Effect Of Concept Mapping On Learner Achievement On Mole Concept

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Abstract: The purpose of this study was to determine the effect of concept mapping on learner achievement on mole concept. Participants comprised 80 grade 11 learners, 38 male and 42 female, at a government co-education secondary school in Kabwe district of Zambia. The study adopted a pretest-posttest counter balanced quasi-experiment research design. Two classes were randomly selected to participate in the study. The classes were then randomly assigned to the experimental and control groups. The learners in the experimental group were instructed with the integration of concept mapping while those in the control group were instructed without integrating concept mapping. Both groups were taught the same content on mole concept. Data were analysed using independent sample t-test and descriptive statistics computed from the collected data using SPSS. Results show that there was a significant difference in the mean scores of the experimental (M= 53.37) and control (M=36.51) groups, $t(63.208) = -4.109$, $p = .000$, $\alpha = .05$ two tailed for the first posttest and $t(78) = 2.163$, $p = .034$, $\alpha = .05$ two tailed for the second posttest. The results indicate that those instructed with concept mapping did better than those instructed without concept mapping. The result also reveal that both males and females benefited from concept mapping and its impact is not gender dependent.

Keywords: Achievement, Concept Mapping, Mole Concept.

1.0 Introduction.

The importance of science, technology, mathematics and engineering in the development of any nation is undisputed. The Zambian Ministry of Education [1] explains the importance of mathematics and science in the agenda to develop Zambia the country. It posited that it will give priority to the improvement of mathematics and science education in high schools of all types by devoting more time and resources to the teaching of mathematics and science. The development of a country depends on its educated citizenry. Science, Technological, Engineering and Mathematics (STEM) subjects are core in fostering national development. The role of science in the development of a nation cannot be over emphasized [2]. Malik [3] posits that throughout history, the development of new technologies is vital for human survival and progress. The third world countries need this most hence the efforts by many of them to embrace science and technology. Indeed, the so-called tiger nations in the Far East were able to rise to where they are now because of the heavy investment in science and technology. There has been increased efforts by the government of the republic of Zambia in investing in education in terms of infrastructure and human resource development. But over the years the results produced in science and chemistry in particular have not been impressive and of expected standards to foster national development. In terms of learner performance by subject it was observed that performance was best in practical subjects and lowest in mathematics, science and commerce [4]. Chemistry is one of the subjects in science and in Zambia it is taught at senior secondary level as a single subject (5070) or as part of science (5124) that comprises chemistry and physics concepts. The performance of learners at grade 12 level in school certificate examinations in some topics of chemistry has been perpetually low. One of such topics is the mole concept. Examinations Council of Zambia (ECZ) [5], in their chief examiner's report posited that the answers given by candidates showed that they had problems in calculating reacting masses. In addition (ECZ) [6] in their 2013 examination performance report for natural sciences, posited that performance was low in rates of chemical reactions and equilibrium, mole concept, energy changes, non- metals and organic chemistry. Various research works have identified specific issues on mole concept. Among the many issues looked at include: students understanding of stoichiometry, and performance in chemical calculations [7]. Lack of understanding of mathematical principles is a real impediment to solving mole concept problems correctly using reasoning [8]. Other issues include its abstract nature, dealing with large numbers for very small particles. But the underlying concepts and how they relate to each other has not been explored. Theses concepts include terminologies that are used and applied on the whole topic of mole concept which relative atomic mass, relative molecular mass, mole, molar mass, molar volume i.e volume of a gas (at room temperature and pressure and standard temperature and pressure), volume of a solution, concentration , limiting reagent, percentage yeild , percentage purity etc. A clear understanding of these terms and how they relate to each other can enhance achievement in mole concept. Furio [9] argue that understanding a scientific concept involves more than knowing its precise definition. It is necessary to know in what context it arises, what other concepts it is related to and differentiated from. This is important because learners will fully understand the topic if they understand the underlying concepts and how they relate to each other. It is this understanding that will help them to answer qestions on mole concept hence enhaching achievement. Learning through concept maps will enable learners link concepts together. Therefore, this study explored the use of concept mapping to enhance conceptual understanding of mole concept and how they will impact on learner achievement and attitude on mole concept.

1.1 Concept mapping

Concept mapping is the visual representation of the relationships between concepts held by an individual, materials of a lecture, text book or laboratory exercise [10]. Concept mapping is a meta-learning strategy based on the Ausubel-Novak-Gowin theory of meaningful learning [11]. It has its origins in research done at Cornell University to study changes in students' understanding of science concepts over a 12-year span of schooling [12]. Thus concept mapping is not only a visual representation of the relationships between concepts but is a meta-cognition learning process. It engages the mental processes of the learner at a high level and makes them think about their thinking. In addition it helps to understand the concepts held by an individual on a topic and how that individual relates those concepts. In the field of science education, concept mapping has been introduced to face the problem of linking the often multidimensional nature of the subject [13]. The principle concepts in chemistry especially on mole concept range from concret to abstract. Relating these concepts become a challenge to most of the learners, hence concept mapping comes in to brigdge the gap. On mole concept learners are faced with three three levels of representation: the macroscopic level, microcsopic level and the dymbolic level [14]. The concepts on mole concept can be represented at each level, and it is the transition from one level to other that posses a challenge. For instance sodium chloride can be reprented in terms of mass which is a macroscopic level, or interms of mole which is a microscopic level or interms of chemical formular which is symbolic. Concept mapping is seen as a means to facilitate the linking of concepts on macroscopic level to those on the microscopic level or help learners link underlying concepts on the microscopic level only [13].

1.2 The mole concept.

The mole concept was introduced by Ostwald at the beginning of the 20th century with a meaning of weight (mass), in a context of skepticism towards Dalton's atomic hypothesis [9]. Since then the mole concept has evolved in meaning and context over time [15]. The concept of mole is leant in grade 11 in the Zambian school system [16]. It comprises of three sub topics: relative masses, the mole and empirical and molecular formulae. Relative masses has two specific objective, the mole has eight specific objectives and the last sub topic has three specific objectives. Thus the mole concept learnt by the Zambian grade 11 learners has 13 specific objectives in total. The teaching and learning of mole concept has been a problem for a long period of time. Teaching and learning the 'amount of substance' concept is a big challenge for learners and teachers [17].

2.0 Problem statement

Many studies show that students have trouble understanding the concept of the mole, concentration, molar mass, the mass of material, chemical equations and the limiting reagent [18]. Musa (2009) [20] argues that students who do not fully understand the mole experience difficulties in understanding the subsequent topics in chemistry Bamidele, Adetungi, Awodele and Irinoye [19] pointed out a number of reasons for students' poor performance in the West African Senior School Certificate examination. Among them is the deficient use of the mole concept and its applications. Similarly, the low achievement by learners in chemistry and mole concept in particular has been reflected in the Examination Council of Zambia, annual performance report for ([21], [6], [22], [23] and [24]). The EZC reports show that Performance has been low in the following topics: rates of chemical reactions and equilibrium, **mole concept**, non-metals and organic chemistry [5]. The 2013 examination performance report for natural science [6] cites lack of in-depth knowledge of the mole concept as one of the challenges learners face in chemistry. Examinations council of zambia [25] posits that questions involving mole concept where pooly answered by candidates. They attributed this to poor teaching. In the same report a question in 5070/3 involving mole concept was not only poorly done by candidates but by supervisors aswell. This poor performance by candidates on mole concepts could be contributing to the low and general poor performance of candidates at grade12 in their school certificate leaving examinations. A comparison of performance over the years show almost the same performance in chemistry and science. Table 1 shows comparison of performance from 2012 to 2015 at national level in chemistry and science.

Table 1: *Comparison of performance in chemistry and science in % from 2012 to 2017 at national level.*

	2012	2013	2014	2015	2016	2017
Chemistry	48.17	47.9	49.12	49.82	48.21	50.06
Science	29.37	33.9	17.76	17.65	32.83	35.28

The trend shows that there has been poor performance of the learners in chemistry and science at national level as shown in Table 1. The mean performance of learners at the secondary school, in terms of the school mean and mean science performance where the research was done from 2014 to 2018 is tabulated in Table 2.

Table 2: *Results for the secondary school and science in % from 2014 to 2018.*

	2014	2015	2016	2017	2018
School	56	60.8	66.7	63.3	57.5
Science	38.39	45.65	48.39	54.07	38.39

Though the school average pass percentages may be slightly higher than the national average the poor performance of learners in science is still evident. Improvement of achievement in this topic may improve the learner achievement in chemistry in their final examination.

2.1 Research objectives.

This research had the following objectives:

1. To determine the effect of concept mapping on learner achievement on mole concept.

2. To determine if the achievement of learners differs significantly with gender of the learners?

2.2 Research questions.

The following were the research questions:

1. What is the effect of concept mapping on learner achievement on mole concept?
2. Does the achievement of learners differ significantly with gender of the learners?

2.3 Research hypotheses

The research had the following hypotheses:

H_1: There is a statistically significant effect of concept mapping on learner achievement on mole concept.

H_0: There is no statistically significant effect of concept mapping on learner achievement on mole concept.

H_2: The achievement of learners statistically differ significantly by gender.

H_0: The achievement of leaners does not statistically differ significantly by gender.

In all the hypotheses the significance level (α) is **set at .05 two tailed and confidence level at 95%.**

2.4 Significance of the research

This study is significant in that its findings will add to the existing knowledge on concept mapping and its effect on achievement on mole concept. The findings may also be useful to teachers, learners, curriculum developers, other stake holders in education and educational researchers.

3.0 Methodology

3.1 Research design

The study adopted a pretest-posttest counter balanced quasi-experiment research design. Two classes were randomly assigned to the experimental and control groups.

R	O_1	X	O_3		O_5
R	O_2		O_4	X	O_6

3.2 Sampling

Random sampling with replacement was used to select the sample. Five pieces of paper, of the same size and color were cut. A letter representing a class was written on each piece of paper, that is, letters from A to E. These were folded in the same way and placed in a box with a hole that could only allow a hand to go through. The box was shaken and a blindfolded person while facing aside will picked a piece of paper at a time. The first paper to be picked represented the class to be in the sample. It was placed back in the box, the box was shaken and a second paper was picked, it represented the other class to be part of the sample. Of the two classes picked, their papers were placed in the same box after emptying the other papers. The same process was followed and the first paper to be picked, was assigned to the experimental group and the other automatically became the control group. This process ensured researcher bias in terms selecting classes and consequently learners to participate in the research was eliminated. The experimental group had 41 participants while the control group had 39 participants.

3.3 Research instruments

Three researcher designed pen and paper mole concept achievement tests (MCAT) were constructed. One was administered as a pre-test and the other two as post-tests.

3.4 Data collection procedure

The following procedure in terms of the activities in the experimental group and the control group were followed leading to the collection of data. The groups were taught for 9 weeks and were meeting twice a week for 80 minutes per session. A pre-test was administered after a week of introducing the learners to mole concept. Thereafter the intervention was introduced to the experimental group. After the pre-test, the groups where assigned to the experimental and the control group randomly as outlined under sampling. After the post –test the groups were swapped to counterbalance. The control group became the experimental and the experimental group became the control group. The intervention was then administered to the experimental group based on the new content that they were learning. The second posttest was then administered.

3.4.1 Experimental group

The learners in the experimental group learnt mole concept with the integration of concept mapping. Concept mapping (appendix A) was integrated into group discussion, class discussion practical work and teacher exposition. It was also be used to introduce the topic and highlight the expected outcomes and conceptual framework of the topic. After learning learners were also asked to draw their own concept maps (Appendix B). The learners were at liberty to expand the initial concept maps they had drawn as they expanded their knowledge. They were asked to draw specific concept maps based on the lessons covered. The concept maps were also used to consolidate the learnt concepts.

3.4.2 Control group

Learners in the control group learnt the same content on mole concept as the learners in the experimental group without the integration of concept maps. They used class and group discussion, practical activities and group work. They were also given regular homework in terms of summaries and calculations except concept mapping.

4.0 Results and discussion.

This section presents the results of the study. The results are presented in the order in which the research questions were asked.

4.1 Effect of concept maps on learner achievement on mole concept.

The research question was:

What is the effect of concept mapping on learner achievement on mole concept? The pretest and posttest scores for the experimental group and control group were analysed to answer the question. Table 3 shows the group statistics for the participating groups and Table 4 shows the independent samples t-test for the same groups.

Table 3: *pretest Group Statistics*

	Group	N	Mean	Std. Deviation	Std. Error Mean
Pretest	CG	39	28.31	10.979	1.758
	EG	41	29.29	15.715	2.454

The control group (CG) had 39 participants, with a mean of 28.31 and standard deviation of 10.979 while the experimental group (EG) had 41 participants and a mean of 29.29 and standard deviation of 15.715. The t-test results from pretest of the control and the experimental groups are presented in Table 4.

Table 4: *Pretest Independent Samples Test*

	Mean diff	T	df	SE diff	p-sig (2-tailed)
Equal variances not assumed	-.985	-.326	71.70	3.019	.745

The p-value was found to be .745 > .05. The means of the two groups were equal since the p > α. Thus the two groups were of similar character at the start of the research.

Posttest 1 results.

The researcher analysed the posttest results and presented them appropriately. Table 5 shows the group statistics of the posttest1 for the experimental group and the control group.

Table 5: *posttest 1 Group Statistics*

	Group	N	Mean	Std. Deviation	Std. Error Mean
posttest 1	CG	39	36.51	12.688	2.032
	EG	41	53.37	22.814	3.563

The CG had 39 participants a mean of 36.51 and standard deviation of 12.688. The EG had 41 participants a mean of 53.37 and standard deviation of 22.814. Table 6. Show the independent samples t-test results for the posttest 1 for the two groups.

Table 6: *Posttest 1 Independent Samples Test*

	Mean diff	T	Df	SE diff	p-sig (2-tailed)
Equal variances not assumed	-16.853	-4.109	63.208	4.102	.000

Table 6 shows a p-value of, p = .000, α = .05 two tailed. The mean of the EG was significantly different from that of the CG.

Posttest 2 results.

The initial CG and EG were swapped. This is because the research design was a counter balance research design. This ensured that no group of learners was denied the learning opportunity in the course of the research and remove the bias towards the experimental group over the control group. The posttest 2 was then administered. The table 7 shows the posttest 2 group statistics and Table 8 shows the independent samples t-test for the posttest 2.

Table 7: Posttest 2 Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
posttest 2	EG	39	48.44	14.151	2.266
	CG	41	40.76	17.353	2.710

The EG had 39 participants a mean of 48.44 and standard deviation of 14.151. The CG had 41 participants, a mean of 40.76 and standard deviation of 17.353. Table 8 shows the posttest 2 independent samples t-test results.

Table 8: *Posttest 2 Independent Samples Test*

	Mean diff	t	Df	SE diff	p-sig (2-tailed)
Equal variances assumed	7.680	.2.163	78	3.551	.034

Table 8 shows a p-value of, p = .034, α = .05 two tailed. The mean of the EG was significantly different from that of the CG. The results indicate that concept maps had an effect on the learner achievement on mole concept. Thus the null hypothesis was rejected and the alternative hypothesis adopted. The findings of the study agree with those of Abayomi and Kehinde [26] who found that concept mapping was an effective instructional tool on secondary school learning outcomes in secondary school. Olorundare and Aderogba [27] adds that students exposed to concept mapping performed better than those exposed to analogy that also performed better than those exposed to expository method of learning. Combining concept mapping with other methods or indeed the traditional or conventional way of teaching has synergistic effect as compared to its unilateral use. This was affirmed by Moono and Singh [28] who found in their research that concept mapping is an effective method of teaching chemistry and that its effect is even significantly higher when it is combined with the traditional method of teaching. These findings are also echoed by [2] who found in their research that learners taught using concept mapping strategy responded better than those taught without concept mapping. Thus based on the results of this research the null hypotheses which stated there was no significant effect on concept mapping on learner achievement was rejected and the alternative hypothesis upheld. And therefore concept mapping had a positive effect on the learner achievement on concept mapping

4.2 Learner achievement by gender.

The second question was: Does the achievement of learners differ significantly with gender of the learners? The scores of the males and females in the experimental groups were analysed to answer the question. Table 9 presents the first experimental group, group statistics and table 10 the independent samples t-test for the same group.

Table 9: *First experimental pretest Group Statistics*

	GENDER	N	Mean	Std. Deviation	Std. Error Mean
PRE TEST	MALE	20	31.05	13.694	3.062
	FEMALE	21	27.62	17.600	3.841

The first EG had 20 male and 21 females. The males had a mean of 31.05 while the females had a mean of 27.62.

Table 10: *First experimental group Pretest Independent Samples t-test by gender*

	Mean diff	T	df	SE diff	p-sig (2-tailed)
Equal variances assumed	3.431	.694	39	4.92	.492

Table 10 shows that the first experimental group had a p-value of, p = .492 > .05, α = .05 two tailed. The mean achievement scores of both males and females was not statistically different before the intervention.

Posttest results by gender.

Since there was no significant difference by gender at the start of the research after the intervention posttests were administered to determine if the achievement would differ significantly by gender. Table 11 shows the group statistics by gender after the intervention in the experimental group and table 12 shows the independent samples t-test for the same group.

Table 11: *First experimental posttest 1 Group Statistics by gender.*

	GENDER	N	Mean	Std. Deviation	Std. Error Mean
POST -TEST 1	MALE	20	61.30	17.171	3.840
	FEMALE	21	45.81	25.258	5.512

Table 11 show that the males had a mean of 61.30 and the females had a mean of 45.81 after the intervention.

Table 12: First experimental group posttest 1Independent Samples Test

	Mean diff	t	Df	SE diff	p-sig (2-tailed)
Equal variances assumed.	15.490	2.285	39	6.779	.028

Table 12 shows that the group had a p-value of, p = .028, α = .05 two tailed. The first EG showed a significant difference by gender. The males had a significant higher mean than the females. The posttest 2 results for the experimental group are shown in table 13 and the independent samples t-test for the same group is shown in table 14.

Table 13: *Experimental group posttest 2 Group Statistics by gender*

	Gender	N	Mean	Std. Deviation	Std. Error Mean
post-test 2	Male	18	46.72	15.036	3.544
	Female	21	49.90	13.542	2.955

Table 14: *Experimental group Posttest 2 Independent Samples t-test by gender*

	Mean diff	T	df	SE diff	p-sig (2-tailed)
Equal variances assumed	-3.183	-.695	37	4.577	.491

The results in Table 14 show that p-value of, p = .491, α = .05 two tailed indicate that the there was no significant difference in the mean score of the male and female learners in the second posttest. These results agree with the findings of Chawla [29]who found that concept mapping method of teaching had a significant effect on achievement of leaners in chemistry over conventional teaching but that this method had no significant effect on gender with regard to achievement in chemistry. Qarareh [30] adds that the method is beneficial irrespective of gender. The results from the two groups by gender show that both males and females can be impacted positively by concept mapping. In one case the males performed better than female and in another the females performed better than males. Thus overall the null hypothesis could not be rejected.

5.0 Conclusion

There were statistical differences between the experimental and the control groups in favour of the experimental groups. The results of the study showed that concept mapping is for teaching mole concept. Concept mapping has the ability to improve student's achievement on mole concept and consequently in chemistry because mole concept is applicable to many other topics in chemistry. Also, concept mapping makes students learn meaningfully to improve upon their capacity to answer high order cognitive level questions. Furthermore, in this study both males and females in the experimental groups performed better than their counter parts in the control groups. Therefore concept mapping as a teaching strategy should be used on both males and females when teaching mole concept.

5.1 Recommendations.

Based on the findings of this study, the following recommendations have been made:

1. Since the integration of concept mapping in teaching and learning of mole concept has proved to be effective and since this strategy is relatively new, it should be included in the curriculum of pre-service teachers of chemistry teachers. This will help popularise this technique and bring about more effective learning of integrated science. This is so because most teachers involved in this study were not familiar with the strategy.
2. During professional body meetings such as Zambia association of science educators (ZASE) and government organised workshops, seminars and short courses well informed science educators should educate practicing chemistry and science teachers in general on what concept mapping strategy is as well as how to use it.

5.2 Recommendations for further research

Based on the findings of this research the following recommendations have been made for further research:

1 More research needs to be done to include other topics so that the effect of concept mapping on senior secondary chemistry can be determined. This is because this research only focused on one topic.

2. Another research to be done to include a large sample and a number of schools so that its results can be generalized to a wide population. The results of this study only apply to the sample involved in the study.

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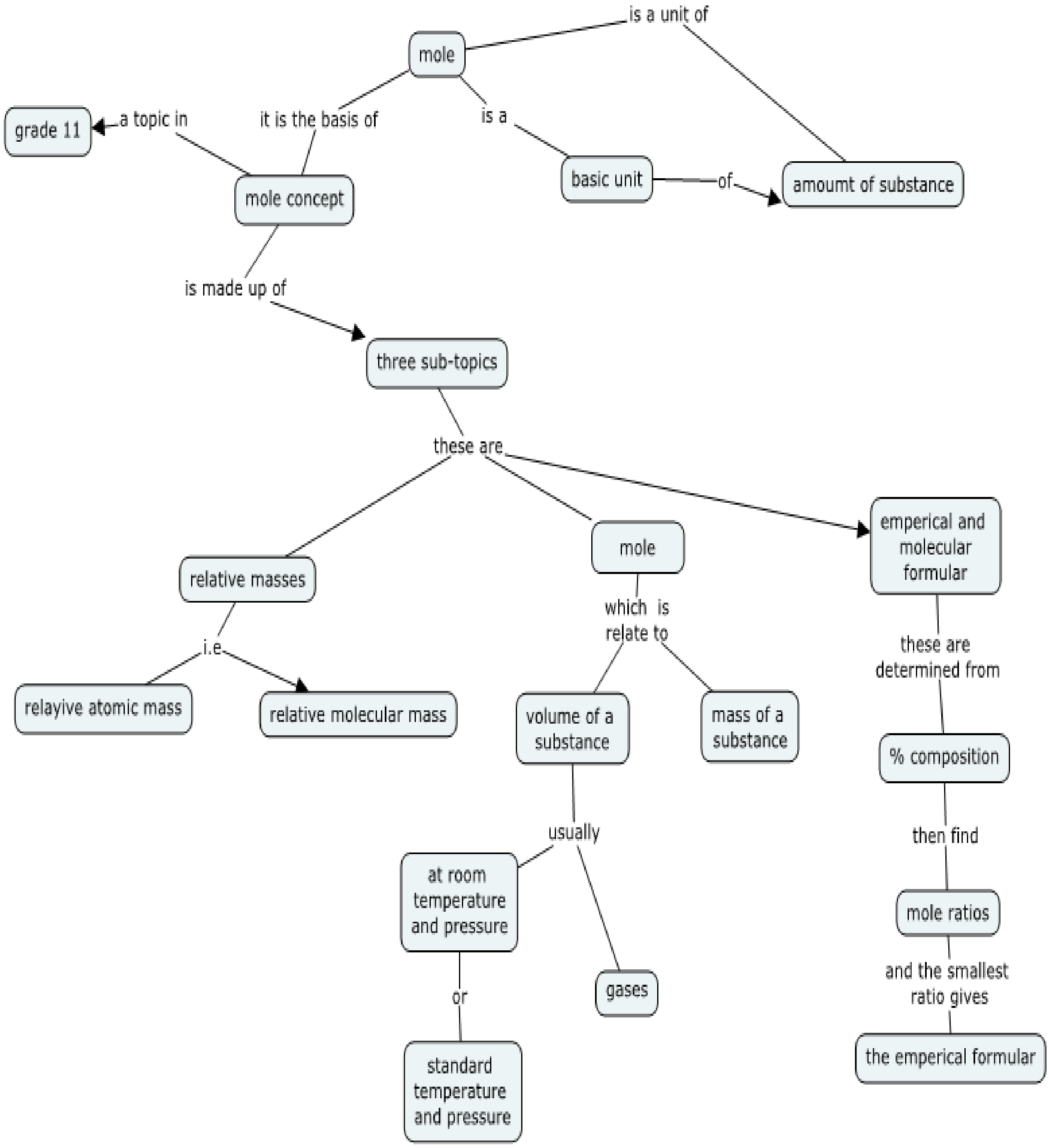
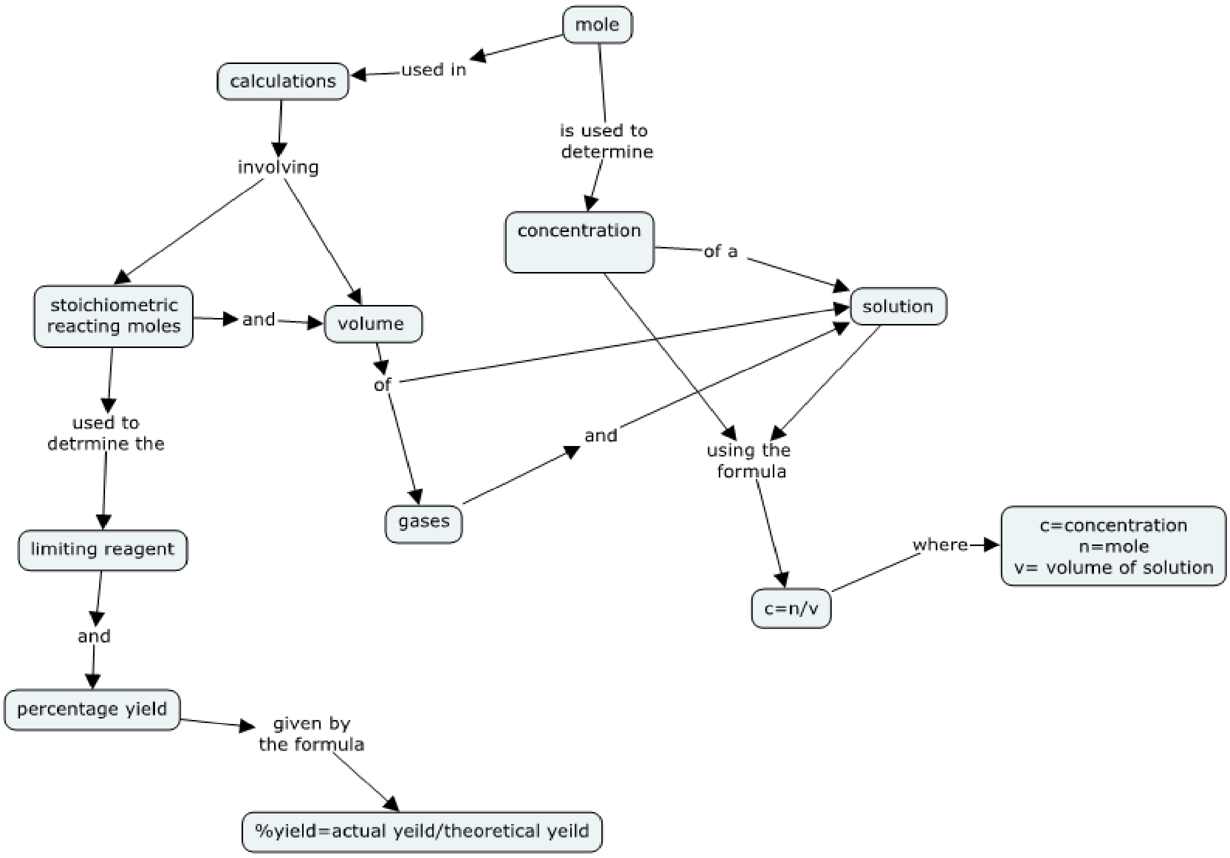
APPENDIX: A

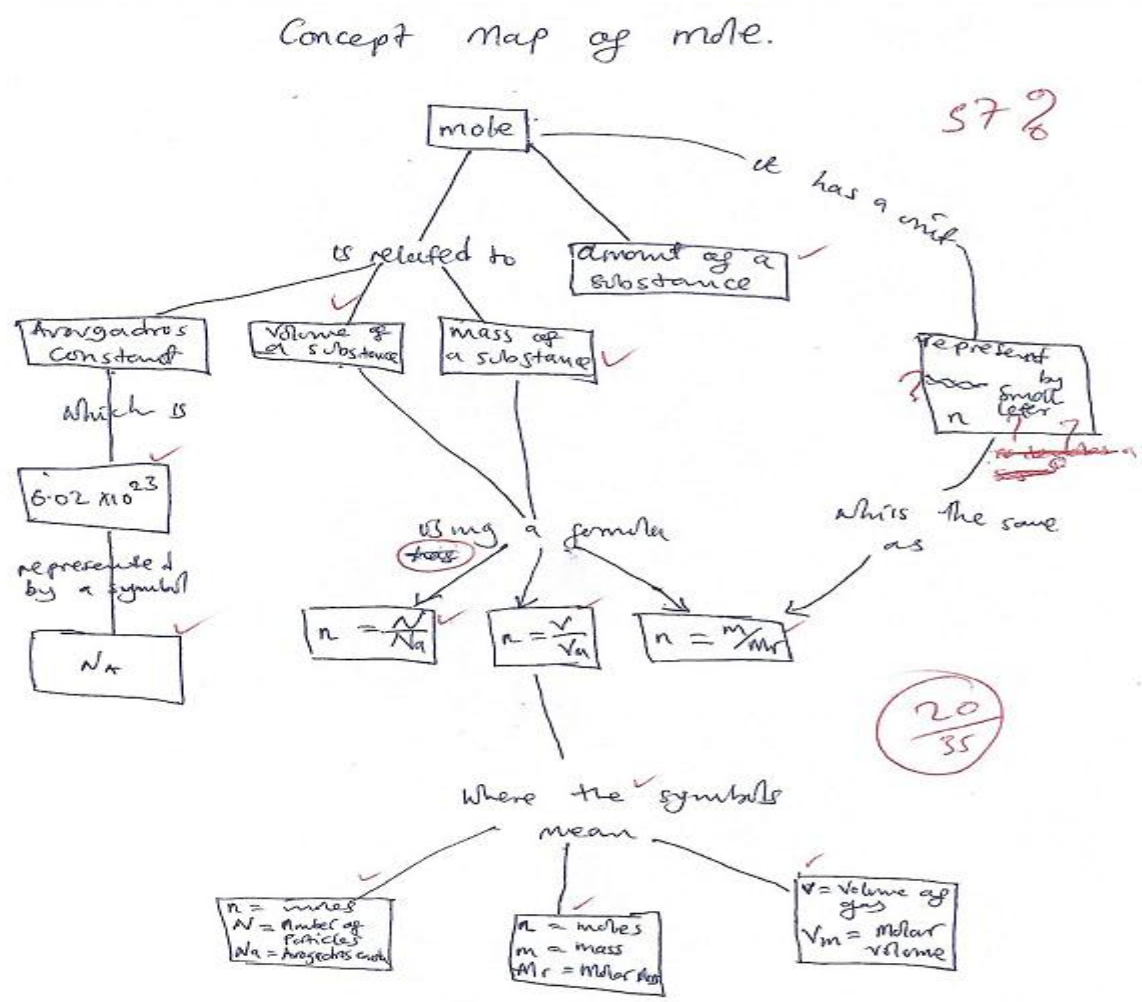
CONCEPT MAPS USED BY THE TEACHER

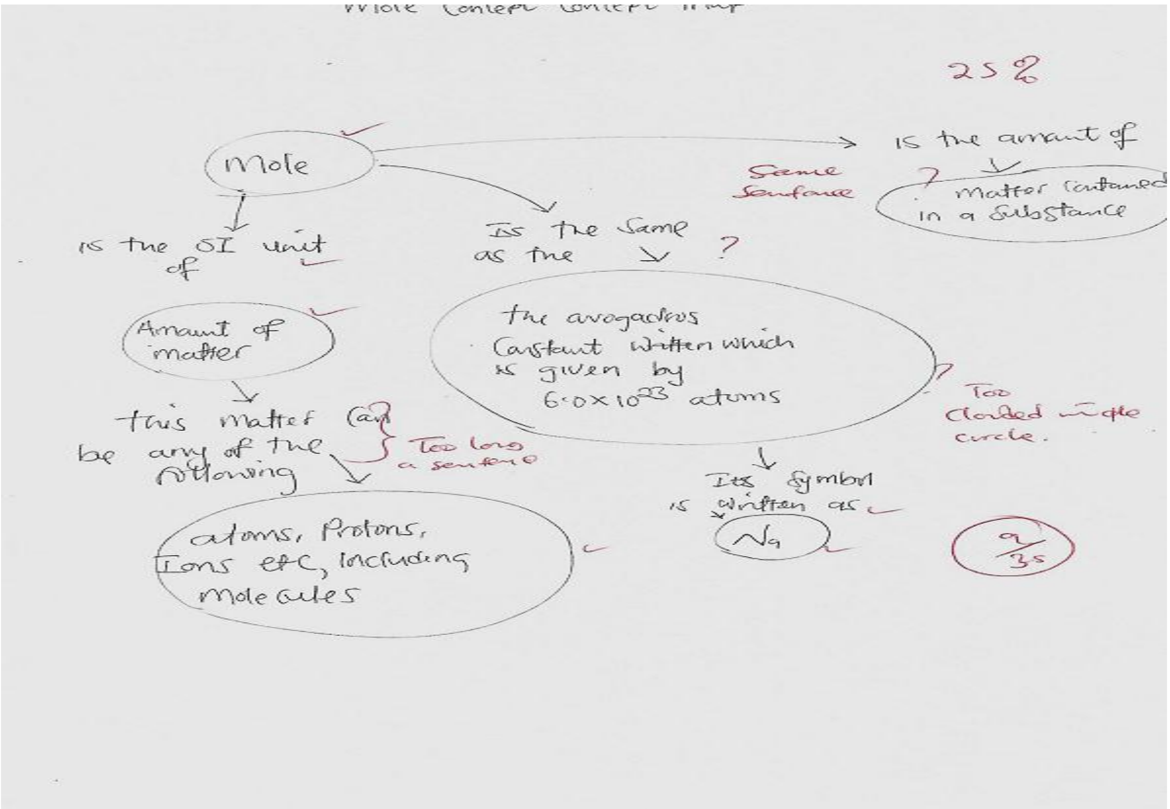
Concept map on the over view of grade 11 mole concept.



Concept map on stoichiometry.






25%
Mole
is the amount of
matter contained in a substance
Same sentence
is the SI unit of
Is the same as the
Amount of matter
the avogadros Constant written which is given by 6.0x10²³ atoms
Too crowded single circle.
this matter can be any of the following
Too long a sentence
Its symbol is written as
Na
atoms, Protons, Ions etc, including molecules
9/35