Abstract

The purpose of the study is to examine the effectiveness of the Simple Explicit Animation (SEA) content for teaching organic reaction mechanism concepts. It is expected this content would improve students understanding of organic reaction mechanism concepts when it is used as a supplementary teaching material in an organic chemistry class. This study examined how the SEA content was used as a supplementary material in a first year Organic Chemistry course and its effect on the performance of students. Using pre and post-test control group design, the study involved a comparison between an experimental group of students (n=18) who followed instruction that integrated SEA in a blended mode and a control group of students (n=21) who followed instruction based essentially on conventional talk-and-chalk mode. The one-way ANCOVA technique was used to evaluate the impact of the intervention, while controlling the pre-test scores. After adjusting for pre-test scores, there was a significant difference between the two groups on the post-test scores, F(1,36) = 21.543, p < 0.05, eta squared = 0.37. Students who had followed instructions carried out in the blended mode displayed significant improvement in their post-test as compared to students who were taught using the conventional mode. The research results suggested the potential of using SEA content as an instructional material to teach organic reaction mechanism concepts.

Keyword: Animation; organic mechanism reaction; electron; content; moving-electron technique

1. Introduction

Although the Ministry of Education, Malaysia aims to achieve 60% of students’ enrolment in science stream, the percentage of students who have opted to study pure science subjects has declined over the years. In Malaysia context, poor teaching practices is believed to be one of the factors leading to reduced students’ interest in learning science (Kamisah, Zanaton & Lilia, 2007). Students consider the topic of Organic Synthesis in Organic Chemistry, for instance, difficult to study. In fact, organic synthesis is probably the most demanding aspect of organic chemistry (Montes, Prieti, & Garcia, 2002). Yet, teaching practices employed by teachers often do not enhance students’ understanding of the abstract concepts of organic synthesis - like moving electrons, and the breaking and formation of chemical bonds.

A central concept in organic synthesis is the mechanism of organic reactions, which most students perceive as a very difficult concept to grasp (Levy, 2008). Unfortunately the teaching approach used in explaining organic reaction mechanism is usually rigid, frequently employing the talk-and-chalk method. Furthermore, it is difficult for students to rapidly transfer their thoughts from one concept to another, like between the sub-micro, macro, and symbolic levels (Gilbert and Treagust, 2009), and
make connections. As a consequence of these factors, students tend to memorize the steps involved in organic reaction mechanism. Due to their minimal understanding of the basic principles in organic chemistry, students encounter problems to understand the more advanced organic mechanism reaction.

Besides students’ difficulty in understanding basic concepts, other challenges that affect the effectiveness of teaching organic chemistry courses in Malaysia are the wide range of abilities, backgrounds and academic interests of students as well as the large class size. The introductory organic chemistry class for undergraduates in University Putra Malaysia (UPM), for example, encompasses students from different faculties such as Education, Science, Veterinary Science, Medical, and Agriculture. Based on this context, research was conducted to study the use of animation as an alternative approach of teaching organic reaction mechanism in an organic chemistry course, with the assumption that animation could assist students to better understand the basic concepts.

Mayer and Moreno (2002) believe that animation has the capability to make an abstract concept at the macroscopic and microscopic levels easier to understand. They conducted extensive studies on the use of animation in diverse learning contexts. The studies found that animations increase student engagement and bring about a significant improvement in learners’ problem-solving skills. However, the studies revealed that if animations are too complex and dynamic, students will face difficulties to extract information from the animations (Ayres, Kalyuga, Marcus & Sweller, 2005). These animations impose an extra cognitive load on students (Gilbert, Reiner & Nakhleh, 2008), thus prove to be unsuitable for learners. Consequently, a relevant question that educators need to answer is, “What kind of animation is suitable for teaching organic reaction mechanism?” An animation that would not enforce extraneous amount of information in the working memory of students before they could infer the information for transfer to long term memory.

2. Animation for Organic Mechanism reaction: The SEA Approach

In this study, a digital content was developed using a computer generated molecular model to teach basic concepts of organic reaction mechanism. The digital content, consisting of animations and explanatory texts is designed for students of diverse backgrounds and levels of understanding. Moreover, students are able to study organic chemistry according to a flexible time frame before they proceed to advanced topics. Besides, the utilization of this digital content as a supplementary material is not only practical, but also economical for mass lectures. Based on concepts that often comprise various abstract ideas, it is pertinent for lecturers to consider how these concepts could be visualized in effective forms for teaching organic chemistry. Through a computer generated molecular model, students may understand better the process of organic reaction mechanism.

Organic reaction mechanism is generally used in the synthesis of new organic molecules through organic reactions. The most basic organic reactions are addition reactions (such as electrophilic, nucleophilic and radical reactions), elimination reactions (E1 and E2 reactions) and substitution reactions (such as SN1 and SN2 reactions). All these organic reaction mechanisms involve the breaking and formation of chemical bonds. In chemistry, a single bond between atoms consists of two electrons that are generally presented by the Lewis structure, using pairs of spheres to represent these two electrons. Other electrons which are not involved in bonding are usually shown as dots on the atoms, representing the so-called free electrons.

![Figure 1: A single bond in CH₃Cl and free electron](image)

The development of this digital content is to demonstrate the organic reaction mechanism explicitly through the electron-moving technique. This technique is used to conceptually describe the mechanistic steps in organic reaction mechanisms to demonstrate the movement of electrons during the breaking and formation of chemical bonds. This technique enables students to extract information explicitly in a step-by-step manner in order to understand the macroscopic and microscopic concepts of organic reaction mechanism. The mechanism of organic reactions is the most important aspect of understanding organic chemistry. It allows students to predict logically the products that are produced in any reaction condition.

The SEA (Simple Explicit Animation) content contains eight fundamental topics in organic chemistry; embracing basic concepts of the three main organic reaction mechanisms which are addition, substitution and elimination as shown in Figure 2. Every topic has its own learning objectives.
The main idea of the SEA content is to display an explicit electron movement, driven by homolytic and heterolytic cleavage, that shows the continuous and dynamic process of organic reaction mechanisms as represented in Figure 3. Then the concepts of polarity, radical and carbocation are introduced using heteroatoms and a common organic functional group.

To actively involve students, it is necessary to provide a means for them to interact with the animation in a meaningful way. The SEA content provides “Play”, “Pause”, “Reverse” buttons and an animation control bar. These buttons give students a choice of either playing the whole animation continuously or going to a specific segment of the animation; consequently students have control over the flow of the animation at any stage. Therefore, the animations bring static reaction mechanisms to life and clearly convey the abstract dynamic concepts to students. Students have the opportunity to observe the movement of the electron explicitly in engaging ways; at the same time the content increases the intelligibility and plausibility of the organic reaction mechanism to students. For example, Figure 4 shows a series of organic reaction mechanism, specifically the elimination reaction, with a simplified explicit animation that utilizes electron moving technique.
Students can also analyze the reaction mechanism by controlling the pace and flow of the animation using the animation control bar. A control bar is an important element in animation (Evan & Gibbons, 2007) because the moving visuals can be stopped at any point in the animation, whether the student wants to speed up or slow down the animation. Students can play the process of organic reactions repeatedly, especially during segments that require several repetitions for more understanding. Besides, students can also observe exactly the movements of the electrons and their associated atoms, as bonds are formed and broken during the process of reaction. These electron movements are shown explicitly to increase students’ understanding without the burden of cognitive load.

Therefore, compared to most traditional teaching and learning content, the SEA digital content with animations that use the electron-moving technique enables students to interact with the animations with the play-pause_reverse buttons and a control bar. Interaction with animations assist students to understand changes in the form and movements of electrons and their associated atoms, because students can analyse the organic reaction mechanism in a simplified and explicit manner.

3. Procedure and Data Analysis

In this research, the experimental method was applied. Aside from testing the effectiveness of the SEA content, another purpose of the research is to compare the consequences of different types of instructional modes on the performance of students. Two sample groups of first year students who were taking the Fundamental Organic Chemistry course were randomly selected to participate in the research. This study examined how the SEA content was used as a supplementary teaching material in a first year Organic Chemistry course and the impact of the content on the performance of first year science students. The study was implemented under strict conditions to ensure reliability and validity. Using pre-test and post-test control group experimental design, the four hour study involved comparison between an experimental group of students (n=18) whose lecturer integrated the SEA content in a blended student centred mode and another group of students (n=21) whose lecturer delivered instruction based essentially on the conventional talk-and-chalk approach.

A one-way between-group analysis of covariance (ANCOVA) was conducted to compare the effectiveness of these two different modes of instruction designed to enhance students’ understanding of organic chemistry concepts. The independent variable was the type of intervention (conventional talk-and-chalk mode versus blended student centred mode) and the dependent variable consisted of scores achieved in the post-test administered after the interventions were completed. Students’ scores on the pre-test were used as the covariate in this study. The group which experienced the conventional intervention is known as the Control group, whilst the group which experienced the blended intervention is known as the experimental group. The data collected were organised and analysed using the SPSS software.

For the ANCOVA analysis, the normality and the conditions of linearity and homogeneity were investigated beforehand. The test of normality using Shapiro-Wilk procedure in Table 1 undoubtedly show the significant at p > 0.05 that indicates these data are retrieved from a normal distribution.
The Levene’s Test of Equality of Error Variances in Table 2 shows the significant value is greater than 0.05 which means the variances are equal, and the assumption of the equality of variance has been met. This test reflects that it has accomplished the conditions of an ANCOVA test.

The hypothesis for this research is as follows: There is no significant difference between the post-test score of the experimental group and the post-test score of the control group after the pre-test was analysed as a covariate.

Table 3 shows the descriptive analysis of the pre-test and post-test scores for both groups. The result in Table 3 shows that mean score of the post-test has increased for both the control and the experimental group. The increased scores demonstrate that the interventions employed by the lecturers, both the blended approach using the SEA content and the conventional talk and chalk method using the whiteboard, had improved the score of students in tests that required them to answer questions related to organic reaction mechanism in an organic chemistry course.

However, Table 4 shows Tests of Between-Subjects Effects from the ANCOVA procedures, including the main effect (p<0.05) for pre-test which is F(1,36) = 8.661 and for group which is F(1,36) = 21.543. This indicates that both groups differ significantly according to a significant difference in the post-test scores for subjects in the control group and experimental group, after controlling the score on the pre-test administered prior to the intervention. Therefore, when the pre-test score is statistically controlled as a covariate, this treatment has influence on the scores of the post-test.

The value of effect size (as indicated by the corresponding eta squared value) is 0.374, a moderate effect size according to Cohen’s (1998) guideline. The larger the effect size, the greater is the impact of an intervention. Cohen (1988) listed that a correlation of 0.5 is large, 0.3 is moderate, and 0.1 is small. This value indicates 37.4 % of the variance in the dependent variable is explained by the independent variable.
3. Conclusion

Preliminary checks were conducted to ensure that there was no violation of the assumption of normality, linearity, homogeneity of variances and homogeneity of regression slopes. After adjustment to the pre-test scores, a significant difference between the two groups on their post-test scores, $F(1,36) = 21.543$, $p < 0.05$, eta squared $= 0.37$ was evident. Students who had followed instruction carried out using the student centred blended mode showed significant improvement in their post-test compared to students who had followed instruction that employed the conventional mode. It can be concluded that the SEA content is an instructional material that has potential to **effectively increase students’ understanding** when it is used to teach organic reaction mechanisms.

References


