals (Ramdass & Zimmerman, 2011). Zimmerman (2002) elucidates that students are regarded as self-regulated to the degree that they are metacognitively, motivationally, and behaviourally active participants in their own learning process. Zimmerman's (2002) cyclical model of self-regulation, however, suggests that learners move through three phases of the learning process, which are (a) forethought, (b) performance or volitional control and (c) self-reflection. The forethought phase comprises of goal setting, selection of strategies and assessing self-efficacy. During this phase, students are expected to have identified their learning goals and plans towards achieving their set goals.

In the case of the performance or volitional control phase students are more focused through self-instruction and self-monitoring of their learning progress. During this phase, students will have tried to learn tasks and executed a plan for excluding distractions from their studies. Students will have also monitored their progression by being aware of conditions that may or may not contribute to a successful learning outcome. The self-reflection phase comprises of self-evaluation of set goals and adaption. Students will self-evaluate their performance against the set learning goals that they have at the beginning of the given task (Zimmerman, 2002). This model implies that all students have tendency to self-regulate their learning, but the degree to which they do so differs between students (Bol & Garner, 2011). It is very important for students to be able to regulate their learning because a lot of the responsibility of mastering a subject is placed on the students. Previous studies opined that when students are taught self-regulation strategies, they can learn to overcome their weaknesses and be successful learners (Schmitz & Perels, 2011; Peters, 2012; Stegers-Jager & Cohen-Schotanus, 2012).

Self-regulated learning has promoted achievement and assisted students in learning how to control their learning environment (Montalvo & Torres, 2004). Students at all levels of education tend not to display high levels of SRL; training in SRL strategies may promote academic achievement in students by offering strategies for comprehending challenging subjects like chemistry (Bol & Garner, 2011; Zimmerman, 2002). There is very little research that investigates the impact of SRL on the chemistry achievement of first year secondary students in Nigeria.

Self-regulation in Science Education

Viewing self-regulation in terms of achievement does not necessarily mean it is universal in its application, but rather it can be situational or contextual. The skills and strategies needed by students to learn one subject do not necessarily apply to all subjects (Avezedo & Cromley, 2004). Winne's and Perry's (2000) and Zimmerman's model of SRL proposes that SRL has three components, which are cognition, metacognition and motivation. The cognitive aspect comprises knowledge and skills that students need in order to engage in the process of science learning. This includes problem-solving, inquiry and critical thinking (Winne & Perry, 2002). The metacognitive aspect involves the knowledge and skills that students need in order to understand and exert control over cognition. The motivational aspect includes attitudes and beliefs students have in relation to the use and development of their cognition and metacognition (Winne & Perry, 2002; Schraw, Crippen, & Hartley, 2006). The cognitive aspect in science learning includes problem-solving, inquiry and critical thinking skills necessary for students to engage in science. It also includes the conceptual and foundational knowledge about the subject matter. Without the foundational and the conceptual knowledge, it will be difficult for students to engage in an authentic scientific inquiry and engage in the depth and richness of discussion that will enable them to think in a scientific way (Schraw, et al., 2006).

In addition to foundational knowledge, students are also expected to be able to use scientific skills and strategies to solve problems in science-related subjects. For example, in secondary schools, science subjects such as biology, chemistry and physics are often taught by asking students to solve mathematical problems in which a particular variable is unknown. Students must often work forward or work backward through these problems using different types of reasoning such as deductive and inductive reasoning to solve the problem (Sandi-Urena, Cooper, & Stevens, 2012; Horowitz, Rabin, & Brodale, 2013). In studies by Sandi-Urena, Cooper and Stevens (2012) and Horowitz et al. (2013), it was found that the particular strategies that students chose to use in solving problems in scientific contexts surely influence their success in those science subjects.

Furthermore, previous studies have examined the benefits of metacognitive strategies such as self-monitoring and self-regulation in chemistry (Sharma & Bewes, 2011; Sandi-Urena et al., 2012; Horowitz et al., 2013). Horowitz and colleagues (2013) found that help-seeking was a good predictor of students' performance in organic chemistry. Another study conducted by Dibenedetto and Bembenutty (2013) revealed a positive association between the use of SRL strategies and science achievement. The study showed that training students in SRL strategies can improve students' performance in sciences.

All these studies established that SRL can be taught when instruction occurs in specific academic contexts, in which teachers provide support to students in adopting strategies and regulating their learning processes. This is not currently taking place in Nigeria secondary schools where the majority of the secondary school teachers instruct students using cognitive strategies only. Therefore, there is need for research into the role of instruction in the development of students' SRL strategies at secondary school level in Nigeria.

Methodology

Research Design

An experimental pre-test post-test design was adopted in this study. Students were randomly assigned to either an experimental group or a control group within the chemistry class. Data for this study were collected over a period of six weeks. The first and last weeks were used for collecting pre- and post-tests, while the remaining four weeks were used for SRL training. The concept of rates of chemical reaction was taught during the data collection. Students attended a series of lessons for two hours a week during the four weeks training period. For the purposes of this study, in order to protect the anonymity of the students who were minors, a pseudonym was assigned to the school, i.e. Community Secondary School (CSS). The researchers adhered to the necessary ethical measures such as obtaining permission from the school, the participants as well as their parents or guardians.

Participants

The participants were 60 SS1 science students in the school (N=60; male=34 and female=26). The experimental group included 30 participants while the control group was also 30 participants. All of the participants studied chemistry as one of their major subjects towards Senior School Certificate Examination (SSCE).

Instruments of Data Collection

Self-regulatory strategies questionnaire (SRSQ)

Participants taking part in the study completed the SRSQ. The SRSQ, a sub-set of motivated strategies for learning questionnaire (MSLQ), was adapted from Pintrich, Smith, Garcia and McKeachie (1993). A motivated strategy for learning questionnaire is a widely used self-reporting instrument designed to assess student motivational orientations and different SRL strategies (SRL) in a course. According to Duncan and McKeachie (2005) and Pintrich, Smith, Garcia and McKeachie (1991), the MSLQ 81-item instrument can be used in its entirety or modified so that sub-scales of the MSLQ are used to evaluate students. This study employed a SRSQ because it addressed the learners' use of cognitive and self-regulatory strategies. The SRSQ consisted of 31 items detailing the cognitive learning strategy scales of metacognitive self-regulation, time and study environment, effort regulation, peer learning and help seeking. Items were rated on a 7-point Likert scale (1=not at all true of me to 7= very true of me). The SRSQ had good construct validity, internal consistency, reliability and predictive validity (Pintrich et al., 1993). The Cronbach's Alphas for the sub-scales used in the study are 0.79 for metacognitive self-regulation, 0.76 for time/study environmental management, 0.69 for effort regulation and 0.76 for peer learning and help seeking. Pintrich et al. (1993) established predictive validity by correlating the MSLQ sub-scales with students' final course grades.

Rates of reactions knowledge test (RRKT)

The RRKT was developed for the purpose of this study to measure students' achievement on the rate of chemical reaction for both experimental and control groups before and after the training intervention. The RRKT consisted of a 14 item paper-based test on the rates of chemical reactions, and represented the conceptual knowledge of the construct. The items comprised short-answer questions, matching, and multiple-choice tasks. Examples of the questions on RRKT are: 1) Collision theory states that a chemical reaction can only take place when particles; A) Collide; B) Get hot; C) Turn blue; D) Get cold; E) I don't know. (2) An increase in temperature. A) Will turn particles positive Collide; B) Will turn particles negative; C) Will increase the rate of reaction; D) Will decrease the rates of reaction; E) I don't know.

The pre-RRKT and post-RRKT were identical in the study, as these tests aimed to capture students' conceptual knowledge of rate of chemical reaction before and after learning in their various groups. It was piloted with 60 SS1 students in another school and the two teachers who were involved in this study to check the content validity and the reliability. They examined the test to make sure that the items were suitable for students' age group, and representative of the content associated with the rate of chemical reaction. In the RRKT, the minimum score was 0 and the maximum was 14. Higher scores indicated higher attainment of conceptual knowledge of rate of chemical reaction.

Classroom observations and interview guide

Qualitative data were collected through classroom observations by using an observation checklist of how students were learning immediately after the training intervention. After the learning sessions, students in both groups were interviewed in which they were asked to use a 'think aloud' protocol to verbalise freely what they were thinking throughout their experience with rates of reaction concept. The goal was to 'get inside the students' heads' and elicit what they were doing. Students were asked questions such as: Did you set goals and regulate the goals in a timely manner? Do you think the SRL training helped you in activating your prior knowledge and connect it to the present learning material? Did you rethink or ask yourself questions to ensure your understanding the topic? What approaches did you use during learning that helped you in achieving success on the given task?

Data Collection Procedures

Approval to carry out the research was obtained from the school. Before the commencement of the data collection, an initial letter was sent to the science department explaining the research project. The two Chemistry teachers in the school were requested to participate in the study. During the first session, students in both experimental and control groups completed the pre-RRKT and pre-SRSLQ. They were given 20 minutes to complete the test and the questionnaire. In addition, students in the experimental group were given instructions for completing the SRL strategies training. Students in the control group did not receive any additional instruction. Additional qualitative data were collected during the class activities through classroom observation and interview. Through the classroom observation, we were able to get a first-hand experience of students' thoughts and feelings about SRL training. The nature of the classroom interaction in terms of who speaks and who listens was recorded in the researchers' note. Six students from each group were interviewed by the first author in order to triangulate the observation data. The interview lasted between 20 to 25 minutes per student. All interviews were recorded and transcribed to analyse students' responses.

Intervention

All the phases of Zimmerman's (2002) SRL model were incorporated into the training for the experimental group, i.e. forethought (goal setting), performance (self-monitoring) and self-reflection. Table 1 below describes the SRL exercises modeled from SRL strategies presented in Zimmerman, Bonner and Kovach (1996). Students were asked to complete four SRL exercises for each week of the training. The exercises and students' responses were collected during chemistry lessons in the school.

Table 1: Design strategies to promote SRL

Phase	Components	Tasks
Forethought	Goal setting Strategic planning Assessing self-efficacy Selection of strategies and methods	Students set learning goals based on the topic and a plan on how they will achieve the goals.
Performance (volitional control)	Attention focusing Excluding distractions Self-instruction Self-monitoring	Students learn tasks and monitor what they are learning in relation to their goals. Students identify distractions and strategies for overcoming these distractions.
Self-reflection	Compare self-monitored information against the set goal	Students assess their success or failure at meeting the goal and make adjustments accordingly.

During chemistry lesson, students in the experimental group were first introduced to goal setting, self-monitoring and self-reflection strategies by first the author after which the chemistry teacher took over the lesson. Students in the experimental group were taught face to face to self-regulate their learning strategies at different stages of the lesson on rate of chemical reaction, while those in the control group were taught the content of the rate of chemical reaction only. Students in the experimental group were asked to set their learning goals for the lesson at the beginning of the lesson.

As the lesson was progressing, the teachers prompted students to monitor their learning by writing or asking any questions that they were not clear about in the lesson. Towards the end of the lesson, they were asked to reflect on their learning and revisit their learning goals in order to see whether they had achieved their set goals. After the lesson, teachers collected students' chemistry activity papers for each week. These processes were repeated for three weeks to cover the topic on the rate of chemical reaction. The control group students were taught by the same teacher using the traditional teacher-centred approach involving 'talk-and-chalk' type lesson which is the dominant teaching approach in the Nigerian schools. Both experimental and control groups were observed during the lessons on rates of chemical reaction by the researcher and the teachers. Four students from each of the group were then interviewed immediately after the, six-week research project.

Data Analysis

An independent t-test was used to test the equivalence of the test scores on SRSQ and RRKT of the experimental and control groups at the beginning of the study. At the end of the experimental process, independent sample t-test was also used to compare the pre-test and post-test scores of the groups for each of the instruments. The significance level was taken as 0.05 in the study. The observation and the interview data were analysed by using thematic content analysis. This involved working with and organising the data, breaking the data into manageable units, synthesising the data in order to search for certain patterns, deciding on vital aspects and dissemination of the findings (Bogdan & Biklen, 2003). Therefore, the existence, meanings, and the relationships of the words or concepts that were related to goal setting, monitoring and self-evaluation were explored and noted down during the process of analysis.

Results: Quantitative

Differences in Achievement

The first research question examined whether participation in SRL training would improve students' achievement in chemistry. A dependent sample t-test was implemented to observe whether there were significant differences in the experimental and the control groups' academic performance scores prior to and after the intervention. The results are presented in Table 2.

Table 2: Comparison of the pre-test and post-test RRKT scores

	Experimental		Control	
Time	**M**	**SD**	**M**	**SD**
Pre-test	5.90	2.03	5.03	2.15
Post-test	9.10	2.04	6.83	2.04

*** Significantly different at the p < 0.005 level**

Furthermore, an independent samples t-test was used to examine the differences in achievement between the experimental and control group for all students with a view to determining whether SRL training would be associated with a statistically significant level of shift in test scores as compared to traditional method of teaching. The shift in means for each group represents the difference in mean score between pre- and post-test scores. Table 2 reveals that both experimental and the control groups scores improve from pre-test to post test. However, significant difference between the experimental group's pre-test and post-test academic performance scores was observed in favour of their post-test scores ($t(30) = -7.602$; $p < 0.005$). This result suggests that flipped classroom model instruction increased students' academic performance in rate of chemical reaction.

Table 3: Means and standard deviation of shift in RRKT

Groups	**Mean(M) Difference pre-test and post-tes**	**Std. Deviation (SD)**
Experimental (n=30)	3.20	1.21
Control (n=30)	1.80	1.13

*** Significantly different at the p < 0.005 level**

The analysis in Table 3 revealed that there was a significant difference between the shift in the means of the RRKT test scores of the experimental group and the control group, $t\ (60) = 4.95$, $p<0.05$. This result shows that SRL training had positive effects on students' achievement in chemistry.

Differences in Metacognitive Self-regulation as Measured by SRSQ

The second research question addressed whether SRL training impacted the metacognition of SS1 students in chemistry. The result presented in Table 4 provides insight into how different learning conditions affect students' ability to self-regulate their learning. The t-test analysis revealed that there is a significant difference between the shift in the means of the experimental group and the control group, t (60) =2.55, $p<0.05$. This result shows that SRL training had positive effects on students' SRL behaviour.

Table 4: Comparison of self-reported self-regulation post-test scores by group

Groups	**Mean(M) Difference in pre-test and post- test**	**Std. Deviation (SD)**
Experimental (n=30)	20.73	16.17
Control (n=30)	2.20	23.09

*** Significantly different at the p < 0.005 level**

Results: Qualitative

The qualitative data that were collected in the form of classroom observations and interview in order to examine the use of self-regulated learning strategies by students in the experimental group. The keywords and phrases on SRL found to be common in the observation note and interview transcriptions resulted in the following emerging themes: planning (activation of previous knowledge), monitoring of learning process, reflection on learning and interest in learning.

Planning (activation of previous knowledge): Planning involves managing the whole leaning process. Students were expected to state what they think they will achieve at the end of the lesson. They were also expected to activate their prior knowledge by linking the present task with what they know. A number of students in the experimental group responded to the interview question: 'Do you think the SRL training helped you in activating your prior knowledge and connect it to the present learning material?' Students A and D responses are summarised by these comments:

> *Yes, the training actually helped me in linking my previous knowledge on rate of chemical reaction to the present topic on factors that affect the rate of chemical reaction between hydrochloric acid and sodium thiosulphate solution. Since I already know the factors that affect rate of chemical reaction, it was easy for me to investigate the reaction between sodium thiosulphate at different temperatures and different concentrations and plot a graph of the average reaction time successfully* (**Student A**).

> *I was able to set my learning goal at the beginning of the lesson on rate of chemical reaction. I read and followed all the instructions in the chemistry activity. Initially, it was difficult for me to follow my set plan for the activity but I am glad I did because I was able to plot my graph successfully* (**Student D**)**.**

Monitoring of learning process: In self-monitoring of the learning process, students monitor their learning content and context in order to establish whether their goals are met or not. Some students expressed how they monitor their learning through self-questioning that is posing questions regarding the activity to themselves. They also stated how they monitored their progress toward the set learning goals by assessing whether a previously-set goal has been met or not. Student B response to the interview question: 'What approaches did you use during learning that helped you in achieving success on the given task?'

> *When working on the task, I was able to ask for clarification on some of the things that I do not understand. For example, in my own opinion, when someone is reacting a substance with other substances and did not change anything at room conditions, then both of these substances are not able to react with each other, for example the magnesium metal that does not react with cold water. I was told the concept was wrong because the reaction can occur in other conditions, magnesium can react with hot water by the reaction: $Mg (s) + 2 H2O (l) \rightarrow Mg2+ (aq) + 2OH- (aq) + H2 (g)$, it's proved by the changing colour of the solution after the addition of phenolphthalein indicator from clear to red which indicates the formation of the base solution* (**Student B**).

Reflection on learning process: In self-reflection, students were able to assess and know whether they had met their set learning goals or not. Some of the students in the experimental group expressed how the SRL training helped them to think about the topic and relate it the real life situation. When students were asked the interview question: 'What can you say about the class activities and your life outside of class?' Student E gave the following responses;

> *For me, the strategy enabled me to think about how the topic is related to what I see in my day-to-day activities. I was also able to understand how the liquid drug I use when I'm sick work faster than tablets because of increased surface area of liquid drug* (**Student E**).

Interest in learning: A significantly large proportion of students in the experimental group expressed interest in the topic during learning, compared with students in the control group. Analysis of the interview suggests that students found SRL training to be very helpful in learning rate of chemical reaction as shown in students' C and E responses to the interview question: 'Do you think introducing SRL training was quite effective in helping you understand rate of chemical reaction?'

> *Yes, SRL training really help me in understanding rate of chemical concept properly, it enabled me to think about the whole learning from the beginning of the lesson to the end. I will be using those strategies in my other subjects too.* (**Student C).**

> *Yes, I think everyone in my class enjoy the activity. Personally, the strategy enabled me to think about the learning right from the beginning of the lesson to the end. I understood better than the way we were being taught science before. I really enjoy being able to reflect and think about the application of this topic to our real life situation* (**Student E**).

Discussion

This article reports an investigation of the effects of self-regulatory training on secondary school students' metacognition and achievement in chemistry. Students in the experimental group were introduced to four exercises aligned with Zimmerman's (2002) SRL model. We found that students who received the SRL training had significantly higher scores on RRKT and higher metacognitive self-regulation than students in the control group who did not receive any SRL training.

Previous studies on SRL in teaching and learning found goal setting to be associated with higher academic achievement (Peters, 2012). According to Peters (2012), exposing students to goal setting and self-monitoring will enable them to understand the nature of science better. Goal setting has shown to be useful in that it makes the tasks specific, prominent, and meaningful to the students (Zimmerman 2008). In a similar study conducted by Stegers-Jager and Cohen-Schotanus (2012), it was found that SRL learning strategies and students' participation in lecture, skills training, and completion of elective homework assignments all had positive impact on performance of the first year medical school students. In addition, Montalvo and Torres (2004) found that SRL training assisted students in learning how to control their learning environment by managing their time properly. All the studies established that teaching SRL to students will surely enable them to be proactively engage in the self-regulatory processes (Avezedo & Cromley, 2004; Kramarski & Gutman, 2006; Schmitz & Perels, 2011). The effects of SRL training on students' achievement and metacognition as it pertains to this study are discussed below.

Effects of SRL Training on Achievement

In terms of students' achievement in chemistry, there were significant differences in mean scores for students in the experimental group compare to the control group. These findings are consistent with previous research which found that students who were taught SRL have higher levels of achievement in science test scores. For example, Avezedo and Cromley (2004) found that SRL training given to the undergraduate students enabled them to improve in the mental representation of the scientific concepts. This study was similar to the present study in the sense that students also received training on the use of SRL variables designed to foster their conceptual understanding while the control students received no training. Similar results were also reported by Leidinger and Perels (2012) in their study with 4th graders in their mathematics lessons over 6-weeks. Self-regulated learning strategies were embedded into the learning material for the experimental group which resulted in higher improvement in their mathematical achievement. In this study, students in the experimental group were taught face to face to self-regulate their learning strategies at different stages of the lesson on rate of chemical reaction while those in the control group were taught the content of the rate of chemical reaction only.

There is a large body of literature suggesting that SRL may positively affect science achievement. However, there is a gap in the research exploring this issue specifically with SS1 students in science classes. Many of the studies were conducted using college students and not even in relation to chemistry achievement. Bail et al. (2008) found that college students who took a course taught in a SRL style were more likely to attain their academic goals and have a higher GPA than students who did not take the course; but again, the study did not target the SS1 students and chemistry achievement. Although this study involved short intervention with only one topic in chemistry, it worth noting that that training in SRL may extend beyond gaining skills to be successful in one chemistry topic. Students who are trained in SRL may apply these skills in subsequent topics and even in other subjects.

Effects of SRL Training on Metacognition

Research has shown that students who are taught self-regulation strategies become successful learners in the classroom (Zimmerman, Bonner, & Kovach, 1996). Designing learning materials to correspond with Zimmerman's (2002) cyclical model of self-regulation could be one way in which students can be taught SRL strategies. This model guides students through three phases: forethought, performance and self-reflection. The results presented in this article show that students in the experimental group get better in applying SRL strategies as they progressed through the three phases. This group of students obtained significantly higher scores on the two MSLQ scales than students who were in the control group and did not receive training in SRL.

Additional qualitative analysis of both classroom observation and students' interview revealed that differences existed in the nature of the SRL behaviour demonstrated by the experimental and the control groups in defining their learning goals in the given task. The students in the experimental group regulated their planning behaviour by setting their learning goals right at the beginning of the lesson. This group of students have proper understanding of the learning context; it was noted from each observed lesson that those students attempted practising SRL strategies through setting of sub-learning goals as well as activating their prior knowledge of the topic, rate of chemical reactions. The findings of this present study are in consistent with the literature that links training in SRL to higher levels of metacognition (Kramarski & Gutman, 2006). Students who were introduced to SRL training perform better in their classes than students who were not introduced to the training.

Students' responses to the interview questions presented above show that it is possible to maintain a rather high level of SRL by using SRL materials which were implemented by teachers in the classroom. It is evident that students generally have ability to self-regulate their learning processes, but the degree to which they do so differs based on student characteristics such as prior achievement and learning strategies (Bol & Garner, 2011). Nevertheless, if students are taught to self-regulate then they have chance to be successful in their academic. The study presented in this article further supports the effectiveness of SRL training in improving metacognition and promoting achievement in science subjects.

Conclusion

Studies examining SRL specific to SS1 students and achievement in chemistry is limited. Nevertheless, there continues to be much conversation about why students are not passing chemistry and other science subjects in Nigeria. In order to improve students' conceptual understanding in chemistry, teachers should consciously enhance their instructional process by incorporating SRL teaching and learning processes. Previous studies support the need for training teachers to embed SRL in their class (Montalvo & Torres, 2004; Sandi-Urena, et al., 2012; Horowitz et al., 2013), which in a way will also help students to become more focused on their learning.

Furthermore, it will be crucial for curriculum developers and school administrators to begin to consider developing curriculum that is beyond method of delivery and consider how students' learning impacts their progression through these subjects. The findings from this study suggest that school districts should include professional development for science teachers in the use and inclusion of metacognitive and SRL strategies and provide for the inclusion of these strategies on a regular basis within the science classrooms.

The study provides opportunity for further studies on the relationship between SRL and chemistry achievement across different topics in chemistry and other subjects like; History, Geography and English. Another area of research that is worth exploring in future is looking at the relationship between the other components of SRL in addition to metacognition in order to have better understanding of the factors that impact students' achievement in science related subjects.

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