MOJES MALAYSIAN ONLINE JOURNAL OF EDUCATIONAL SCIENCES JULY 2020, 8 (3)

KNOWLEDGE ON MOLE CONCEPT: THE STRUCTURE OF MEMORY NETWORK

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ABSTRACT

Over the past few decades, researchers have focused on the lack of conceptual understanding of mole concept because it is considered to be difficult for students globally. Due to its abstract and mathematical nature, chemistry teachers tend to use algorithmic teaching strategies to provide learning experiences for students, resulting in superficial understanding of the concept. Past researchers have focused more on teaching strategies and learning experiences in the classroom for the topic but relatively less on students' mental processes. The knowledge embedded in the mind of learners is the result of the learning experiences they are subjected to by their teachers. The objective of this study is to investigate how knowledge on mole concept is organised in the brain of learners using the Connectivity Model of Semantic Processing (CMSP). This theory explains that knowledge is structured in the form of memory networks in the brain, either in the form of hierarchical memory network (HMN) or interconnected memory network (IMN). The mind maps generated by research participants on this concept were analysed based on CMSP as the representation of their memory networks. Then it was compared with their learning experiences in the classroom. The findings show that those who had IMN were able to inter-relate concepts as they were given more emphasis on thinking process during the lesson and the concepts were taught simultaneously. On the contrary, those who learnt one concept after another, separately, had HMN and were not able to relate concepts.

Keywords: *Mole Concept, Abstract, Memory Network*

INTRODUCTION

Over the past few decades, science education has been making continuous efforts to promote meaningful learning and higher order thinking skills globally as well as to slowly scrape of traditional learning strategies such as rote learning. The efforts to infuse meaningful learning has become more challenging especially for chemistry education due to its microscopic nature (Treagust, Chittleborough, & Mamiala, 2003). Furthermore, students find it hard to engage into conceptual understanding of chemistry as it has its own specialised language of formulae, unlike other pure science subjects (Treagust et al., 2003; Gkitzia, Salta, & Tzougraki, 2011; Cardellini, 2012; Gafoor & Shilna, 2015; Akcay, 2016; Shadreck & Enunuwe, 2017). Past research findings have narrowed down their study into the more challenging core of chemistry, the concept of mole. The findings indicate similar problems faced by students worldwide, which is algorithmic method of problem solving for the concept of mole. This is because mole concept is considered as a difficult topic due to its abstract and mathematical nature (Kimberlin & Yezierski, 2016; Sopandi, Kadarohman, Rosbiono, Latip, & Sukardi, 2018).

The education systems worldwide are turning their lens towards the learning process of students instead of focusing on the students' final score of their performance, the product. The change of view from product to process has become the central attention of educationists to enhance conceptual understanding of the subject. As an effort to contribute to this, a lot of research has been carried out to identify the root causes and the problems that are the stumbling blocks to it, in view of teaching strategies. In order to nurture thinking skills among learners, it is necessary to plan suitable learning experiences that help to develop one's thinking skills, beginning from their classroom.

Mole concept is introduced in the students' fourth form of Malaysian government schools as the third chapter (Ministry of Education, 2018). It requires calculations of quantity of substances involving the unseen particles as well as formulae representing various substances. The unit for quantity of "mole" itself does not have any device to measure the quantity of substances physically. Instead, they are required to relate concepts, such as number of particles, mass of substances and volume of gases, by using equations and substitution of mathematical formula to calculate it. Past research findings probed deeper into the teaching strategies to promote mastery as well as to enhance the conceptual understanding of this topic (Espinosa, Espana, & Marasigan, 2016; Gafoor & Shilna, 2015; Molnar & Hamvas, 2011). However, relatively less studies are done on the mental process of learning about mole concept, especially on how the learners construct knowledge in their mind on mole concept and how they are going to apply the constructed knowledge for the purpose of problem solving.

This paper focuses more on the mental processes on how the knowledge constructed on mole concept is embedded in the mind of learners. The structure of the knowledge embedded in the mind of learners have an effect on how it is applied in problem solving of mole concept. The problem on lack of conceptual understanding has been given so much emphasis by past researchers worldwide by contributing solutions to it such as various teaching strategies to help students master the topic (Espinosa et al., 2016; Gafoor & Shilna, 2015; Molnar & Hamvas, 2011). However, the on-going worldwide researches on this matter, proposing various teaching strategies, is an indication that the problem has not been addressed completely yet. Recent studies have been found to be focusing more on the teaching strategies but relatively less on the mental processes and how the knowledge on mole concept is organised in the student's mind (Moss & Pabari, 2010). There is a need to study on the structure of the knowledge embedded in the learner's brain in order to put things right by proposing an appropriate learning experience to learn mole concept via meaningful learning. Therefore, it is timely to investigate further on the organisation of the concept in the brain of learners. The objective of this study is to investigate the structure of memory network for the knowledge constructed on mole concept in the mind of learners. The research question of the study is, "What is the structure of memory network for the knowledge constructed on mole concept in the mind of learners?".

THEORETICAL FRAMEWORK

The objective of this study is to investigate how knowledge on mole concept is organised in the brain of learners using the Connectivity Model of Semantic Processing (CMSP). This theory explains that knowledge is embedded in the form of memory networks in the brain. The memory network has two main structures based on Klimesch (2015). It can be in the form of hierarchical memory network (HMN) or interconnected memory network (IMN). These are two main categories, but the structure of memory network varies for every individual.

a) Hierarchical memory network (HMN)

The HMN is the structure constructed when a few new codes link to one code to form a fan structure as shown in Figure 1 below. For example, the Figure 1 shows that the new information, B, C, D are linked to pre-existing knowledge, node A. Each node B, C and D are not linked to each other. New information, E, F and G, are linked to the nodes in the tier above, to nodes B, C and D respectively, but not linked to node A. Node E, F and G are not inter-related either.

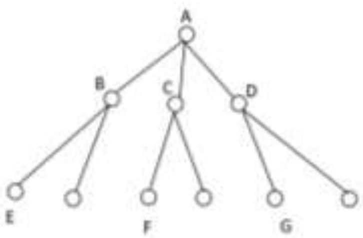


Figure 1. Hierarchical memory network (Klimesch, 2015)

According to Klimesch (2015), HMN have more links than nodes with a formula of (m=n-1) where the m is the number of links and n is the number of nodes. Figure 1 shows n=10 whereas m=9 with a linear relationship as represented by the formula. However, not all memory networks have clear cut distinct patterns in reality.

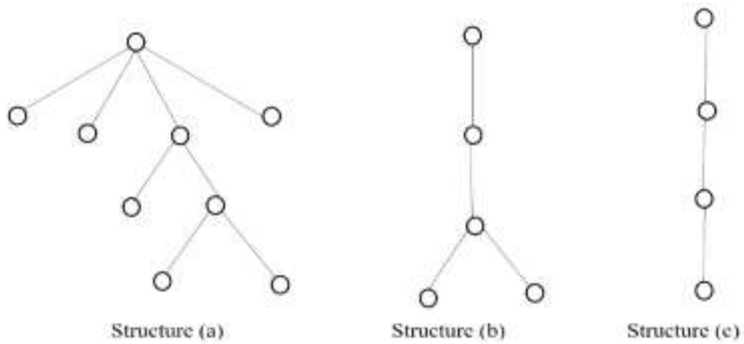


Figure 2. Non-strictly hierarchical memory network (Klimesch, 2015)

There are non-strictly HMN as shown in Figure 2(a), 2(b) and 2(c) which do not have a full fan structure. Figure 2(c) is different from the other two, where there are no branches, but the nodes are linked one after another representing rote learning where the learner is unable to link it to other pieces of knowledge.

b) Interconnected memory network (IMN)

Figure 3 is a representation of an IMN, which has a different layout form the HMN. All the nodes are interrelated to one another. Node E is linked to all other nodes in the structure, forming a closed structure.

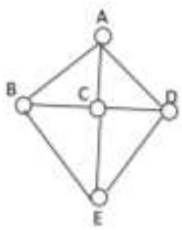


Figure 3. Interconnected memory network (Klimesch, 2015)

The new information received is linked to pre-existing knowledge stored in the Long-term Memory (LTM) in different patterns for the HMN and IMN. For the IMN, the number of links exceed the number of nodes ($m>n$) when $n>3$. There are also structures that are partially interconnected, with partially closed structure, as in Figure 4.

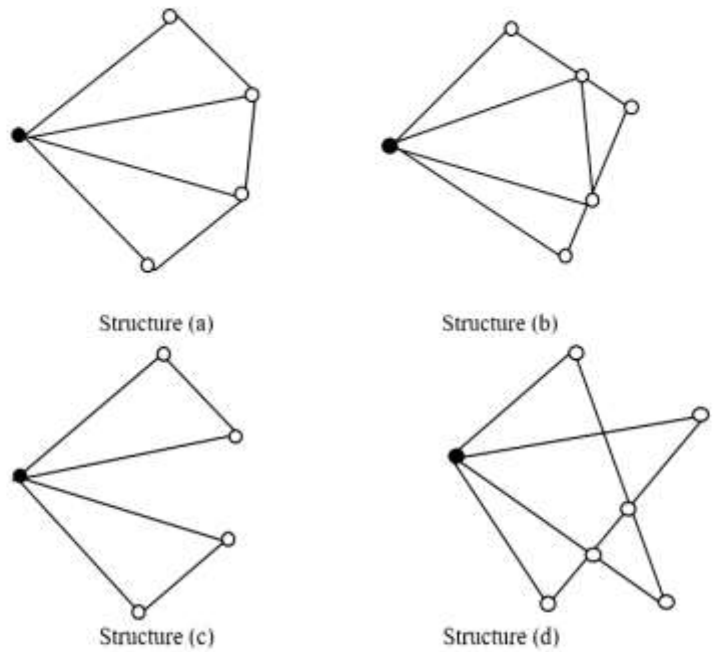


Figure 4. Examples of partially interconnected structure of IMN (Klimesch, 2015)

The memory network as the organisation of codes embedded in one's memory has more in-depth explanation on retrieval of facts when there is a need to recall. The LTM has countless number of memory storage of codes similar to a closet full of clothes. Search time for a particular shirt from the closet is similar to the search process of stored facts in the LTM. If the clothes are arranged in order, according to categories, the search process is faster. The speed of retrieval of facts from the LTM depends on how the facts are organised in the form of memory network in the brain. The retrieval is faster for an IMN as there are more links. On the contrary, the HMN takes more time of retrieval due to lower number of links to connect the nodes. In short, the speed of memory search increases as the complexity of networks increases. This also reflects on the ability of a learner to solve problems by retrieving and relating the appropriate nodes stored as the memory network.

An IMN has a structure where new knowledge is embarked on pre-existing knowledge as one piece of knowledge. Therefore, the concept is understood conceptually. A memory network that does not link to the pre-existing knowledge and with an isolated structure as in Figure 2(c) is said to be rote learning and has only superficial understanding of the concept. The ability of a learner to solve problems in a new situation involves in-depth conceptual understanding of the concept. A closed structure such as the IMN enables a learner to relate new information stored in the memory storage and link to other concepts that are related.

This study sought to investigate about how knowledge on mole concept is constructed and embedded in the brain of students. The structure of the organisation of facts determines the ability of a learner to relate and apply the knowledge appropriately. This research is not focusing on the speed of retrieval but specifically on the structure of the memory network of students on mole concept

METHODOLOGY

Research Design and Participant

This study adopted a qualitative approach to probe deeper into the embedded knowledge on mole concept. Hence, there were relatively less research participants selected via purposive sampling. A total of twelve (12) chemistry students of two (2) different chemistry teachers from the same school were selected to analyse on their memory networks. Students of two teachers were selected because the students of each teacher have different learning experiences as their respective teachers impart the lesson on mole concept using their own teaching approach. The two chemistry teachers, Anna and Bella, were from the same school. Six research participants from the students of each teacher were selected purposively based on their willingness to participate in this study. The research participants were approached after the lesson on mole concept had been imparted by their respective teachers. They were required to generate mind maps on mole concept, which were analysed based on the CMSP, as the representation of their memory networks. Then it was compared with their learning experiences provided by their respective teachers in the classroom.

Research Procedure

The teachers in this study were requested to describe how they imparted the lesson on mole concept during the lesson in the classroom. The description was audio recorded in order to analyse the lesson structure to be compared with the type of memory networks the students constructed.

Data collection with the students was conducted in their chemistry laboratory. The students were requested to represent their knowledge on mole concept in the form of mind maps. They were reminded that every link between nodes has a meaning and need to be explained. It is not a creativity competition, therefore, the researcher explained that the relatedness between terms in mole concept is the main priority. They were provided with a set of cards containing important terms for mole concept, which were listed by two expert chemistry teachers. A big white piece of paper, coloured ink pens, glue and scissors were also provided in order to create the mind map of how they understand the concept. However, the research participants were briefed that it is not compulsory to use all cards given and that they were allowed to add any terms that is necessary based on their knowledge on mole concept.

The mind map activity was conducted simultaneously for all the research participants in the same laboratory and without limitation of time to complete the task. This is to ensure that they are not rushed, and sufficient time is given for them to generate the mind maps. They were seated not facing each other in a distance, in order to prevent any distraction of peer influence. The researcher was careful not to make any announcements aloud in order not to distract them during their thinking process. The research participants were free to submit their mind maps once they have completed it. Each and every research participant verified their mind maps respectively upon submission. The research participants were given codes as fictitious names, to be written on their mind maps. For students of Anna, the research participants were coded as A1, A2, A3, A4, A5 and A6 whereas for Bella, the research participants were coded as B1, B2, B3, B4, B5 and B6.

Data Analysis

First and foremost, the lesson description of the teachers was audio recorded and transcribed back to back to be analysed. The sequence of activities during the lesson were then listed down based on its timeline and duration. Then, the lesson structure and the type of learning activities provided by the teachers were summarised to be compared with the type of memory network the students had constructed in the mind.

The research participants were required to explain briefly what they have drawn as a measure to verify that it represents what they understand and also making sure that every link and node were meaningful.

Table 1
Analysis of mind maps in four steps

Step	Stage	Description of process in each stage
1	Verification	The RP is allowed to verify the nodes and links verbally to obtain confirmation on the structure presented
2	Coding	Every link and node in the MM is given a code
3	Formula verification	Calculation of total number of nodes and links to be analysed based on the formula (Klimesch, 2015)
4	Identification of type of network	Analyse the organisation of nodes in the fragments to identify the type of network

The analysis of the mind maps was done in four steps, verification by the research participants, coding, formula verification and identification of the memory network structure. Table 1 represents the steps involved during the analysis.

The research participants were allowed to make any amendments during the verification upon submission of the mind maps. The audio recordings of their verbal verification were transcribed back to back in order to be able to be used in the analysis. The coding of the mind maps was done whereby the links between nodes were done by numbering them in sequence preceded with "*m*" whereas the nodes were numbered as a new series of numbers preceded with "*n*". The total number of nodes and codes of each mind map were compared and the structure of each were identified by analysing the relationship between the values of *m* and *n* as well as the overall layout of the mind map. Then, presence of closed structures as well as links between concepts were identified.

FINDINGS

The findings of this study have two components, namely the lesson structure of both teachers and the mind map analysis of the research participants.

Summary of lesson description for mole concept

Anna and Bella had completely different way of imparting their lesson, as shown in Figure 5. Both teachers had imparted the whole lesson on mole concept in two lessons.

Anna's lesson description

Anna had three main components in her lesson whereby MP (mole and particle) and MM (mole and mass) and MV (mole and volume of gas) were imparted one after another. For the first component, Anna introduced the lesson on mole concept by using the analogy of cells to particles to introduce Avogadro's constant. Then the value of the constant and definition of mole were written on the whiteboard and explained verbally. The lesson was directed towards the usage of formula to determine the number of moles in various numerical problem solving. Then she introduced the second component, "mass of substances", by demonstrating the weighing of an object, labelled as sodium. Consequently, the meaning and the introduction of the formula to determine the number moles was presented by her on the whiteboard. The third component was introduced in the second lesson, by drawing three balloons on the whiteboard to represent the volumes of three examples of gases. Last but not least, she introduced the formula volume of gas to determine the number of moles. Each component of the lesson had the same pattern encompassing the meaning of concept, introduction of the formula to calculate number of moles and lastly the formula application to solve various numerical problems on mole concept. The results show that Anna imparted MP, MM and MV as separate components resulting in hierarchical memory network (HMN) of the research participants under her. Furthermore, the HMN showed three branches, one for each concept, although they had different way of drawing the mind maps. The research participants were unable to link the three concepts, MP, MM and MV, to each other.

Bella's lesson description

Bella introduced her lesson by using an analogy of dozen to the Avogadro's constant, followed by the introduction of the three concepts, MP, MM and MV simultaneously. Once the students were able to make the analogy, she drew a table with three columns on the whiteboard. The first column was labelled as "mass", the middle column as "mole" and the third one as "number of particles". She wrote examples of substances to compare their quantities in terms of "mass", "number of moles" and "number of particles" simultaneously, in the table. She made comparison and calculations based on the "part and whole" concept without the introduction of any formula. Then she added on the concept of "volume of gases" to the table as the fourth column during the second lesson. It was followed by an opportunity for them to deduce a formula to calculate number of moles. Finally, she introduced the formula and gave opportunities to students to solve various problems on mole concept. The research participants under Bella had a mix of both type of memory networks interconnected (IMN) and hierarchical (HMN).

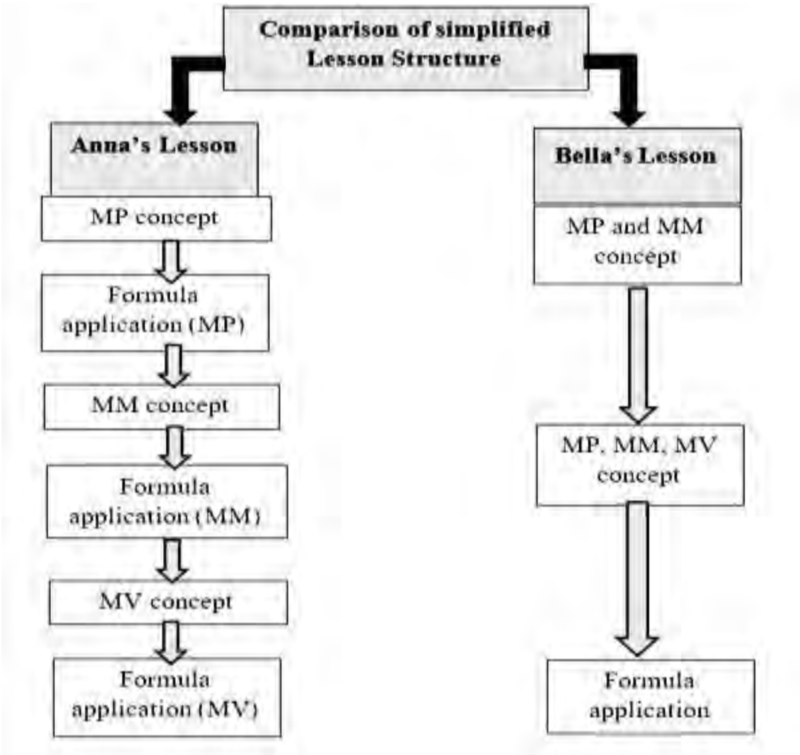


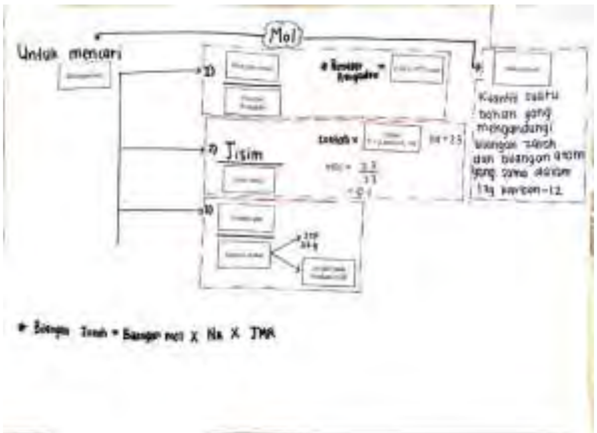
Figure 5. Summary of lesson description of Anna and B on mole concept

Her lesson was relating MP and MM in the same lesson and added on MV to the comparison. Her lesson also gave room for students to build up knowledge on pre-existing knowledge, the part and whole concept. Using this foundation, the learners were required to deduce a formula to solve numerical problems. The students were provided an opportunity to think based on their understanding of the comparison of concepts in order to deduce a formula. The memory network structure shows closed structures inter-relating concepts. However, MV was an addition to the lesson on the second day. Therefore, some of them were unable to link MV to the other concepts.

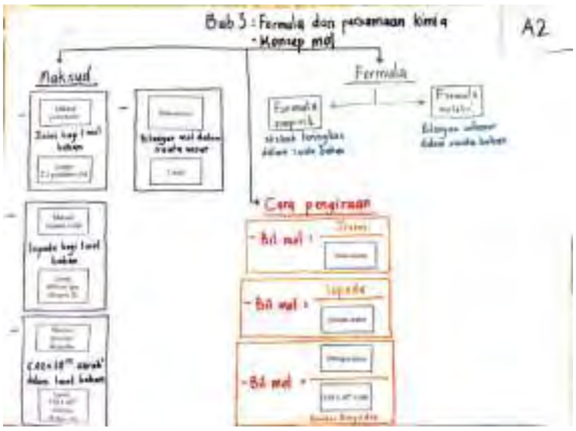
The lesson structure of both teachers were compared with the knowledge acquired on mole concept by their respective students.

The mind maps of the research participants

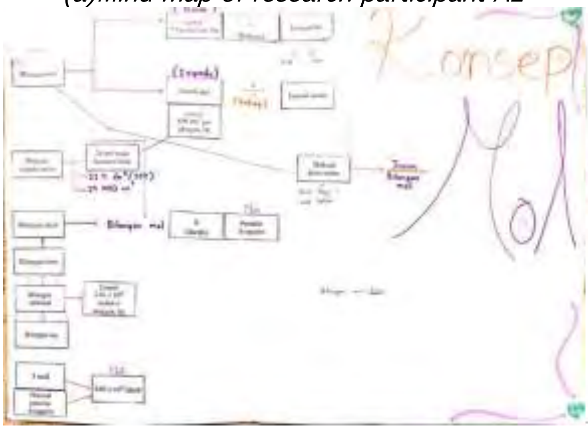
The mind maps generated by students of Anna are shown in Figure 6 below whereas that of Bella's students are shown in Figure 7.



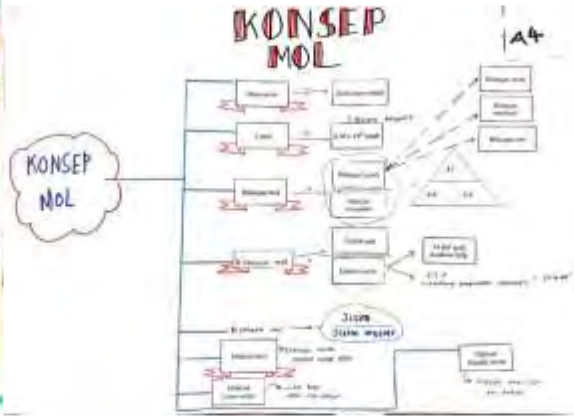
(a)Mind map of research participant A1



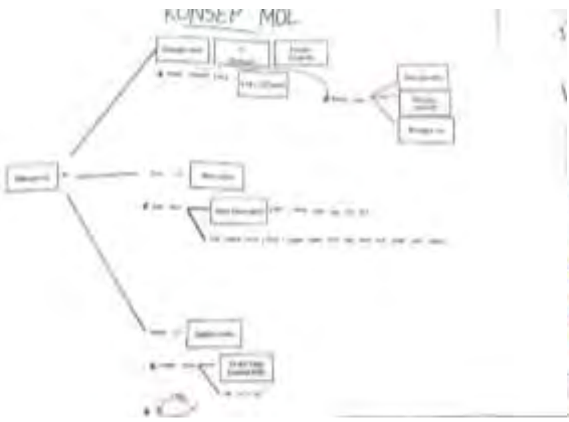
(b)Mind map of research participant A2



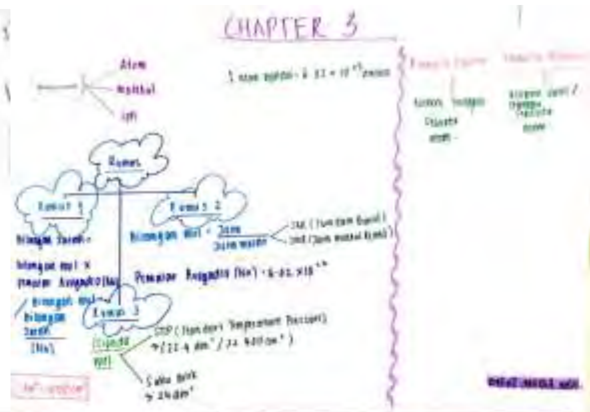
(c)Mind map of research participant A3



(d)Mind map of research participant A4

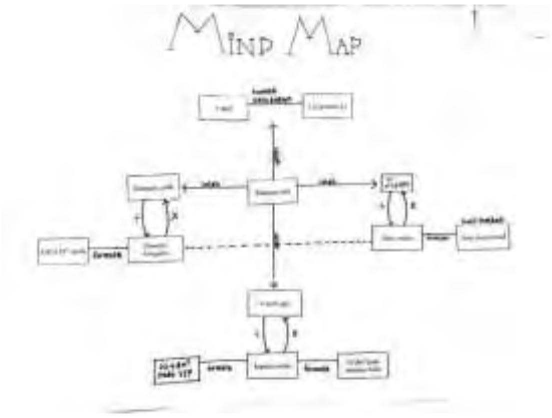


(e)Mind map of research participant A5

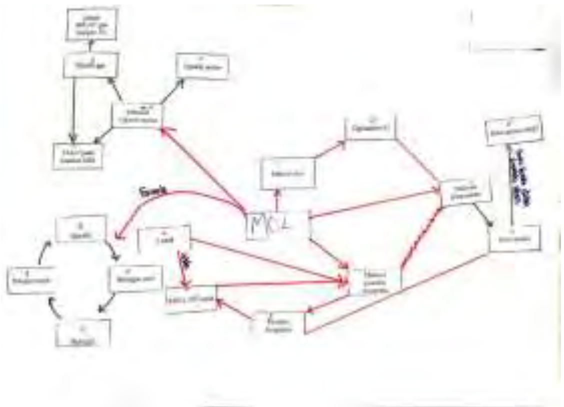


(f)Mind map of research participant A6

Figure 6. The mind maps of research participants who were students of Anna

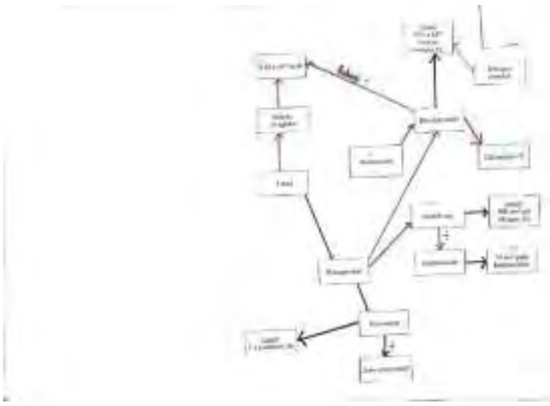


(a)Mind map of research participant B1

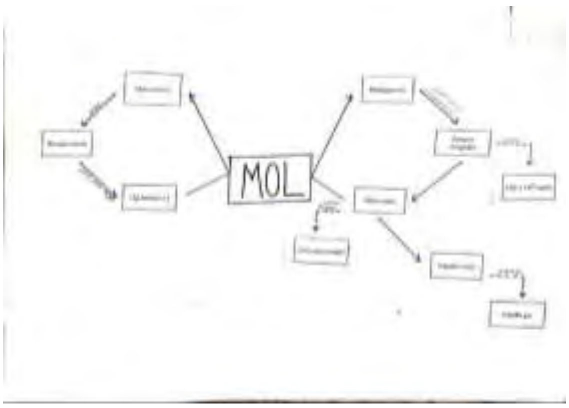


(b)Mind map of research participant B2

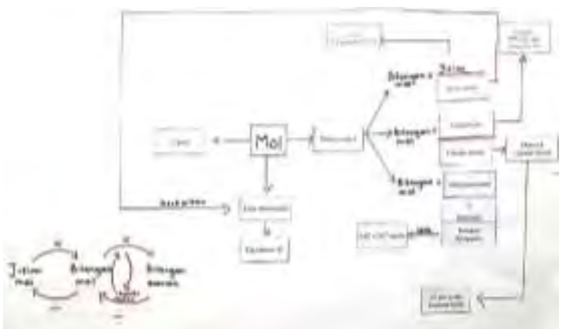
(a)Mind map of research participant B3



(b)Mind map of research participant B4



(a)Mind map of research participant B5



(b)Mind map of research participant B6

Figure 7. The mind maps of research participants who were students of Bella

Mind Map Analysis

Based on the data analysis procedure for the students' mind map (refer Table 1), there are three types of memory network emerged, which are the hierarchical memory network, interconnected memory network and non-strictly hierarchical memory network. Research participants A1, A2, A3, A4, A5, A6, B1 and B6 showed the HMN. For example, research participant A5 has three branches from "number of moles". It has a typical fan structure as discussed in the CMSP. Research participants B2, B3 and B5 have displayed the IMN. For example, B3 has shown links that are inter-relating between "number of particles", "volume of gas" and "mass of substance". However, there is also one participant, B4, who portrayed a non-strictly hierarchical memory network, having a fan structure but one of its branch has a closed structure. B4 was able to relate "number of particles" to "mass of substances". The variation in memory network structure shows different organisations of knowledge constructed in the mind from their learning experience in the classroom.

Table 1
Summary of analysis of Mind Maps on mole concept

Teacher	Research Participant	*n* (number of nodes)	*m* (number of links)	Comparison of values of *n and m*	Type of memory network
Anna	A1	12	10	$n > m$	Hierarchical
	A2	23	22	$n > m$	Hierarchical
	A3	22	17	$n > m$	Hierarchical
	A4	23	21	$n > m$	Hierarchical
	A5	14	13	$n > m$	Hierarchical
	A6	25	18	$n > m$	Hierarchical
Bella	B1	19	14	$n > m$	Hierarchical
	B2	18	21	$m > n$	Interconnected
	B3	20	25	$m > n$	Interconnected
	B4	16	16	$n = m$	Non-strictly hierarchical
	B5	11	12	$m > n$	Interconnected
	B6	16	13	$n > m$	Hierarchical

The values of ($n>m$) shows HMN structure, with a greater number of nodes than links, whereas the values of ($m>n$) shows IMN structure, with more links than nodes. However, one student of Bella had shown the values ($n=m$) with same number of nodes and links. This relationship shows more links than the general formula of HMN according to CMSP, which is ($m=n-1$) (Klimesch, 2015). Therefore, it is further analysed based on its layout and number of closed structures within the mind map. Firstly, further analysis was done on the presence of links between the smaller concepts within one big concept of mole, which are "moles and particles" (MP); "moles and mass" (MM) and "moles and volume" (MV). Table 2 below shows the presence of links between the smaller concepts MP, MM and MV.

Table 2
Presence of links between concepts in the mind maps of the research participants

Link between concepts	Presence of links for research participants											
	Teacher A						Teacher B					
	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6
Mole → Particle	/	/	/	/	/	/	/	/	/	/	/	/
Mole → Mass	/	/	/	/	/	/	/	/	/	/	/	/
Mole → Volume of gas	/	/	/	/	/	/	/	/	/	/	/	/
MP→ MM							/	/		/		
MP→ MV									/			
MM→ MV									/		/	

All the research participants of Anna were able to link "number of mole" to the three concepts respectively but not able to inter-relate the three concepts to one another. On the contrary, four of Bella's research participants showed more interconnection between the smaller concepts. B3 was not able to link between MP and MM but was able to link all the others. B4 was able to link all except MP and MV whereas B5 was unable to link MP and MM. The mind maps were then analysed in terms of presence of closed structures within the map as displayed in Table 3.

Table 3
Number of closed structures present in each mind map

Research participants of Anna	Closed structures within the mind maps	Research participant of Bella	Closed structures within the mind maps
A1	Nil	B1	1
A2	Nil	B2	7
A3	Nil	B3	6
A4	Nil	B4	1
A5	Nil	B5	2
A6	Nil	B6	1

The analysis shows that Anna's research participants did not show any closed structures within their mind map. There was a similarity between all six research participants of hers where all showed three main branches from the main node, "number of moles". Each branch represented the formula relating mole to each concept ("number of particles", "mass of substance" and "volume of gas"). Bella's research participants had closed structures within the mind, with a minimum of one, shown by B1, B4 and B6. Most number of closed structures were displayed by B2 and B3, with seven and six closed structures, respectively.

DISCUSSION

The results revealed that all of Anna's research participants had HMN whereas, those under Bella had a mix of both HMN and IMN among the research participants. Anna's students were not able to relate the three concepts, "number of particles", "mass of substances" and "volume of gas", to one another. They did not show any closed structures as a relationship between concepts. The analysis shows that Bella's students were able to relate concepts represented by the closed structures.

These findings indicate how the students have constructed their knowledge on mole concept in the form of memory network as a result of different learning experiences provided by their respective teachers. Anna imparted each concept, "number of particles", "mass of substances" and "volume of gas" one after another, although she tried to relate them as one big concept of mole. When the concepts are taught as three separate lessons, though sequentially, students tend to show a hierarchical memory network, with three separate branches, one for each concept. Bella imparted the lesson by introducing two of the concepts simultaneously by comparing both, then gradually adding on the third. This learning experience showed more interconnectedness between concepts. Therefore, Bella's students were able to relate the concepts, though not all, but relatively more than students of Anna.

How students perceive a concept is how they embed it in their mind in the form of a mental image via mental processing. It might indicate how the teacher presents the concept in the classroom. The students of both teachers showed a difference in the structure of the mind map as the representation of their mental image in the form of memory network corresponding to their learning experiences. The findings of this study indicate how the memory network is embedded similar to the flow and nature of the lesson planned by their teachers. Hence, it is important for teachers to relate concepts in a well-planned lesson to enable students to enhance their understanding by relating concepts.

A concept that embarks on pre-existing knowledge has a stronger foundation based on the constructivist approach. Bella introduced the abstract concept of Avogadro's constant using the analogy of dozen already known by the students. Furthermore, the concept was built on "part and whole" method of calculation by Bella to enable her students to use their prior knowledge to build up new knowledge. In contrast to that, Anna used the analogy cells in the body to particles. Although it was embarked on prior knowledge, but it was not an aid to develop the meaning of the new concept of Avogadro's constant. Moreover, Anna was more dependent on the usage of the new formula introduced as a tool to solve numerical problems on the concept. Anna gave more time for them to apply the formula in contrast to Bella who showed an element of constructivism in her lesson. The start of a new lesson is important too in determining how the memory network is constructed in order to be able to relate concepts and understand it better.

In order to enhance conceptual understanding, sufficient time should be provided for the mental processing in order to form a mental imagery of a concept that can be related to other memory network in the brain. Bella encouraged her students to think of how the concept introduced can be related by asking them to deduce a formula. However, this was done collectively in a classroom and she claimed that some were able to deduce a formula. This scenario enabled only some students to verbally participate but not all had shown the thinking process. Opportunities for mental processing requires more time as every student has a different rate of mental processing as well as different way of transforming information to knowledge (Cardellini, 2014; Sim & Arshad, 2015). The scenario was more teacher-centred and unable to trace the progress of each student in the classroom. Furthermore, Bella taught the concepts in a parallel manner but compressing it into only two lessons. As a result of the time limitation, more time was allocated for the problem solving and relatively less time for their mental processes to construct the memory network by relating concepts. If the conceptual understanding is developed by learners at their own pace, the concepts have stronger foundation and one can apply the knowledge in new situations.

The lesson planned by the teacher is the learning experiences for students to transform information into knowledge. The information provided by the teacher is a set of stimulus to enable students to acquire knowledge from the lesson Paivio (1969). Both teachers imparted the lesson using the whiteboard focusing on numbers related to the concept mainly during their mental processes. Hence, the type of stimulus received by them is confined to visual stimulus of numbers and name of substances seen on the whiteboard as well as auditory stimulus of teachers' explanations heard (Cui, Popescu, Adamo-Villani, Wagner, Duggan, & Friedman, 2017). The Piagetian theory describes how the mental imagery formed is based on the experiences encountered by a learner. In order to strengthen the foundation of their knowledge to be constructed, teachers should vary the type of stimulus to represent the concept imparted. Furthermore, the lesson should be made more interesting to engage students into the lesson with more interest (Gafoor & Shilna, 2015). The development of technology has enabled animations of the unseen particles as well as to present lesson with more impact using projectors and audio. Teachers can use these to relate the concepts with appropriate visual that aid to strengthen their mental imagery of the concept. Thus, it is in the hands of teachers to organise the lesson on how they want the memory network structure to be embedded in the brain of students.

CONCLUSION

The findings of this study are limited to the structure of knowledge on mole concept embedded in the mind of learners in the form of memory network via mental processes. It is dependent on the learning experiences the students experienced during the lesson. There are two implications derived from the findings of this study. First and foremost, the results show that imparting knowledge simultaneously for the three concepts, "number of particle", "mass of substance" and "volume of gas" enables learners to relate concepts better. It enables learners to see the relationships between smaller concepts that make up the bigger concept of mole, as one entity. The relationships between concepts show a better understanding of the concept (Klimesch, 2015). Secondly, the usage of pre-existing knowledge such as "part and whole concept" to solve simple numerical problems enabled students to construct their own understanding on problem solving for mole concept. The learners were given thinking opportunities using their prior knowledge to build up new knowledge showing more interconnectedness between concepts rather than introducing the formula via a set of steps to solve numerical problems. This enabled the mental processes of learners to construct the concept for the mathematical part of mole concept.

Therefore, it can be concluded that the role of a teacher is crucial in ensuring the important elements that are the bricks of building up knowledge among learners. Understanding how students have transformed the learning experience into knowledge will enable teachers to be able to plan appropriate strategies to impart the lesson on mole concept with conceptual understanding. The results of the study will give light to researchers on future studies to address the problem in other possible ways.

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