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The Effect of using Concept Maps on Student Achievement in Selected Topics in Chemistry at Tertiary Level

Indra Sen Singh (corresponding *author*)
School of Mathematics and Natural Sciences, Copperbelt University. P.O box 21692 , Kitwe, Zambia.
Tel :+260 955 950 164 E-mail:indra@cbu.ac.zm

Karren Moono
Mufulira College of Education, P.O box 40400, Mufulira ,Zambia, Central Africa.
Tel: +260 977 545 660 E-mail: karrenmoono@yahoo.com

Abstract

The performance in chemistry at tertiary level in Zambia has not been as expected. It has therefore been a matter of concern. There has been a continuous focus on exploring new teaching strategies to improve the understanding of this difficult subject. This study investigated the effectiveness of composite use of concept maps and traditional method on student achievement in selected topics in chemistry. The study was conducted in view of determining the method which is more effective in enhancing student understanding in chemistry. There were three groups involved in the study i.e. Control, experimental group1 and experimental group 2. The pre-test, post –test true experimental research design was used for the study. The sample of the study consisted of thirty nine (39) first year students at Mufulira College of education. Each of the three groups was randomly assigned 13 students. The treatment took four weeks using the topics “atomic structure” and “chemical bonding”. The control group was treated using the traditional method, the experimental group 1 was treated using the concept map method while experimental group 2 used composite of both the traditional and concept map methods. One way ANOVA at an alpha (α) = .05 was conducted to analyze the results of the pre- test and post test scores. The means of the pre-test scores were; control group = 6.46, Experimental group 1 = 7.07 and experimental group 2 = 6.61. These results show that there was no significant difference in the performance of the students in all groups. This result implied that the entry level performance for all the groups was not significantly different. The means of the post-test results(control group = 4.53,experimental group1 = 5.46, experimental group 2 = 6.61) showed that there was a significant effect on the use of both traditional teaching method and concept map teaching method at $p < .05$ level for the three groups at $F(2,36) = 17.156$, $p = 0.00$. The experimental group 2 performed better than both control group and experimental group 1 in the post test scores. Post hoc comparisons using the Turkey HSD test indicated that the mean scores were significantly different.

The results strongly support that when students are taught using both the concept map teaching strategy and traditional teaching strategy, they achieve the best scores. This study therefore offers an encouraging solution towards improvement of student performance in Chemistry at tertiary level.

Key words: Concept map, Traditional method, experimental group, achievement, effective method.

1.0 Introduction

Chemistry is a central science and the students’ poor understanding of the subject has enormous adverse effect on almost all the sectors of economy and every walk of life. It has been a matter of great concern for quite some time that the performance of students in this subject has been persistently below our expectations, and what has been even more worrying is the poor understanding level of the subject. In this vain therefore, it would be meaningful to innovate newer strategies leading to the better achievement and understanding of the subject. Chemistry is deemed difficult to teach and to learn because it consists of unfamiliar concepts involving complex relations. The highly conceptual nature of Chemistry makes it particularly difficult for students to understand. The strategies commonly used in the classroom have not sufficiently eased the learning process of the subject almost at all levels. The continued unsatisfactory performance in Chemistry in Zambia has been a matter of concern by education deliverers and many other stake holders (ECZ 5070 Chief examiner’s report 2013). The knowledge level of pre – service students in Chemistry is in most cases not coherent with the demand of the subject matter hence, the majority of them engage in rote learning mostly in order to pass examinations.(BouJaoude and Barakat,2000, Brandt et al., 2001; Jack, 2005).

Rote learning contributes very little to the knowledge structure of the learner and therefore cannot promote reflective thinking in more critical and abstract manner. If students can see a clear organized picture of a broad unit covering various concepts, then they would build a deeper understanding and appreciation of these concepts.

Every country often changes and redesigns her curriculum to include new teaching methods and techniques in order to help students develop scientific concepts better (Aboagye, 2009).

For Chemistry teachers in the country who use a fixed curriculum, Wood (2007) suggested they must be informed that the instructional method is one of the options the teacher could modify to enhance students' achievement. The traditional approach largely encourages students to memorize concepts even in the area of problem-solving, explanation of observed phenomena and comprehension. Capper (1996) asserted that much of the learning in the classroom is superficial; in that facts, rules, laws and formulae are memorized, and information is not usually connected to a coherent frame work that would allow students to make sense of it and to apply in other new situations. It is therefore suggested that teachers adopt constructivists approach to learning of which the learner is an active participant in the learning process, and also construct his own knowledge. Many researchers in science education, addressing effective concept development base their studies on the constructive perspective of learning.

In chemistry teaching various teaching strategies such as discussion, lecture, question and answer, field trip and brain storming are in use but the performance has still not been as good as expected among tertiary students in both national and promotion examinations (ECZ 5070 Chief Examiner's report 2012). This has hindered the academic progression of students in subjects like chemistry. In light of this, there is a general concern from parents, teachers, lecturers, curriculum developers and all stakeholders in general, about the low performance of learners in chemistry (63.4%) (ECZ 5070 Chief Examiner's report 2013). In 2012 the percentage pass for chemistry 5070 was 60.8%(ECZ 5070 Chief Examiner's report 2012)

Generally, there seems to be a lot of emphasis of a chemistry course to instill a sound knowledge of content. Factual knowledge is taught in class, assigned as home work and memorized for tests. A mastery of the facts as a criterion used for student assessment compromises the main objective. In order to better their contribution ,Chemistry students today must be able to; understand key concepts in chemistry, demonstrate proficiency in skills such as, problem solving, critical thinking, mastery and grasping of scientific methods and processes and apply knowledge in real life situations. The problem of poor conceptual understanding seems to be recurring also from the fact that students come to the tertiary level with a weak background in Chemistry. The poor articulation of chemical concepts by students is reflected at Mufulira College of Education (MUCE 51.2% and 54.2% in 2012 and 2013 Diploma Examination results respectively).

For making chemistry learning more meaningful and for better students' achievement in chemistry, there is need to explore and adopt more effective delivery techniques. Concept Mapping is reportedly one such strategy that may be used to enable students to think about connections on what is being learned, organize their thoughts, visualize relationships between key concepts in a systematic way and be able to reflect on their understanding. According to Capper (1996), one powerful way of organizing knowledge is through the use of concepts. To Crowl, Kamisky & Podell, (1997), "concepts are classifications of a set of related ideas or events" (p.142). Klausmeier (1990) avails information about how teachers are to teach concepts. Concepts play a crucial role in guiding the production of knowledge and meaningful learning (Novak, 1979).Meaningful learning is therefore the formation of viable relationships among ideas, concepts and information (Otor, 2011).Ault (1985) also supports the view that concept mapping enhances meaningful learning by leading students "away from rote learning and toward true understanding of concepts and their relationships." Concept mapping is a useful tool for helping students learn about the structure of knowledge and the process of knowledge production or meta-knowledge (Novak & Gowin, 1984).Novak and Gowin (1984) have developed a theory of instruction that is based on Ausubel's meaningful learning principles that incorporates "concept maps" to represent meaningful relationships between concepts and proposition. The value of prior knowledge in students' learning and linking new information to existing knowledge is a necessary requirement for meaningful learning to take place (Ausubel 1968).Novak (1991) states that concept maps serve to clarify links between new and old knowledge and force the learner to externalize those links. Stice and Alvarez (1987) suggest that meaningful learning may be enhanced as a result of students' social interactions during brainstorming, initial mapping, discussions and revisions. Concept mapping has been found not only useful in promoting students' understanding of concepts but also in facilitating students' abilities to solve problems and to answer questions that require application and synthesis of concepts (Johansen 1983).

Concept mapping is a teaching and learning strategy that has been developed by Novak (1977) and which helps students to organize concepts into hierarchies. It is a pedagogical/Meta cognitive tool designed to help students learn how to learn (Novak, 1998).There are two features of concept maps that are important in the facilitation of creative thinking: the hierarchical structure that is represented in a good map and the ability to search for and characterize new cross-links (Novak and Canas, 2008). It has been developed as an outgrowth

of Ausubel's (1968) theory of meaningful learning which highlights the importance of prior knowledge in the learning of new concepts. Ausubel (1968) asserted that students learn meaningfully by building knowledge on the basis of what they already know. In other words, new knowledge (or new concepts) acquire their meanings through relationships with existing knowledge (or concepts) and meaningful learning occurs when new knowledge is consciously related to relevant concepts which the student already possesses (Cliburn, 1990). According to Novak and Gowan, (1984) "concept maps can make clear to the student (and the instructor for curriculum development purposes) how small the number of truly important concepts they have to learn."Lambiotte and Dansereau (1991), state that the students that viewed or made concept maps would have a broader knowledge base and therefore be more able to solve problems compared to those students that learned by rote memorization.
Alberto Regis and pier Giorgio (1996) proposed application of concept maps in chemistry teaching in high schools. Gladys U Jack (2013) reported that concept mapping would be an effective teaching strategy for teaching difficult concepts in chemistry at secondary school level.

From the literature survey conducted, there does not seem to be any study on the use of concept map methodology to test its effectiveness on the understanding and achievement of students in Chemistry at tertiary level. Therefore, it would be worthwhile to carry out a research on this strategy applied to tertiary level chemistry teaching in the Zambian perspective. In addition, the reported studies seem to have focused on comparison between the effectiveness of traditional and concept mapping strategy. As such, it would be even more interesting to carry out a comparative study on effectiveness of traditional teaching strategy, concept map teaching strategy and combination of both strategies on student's performance.

2.0 Methodology

2.1 Sample.

The sample consisted of thirty-nine (39) first year students at Mufulira College of Education who were purposefully sampled. The participants were put into three (3) homogenous groups of 13 each for the Control group, Experimental group1 and Experimental group 2.

2.2 Instrument.

A set of Tutor Constructed Chemistry Achievement Test (TCCAT) items were used as the main tool for collecting data. The achievement test items consisted of multiple choice and descriptive questions related to the selected topics (i.e. atomic structure and chemical bonding). Each multiple choice question had four options with one correct answer. The structured questions required own expression of conceptual understanding. The pre-test questions served to ascertain equivalence of ability and the post-test to determine the effect of the treatment on the two chosen topics atomic structure and chemical bonding. The results of the pre-test and post –test were kept for analysis.

2.3 Procedure

Two instructional strategies were used. The experimental group 1 and experimental group 2 received the concept map instructional treatment, while the control group and experimental group 2 were taught using the traditional method.

All the three study groups covered the same content material. Each time either experimental group1 or control group met, the experimental group 2 was in attendance. Each group was met three times per week for four weeks. The content covered was extracted from the national College curriculum.

The units covered in atomic structure were, atomic models, atomic particles and charges, mass spectrometry, atomic orbitals and shapes, energy levels and quantum numbers and electron configuration using Aufbau principle while those under chemical bonding were Ionic, covalent, metallic, hydrogen and dative/ coordinate bonding, bond polarity, bond energy and valence bond theory.

In the traditional teaching method, the main methods used were lecture- note-taking sessions, discussion and question and answer methods. The control group and experimental group2 were given an introductory lesson on the first day, which included the unit objectives of the sub topics given above and some other questions which were designed to instill motivation. The succeeding days consisted of regular class discussions, paper and pencil activities, informal assessments and textbook exercises.

First and foremost, the basic elements of concept mapping were introduced to the experimental groups 1 and 2. The lesson on day one started by defining what a concept map is and the actual steps that are followed in constructing concept maps.

A concept map was defined as a tool that presents the relationships among a set connected concepts and ideas. Concept maps were defined in terms of graphic organizers and terms in advance. The studies by Gowin and Novak (1984) were applied to in preparing the teaching method in a normal classroom situation.

General procedure for constructing a concept map: The students were introduced to the following general approach to construct concept maps in relation to the topics chosen;
Contextualization*:* Involved defining the context for the concept map. This was done by constructing a focus question for each of the topics. The focus question for atomic structure was "what is an atom?" (appendices A & B) while that of Chemical bonding was "what is chemical bonding? (appendices C and D).
Brainstorming phase: In this phase, students were asked to write on small pieces of paper, the terms they knew in the topic "atomic structure". Examples of concepts students wrote included; atoms, proton, nucleus, orbital, electron, neutron, e.tc.
The concepts were ranked according to how related they were hierarchically from general to specific. The more broader and inclusive concept was placed on top.
Lay out phase*:* In this phase students were asked to connect concepts with linking words by means of lines with arrows to show the relationship between concepts. These linking words in between concepts help to illustrate how the domains of knowledge were related to one another.
Finalizing the concept map**:** In this phase specific examples were given below concepts to solidify meaning. Students during this stage were now asked to put their concept map into a permanent form.
It is important to recognize that a concept map is never finished. It depends on what domains of knowledge one is looking for. The steps that are stated above were just meant to serve as a guide to explore even more complex concept map structures.
On the second day, students in the experimental groups 1 and 2 were given a passage in the text book "Mathews Phillip, (1992): Advanced Chemistry, on the topic "atomic structure . Students were instructed to underline the concepts as a matter of practicing to construct concept maps. A list of the underlined words was written by each group as a phrase bank. After the session, students were instructed to list the words that they wrote.
On the same day, the experimental group1 and experimental group 2 received blank concept map with spaces assigned for the concepts in hierarchical fashion. Arrows showing the linkage between the concepts were included. The students completed their concept maps by copying from the example which was given. The maps were also used as basis for discussion to emphasize the meaning of the concepts.
All concepts with equal importance or value were placed next to each other horizontally, guiding the students in relating concepts by positioning linking or connecting words on directional arrows.
These concepts were supported in some cases with examples to accrue meaning. For the rest of the week students in the experimental1 and experimental group 2 were given some time to practice the construction of concept maps using a concept list according to the subtopics outlined in atomic structure and chemical bonding. Students received feedback on their concept maps. Each student's concept map was checked for accuracy and completeness at the end of the activity. To help self check, a concept map rubric adopted from JD Novak and Gowin (1984) was used. Students were also told they could modify their concept maps and add more concepts if they wished so. The same procedure was done for the succeeding lessons. The students constructed the first concept map on atomic structure using concept list provided. On the third week, the students constructed concept maps on chemical bonding.

The concepts were arranged according to Novak and Gowin (1984) scoring scheme as;
Main concept ⟶General concept ⟶ sub concept ⟶examples

3.0. RESULTS.

3.1 Analysis of Pre-test Scores using frequency tables.

The pre- test results were analyzed using frequency tables, mean, mode, median and standard deviation. The tables below show the results of analysis from the SPSS.

Table 1. Statistical data of the pre –test scores

Statistics

		CO	EXP 1	EXP 2
N	Valid	13	13	13
	Missing	0	0	0
Mean		6.4615	7.0769	6.6154
Median		7.0000	7.0000	7.0000
Mode		7.00	7.00	7.00
Std. Deviation		1.12090	1.18754	1.55662

The overall statistical table 1shows that the average mean scores of the pre-test scores for the Control group (CO), Experimental group 1 (EXP 1) and Experimental group 2 (EXP 2) were 6.5, 7.1 and 6.6 respectively. The calculated standard deviations for the Control group (CO), Experimental group 1 (EXP1) and Experimental group 2 (EXP 2) were 1.12, 1.18 and 1.55 respectively. There was no significant difference in the mean scores of the groups. This implies that the background knowledge of the students before treatment was homogenous before treatment. In other words, the students entered the study on equal strength. This meant that the groups were suitable for study when comparing the effect of concept maps on their achievement with the traditional teaching strategy on atomic structure and chemical bonding. This then would confirm that if any observable significant difference is seen in the post test mean scores of the three groups, then such difference would not be attributed to chance but the effect of the treatment which is the concept mapping strategy or a combination of concept mapping and traditional teaching model.

Table 2: Pre- test scores ANOVA table

Score

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.667	2	1.333	.869	.428
Within Groups	55.231	36	1.534		
Total	57.897	38			

The main interest in this table is the column marked sig. Since the value .428 is more than .05, and then there is no significant difference in the mean scores of all groups. The interpretation of this result suggests that the entry level knowledge of the three groups before treatment was homogenous. This result is in agreement with frequency descriptive analysis stated in the frequency tables.

3.2 Analysis of Post-test Scores using frequency table.

Table 3. Statistical data of the post –test scores

Statistics

		CO	EXP 1	EXP 2
N	Valid	13	13	13
	Missing	0	0	0
Mean		4.5385	5.4615	6.6154
Median		5.0000	5.0000	7.0000
Mode		5.00	5.00	7.00
Std. Deviation		.87706	.66023	1.12090

3.3 Interpretation of post –test scores using frequency tables.

The overall statistical Table 3shows that the average mean scores of the post -test scores for the Control group (CO) , Experimental group1 (EXP1) and Experimental group 2 (EXP 2) were 4.5 , 5.5 and 6.6 respectively There was a significant difference in the mean scores of the groups with experimental group2 having done

significantly better followed by the experimental group 1 and lastly the control group. The results suggest that combining the existing traditional method of teaching with concept mapping methodology brings about significant results as opposed to exclusively using the concept map methodology.
Taken together these results imply that combining concept mapping teaching strategy with the traditional teaching strategy bring about a significantly better result.
The results strongly support that when students are taught using both the concept map teaching strategy and traditional teaching strategy, they achieve the best scores.

Table 4: **Post- test scores ANOVA table**

Score					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	28.154	2	14.077	17.156	.000
Within Groups	29.538	36	.821		
Total	57.692	38			

From the main ANOVA table, the sig value of 0.00 is less than .05. These results suggest that there was a significant difference in the mean scores of the three groups. However, this does not state the degree of difference among the groups. Pursuant to this, a post hoc test was conducted to ascertain individual differences between groups as is indicated in the multiple comparison test table 5.

3.4 post hoc tests analysis

Table 5:Multiple Comparisons

Tukey HSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Control	Experimental 1	-.92308*	.35529	.035	-1.7915	-.0546
	Experimental 2	-2.07692*	.35529	.000	-2.9454	-1.2085
Experimental 1	Control	.92308*	.35529	.035	.0546	1.7915
	Experimental 2	-1.15385*	.35529	.007	-2.0223	-.2854
Experimental 2	Control	2.07692*	.35529	.000	1.2085	2.9454
	Experimental 1	1.15385*	.35529	.007	.2854	2.0223

*. The mean difference is significant at the 0.05 level.

In order to determine exactly where the differences among the groups occur, a post hoc test was conducted as seen in the table 5 above. From the mean difference column in table 5, asterisks (*) next to the values indicate that the paired groups are significantly different from each other at .05 level.

3.5 Summary of results

One way ANOVA was conducted to compare the effect of using concept maps on student achievement in Chemistry. Pre-test scores indicated that there was no statistically significant difference in the mean scores at $p < .05$ level for the three groups [$F(2, 36) = .869$, $p = .428$].
Post hoc comparisons using the Turkey HSD test indicated that the mean scores for the control group was ($M = 6.5$, $SD = .88$) , experimental group 1 ($M = 7.1$, $SD = 1.19$) and that of the experimental group 2 ($M= 6.6$, $SD = 1.56$). The mean scores are not statistically significant for the pre-test scores.
The post –test results indicated that there was statistically significantly different at $p < .05$ in the mean score of the three group [$F(2,36) = 17.16$, $p = .00$].
Post hoc comparisons using the Turkey HSD test for the post test scores indicated that the mean scores for the control group ($M = 4.5$, $SD = .88$) was significantly different from the experimental group 2 ($M = 6.61$, $SD = 1.12$). The experimental group 1 scores were ($M= 5.5$, $SD = .66$).

Taken together, these results strongly support that there is a better option than teaching through the traditional method or teaching through concept mapping to improve student achievement in Chemistry. Specifically, the results strongly support that when students are taught using a combination of both the concept map teaching strategy and traditional teaching strategy, they achieve the best scores.

4.0 RESULTS AND DISCUSSION

The study reveals that the students had homogenous understanding of the topic atomic structure in the pre- test. The mean scores obtained in the pre-test for the control group, experimental group 1 and experimental group 2 were 6.5, 7.1,6.6 respectively. This result implies that the pre- test mean scores were not significantly different, hence were homogenous.

Further findings assert that that the concept mapping teaching method is more effective in student achievement in chemistry than the traditional teaching method. The mean scores from the results are clearly stating that the concept map teaching is more effective than traditional teaching method.

The achievement of control group 2 suggests that when students are exposed to both Concept map teaching methodology and traditional method of teaching, the results are significantly better than teaching exclusively through either concept mapping method or traditional teaching method.

Finally, to determine which strategy (traditional, concept mapping or a blend of both) is more appropriate for teaching Chemistry at tertiary level?", it is better to combine traditional method and concept map method in teaching chemistry in order for the students to have a better understanding and comprehension of chemistry concepts at tertiary level. The mean scores of the post- test results (control group = 4.5, Experimental group 1 =5.5 and experimental group 2 = 6.6) confirm the statement given above.

5.0 CONCLUSION

Based on the findings of this study, the following conclusions were made.

1. Concept mapping teaching methodology is an appropriate teaching method that can be used to teach chemistry at tertiary level. The method employs independent thinking in the students and imparts more of conceptual understanding than the usual rote learning that most of our students engage themselves in. The mean scores of the groups in the pre-test results showed that the student's entry knowledge level was homogenous before treatment. The variance that was noted could have been as result of individual error and ability of the students
2. More importantly, the study has indicated that the student achievement in chemistry is even more significantly different if both concept mapping and traditional method are used in teaching concepts to the students. The reason that could perhaps be given to explain the results could be that the students in the blending group had a better connection to look at concepts from both the traditional perspective and the concept map perspective.
3. Conceptual formation added with traditional classroom teaching can help students use their existing knowledge to solve real life problems and develop complex skills and concepts.

This is another window of research that can further be explored in other parts of the world other than from the Zambian perspective, in which the combination of the concept map and traditional method is being done for the first time at tertiary level in Chemistry. This research can be extendable to higher year tertiary level chemistry topics. It can also be tried to other sciences at tertiary level.

6.0 RECOMMENDATIONS

From the findings of this study, the recommendations for the improvement in teaching and learning of chemistry are:

- Students should be taught how to construct concept maps on their own on various topics in Chemistry because this improves the cognitive structures of the students.
- Concept map teaching model should be incorporated in the new curriculum to supplement existing methodologies in order to enhance student understanding and linking of concepts. T
- The traditional lecture method of teaching should be used together with the concept map teaching method in teaching Chemistry.

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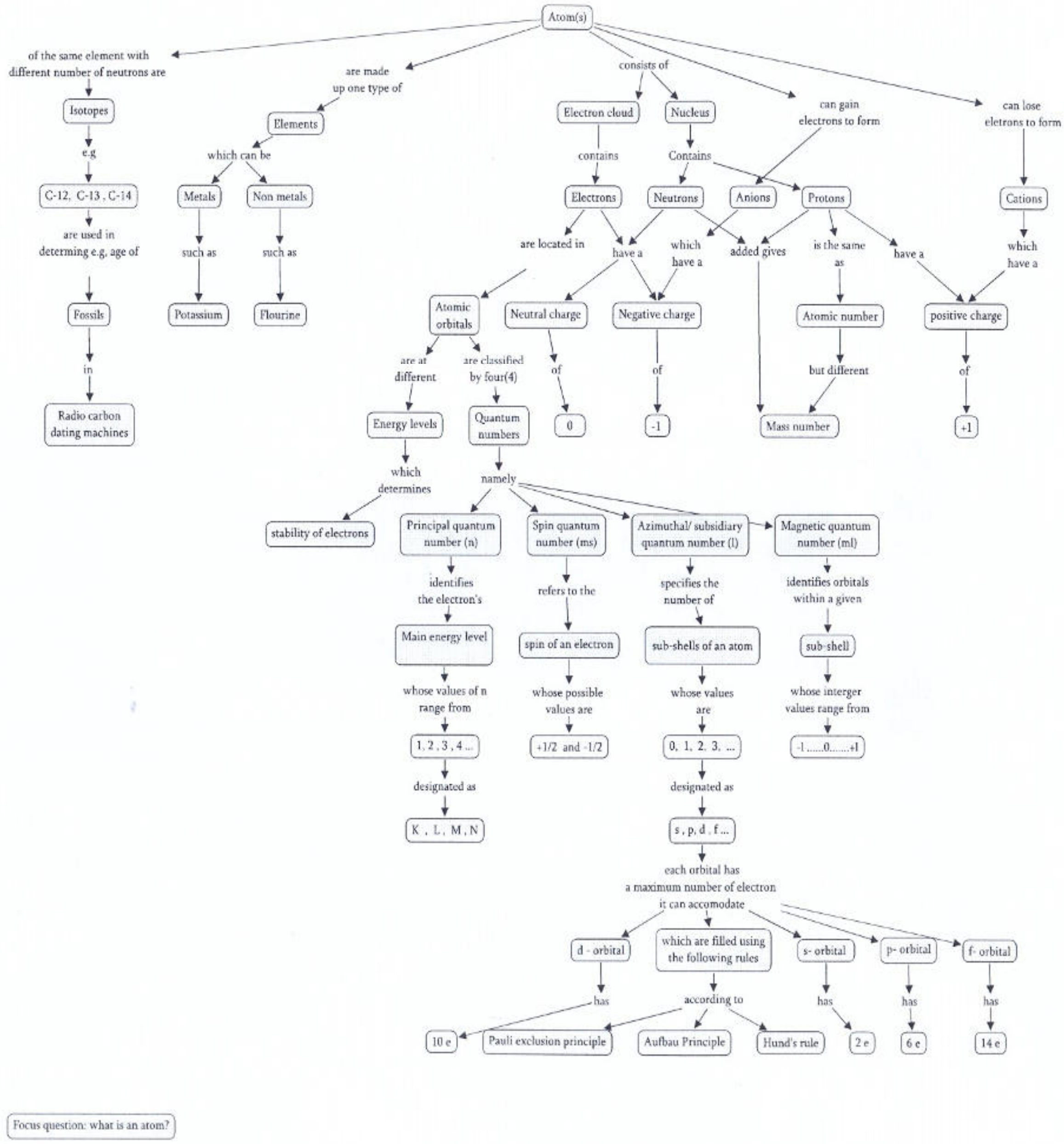
Appendix A: Atomic structure Concept map



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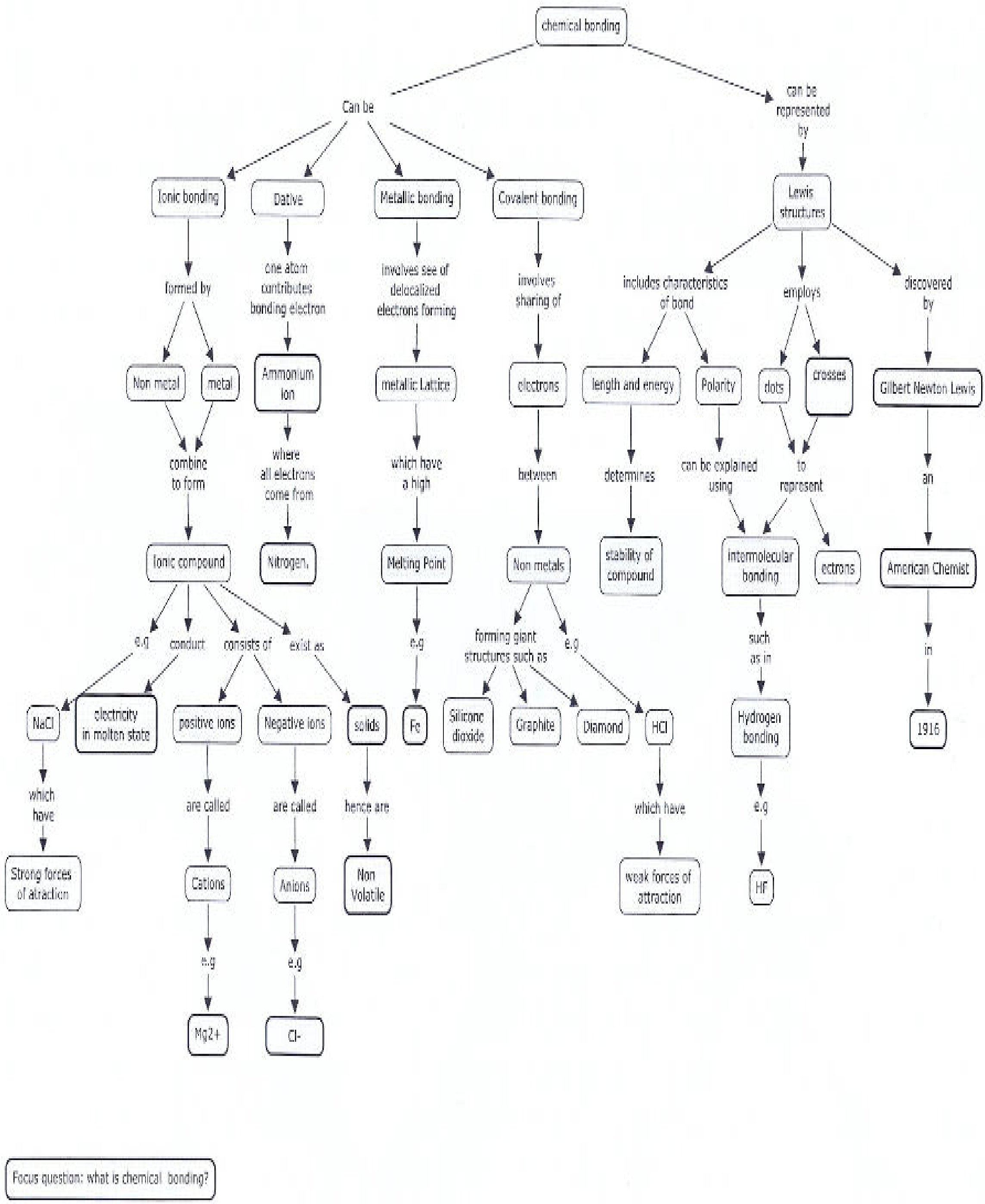
Appendix B; Chemical bonding Concept map



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Appendix C; Sample of student constructed concept map