USING MULTIPLE MODES OF REPRESENTATIONS IN ANSWERING OPEN-ENDED QUESTIONS FOR LEARNING RATE OF REACTION

BACHELOR OF EDUCATION (CHEMISTRY) WITH HONORS

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UNIVERSITI PENDIDIKAN SULTAN IDRIS

SULTAN IDRIS EDUCATION UNIVERSITY

DECLARATION OF ORIGINAL WORK

This declaration is made on the 22 February 2024.

i. Student's Declaration:

I, **Mandy Law Shin Joe, D20201093702, Faculty of Science and Mathematics** hereby declare that the work entitled **Using Multiple Modes of Representation in Answering Open-Ended Questions for Learning Rate of Reaction** is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person.

Mandy Law Shin Joe

ii. Supervisor's Declaration:

I, Nilavathi A/P Balasundram, hereby certifies that the work entitled **Using Multiple Modes of Representation in Answering Open-Ended Questions for Learning Rate of Reaction** was prepared by the above name student, and was submitted to the Institute of Graduate Studies as a full fulfilment for the conferment of Bachelor of Education (Chemistry) (Hons), and the aforementioned work, to the best of my knowledge, is the said student's work.

Date | **Nilavathi A/P Balasundram**

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ABSTRACT

Students often struggle with understanding the rate of reaction due to traditional teaching methods and a technology integration gap. This study aims to evaluate Form 4 students' ability to use Multiple Modes of Representation (MMR) in answering open-ended questions and their conceptual understanding of the rate of reaction. The research employed a quasi-experimental approach with a One-Group Pretest-Posttest Design, involving 107 Form 4 science stream students randomly selected from four intact classes. The study utilized understanding test and MMR rubric, consisting of pre-test and post-test. Instrument validity achieved an 80% agreement, while Intraclass Correlation Coefficient yielded a reliability score of 0.869. Data were collected and analysed descriptively and inferentially. After analysis, null hypothesis one (H_{01}) and two (H_{02}) were successfully rejected. This shows that there were significant differences in the mean of MMR scores in answering open-ended questions for the pre-test and post-test, where the t-value = -71.444 and $p = 0.000 < 0.05$. Likewise, there were also significant differences in the mean of understanding score in answering open-ended questions for the pre-test and post-test, where the t-value = -52.813 and $p = 0.000 < 0.05$. In conclusion, this study shows that using Multiple Modes of Representation in answering open-ended questions improves students' understanding of reaction rate. The implications of using Multiple Modes of Representation in answering open-ended questions help students to connect different concepts of rate of reaction, and enhance their understanding. It also diversifies teaching strategies for teachers in the classroom.

Keywords: Multiple Modes of Representation, Open-Ended Questions, Rate of Reaction

PENGGUNAAN PELBAGAI JENIS MOD PERWAKILAN DALAM MENJAWAB SOALAN TERBUKA BAGI PEMBELAJARAN KADAR TINDAK BALAS

ABSTRAK

Pelajar sering menghadapi kesukaran dalam memahami konsep kadar tindak balas, disebabkan oleh kaedah pengajaran tradisional dan jurang integrasi teknologi. Kajian ini bertujuan untuk menilai keupayaan pelajar dalam menggunakan Pelbagai Jenis Mod Perwakilan (MMR) dalam menjawab soalan terbuka dan pemahaman konsep mereka dalam kadar tindak balas. Kajian ini menggunakan reka bentuk kuasi-eksperimen jenis ujian pra dan ujian pasca kumpulan tunggal, dengan melibatkan 107 pelajar Tingkatan 4 aliran sains yang dipilih secara rawak dari empat kelas tanpa dipisahkan. Kajian ini menggunakan ujian pemahaman dan rubrik MMR, yang merangkumi ujian pra dan ujian pasca. Kebolehpercayaan instrumen dalam kajian ini mencapai persetujuan sebanyak 80%, manakala Koefisien Korelasi Intra-kelas menunjukkan nilai 0.869. Data dikumpul dan dianalisis secara deskriptif dan inferensial. Selepas analisis, hipotesis nul satu (H_{01}) dan hipotesis nul dua (H_{02}) berjaya ditolak. Ini menunjukkan terdapat perbezaan yang signifikan antara skor min MMR dalam menjawab soalan terbuka antara ujian pra dan ujian pasca, di mana nilai $t = -71.444$ dan $p = 0.000 < 0.05$. Begitu juga, terdapat perbezaan yang signifikan antara skor min pemahaman dalam menjawab soalan terbuka antara ujian pra dan ujian pasca, di mana nilai $t = -52.813$ dan $p = 0.000 < 0.05$. Kesimpulannya, kajian ini menunjukkan bahawa penggunaan MMR dalam menjawab soalan terbuka dapat meningkatkan pemahaman pelajar terhadap kadar tindak balas. Implikasi penggunaan MMR dalam menjawab soalan terbuka membantu pelajar menghubungkan konsep-konsep berbeza dalam kadar tindak balas, dan meningkatkan pemahaman mereka. Ia juga mempelbagaikan strategi pengajaran untuk guru di dalam bilik darjah.

Kata Kunci: Pelbagai Jenis Mod Perwakilan, Soalan Terbuka, Kadar Tindak Balas

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LIST OF ABBREVIATION

MMR	Multiple Modes of Representation
MOE	Ministry of Education
WTL	Writing-to-learn
IGCSE	International General Certificate of Secondary Education
SPM	Sijil Pelajaran Malaysia
EFL	English First Language
CLT	Cognitive Load Theory
SPSS	Statistical Package for the Social Sciences
ICC	Intraclass Correlation Coefficient
ERPD	Education Research and Planning Division
JPNNS	Jabatan Pendidikan Negeri Sembilan

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CHAPTER 1

INTRODUCTION

1.0 Introduction

Studies in science education for over the past two decades have focused intensively on the role of language, and increasingly the languages of science, to understand how to deepen student engagement and learning in this subject. Norris and Phillips (2003) ever stated that science, without language (writing, reading, speaking), cannot function. This claim is related to one of the elements in the Malaysian 21st-century education that emphasis on the mastery of effective communication skills (Osman et al., 2010). To keep students up with the rapidly changing times, it is crucial to incorporate innovative and effective teaching techniques that enhance student in communicating in science and science discourse (Tan, 2021).

Effective communication in science is of paramount importance as it enables students to engage deeply with the subject and enhances their learning experiences. This is especially important because scientific concepts and ideas can be complex and abstract, making effective communication essential for students grasp these concepts more easily. When students are able to effectively communicate their understanding of scientific principles, it increases the likelihood of them developing a deeper comprehension of the subject matter (Osman et al., 2010).

Building upon the significance of effective communication, the purpose of this study is to evaluate students' ability to embed Multiple Modes of Representation (MMR) in answering open-ended questions on learning rate of reaction with the aid of *'Popplet' application*. Additionally, this study seeks to measure students' conceptual understanding in rate of reaction by embedding MMR in open-ended questions.

1.1 Background of the Study

In Malaysia's curriculum, the topic rate of reaction is studied by Form 4 science stream students. This topic is important because it helps them to understand the speed at which chemical reactions occur (Houston, 2012). By studying the rate of reaction, students gain insights into the factors that influence reaction rate, such as temperature, concentration, reactant size, and the use of catalysts (MOE, 2018). Understanding these factors is crucial for predicting and controlling chemical reactions in various contexts. The topic of rate of reaction is interconnected with other topics within chemistry and has links to other subjects as well. Within chemistry, the concepts learned in the study of rate of reaction are related to topics such as redox equilibrium, thermochemistry, and chemical equilibrium (Peters, 2017). Therefore, it is essential for students to possess prior understanding of the prerequisites concepts before engaging in another topic (Effendy, 2002).

There is limited research available regarding improving students' understanding on rate of reaction concepts. Fahmi and Irhasyuarna (2017) conducted a study investigating misconceptions related to rate of reaction among high school students in Banjarmasin. The study aimed to identify common misconceptions students had regarding reaction rates and understand the extent of these misconceptions. The specific misconceptions examined could include misconceptions related to concentration, temperature, catalysts, and surface area. However, there is no specific ways stated to improve students' understanding in this topic.

One teaching strategies to enhance students' science communication and to clarify abstract concepts in rate of reaction is by using MMR. Numerous studies have indicated that the appropriate integration of MMR in teaching chemistry can enhance students' conceptual understanding of rate of reaction topic. In addition, it provides insights into how they interpret and apply these modes to represent concept in rate of reaction topic (Ardac & Akaygun, 2004; Chandrasegaran, Treagust, & Mocerino, 2007, 2008; Sanger, 2000; Stieff, Hegarty, & Deslongchamps, 2011; Tasker & Dalton, 2006). The multiple modes embedded to represent concepts throughout this topic include text, symbols, tables, graphs, chemical equations, and mathematical equations. Research done by Gunel, Hand, and McDermott (2009) also provides evidence of a positive relationship between embeddedness of MMR in written products and students' conceptual understanding. To show evidence that MMR can improve students' conceptual understanding, a study done by Al Kamli (2018) proved that students who embed MMR in writing has higher mean score in pre-test and post-test than those who did not use. According to the chart done by Al Kamli (2018), students from experimental group score 84.035% while students from control group scores 74.549% in the total score on post-test. From this finding, it is believed that MMR can help students to manage information explicitly and therefore, students' conceptual understanding will be enhanced.

There is indeed limited research specifically focused on activities to encourage the use of MMR in the classroom context. However, a study by Nixon, Smith, and Wimmer (2015) investigated the effects of teaching MMR in middle-school science classrooms on student learning and the use of multimodal approaches. The findings of the study indicated that students who received instruction incorporating MMR demonstrated significantly greater gains in their conceptual understanding compared to those who received traditional instruction. Moreover, the experimental group exhibited a higher level of multimodal use, employing a wider range of representation modes in their learning process. However, due to the limited research in this specific area, further studies are needed to explore and identify effective instructional strategies for promoting MMR utilization in educational settings.

Research studies have indicated that the utilization of writing-to-learn (WTL) activities is effective in facilitating learning and improving comprehension in the field of chemistry. When teachers or students engage in these activities, they are prompted to establish connections between new concepts and their prior knowledge, identify patterns and relationships, and develop a comprehensive understanding of the subject matter (Balasundram & Karpudewan, 2021; Fatih Kayaalp, Meral, Kayaalp & Basci Namli, 2022). It serves as an active learning strategy that fosters critical thinking and improves understanding of chemical concepts, motivating students to engage in active learning, develop critical thinking skills, and gain a more profound understanding of the subject matter.

In the 21st century, classrooms have started to move away from the traditional method of creating mind maps on *mahjong* paper and towards technology-based tools. The integration of MMR in the topic of rate of reaction has become more effective and creative using technology-based tools like the *'Popplet'* application. This was proven by Sessions, Kang, and Womack (2016), who found that students who used the *'Popplet'* application produced more organized and cohesive written work for their English essays compared to those who used traditional pencil and paper methods. When students employ MMR in open-ended questions, their understanding of the rate of reaction improves. This is because the ability to represent the same concepts using different modes allows students to visualize the concepts involved in the rate of reaction and provide comprehensive answers in open-ended questions. Therefore, embedding MMR in open-ended questions with '*Popplet'* application can enhance students' conceptual understanding towards rate of reaction**.**

1.2 Problem Statement

Currently, the traditional chalk-and-talk teaching method is widely employed to cover the syllabus and prepare students for examinations, often without considering their actual needs in chemistry lessons (Elijah, 2023). However, the actual need for chemistry education is to equip students with the ability to solve real-life problems using the knowledge they have acquired in school. Therefore, students should strive to understand the concepts rather than simply memorizing them to pass exams (Willingham, 2021).

Often, students struggle to grasp the concepts in chemistry due to its abstract nature. This can result in misconceptions and difficulties in understanding rate of reaction Kırık and Boz (2012). For example, the common misconceptions include the belief that faster reactions involve larger reactant molecules, the assumption that increasing the amount of catalyst can indefinitely increase the reaction rate, the generalization that all reactions slow down as temperature decreases, and the misconception that the concentration of the product continuously increases as the reaction progresses (Jusniar et al., 2020).

Previous studies have shown that the use of MMR, such as diagrams, chemical equations, tables, and graphs, can enhance students' understanding of science concepts (McDermott, 2009; Gunel, Hand & Prain, 2007). However, the emphasis on MMR among students is often lacking and students frequently fail to fully utilize the benefits of MMR or encounter challenges when transitioning between different modes (Bollen et al.,2017). Therefore, incorporating technology-based graphic organizer has the potential to enhance students' test performance and increase their satisfaction with the learning process (Wang & Lv, 2020). *'Popplet'* is an innovative and interactive application that allows students to create mind maps and concept maps, aiding in organizing their thoughts and learning visually by brainstorming (Balasundram & Karpudewan, 2021).

A study by Sessions, Kang, and Womack (2016) found that students who utilized the *'Popplet'* application demonstrated improved organization and cohesiveness in their written work for English essays compared to those who relied on traditional pencil and paper methods. Additionally, Zammit (2016) implemented the *'Popplet'* application in literacy learning, resulting in positive benefits for the students.

Moreover, the lack of technology-based tools like *'Popplet'* can hinder the provision of timely feedback and assessment to students. With *'Popplet'* application, teachers can provide instant feedback on assignments and projects, facilitating students' understanding of the taught concepts. Without this tool, teachers may have to rely on traditional assessment methods that may not be as efficient or timely. Overall, incorporating MMR and technology-based tools like the *'Popplet'* application in chemistry education can enhance students' understanding, engagement, collaboration, and feedback in the learning process. However, a thorough review of related literature has shown that very little research has been done regarding the effectiveness of '*Popplet'* application in enhancing students' ability to embed MMR. Therefore, there is a need for research to investigate the relationship between the ability of students to embed MMR in open-ended test and their conceptual understanding in rate of reaction.

1.3 Research Objectives

The research objectives in this study are as follows:

1.3.1 To evaluate Form 4 students' ability to embed MMR in answering open-ended questions on learning rate of reaction.

1.3.2 To measure Form 4 students' conceptual understanding in rate of reaction by embedding MMR in open-ended questions.

1.4 Research Questions

The research questions in this study are as follows:

1.4.1 Do Form 4 students have the ability to embed MMR in answering open-ended questions on learning rate of reaction?

1.4.2 What is the level of Form 4 students' conceptual understanding in rate of reaction by embedding MMR in answering open-ended questions?

1.5 Research Hypothesis

The hypothesis in this study are as follows:

H_{01}: There is no significant difference in the mean of MMR scores in answering open-ended questions for pre-test and post-test.

H_{02}: There is no significant difference in the mean of understanding score in answering open-ended questions for pre-test and post-test.

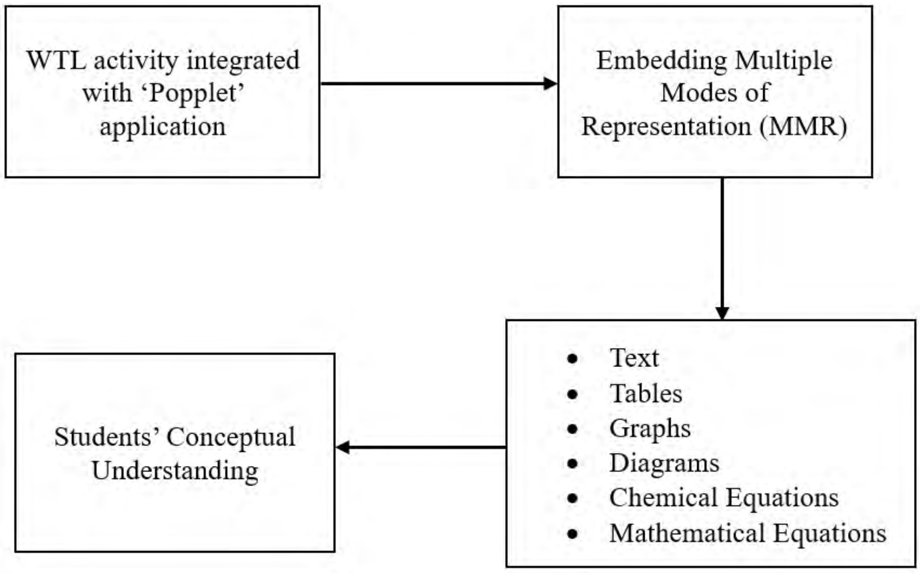
1.6 Conceptual Framework

The conceptual framework is used to illustrate the relationship between variables in the study (Chua, 2014). In this study, the conceptual framework outlines the details that will be investigated in this study on students' ability to embed MMR in open-ended questions using '*Popplet'* application on learning rate of reaction. Additionally, this study seeks to measure students' conceptual understanding in rate of reaction by embedding MMR in open-ended questions.

Students' conceptual understanding can be enhanced by embedding MMR effectively in open-ended questions with the aid of *'Popplet'* application. To make the content more intelligible, modes such as tables, graphs, diagrams, and equations can be incorporated into the writing. Strategies for embedding MMR in the text include linking the modes, linking the modes and the text, placing the modes near the corresponding text, providing captions for the modes, and generating original modes instead of obtaining them from external sources. These strategies contribute to the effective embeddedness of MMR in open-ended questions.

Figure 1.1

Conceptual Framework of the Study



1.7 Significance of the Study

This study hopes to make the following contributions:

1.7.1 Chemistry Students

This study may help the chemistry students to understand better about the abstract concepts and ideas in rate of reaction topic by embedding MMR in answering open-ended questions. It helps students to better express their understanding rather than just using text only. In addition, the utilization of '*Popplet'* application gives greater impact on students' attitude to learn chemistry as compared to the usual chalk-and-talk lesson.

1.7.2 Chemistry Teachers

This study may motivate and challenge the chemistry teacher in their pursuit to help the majority of students learn chemistry better and thus encourage them to become innovative in their teaching methods.

1.8 Limitations of the Study

There are several potential limitations that may occur during the study. Firstly, the findings may not be generalized to all Malaysian students. Next, a lack of control group can limit the study's ability to draw conclusions about the effectiveness of the '*Popplet'* application in embedding MMR in rate of reaction. Besides, technical difficulties may affect the validity of the study's findings, while learning styles may limit the usefulness of the '*Popplet'* application for some students. Finally, a focus on short-term impact may not provide insights into the long-term effectiveness of the '*Popplet'* application in teaching Chemistry.

1.9 Operational Definitions

There are few key terms used in this study and they were defined as:

1.9.1 Writing-To-Learn (WTL) Activities

WTL activities refer to a specific learning activity that involves students actively engaging in the process of writing about their understanding of a particular topic (Dunker, 2019). WTL activities are informal and short writing tasks designed to help students think through key concepts or ideas central to a particular topic, which offers formative assessments of content synthesis and comprehension. This activity is designed to promote deeper learning by requiring students to engage in the process of summarizing and synthesizing information, making connections between concepts, and reflecting on their learning. The activity may involve writing short essays, summaries, reflections, or other types of written responses. The purpose of the activities is to help students develop their critical thinking skills and improve their ability to apply what they have learned to real-world situations related to the rate of reaction. In this study, WTL activities is integrated with graphic organizer named '*Popplet'* application to embed MMR. An example of WTL activities in this study could be a prompt given to students such as: "Use the '*Popplet'* application, describe the effect of reactants size with the rate of reaction, using MMR like text and visual representations. Students would then use the '*Popplet'* application to organize their thoughts and write a response to the prompt, including sketch a graph to show relationship between the size of reactants with their reaction rate during WTL activities.

1.9.2 Multiple Modes of Representation (MMR)

Multiple Modes of Representation (MMR) refers to the use of different types of visual and conceptual models to represent scientific concepts related to the rate of reaction. These modes can include text, diagrams, tables, graphs, chemical and mathematical equations, and other tools that can help to illustrate the concept of rate of reaction in different ways (McDermott, 2009; McDermott & Hand, 2013). Firstly, chemical equation is one of the MMR used in rate of reaction where the symbolic representations of chemical reactions are used to show the reactants, products, and the stoichiometry of the reaction. Next, graphs are used to show the change in concentration of reactants and products over time, and to illustrate how the reaction rate varies with changes in concentration, temperature, or other factors. Besides, tables can be used to organize and compare data related to the reaction rate, such as the initial and final concentrations of reactants and products, or the time taken for the reaction to proceed to a certain extent. Moreover, text can be used to describe the factors that affect the reaction rate, such as the nature of the reactants, the temperature, or the presence of a catalyst. By using

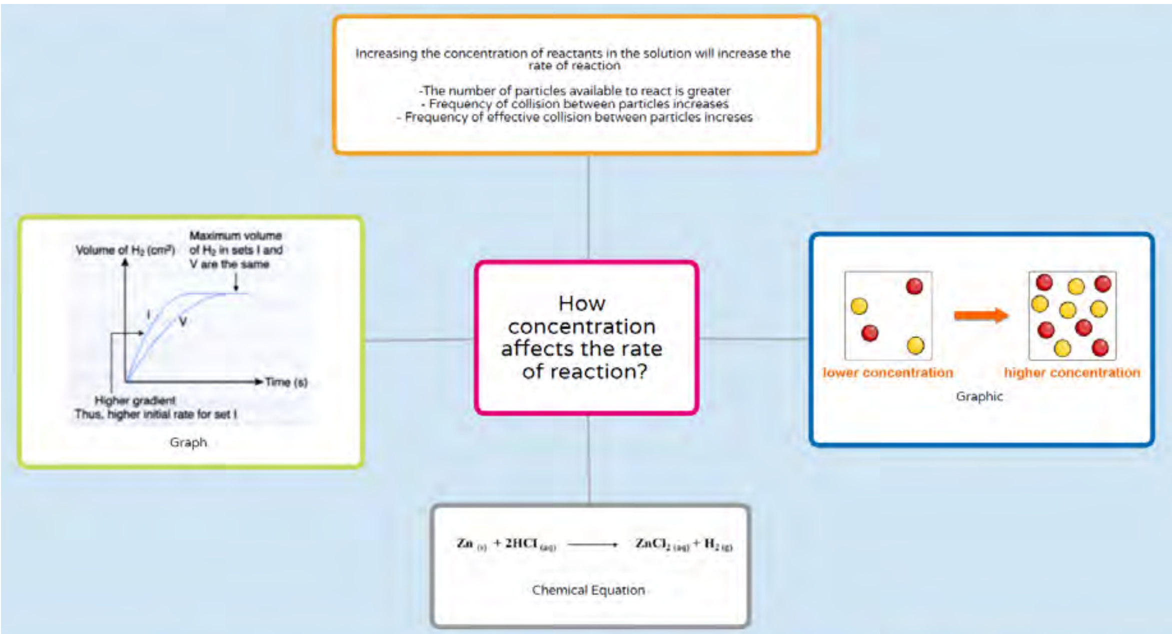
MMR, students can engage with the material in different ways and develop a more robust understanding of the rate of reaction.

1.9.3 ‘*Popplet’* Application

‘*Popplet’* application is a graphic organizer used in education that helps organize and represent information in a structured and meaningful way. It is designed to visually display relationships, concepts, and ideas, making it easier for students to understand and remember information (*Popplet*, 2020). They can be used in various educational contexts, including note-taking, brainstorming, planning, summarizing, and problem-solving. In the context of this study, the ‘*Popplet’* application is used to facilitate the teaching of rate of reaction by embedding MMR to enhance students’ conceptual understanding.

Figure 1.2

Embedding MMR using ‘Popplet’ Application in Rate of Reaction



1.9.4 Rate of Reaction

Rate of reaction for a given chemical reaction is the measure of the change in concentration of the reactants or the change in concentration of the products per unit time. The topic of rate of reaction is presented with four subtopics in Form Four Chemistry syllabus. In learning rate of reaction, students required to determine the rate of reaction; determine the factors that affect the rate of reaction; state application of factors that affect the rate of reaction in daily life and describe the collision theory (MOE, 2018).

Firstly, the students are required to classify fast and slow reactions that occur in daily life; explain the meaning of rate and reaction; identify changes which can be observed and measured during chemical reaction through activity; determine the average and instantaneous rate of reaction; solve numerical problems based on the average and instantaneous rate of reaction. Next, they are required to investigate the factors affecting the rate of reaction through experiment, based on size of reactant, concentration, temperature, and presence of catalyst. From this topic, students also required to explain with examples the application of factors that affect the rate of reaction in daily life. Lastly, they are required to describe the collision theory; explain activation energy using examples; and interpret an energy profile diagram for exothermic and endothermic reactions (MOE, 2018).

In the context of this study, it is used as a specific scientific concept that is taught using MMR with the aid of the '*Popplet'* application.

1.9.5 Understanding

Understanding is a cognitive process that involves grasping, comprehending, and making meaning of information or knowledge. It goes beyond mere knowledge acquisition and involves the ability to interpret, apply, and connect ideas in a meaningful way. Understanding entails more than memorizing facts or concepts; it involves the integration of new information with existing knowledge and the ability to perceive relationships and patterns within the information. It requires a deep comprehension of the subject matter, enabling individuals to explain, analyse, synthesize, and evaluate information within a particular context.

One definition of understanding is provided by Mayer and Moreno (2003), who state that understanding involves "the construction of coherent mental representations, such that new information can be meaningfully integrated with existing knowledge" (p. 315). They emphasize the importance of creating meaningful connections between new information and prior knowledge to develop a deep and comprehensive understanding.

1.10 Summary

To summarise, this chapter has discussed and explained the background of study, problem statement, research objectives, research questions, research hypothesis, conceptual framework, significance and limitations of the study, and the operational definitions. By embedding MMR in answering the open-ended questions using '*Popplet*' application, students' conceptual understanding in rate of reaction can be improved.