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# *Class Map*: Improving Students' Skills of Organic Synthesis in Learning Organic Chemistry for Pre-University Students

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## Abstract

This action research uses the Kemmis & Mc Taggart Model (1988) to improve the skills for science stream of pre-university students in organic synthesis topic to convert one functional group to another by using *Class Map* in learning Organic Chemistry. The objectives of this study were to improve memory skills in conversion of functional groups in an Organic Chemistry reaction and to cultivate students' interest in the subject of Organic Chemistry. A total of six students of 6 Delta 2, SMK Sultan Abu Bakar were involved in this study. Preliminary surveys were conducted through observations, document analysis and interviews. The results of the survey showed that students could not remember the conversion of functional group well because in the Semester Three chemistry syllabus, there are too many chemical reactions, causing students less interested in learning Organic Chemistry. Students were exposed to the *Class Map* within two months. The test results displayed that (i) students can recall the functional group conversion reaction in an Organic Chemistry and (ii) students can apply the organic reactions learned in answering questions. The findings of the interviews showed that students can cultivate an interest in Organic Chemistry subject.

**Keywords:** Mnemonic Loci, Organic Chemistry, Action Research, *Class Map*

## Introduction

Chemistry is one of the foundational sciences courses required for Science, Technology, Engineering, and Mathematics (STEM) undergraduate majors. Chemistry itself can be separated into organic and inorganic disciplines. Organic Chemistry course is basically offered after General Chemistry or Physical Chemistry. This course is considered as the gatekeeper for many students who find Organic Chemistry a very challenging and difficult subject (Salame et al., 2020; Schweiker et al., 2020). Synthesis organic is the first subtopic introduced for Organic Chemistry course and is widely deliberated as one of the tough topics which leads to students' low performance and motivation towards Organic Chemistry (Finkenstaedt-Quinn et al., 2020; Habig et al., 2018).

According to O 'Dwyer et al. (2012), there are three difficulties found in Organic Chemistry : (i) the content of this subject does not have algorithms to solve problems, (ii) this subject requires three-dimensional (3D) imagination and (iii) new vocabulary is learned intensively. The classification of each organic reaction is seen difficult for students. They do not have the same background as well as prior knowledge on functional group or homologous series like their teachers or the experts. This is because every reaction that occurs in organic compounds appears to be the same and students have

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difficulties even in distinguishing nucleophiles and bases (Ferguson & Bodner, 2008; Graulich & Bhattacharyya, 2017). Yet, understanding these organic reactions requires high cognitive skills especially in remembering the products produced from the reaction (O 'Dwyer et al., 2012; O 'Dwyer & Childs, 2017).

The cognitive domain plays a very crucial role in teaching and learning (T&L) of the entire instructional system of education. The cognitive domain encompasses a series of hierarchical intellectual skills that involve the procurement and application of knowledge ranging from simple recall (remembering) to the ability in evaluating the learning materials (Alhaji Liman & Isma'il, 2015). In reference to Bloom's Taxonomy, six levels are categorized within the cognitive domain which consists of remembering, understanding, applying, analyzing, creating and evaluating (Bloom, 1956). At the "remembering level", learners usually derive values from their ability to memorize some of the ideas received from learning as structured by Bloom, before we understand a concept, we must remember it. In relation, modern memory research clearly shows that a mnemonic can be a powerful learning tool in certain contexts, such as remembering a list of concrete objects (Bower, 1973). From a cognitive perspective, mnemonic strategies are powerful and very practical because they form an effective acoustic-imaginal link between the stimulus and response (Jurowski et al., 2016).

A mnemonic is a system of memory codes that allow humans to remember perfectly whatever they want. This technique helps humans to investigate the extraordinary storage capacity they possess and the human ability to extract whatever facts are needed (Buzan, 2003, 2018). Mnemonics are teaching or learning strategies designed specifically to enhance memory, by linking unknown information with something already known in strategic ways that aid in memory. This may indicate that this mnemonic technique is very practical to be applied especially for remembering chemical facts (Scruggs et al., 2010). However, mnemonic tools are not teaching methods when there have also been proven that a mnemonic can be used as a strategy to enhance science learning when the curriculum involves a lecture, textbook format or hands-on, as well as inquiry learning format (Jurowski et al., 2016; M. A. Mastropieri & Scruggs, 1998; Scruggs et al., 2010). Bower (1973) had argued that mnemonics were designed to enhance recall, not to promote higher order learning. It has been even emphasized that education still requires a great deal of fact learning, which mnemonics can help with. Substantially, the preeminent task of mnemonic strategies to be implemented in classroom is to find an effective and accessible way to connect the new information to some information which are already locked in students' long-term memory according to the familiarity of the term used (Jurowski et al., 2016). Hence, in order to make sure the memory will last in a very long time, strong connections between the links must be precisely and jointly implemented. Thus, Mnemonics of Loci (MoL) is revived to accomplish this aim and to respond to a recent call for research since the mnemonic cues in MoL are occasionally used in more realistic situations and familiar to students.

## *Background of study*

Referring to Semester Three chemistry syllabus of Malaysian Higher School Certificate (commonly abbreviated as STPM), the whole topic in Organic Chemistry emphasizes a lot on the reactants and products of an organic reaction. Each chapter contains subtopics to synthesize the functional group and convert one functional group to another as well. In fact, each of these subtopics is interrelated with each other. Previous studies (Dani Asmadi Ibrahim et al., 2015; Finkenstaedt-Quinn et al., 2020; Galloway et al., 2017; Graulich, 2014; O 'Dwyer & Childs, 2017) have evidently identified that Organic Chemistry is the most difficult subject compared to other chemistry subjects especially for novice students. In the study of Salame et al. (2020), they found that students struggle with synthesis problems due to several factors such as lack of effective problem-solving methods, no appropriate approach to construct the correct reaction mechanism, and misconceptions in understanding the concept of Organic Chemistry. Through observations, interviews and document analysis conducted by researchers during teaching and learning of Organic Chemistry lesson, there were several problems faced by students in the mastery of this subject; (a) Students were unable to apply the organic synthesis learned while answering questions; (b) Students were not interested to learn Organic Chemistry; and

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(c) Students were unable to recall each functional group conversion reaction in an Organic Chemistry reaction.

Through authors' personal observations conducted in the early stages of teaching for the topic of hydrocarbon compounds, students could still follow each content of the lesson. However, upon entering the next functional groups such as alcohol, carbonyl, carboxylic acids and its derivatives, the students had begun to lose focus and were confused when the teacher had started teaching because they were burdened with too many chemical reactions. Through the analysis of the students' module, it was found that students could simply answer questions involving alkanes and alkenes but could only answer part of the questions involving haloalkane, alcohol, carbonyl, and derivatives of carboxylic acid topics since the questions became more complex and might need a longer waiting time. On the other hand, through the analysis of mind maps document of students provided by teachers, they had been able to build mind maps for the topic of alkane, alkene and some haloalkane but for the topic of alcohol, carbonyl and derivatives of carboxylic acids, the majority of students could not write the functional group conversion correctly. They even left them blank.

Students were unable to apply the synthesis organic learned while answering questions. Through the document analysis of students' worksheets, the researchers found that the students misjudged the products produced and could not state the conditions of reaction. For instance, temperature, catalyst, and pressure. Students could answer questions that required only one step but could not answer questions involving functional group conversions that have more than one step. Due to heavy syllabus with shorter time allocated in every semester for pre-university curriculum, they do not have enough time to memorize each specific chemical reaction. The researchers regularly hear the complaints from students. The followings were excerpts from students:

*"There were so many things to remember teacher. How do we remember for all the reactions? I prefer chemistry semester one (physical chemistry)"*

According to the redundant of organic reactions in semester three syllabus, the students are not interested in Organic Chemistry. Based on the researcher's interviews on eight students, they lost interest because it was difficult to memorize each chemical reaction for each functional group. Notably, two of the students expressed interest in Organic Chemistry while the rest were not interested in this subject and preferred Physical Chemistry. This is because every single organic reaction needs to be memorized. Some of the students simply copied the notes without fully understanding what was written. Considerably, empirical studies spanning several decades have proven for centuries the anecdotal praise for the effectiveness of MoL in improving mnemonic memory (Bower, 1973; Mccabe, 2015; Twomey & Kroneisen, 2021). The purposes of this study are:

i. Students can recall the functional group conversion reaction in an Organic Chemistry
ii. Students can apply the organic reactions learned in answering questions.
iii. Students can cultivate an interest in Organic Chemistry subject

## Literature Review

MoL or memory palace is one technique among various types of existed mnemonics to improve students' skills in recalling facts and transferring them into problem-solving related to the subject studied that allows fast, sequential memorization of a large amount of information (Liu et al., 2019; Qureshi et al., 2015). MoL applies spatial relationships between 'loci' or locations that are familiar to an individual such as a room or entrance to a building or house. According to Blunt and VanArsdall (2021), MoL is a mnemonic technique which involved structured encoding and recalling processes to the powerful imaginary component or well-known route to create an easy memory palace and take a mental walk through the route to retrieve the remembered list (Blunt & VanArsdall, 2021; Mccabe, 2015). In addition, MoL which is known as memory palace has been used since thousands of years ago to help remember facts or speeches based on the surrounding environmental space (Qureshi et al., 2015).

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The MoL technique is a memory system that can encode, store, identify, assimilate and recall (Madl et al., 2015). As highlighted by Qureshi et al., (2015) who studied the effect of MoL techniques on student achievement in endocrinology, MoL can assist in student learning by: (i) Helping students to build new concepts (ii) Assisting students in building self-study skills and (iii) Providing a very integrative learning tool. Therefore, the application of MoL in Organic Chemistry can help students to remember and describe each reaction of organic compounds easier. The process of generating images or visualizations requires students to master information processing skills which include the process of receiving verbal stimuli, storing information and the process of recalling (Roszelina Abd. Rahman & Maria Salih, 2014). According to Roszelina Abd. Rahman and Maria Salih (2017), there are three patterns of visualization that students show in understanding the concept of abstract: (i) generate visualization from word to word, (ii) word to picture and (iii) picture to picture. This visualization is the result of students' mental picture of a given abstract concept or problem whereas the mental image can be expressed as an image formed in the individual mind spontaneously as the result by past experiences (Abdul Rahim & Sulaiman, 2006; Ibrahim & Rebello, 2013; Prokhorov et al., 2018).

Several studies (Caplan et al., 2019; Kurniarahman, 2019; O'Grady & Yildirim, 2019; Sandberg et al., 2021) have shown beneficial effects of MoL since mnemonics can make difficult things become more explicable even for boosting to long-term memory. Bellezza and Reddy (1978) concluded that the use of familiar cues for loci leads to better recall performance compared to unfamiliar set of loci. Familiar loci allow them to be used as retrieval cues and strengthen the episodic memory. Most previous studies have controlled lab studies to establish the effectiveness of MoL (Ikei et al., 2007; O'Grady & Yildirim, 2019; Peeters & Segundo-Ortin, 2019) and also reported an initial mental effort when loci are created (Bower, 1970; Caplan et al., 2019).

In 1970, Bower published a paper in which he identified nine distinct components that contributed to mnemonic of loci effects whereas mental creation of locations was essential for the mnemonic's effectiveness. As highlighted by Kurniarahman (2019), the effects of the mnemonics loci technique on student's vocabulary memorization towards repetition technique had been investigated. The findings revealed the fact that MoL was more effective than repetition technique. Other studies by quantitative empirical investigations of mnemonic strategy have indicated similar positive learning outcomes for students across grade levels, experimental settings, and subject matter content (Balbuena & Buayan, 2014; Maghy, 2015; Mccabe, 2015). Moreover, recent studies interestingly have reported the explicit MoL strategy presented by virtual memory palaces and Augmented Reality (AR) technology (Huynh et al., 2019; Lim & Lim, 2020; Schneider et al., 2020; Vindenes et al., 2018).

## Methodology

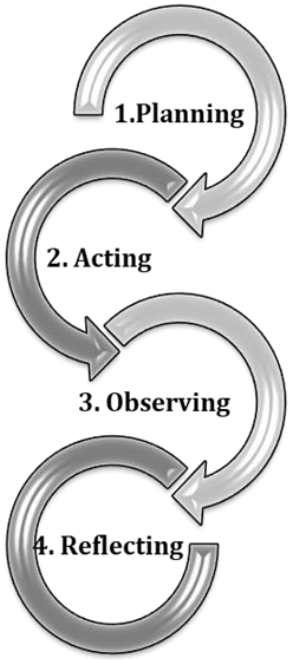
### *Research Design*

To implement this action research, the researchers have used the action research model founded by Kemmis and McTaggart (1988) which describes a design in the implementation process of action research. The figure below is a Kemmis and McTaggart action research model that consists of the process of planning, acting, observing, and reflecting.

The study used document analysis to review and analyse printed or electronic documents that have been reached by the researchers on this subject (Bowen, 2009). Document analyses were carried out on students' *Class Map* (proposed memory palace) given at the end of every T&L session. Students built the *Class Map* to track their memory after the intervention was given. After two months of intervention, students answered the Achievement Test.

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Figure 1: Action Research Process (Kemmis & McTaggart, 1988)




Document analysis was again carried out on the Achievement Test to measure students' understanding in applying the *Class Map* technique on the examination questions. Right after answering the test, interview sessions were conducted to observe students' interest in Organic Chemistry subject. The target group consisted of six students from 6 Delta 2 class which included one male and five females. The researchers conducted the study on 6 Delta 2 class because one of the researchers has taught the students, and this facilitated the observations to be made on them. In addition, this study can also help students to answer synthesized questions in determining products that are always being asked in examinations. Table 1 describes the data collection tools in this study. Throughout the research, ethical considerations were to bear in mind. The students provided a clear explanation regarding the purpose of the study, how informed the consent can actually be, and how much privacy and protection from harm had afforded them. As Creswell & Creswell (2018) specified that researcher cannot pressure participants into signing consent forms. Students were also given the freedom to withdraw anytime without penalty if they wished (Cohen et al., 2018).

Table 1: Data Collection Tool (Instrument)

| Objectives | Observation Tools (Instrument) |
|---|---|
| i. Students can recall the functional group conversion reaction in an Organic Chemistry | Document Analysis (*Class Map*) |
| ii. Students can apply the organic reactions learned in answering questions | Document Analysis (Achievement Test) |
| iii. Students can cultivate an interest in Organic Chemistry subject | Interview (Semi-structured question) |

## *Teaching Intervention*

The researcher began sketching a *Class Map* in which each furniture or item found in the classroom would represent each functional group of organic compounds. This *Class Map* is an application of the MoL technique which served as remembering methods. MoL is the researcher's proposed solution in studying synthesis organic because this technique can improve students' ability to memorize and recall

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facts, then transfer them into solving the problems of the subjects studied (Qureshi et al., 2015; Reggente et al., 2020).

In creating the personalized memory palace, students can use the *Class Map* (Figure 2), mnemonics cues (Figure 3) and the characters (Figure 4) suggested by the researchers. The researchers had used the classroom furniture as the memory palace. According to Scruggs et al. (2010) and Tullis and Qiu (2021), information can be organized by its familiarity as well as matching to the environmental and mental states at the time of retrieval, so that appropriate reconstructions will be created effectively. Meanwhile, self-generated cues help students in their long-term memory since they connect the information to their personal experience. In addition, the previous studies have shown that the combination of student-generated and teacher who created the mnemonic strategies are the best way for an effective lesson (Jurowski et al., 2016; Mastropieri et al., 2000). Figure 3 refers to the mnemonic cues constructed for this *Class Map* technique.

Figure 2: *Class Map*

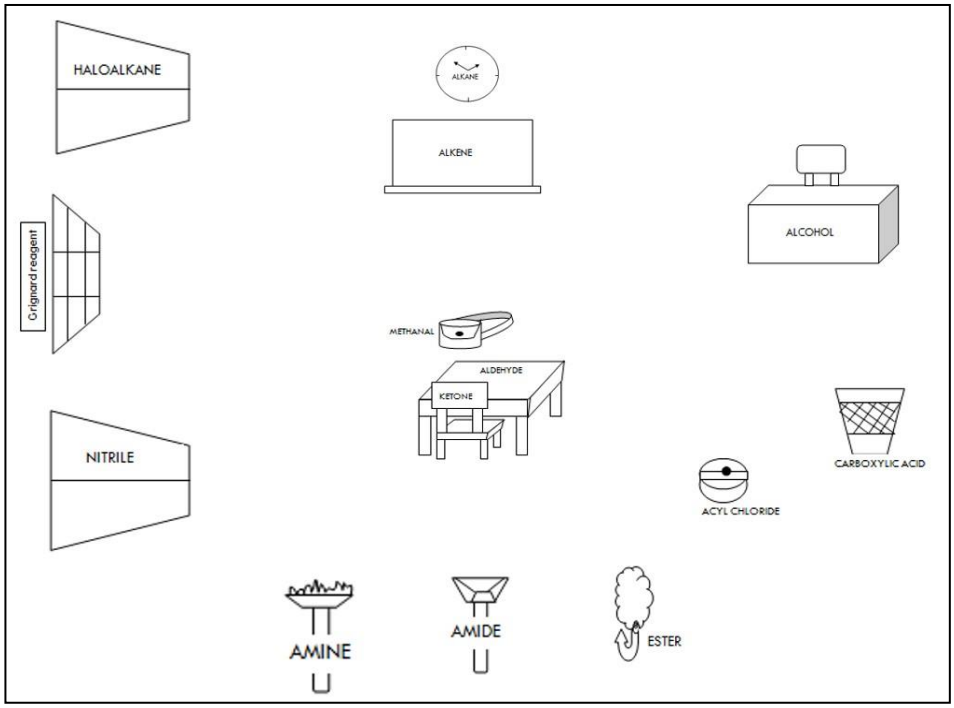



Figure 3: Mnemonic Cues

| | Mnemonic Cues | | |
|---|---|---|---|
| 1 | Alkane = clock | 8. | Ketone = students' chair |
| 2. | Alkene = white board | 9. | Methanal = school bag |
| 3. | Haloalkane = front door | 10. | Carboxylic acid = basket |
| 4. | Alcohol = teacher's table | 11. | Ester = feather duster |
| 5. | Grignard reagent = windows | 12. | Amide = dustpan |
| 6. | Nitrile = back door | 13. | Amine = broom |
| 7. | Aldehyde = students' desk | 14. | Acyl chloride = sharpener |

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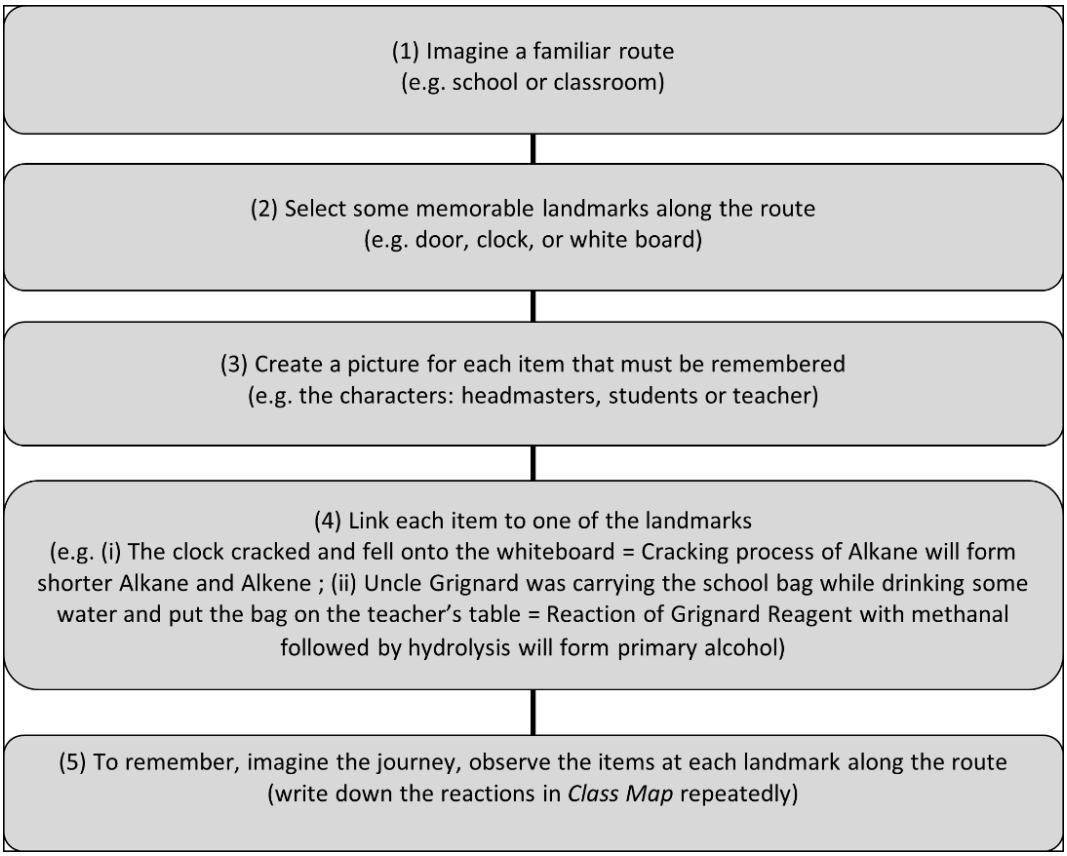
There are six characters available in this *Class Map*. Figure 4 shows the characters involved in the *Class Map*.

Figure 4: Characters in *Class Map*

| **Characters in *Class Map*** | | | |
|---|---|---|---|
| 1. | Headmaster | 4. | Miss Cleaner |
| 2. | Students | 5. | Uncle Grignard |
| 3. | Teacher Rose | 6. | Teacher Maggie |

Based on literature studies by Caplan et al. (2019), MacDonald and Dressler (2018), and Maguire et al. (2003), there are five steps that can be followed in implementing the MoL technique as shown in Figure 5 (refer Figure 2, Figure 3 and Figure 4) :

Figure 5: Steps in Implementing the MoL Technique




## Result

As a result of the implementation of an intervention using *Class Map*, students have been able to remember the functional group conversion reaction in an Organic Chemistry, students can apply the organic reactions learned in answering questions and students can cultivate interest in the subject of Organic Chemistry. The followings are the findings from this study:

### *Students can recall the functional group conversion reaction in an Organic Chemistry*

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Through the analysis of the *Class Map* document (refer Figure 6) distributed to the students, they were able to remember the organic reaction well when the number of organic reactions written by all the students was between 17 to 31 respectively (refer Table 2). Resulted numbers were more than half of the total number of organic reactions questioned (36 numbers of functional group conversions).

Figure 6: Student's *Class Map*

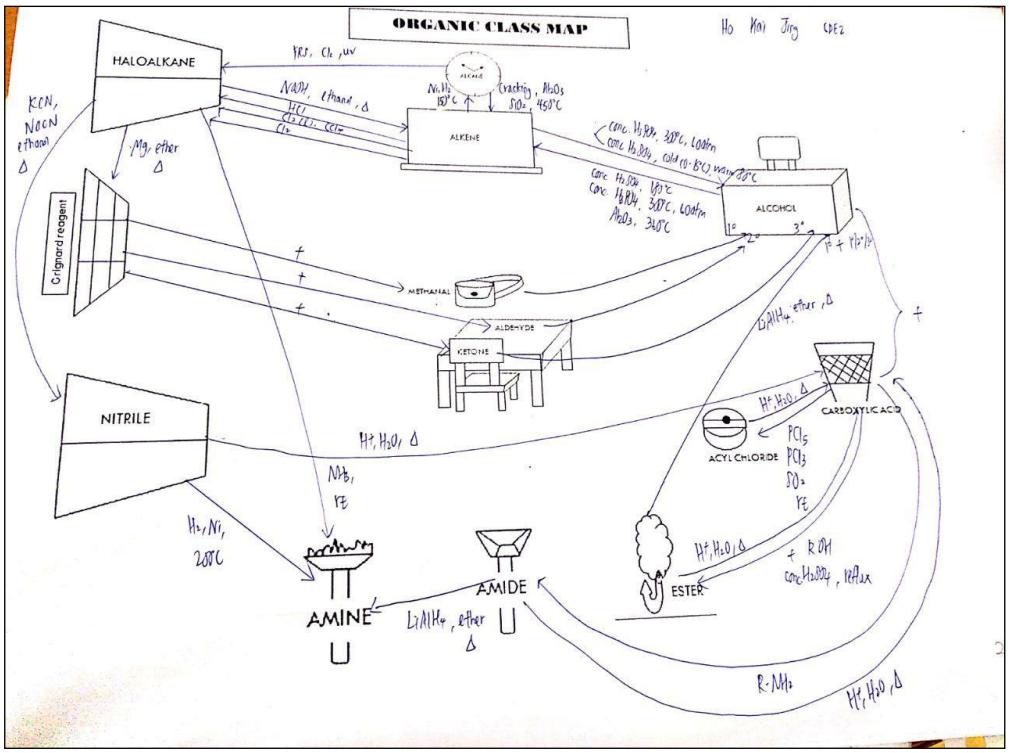



Table 2: Score for the number of organic reactions remembered in the *Class Map*

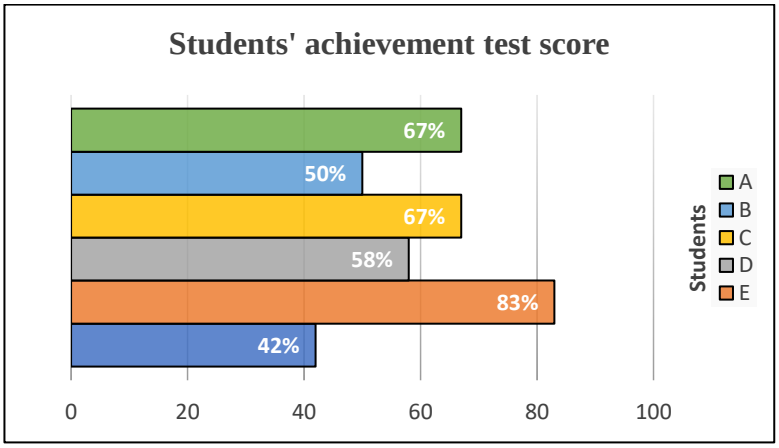
| Students | Score for students' response on the number of organic reactions for functional group conversions (Total = 36 functional group conversions) |
|---|---|
| | ***Class Map*** |
| A | 31 |
| B | 28 |
| C | 25 |
| D | 27 |
| E | 29 |
| F | 17 |

## *Students can recall the functional group conversion reaction in an Organic Chemistry*

Figure 7 shows students' achievement in a percentage form. Student E was found to obtain the highest score of 83% followed by students A and C with a score of 67% respectively. Through the analysis of Achievement Test documents given after students had received the intervention, it was found that students could apply the use of *Class Map* while answering Achievement Test questions.

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Figure 7: Achievement Test Score

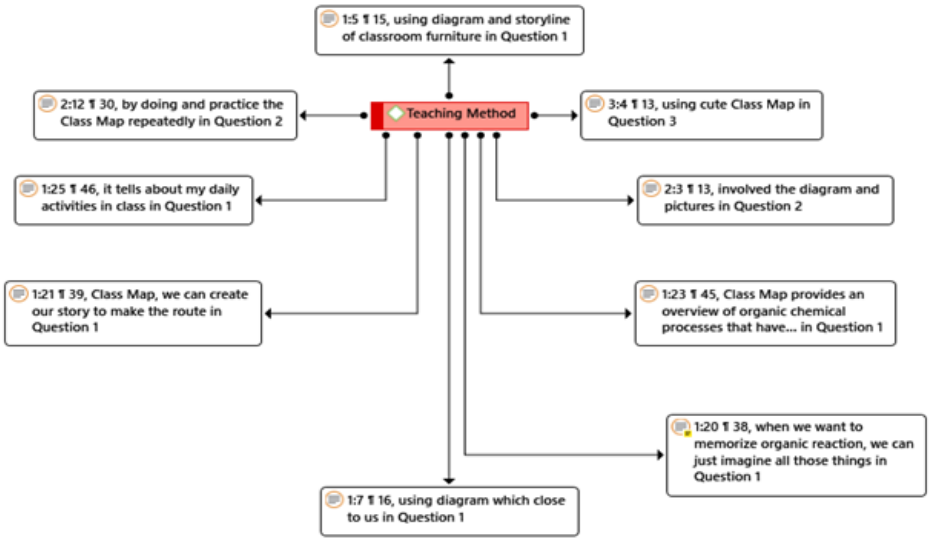



## *Students can cultivate an interest in Organic Chemistry subject*

Through the analysis of students' interviews, the researchers had constructed three themes namely teaching methods, teaching effects and feelings. The thematic analysis had used the Atlas.ti software for version 9.0. The researchers used colour codes which were teaching methods (red), teaching effects (purple) and feelings (green). Each quotation that met the theme would be code according to their appropriate theme and finally, the researchers could interpret the data to answer the objectives of the study (refer Figure 8, Figure 9 and Figure 10).

Based on the analysis of the answers from the students' interviews, all students have agreed that the use of *Class Map* can improve their memory. They have more fun and do not get bored when using *Class Map* because each storyline used is closer to them because the mnemonic cues and storylines created are related to their daily activities in the classroom. The *Class Map* technique has also attracted the students to study Organic Chemistry.

Figure 8: Data Display of Theme 1 (Teaching Method)



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Figure 9: Data Display of Theme 1 Data Display of Theme 2 (Teaching Effects/ Motivation)

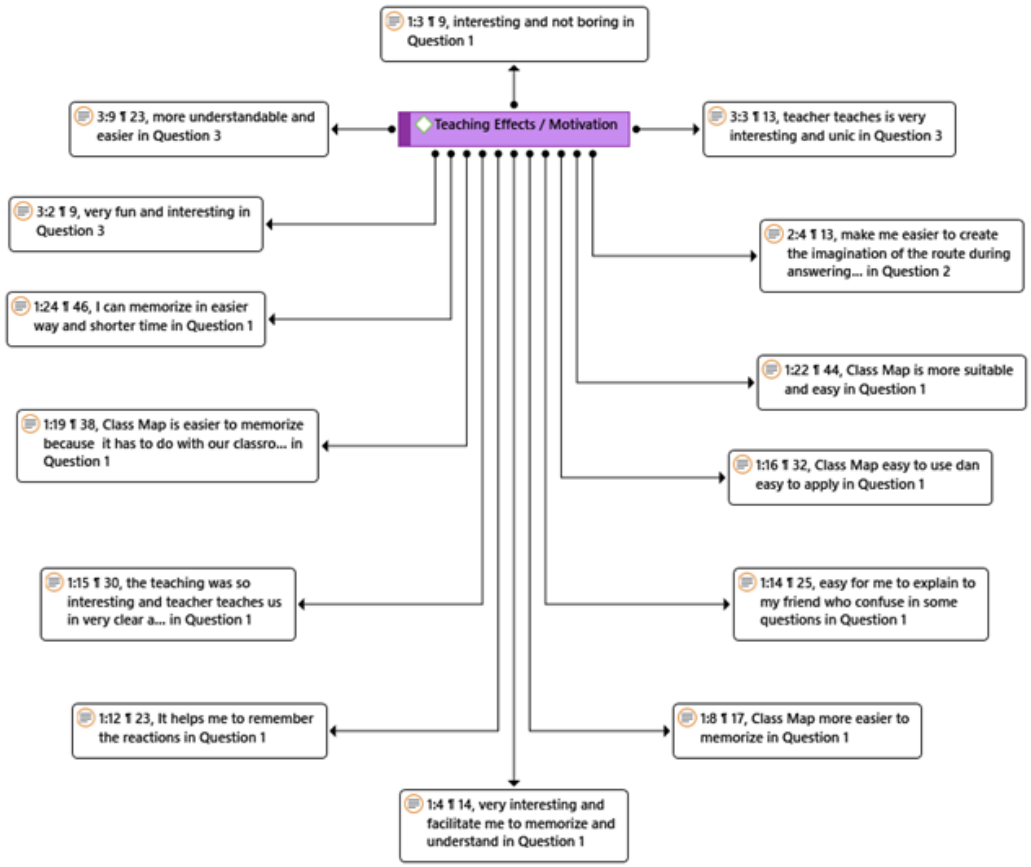
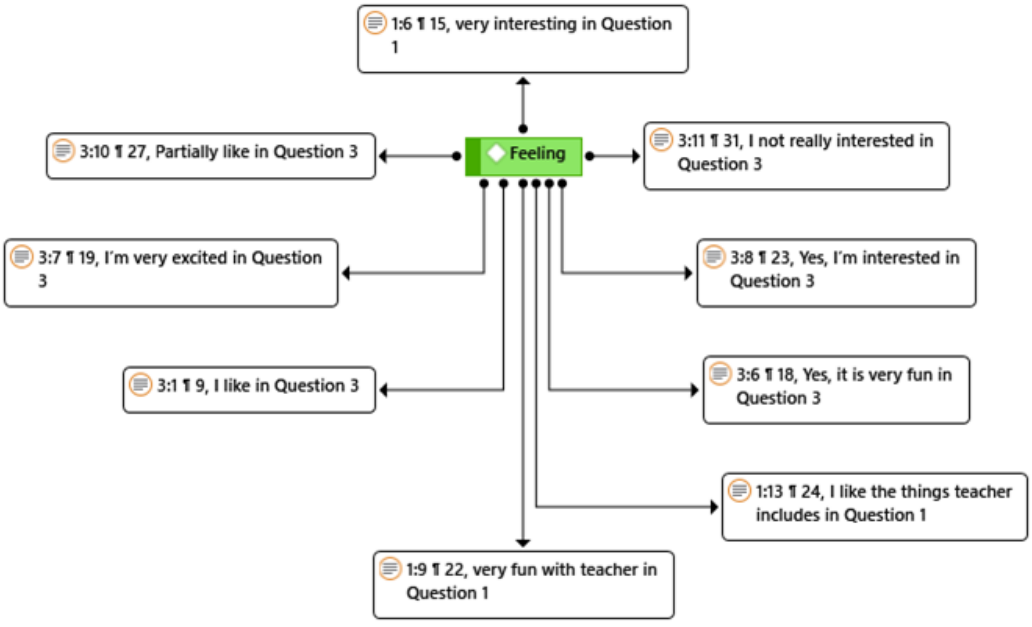



Figure 10: Data Display of Theme 3 (Feeling)




Student B said that the *Class Map* technique which uses the diagram and classroom furniture is easier to remember and understand compared to Mind Map which only contains words. Student E stated that it is easy to use the *Class Map* because they only need to imagine the objects in the classroom. Students

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A, C, D and F showed pleasure in learning using *Class Map* as they were able to remember in shorter time and this had eased the burden of students to memorize too many organic reactions. Each agreed that the *Class Map* built makes them easier to remember and cause them to pay attention in Organic Chemistry lessons.

## Discussion

### *Reflection*

As a result of the implementation of this action research, an effective impact and implications to students, teachers, T&L and the researcher own self have been gained. In terms of students, this action research has been able to help students increase their self-confidence in remembering and learning Organic Chemistry. In addition, using *Class Map* which is a diagram of the classroom's furniture makes T&L more cheerful, interesting, and exciting. Furthermore, a greater number of organic reactions can be remembered by students for functional group conversions. Students are able to create their memory palace on *Class Map* faster because the diagrams used in *Class Map* are closer to the students' environment and this makes it easier for them to build relationships with each other. Through the interview sessions, most of the students had a high interest in the use of this *Class Map*. In fact, the entire students stated that the *Class Map* had a good teaching effect on themselves in remembering organic reactions and answering questions. However, from the researchers' reflection on students' work after the *Class Map* intervention, one student was found unable to answer the synthesis question involving multistep. The student disclosed that he needed more time to familiarize himself with the storyline suggested by the teacher. Plus, he started to mix up all the stories while answering questions.

The researchers were also impressed when some students still asked about this *Class Map* even outside of T&L period. In fact, students from other classes had asked the students of class 6 Delta 2 about the *Class Map* technique because they think this method is very interesting and easy to improve their memory. The researchers are confident that *Class Map* can improve their achievement in Organic Chemistry subject as well as encourage students' interest to pay attention to Organic Chemistry which has always been a killer subject for students. The MoL as implemented in this *Class Map* also promotes self-learning among students and even easier for them to transfer information because mnemonic cues are constructed using objects that are in the student's own environment (Reggente et al., 2020; Richmond et al., 2008). Based on the action which had taken place, most students still have problems in managing self-learning since they entirely depend on the teacher's instruction to promote their active learning.

The researchers realized that the improvement of the action must be implemented. The MoL technique will be improved in the second loop of this action research by giving students the space to build their own mnemonic cues and storylines so that, it is closer to themselves yet helping them to participate in their individual learning processes. In addition, the researchers believe that students must master the reaction mechanism first before learning the organic synthesis. As the backbone of an organic synthesis, a mechanism through electron pushing formalism is able to predict a product ultimately (Bhattacharyya & Harris, 2018; Salame et al., 2020). Besides, the researchers suggest incorporating the element of self-regulated learning (SRL) to improve the intervention. With such integration, students are able to plan, implement, control and evaluate all their learning activities concurrently while using the *Class Map* since SRL can promote active learning (Alvi, 2020; Lopez et al., 2013; Silverajah & Govindaraj, 2018). Still, students need to do more training and drilling on *Class Map* to fully master the organic synthesis.

Meanwhile, the researchers can also improve their teaching practices for Organic Chemistry curriculum especially focusing on pre-university syllabus. The *Class Map* technique can also give ideas to other Chemistry teachers as an alternative method in T&L process for teaching organic synthesis. Overall, this action research has been able to improve the T&L process that should be practiced by pre-university Chemistry teachers since this subject is compulsory for the STPM science stream candidates as well as to the undergraduate students who are majoring in Chemistry, Biology, Pharmaceutical

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Sciences, Chemical Engineering, Applied Science or Public Health. Although action research cannot be generalized, in the same circumstances and situations, teachers can apply it to their respective needs accordingly.

## Conclusion

The method of teaching Organic Chemistry subjects using *Class Map* is the first method developed by the researchers. The researchers will use this method in the T&L process for years to come. In response to the first objective, students can recall the functional group conversion reactions where the *Class Map* can help them remember better. Memory palace seems a good technique to help students in expanding their working memory and accessing long term memory. Nevertheless, after using the *Class Map*, students should be provided with questions that can help them to improve their understanding and speed in answering questions.

The researchers also feel the need for a study to be conducted in developing modules for teachers and students that provide the guidelines on how to apply the *Class Map* technique effectively and systematically. The second objective which students can apply the organic reactions learned in answering questions was answered clearly when five of them could solve the questions involving one and two steps in synthesis organic accordingly. A collective of examination questions format must also be exemplified in the suggested module so that students will be familiar with the questions.

Through the *Class Map* intervention, students can also cultivate an interest in Organic Chemistry subject. Since the researchers has only scoped the initial study on the use of *Class Map* through paper, it is likely that in the future the researcher will expand the *Class Map* by creating animations to represent the storyline of each functional group. This innovation will be able to provide more positive and effective impact on students. As a result of the research conducted, the researchers found that there are positive changes in terms of teachers' teaching practices and students' learning processes. Hopefully, the results of this study can be utilized and make the T&L process more interesting, effective and fun.

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