MIND-MAPPING AS A SELF-REGULATED LEARNING STRATEGY FOR STUDENTS’ ACHIEVEMENT IN STOICHIOMETRY

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Abstract
This paper attempts to investigate the efficacy of mind-mapping subsumed in self-regulation on the achievement of students in Stoichiometry. The design was a pretest-posttest quasi-experimental group design which employed 320 students (150 girls and 170 boys). The instrument used for data collection was Stoichiometry Achievement Test (SAT) which comprised 20-item objective test questions. The instrument was validated and the internal consistency was found to be 0.96. Two research questions were used and means and standard deviation were used to answer them. It was found that students achievement in stoichiometry (mole concept) was enhanced since the experimental group scored higher than the control group. Educational implications included that teachers employ self-regulated strategies in teaching sciences (especially the physical sciences).

Introduction
The importance of chemistry as a science subject has tremendously grown since the first and second world wars (Ali, 1998). In spite of this, students’ achievement in chemistry recorded over several years have been poor. Research evidence on this issue abound and Chief examiners have perennially reported on the weakness of students in many aspects of the curriculum content especially stoichiometry.

Stoichiometry is an essential part of various arms of chemistry. It is therefore not surprising that among other reasons, students’ lack of basic understanding of the concepts in stoichiometry affect their overall performance. In order to address this issue, research in science education in Nigeria has continued to seek better ways of teaching to maximize meaningful learning.

Meaningful learning demands that learners construct their own meaning of scientific concepts and not just memorize the right answers or regurgitate someone else’s meaning. Therefore, “what the teacher considers meaningful for his or her students may not be assumed as meaningful for them” (Zohar, Aharon-Kravetsky, 2005). Therefore, in meaningful learning students have “executive control” of the chemistry content and they are aware of their own cognitive processes. When a student arrives at this stage in the learning process he/she is able to self-regulate.

Self-regulation refers to students’ ability to understand and control their learning (Schunk and Zimmerman 1994; Zimmerman 1994; Winne 1995). On the contrary, students who do not understand thoroughly concepts underlying solutions, try to memorise formulae (Perry and Downs, 1985). According to Novak (1984:608) students learn their chemistry in rote manner by “incorporating new information into cognitive structure in arbitrary, verbatim,
non-substantive way”. This contrasts with meaningful learning which is subsumed in self-regulated mind-mapping useful for positive learning outcomes in stoichiometry.

Mind-mapping is a related technique to concept mapping. Mind-mapping was invented by Buzau (1995) in the UK. A mind map consists of a central word or concept, around which five (5) to ten (10) main ideas that relate to that word are drawn. The difference between concept maps and mind maps is that a mind map has only one main concept which can be represented as a tree.

A mind map provides opportunity for convergent thinking by fitting ideas and linking old ideas to new ones. Thus, it is a meaningful learning strategy because Novak (1993) described meaningful learning as the assimilation of new concepts and proposition into existing structure. It is like a “window” into students’ minds”. (Kuchin, 2000).

Mind-mapping allows students to see complex relationships among ideas – a fundamental prerequisite to understanding stoichiometry concepts, especially the mole. The mole subsumed a large number of related concepts which require critical thinking, intellectual curiosity, problem solving and independent thought. The application of mind-mapping to the teaching and learning of the mole concept gives room for constructive, goal-directed activity, with subsequent enhancement in achievement. When students are actively engaged in cognitive processes which also includes collaborative and co-operative learning, they are able to discuss concepts and the relationships between concepts (Plotnick, 1997). They may also agree on a common structure to use for further action which will provide positive feedback for them.

This paper therefore attempts to investigate the extent to which mind-mapping subsumed in self-regulated learning will enhance secondary school students’ achievement in stoichiometry with particular reference to the mole concept. Science educators such as Ezeudu (1998), studied the effect of concept-mapping on students’ achievement in organic chemistry. However, not much studies have been done on stoichiometry – a topic which is at the heart of chemistry.

**Statement of the Problem**

A few studies have highlighted the efficacy of concept-mapping on students’ learning outcomes. There is however, no evidence of an existing study on the likely effect of mind-mapping as a self-regulated strategy for improving students’ achievement on the mole concept. Posed in question form therefore, the statement of the problem of this study is: To what extent will mind-mapping as an integral aspect of self-regulation enhance students’ achievement in stoichiometry?
Research Questions

1. What are the mean achievement scores of secondary school students taught stoichiometry by mind-mapping in self-regulation and those taught by conventional method?

2. What is the effect of gender on mean achievement scores of secondary school students in stoichiometry?

Method

This study is a quasi-experimental pretest-posttest control group design. The population of this study comprised senior secondary class 1 (SS 1) students of Nsukka Urban Area, Enugu state. The sample was drawn from this population.

The sample for this study was made up of 320 (150 girls and 170 boys) chemistry students from two male only and two female only schools from the total number of twelve schools in Nsukka Urban. Purposive sampling technique was used to draw four schools that have at least two streams offering chemistry. Eight intact classroom groups were therefore randomly assigned to treatment and control groups. The treatment group comprised 160 subjects (75 girls and 85 boys) while the control group comprised 160 subjects (75 girls and 85 boys) at the conclusion of the investigation.

The instrument for the data analysis was a Stoichiometry Achievement Test (SAT) which comprised 20-item multiple choice objective test. The instrument was validated by experts in science education and two secondary school chemistry teachers. The estimate of internal consistency using Kuder-Richardson formula 20 (K-R) was 0.96.

The data collection phase lasted three weeks comprising 80 minutes of three double periods per week and it involved the treatment and control groups. The control group was taught with the conventional method without cognisance of students’ previous knowledge on quantities and proportional relationships. There was no time for students’ interaction in groups. There was no teaching model. Students were not actively engaged. The teacher used only board and chalk and she did most of the talking. For the treatment group the mole was related to quantities of oranges, eggs etc. With teacher’s guidance, the students themselves constructed the mind-map for the mole concept. Example is given below:

Phase 1

How many eggs are in a dozen of eggs?
How many dozen are in 36 oranges?

Phase 2

The term, mole is used to talk about atoms, molecules, ions or electrons in the same way we talk of a number of eggs, oranges etc.
What then is the mole?
Two dozens of atoms are too small to be seen in the most powerful microscope. The mole is the amount of a substance that contains $6.02 \times 10^{23}$ particles – atoms, molecules, ions, eggs, oranges, tennis balls.

**Phase 3**

What is the name given for the accepted standard of a mole? It is called Avogadro Number. It is $6.02 \times 10^{23}$. Can you count $6.02 \times 10^{23}$ tennis balls? Because $6.02 \times 10^{23}$ is large to count, the number of atoms is determined by measuring the mass of the substance. Use the weighing balance supplied on the bench to measure 12 of the oranges supplied.

**Phase 4**

What is the mass of the dozen of oranges supplied?

Teacher now measures 63.5g of copper turnings. (To avoid waste of the copper turnings the teacher had to do this weighing.) 63.5g of Cu = 1 mole of Cu. This is equivalent to $6.02 \times 10^{23}$ Av. No. The students were then asked the following questions:

1. How many dozen oranges are in 9 oranges?
2. How many moles of oranges are in $3.01 \times 10^{23}$ oranges?
3. i. If 12 oranges weighs 63.5g, what is the ratio in mole of oranges to copper
   ii. What then is the average number of 63.5g oranges?

**Evaluation**

To enable the students assess themselves on their depth of understanding, the teacher asked them the following questions for general discussion:

1. A bicycle has 2 wheels. If there are 20 bicycles in the parking lot, how many dozen bicycle wheels are in the lot?
2. If grains of rice are weighed on a kitchen balance and corresponding masses of grains of rice are as following:

<table>
<thead>
<tr>
<th>No. Of Grains of Rice</th>
<th>Corresponding Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>7g</td>
</tr>
<tr>
<td>200</td>
<td>3.5g</td>
</tr>
<tr>
<td>100</td>
<td>1.75g</td>
</tr>
<tr>
<td>800</td>
<td>14g</td>
</tr>
<tr>
<td>1000</td>
<td>28g</td>
</tr>
</tbody>
</table>
Assume that 100 grains of rice = 1.75g = 1 mole. Now convert the remaining into moles of rice and into Avogadro number of rice. Further relational concepts of the mole in terms of volume of gasses, the ideal gas equation, and amount of species in an equation were taught in similar ways.

At the end of the lesson on the mole, the students now guided by the teacher, constructed a mind-map model of the mole concept that included all previous lessons. They were supplied with clay to be used in groups of 5 (five).

1. Using the supplied clay, mould a square box.
2. 5 candlesticks were supplied to each group. They were asked to build the candlestick into the square clay box at five different points.
3. Insert tooth picks (these tooth picks were carved from chewing sticks by the students themselves, - 5” length) so as to make 5 or more branches from the candle stems.
4. Prior to this last lesson, the students were asked to write out on cardboard papers or cut-outs from empty cartons, a sentence or phrase of what they understood as the mole. The teacher supervised their cut-outs and guided the students where they had wrong ideas.
5. Finally, using the pointed sticks, they were asked to connect the relationships. At this stage, they were challenged in their various groups to think critically and to arrive at consensus in their various groups. At the end of eight weeks, a 20-item multiple choice questions was given to both groups.
MOLE

\[ N = \frac{PT}{RT} \]

Relative atomic mass of an atom

\[ \text{Relative molar mass of a compound} \]

\[ AA + bA \rightarrow \text{Product} \]

Amount of species in a balanced equation

Such that

\[ \frac{\text{No. of } A}{\text{No. of } B} = \frac{a}{b} \]

No. of atoms of an element

Amount of substance

No. To express one mole of electrons

Can be expressed in

Molarity = moles of solute 1 dm³ of solution

No. To express the rel-mass of a mole of atoms

\[ 6.0 \times 10^{23} \text{ Avogadro No.} \]

No. To express one mole of ions

No. of molecules of a compound

Avogadro Number

\[ 22.4 \text{ m}^3 \text{ at STP} \]
Research Question One
What is the mean achievement scores of secondary school students taught stoichiometry by mind-mapping in self-regulation and those taught by conventional method?

From table 2, it can be seen that the overall mean achievement score in stoichiometry for the treatment group is 59.9 as against 27.45 for the control group. This suggests that the experimental group performed better than the control group.

Research Question Two
What is the effect of gender on mean achievement scores of secondary school students in stoichiometry?
Table 2 also shows that the overall mean achievement score of female students is 43.25, while the overall mean score of male students is 44.20. The difference appears to indicate that male students scored higher than the female students. The extent of the difference (0.9) is not high enough to be considered significant. Therefore, gender has no significant effect on students’ achievement in stoichiometry.

Discussion of Findings
The findings of this study is in agreement with earlier research reviewed. For instance, (Pressley and Warton-McDonald, 1997) found that teaching with self-regulated strategies improves learner performance and metacognitive awareness of their own learning. It was also found that the teaching method is
not gender bias and therefore significantly enhanced the achievement of both the male and female students.

**Educational Implication**

A number of learning strategies came into play during the lessons: viz, the use of analogy, cooperative/collaborative learning, inquiry and modelling. Self-regulation attempts to

(a) Help students’ have control of their own learning
(b) Enhance metacognitive awareness of their own learning and
(c) Enhance achievement by employing more than one strategy in teaching science concepts.

Students’ active involvement in the learning process gingered even the lower achieving students (male and female) with resulting improvement in achievement. Teachers should therefore structure their lessons to include a number of strategies that can captivate students to explore, experiment and develop their creative abilities/skills. What teachers know and do is the most important influences on what students learn; achieving high level of student understanding requires skilful teachers (Darling-Hammon, 1996 in Anneta & Shymansky, 2006) studies for example (Ruiz-Primo, Shavelson and Schultz, 2006) have shown that students apply different strategies when completing or constructing map tasks. Therefore, teachers should be able to engage students in different types of cognitive activities when completing maps as this will enhance their understanding and encourage them to regulate their own learning process. Authors can organise books to include concrete explorations and questions that would have great potential to provide supportive scaffolding for learners. Students need support to execute the various activities involved in designing ways to achieve meaningful learning. Textbook writers should include designs such that students will productively learn science content through hands-on and minds-on practices. Central to successful scaffolding is

(i) the motion of shared understanding of the activity
(ii) that the adult (writer, teacher) have a thorough knowledge of the task and its components
(iii) that it enables the teacher an ongoing assessment of the students’ understanding as well as allowing students to play a role in negotiating the interactions between teacher and learner.

Finally, fading the support provided to the learners so that the learner takes control and becomes responsible for his/her learning; he/she internalises and is capable of independent learning. (Puntambekar & Lolodner, 2005).
References


