OCRA, A MOBILE LEARNING PROTOTYPE FOR UNDERSTANDING CHEMISTRY CONCEPTS

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ABSTRACT

This research studies the effects of an interactive multimedia mobile learning application on students' understanding of chemistry concepts. The Organic Chemistry Reaction Application (OCRA), a mobile learning prototype with touch screen commands, was applied in this research. Through interactive multimedia techniques, students can create and visualize the mechanistic steps of an organic chemistry reaction. Ninety-two students who were either assigned to a control or an experimental group participated in the research. Data collection included achievement in the pre- and posttest, and students' responses in a questionnaire that examined their perception towards the OCRA. The findings demonstrated that students' attitudes towards the OCRA were positive while their test scores have improved. It is concluded that the teaching and learning approach applied in the OCRA has engaged students in learning organic chemistry and develop their conceptual thinking, leading to deeper understanding of chemistry concepts.

KEYWORDS

Interactive multimedia, Mobile Learning, Engaging, and Chemistry Concepts

1. INTRODUCTION

In the last decade, there has been intense research in studying the impact and advancement of multimedia and mobile technology on learning environments that involved students in diverse learning activities. These technologies have influenced the design of curriculum in many universities for they offer flexibility and mobility in everyday learning. Mobile learning, (M-learning) for example, provides four universal qualities that add value for learners: any time, any place, widen participation and personalized learning (Park, 2011). Additionally, multimedia has revolutionized traditional educational methods. Integrating multimedia elements increase student retention, and create interesting and interactive learning environments (Mayer and Moreno, 2010).

When combined with multimedia, learning then becomes a more dynamic process. Mayer (2009) championed multimedia as the means to "engage learners in the cognitive processes required for meaningful learning within the visual and verbal information processing systems" (p. 4). Meaningful learning in a multimedia environment occurs when students are given the choice of selecting words and images from a learning material, and independently organize and integrate these verbal and visual representations into a coherent mental representation (Mayer and Moreno, 2010). This study demonstrates that the use of an interactive multimedia content with a mobile device provide students with opportunities to reflect and build their understanding of chemistry concepts through a meaningful, and cognitively engaging task.

2. PROBLEM STATEMENT

One of the current aims of chemistry education in Malaysia is to provide students with the knowledge and skills that would enable them to solve problems that range from specific types of calculations to open-ended situations. However, the latest findings of the *Secondary School Performance Report 2015* (Ministry of Education, 2016) by the Ministry's Examination Division regarding the chemistry performance of students are incongruent with this aim. It was found that the "majority of candidates did not understand and have not

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mastered the concepts of chemistry" (MOE, 2016, p.14). In particular, the report found weaknesses in the responses towards organic chemistry questions and concluded that the majority of candidates have failed to acquire basic conceptual understandings (MOE, 2016). Students were able to provide answers for questions that required simple recall of scientific facts, but had problems with analyzing abstract processes and failed to classify, synthesize and evaluate information. Farhan and Zainun (2013) revealed that the traditional direct transmission approach is a practice widely used by chemistry teachers in Malaysia to explain and draw chemical reactions, while students passively listen and take notes. They stated that chemistry teachers preferred to use only the whiteboard or static images to illustrate the organic synthesis process although constructivist teaching strategies are encouraged by the MOE. Consequently, students who function largely as passive recipients of knowledge have a negative attitude towards chemistry; they often perceive the subject as being boring and difficult to comprehend. These views are consistent with those of Hutchinson (2000, p.3), when he claimed that in general, chemistry in the United States of America is taught to students mostly based on "expository and explanatory statements of concepts and applications……clearly verifies the pervasiveness of traditional approach." The guided-inquiry approach promoted by the MOE is mainly implemented in science laboratory activities. However, most teachers are only interested to conduct selected guided-inquiry experiments for the purpose of answering examination questions rather than developing students' process skills or conceptualizing scientific phenomena (MOE, 2016). It can be argued then that the direct transmission approach and the minimal implementation of the guided-inquiry approach has not led to positive changes in students' conceptual understanding of science that go beyond rote memorization.

3. LITERATURE REVIEW

Learning is an active process of knowledge construction that humans perform naturally, but not everyone is an effective and efficient independent learner. Indeed, most learners benefit from some level of support. First, successful teaching and learning involve a variety of strategies for engaging, and motivating learners over and above merely presenting them with well-designed learning materials (Lukerson, 2014). There are a number of pedagogical techniques that focus on providing activities for learners to perform either in groups or as individuals that help to create deeper, swifter and more effective learning like discussion, simulations, or problem based learning. Secondly, successful teaching and learning is not just the creation of thoughtful and engaging activities for students to undertake, but also giving thought to the sequential order and timing of the various activities and the presentation of the resources needed to support them (Lukerson, 2014). Over the last two decades the mode of learning has gradually shifted away from education that is teacher-centered to student-centered, from rote learning to learning as reflection and from face to face learning to mobile learning (Jarvis, Holford and Griffin, 2003). According to Conole and Oliver (2007), the emergence of new approaches to learning has led to new perspectives on learning presented through different theoretical lenses.

The teaching and learning of science is always perceived as the teaching and learning of concepts that are often organized from the simple to the most complex. In the context of teaching and learning organic chemistry, the "arrow pushing" technique is widely used to present the mechanic aspects of the organic reaction mechanism under investigation. However, this talk and chalk technique is incapable of visualizing the actual processes during the organic reaction mechanism; consequently, students have failed to grasp the organic reaction mechanism in the same way as their teachers (Berg and Ghosh, 2013). Interactive multimedia offers great potential for bridging the gap between what students already know and the targeted concept that needs to be understood. For example, through a multimedia content, students can visualize the abstract and dynamic chemical processes that occur in an organic reaction mechanism. As stressed by the MOE (2016, p. 14), "multimedia are effective tools for the teaching and learning of abstract or difficult science concepts." A teacher can also convey a meaning or concept clearly which might be often difficult to explain verbally to students. According to Lafarge, Morge, and Meheut (2014), conceptual questions in chemistry often involve the solution of a problem through a step by step approach. Since chemistry concepts have diverse characteristics with different types of abstractions, it is necessary to consider how these concepts can be visualised to students. This is in line with Montes, Prieto and Garcia (2002) view that a multimedia content could enhance students' understanding of the chemistry reaction processes that are dynamic and abstract in order to solve a problem.

One of the rapidly advancing areas of education in the world today is the development of mobile learning content, which adopts multimedia and mobile technology for education purposes. Multimedia has been shown to elicit the highest rate of information retention and results in shorter learning time (Alessi & Trollip, 2001), whereas Kulkuska-Hulme (2005) has asserted that mobile learning facilitates learner engagement without the constraints of a fixed, pre-determined physical environment. However, Ng and Nicholas (2013) have cautioned that mobile learning is not just learning using mobile devices, but learning through context. Mobile devices have the capability of catering to various learning theories and methods, either behaviourist, cognitivist, or constructivist theories, or whether through games, social networking, video or multimedia applications (Keskin and Metcalf, 2011) to enhance and extend the incentives and mechanisms of teaching and learning to support and motivate students individually or collaboratively. The emergence of mobile technology fosters teachers to experiment with digital materials in and outside the classroom. When preparing mobile learning experiences, it is advisable to avoid replicating the direct instruction model applied in classrooms; instead teachers should strive to apply more effective models to convey instruction (Ng and Nicholas, 2013). Understanding the use of M-learning tools for mediation will be crucial to discourage educators and designers from simply swapping printed worksheets for mobile devices with the expectation that students or learners will perform better (Liaw, Hatala, and Huang, 2010).

4. AN INTERACTVE MULTIMEDIA MOBILE PROTOTYPE

This paper presents an interactive multimedia mobile learning prototype, namely the Organic Chemistry Reaction Application (OCRA) which is used for learning fundamental concepts of organic reaction mechanism. This application), as shown in Figure 1 below, can be used effectively with mobile devices, such as smartphones and tablets. OCRA is not intended to be used as a prime teaching tool in a classroom but only as a supplementary tool to learn and understand organic reaction mechanism.

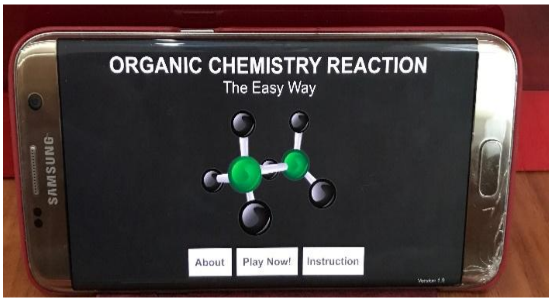

Figure 1. An Interactive multimedia M-learning prototype

For the Net-generation students, those who have grown up with Internet access and are accustomed to using mobile devices in their daily lives, OCRA is considered a M-learning solution that facilitates understanding through multimedia, including digital imagery, sound, and animation, as well as through coordination of students' interactivity with the animation to generate immersive learning experiences. According to Anderson (2008), "this new generation of learners is smart and creative, but impatient, expecting results immediately, and like to customize the objects they choose (p. 203).

OCRA offers convenience and flexibility, and uses a touch screen feature to demonstrate and conceptually visualize the mechanistic steps in an organic reaction mechanism. By transferring the control of learning to students with its touch-screen feature, students are able to form and break apart a chemical bond by sliding their fingers on the screen to move electrons or atoms, and predict logically the mechanistic steps of the three fundamental organic reactions - addition, substitution, and elimination. This technique enables the users to understand the particulate nature of organic reaction mechanism. Mediated through interactive practice activities, the interactive multimedia content enhances students' confidence in learning organic reaction mechanism. Developed based on the revised Bloom's taxonomy model – Remember, Understand, Apply, Analyses, Evaluate, and Create (Krathwohl 2002), the basic premise of OCRA is to immerse students in hands-on experiences that apply the principles of nucleophile, electrophile, and free radicals in the organic reaction mechanism. An example is illustrated in Figure 2 below.

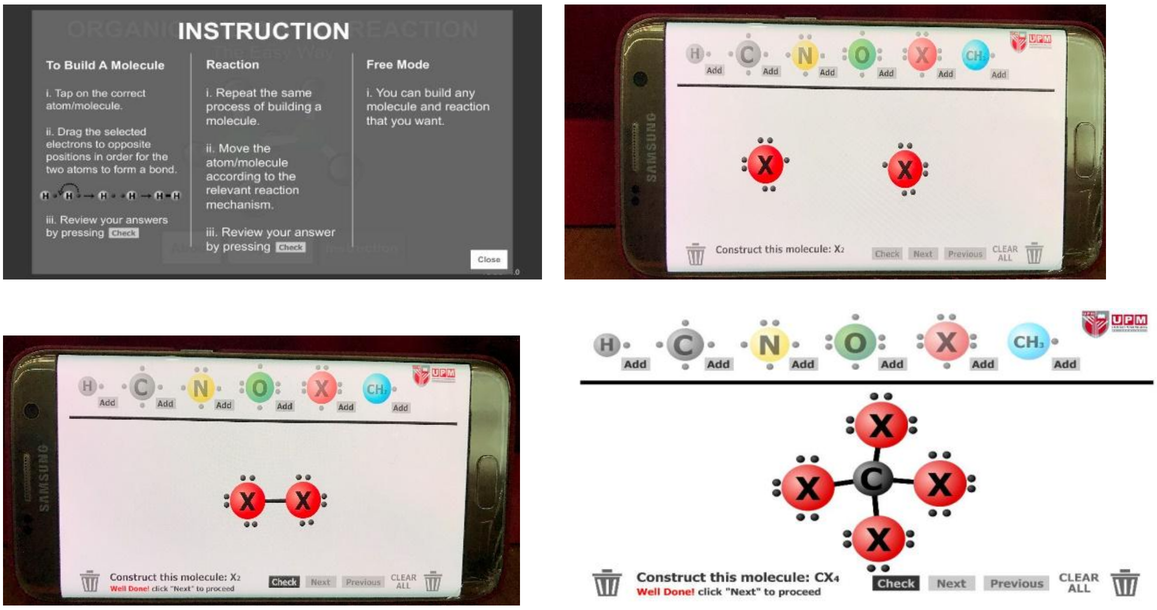

Figure 2. An example of an interactive practice activity using multimedia content

These immersive experiences enable students to analyse every movement of the electrons, including the breaking apart and the formation of covalent bonds. Moreover, critical thinking is encouraged since they are expected to observe, evaluate and come to a decision regarding the arrangement of the molecules to create a possible final product. Finally, the students can check if they have completed the process accurately. Thus, OCRA has the capability to activate users' learning by aiding students to create their own molecules and organic reaction mechanism.

4.1 Interface

The interface of OCRA consists of the five basic atoms in organic chemistry that are shown in different colours with their valence electrons, in terms of the Lewis dot structure, at the top of the screen as shown in Figure 3 below.

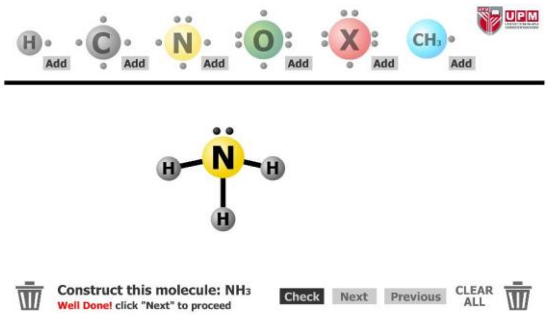

Figure 3. The Interface of an Interactive multimedia M-learning prototype

Most organic molecules are made up from these atoms. Students need to click or tap on the atoms to build a molecule with single, double or triple bonds. Then, students can refer to the simple instruction at the bottom of the screen to construct the different molecules listed before they proceed to interactively try out any basic organic reaction mechanism, leading to the creation of a molecule. The users can try the next exercise by tapping on the "CLEAR ALL" button, and then, the 'NEXT' button. After an activity has been completed, the students can tap on the "CHECK" button to check their answers.

5. METHOD AND PROCEDURE

For this research, the researcher had used the quasi-experimental method. To test the effectiveness of an interactive multimedia approach through the use of a mobile device, two sample groups participated in the research which were a control group and an experimental group. The two groups consisted of 92 students from the Science Foundation Program of a university in Malaysia who were taking the Introduction to Chemistry course with 46 individuals in each group. The control group had learned the organic chemistry concepts fully using traditional teaching and learning methods while the experimental group had learned the organic chemistry concepts with the assistance of the interactive multimedia m-learning prototype, Organic Chemistry Reaction Application (OCRA).

To recognise the perception of students towards the interactive multimedia m-learning prototype, questionnaires were distributed among 100 students, fifty four (54) students from an earlier cohort who had taken the Introduction to Chemistry course during the previous semester as well as the forty six (46) students who were taking the Introduction to Chemistry course at the time of the study. The questionnaire was divided into 4 sections and used the Likert scale that has a ratio of 1 to 4. The key question of this study was, “If students are using interactive multimedia content for learning organic chemistry concepts with a m-learning prototype, what are the outcomes in relation to learning, motivation and engagement? A complementary question is “What are the benefits of using an interactive multimedia m-learning prototype as perceived by students?” These two questions seek to measure the effectiveness of using the interactive multimedia content, provided in the m-learning prototype and accessed through a mobile device, by examining students’ perception about their learning preferences as well as their experiences in understanding organic chemistry reaction concepts.

6. RESULTS AND DISCUSSION OF DATA

A comparison was made between two groups, the control group and the experimental group, with an assumption that these two groups had similar levels of academic achievement. The analysis was carried out using the t-test approach. Through the t-test analysis, a comparison between the minimum achievement value of the tests conducted on the control group and experimental group was performed.

Analysis of the t-test between the Pre-Test and Post-Test achievement for the Control Group is presented in Table 1:

Table 1. t-test for control group

Test	Number of Sample, N	Min	Standard deviation	t value
Pre	46	22.62	7.79	-9.77
Post	46	40.86	10.90	

Table 1 demonstrates there is a significant difference ($p<.05$) between the scores of the pre-test and post-test for the control group which is a total increase of 18.24 marks. This means that the traditional approach of teaching and learning was able to improve students’ understanding of organic chemistry concepts. However, the achievement of students is not outstanding.

Analysis of the t-test between the Pre-Test and Post-Test achievement for the Experimental Group is presented in Table 2:

Table 2. t-test for experimental group

Test	Number of Sample, N	Min	Standard deveiation	t value
Pre	46	27.86	7.00	15.83
Post	46	62.24	12.22	

Table 2 demonstrates there is a significant difference ($p< .05$) between the scores of the pre-test and post-test for the experimental group which is a total increase of 34.38 marks. This shows that the teaching and learning approach of using the interactive multimedia m-learning prototype among the experimental group is more effective to improve students' performance in the organic chemistry reaction topic compared to the traditional approach.

Analysis of t-test for the Pre-test Achievement between the two groups of students is presented in Table 3:

Table 3. t-test for pre-test achievement between the control group and experimental group

Group	Numberof sample, N	Min	Standard deviation	t value
Control	46	22.62	7.79	-3.43
Experimental	46	27.86	7.00	

Table 3 shows that the two groups have the same level of achievement ($p> .05$) even though the minimum score for the experimental group is higher than the minimum score for the control group although there is only a difference of five marks. This imply both groups have the same level of pre-knowledge understanding of the organic chemistry concepts.

Analysis of t-test for the Post-test Achievement between the two groups of students is presented in Table 4:

Table 4. t-test for post-test achievement between the control group and experimental group

Group	Number of sample, N	Min	Standard deviation	t-value
Control	46	40.86	10.90	-8.12
Experimental	46	62.24	12.22	

Table 4 shows the minimum score for the experimental group is significantly higher ($p < .05$) compared to the control group. This suggest that students were able to improve their understanding of organic chemistry concepts, especially for the fundamental organic reaction mechanism concept, with the assistance of the interactive multimedia m-learning prototype.

Generally, the t-tests conducted on every minimum score achievement showed that both the traditional teaching and learning approach and the interactive multimedia m-learning approach increased students' understanding. However it is discovered that the use of the interactive multimedia content, delivered through the m-learning prototype, has more effectively improved the performance scores of students; in fact students in the experimental group obtained a higher percentage of improvement in performance their scores compared to the control group. Table 5 clearly shows that the post test for the experimental group has a higher percentage which is 62.24% compared to the control group which is 40.86%.

Table 5. Pre- and Post-Test Achievement for the Control and Experimental Group

Group	Number of sample	Pre-test	Post-test
Control	46	22.62	40.86
Experimental	46	27.86	62.24

Finally, a survey was conducted among the students to investigate the perception of students about the OCRA, the interactive multimedia m-learning prototype. Two main factors were studied in this survey namely the suitability of the OCRA for teaching and learning and the quality of the Interface. Data for the average score of students' perception towards the suitability of OCRA for teaching and learning is given in Table 6 below:

Table 6. Average mean of students' perception of the M-learning prototype for teaching and learning

No.	Statement	Average Score
1	The interactive multimedia content helped in my learning process to understand the topic in organic chemistry reactions.	4.41
2	The interactive activity of multimedia content enabled me to learn the steps of organic reaction mechanism through practice.	4.21
3	The sequence of content delivered with interactive multimedia content is easy to follow.	4.50
4	The sequence of content delivered with interactive multimedia content engages my attention.	4.26
5	The interactive multimedia content is relevant with the organic chemistry reaction mechanism topic.	4.45
6	The interactive multimedia content motivated me to further foster my knowledge of these topics.	4.56
7	The presentation for the topic improved my memory retention of the topic.	4.44
8	The interface of the M-learning prototype is easy to use so I am able to continue following the content until the conclusion.	4.51
9	Learning the organic chemistry concepts wth the M-learning prototype is enjoyable because it is convenient.	4.49
10	The M-learning prototype provided a supportive learning environment to enhance understanding of concepts and topics covered in the chemistry course.	4.58
	Average Mean	**4.44**

Table 6 shows the mean score of students' perception towards the suitability of the interactive multimedia M-learning prototype for teaching and learning chemistry concepts; the results demonstrated that there is no apparent difference between all items. The total average mean for this part is 4.44; the results of the survey confirm that majority of students have a positive perception on the suitability of OCRA to positively impact their experiences, motivation and engagement in learning organic chemistry concepts. The use of multimedia based presentations in science education may not necessarily be effective in assisting students to understand a concept. The mere movement of words or objects, and changes to the colours or size of objects may not be able to fully explain a science concept that is often abstract and dynamic, and needs detailed explanation at the macroscopic and microscopic level (Lowe, 2004). Conversely when multimedia based content is used in an interactive task that expected students to be actively involved in applying the Bloom's 'Remember, Understand, Apply, Analyses, Evaluate, and Create' Model, it is found that eventually the students were able to produce a solution to a difficult organic chemistry problem.

7. CONCLUSION

The findings of the study has demonstrated that the interactive multimedia content in the m-learning prototype has served as a learning aid for students and has significantly improved students understanding of organic chemistry concepts, particularly for the organic reaction mechanism topic. In testing the effectiveness of the interactive multimedia m-learning prototype, it is found that the experimental group experienced an increase in percentage in their test score compared to the control group. Moreover, the survey conducted has identified that students have a positive perception of the interactive multimedia m-learning prototype with an overall mean average of 4.44 from the Likert scale that ranges between the degree of 1 to 5. Even though this research has shown promising results, to date the research has not yet included other instruments to obtain data such as interviews. A more detailed statistical analysis is needed to identify and confirm students' perception and acceptance of the interactive multimedia m-learning prototype. Therefore, field trials with different groups of students and the shifting of focus from only organic chemistry reactions to other difficult concepts will be conducted and further explored.

Mobile applications that highlight student-centred content generation, like OCRA, provide ample opportunities for students to optimize their understanding of concepts through multimedia content; the content offer interactivity and information related to the fundamental concepts of organic reaction mechanism. As an alternative learning tool, students are able to experiment with examples of the substitution, elimination and addition reaction for any basic form of molecule in organic chemistry. As mentioned before, continual use of the traditional talk and chalk approach has limited students' ability to visualize the electrons involved in making or breaking a bond nor are they able to conceptualize a synthesis reaction where two or more substances combine to form a new compound. However, the comprehension of electrophile, nucleophile as well as the octet rule concepts can be assessed through OCRA. In Malaysia, the most common initiative in educational technology has been focused on developing and delivering digital content to students as online study notes or guidelines which students tend to download and study off line. From this study, we have observed that true education must go beyond mere access to information, but should involve students in constructing and applying knowledge (Miyazoe, 2010). It is highly recommended that mobile learning applications that take into consideration the current pedagogical approaches in education, especially for the Net Generation, should continue to be developed. OCRA, an interactive multimedia m-learning prototype, is a promising example of an alternative teaching and learning tool that improvises on the traditional teaching and learning approach. This educational approach is a step towards upgrading the effectiveness of teaching and learning in Malaysia, especially in this era of innovative technological advancement.

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