An Investigation On The Use Of A Mobile Augmented Reality Application In Chemistry

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Abstract

The primary objective of this pilot project was to investigate the effectiveness of a mobile augmented reality (AR) application in chemistry learning. The mobile AR app was tested to 23 students enrolled in a public high school in Metro Manila. The study aimed to address the following questions: (1) Is there a statistically significant improvement in students’ post-test scores after using the AR tool? (2) What types of learners based on their characteristics (i.e. gender and learning achievement) benefited more from the use of the AR tool? The research instruments used in this study were a pre-test, a post-test and an inquiry-based worksheet developed following the principles of David Kolb’s four-stage experiential learning model for a topic on chemical reactions involving oxygen. Test scores and learning gains were analyzed using descriptive statistics. The results indicated that students’ post-test scores are significantly higher compared to their pre-test scores and that low-achieving female students gained the most after using the mobile AR app. These findings contribute to the growing body of literature and evidence that supports AR in education. The study concludes with potential future work to build upon this pilot study.

Keywords: augmented reality learning, mobile learning, experiential learning, chemistry learning, Elements 4D
1. Introduction

Background of the study

Augmented reality is an emerging and mature technology that presents limitless potential, especially in the area of science learning. Difficult science concepts that require multiple attempts at experimentation and exploration makes the subject not just even more aversive to the typical student, but also raises costs for laboratories and other necessary tools. With the use of augmented reality-based applications, learning can become experiential and provide more meaningful experiences for the students especially in the field of science. In a study by Dunleavy, et. al. (2009), immersive learning with the use of augmented realities help develop the learning styles, strengths, and preferences of students in new ways beyond traditional computing technologies, thus ushering in multiple implications for K-12 education.

According to Kolb’s (1984) Experiential Learning Theory composed of a four-stage model, the more stages used would lead to enhanced student learning or retention. This study is designed to test whether the use of a mobile augmented reality app called Elements 4D would be effective in a learning activity designed after Kolb’s theory. The class activity will be structured using a worksheet to reflect the stages of Kolb’s theory.

Context

Here in the Philippines, most exclusive schools would be willing to invest in more “world-class” science laboratories and equipment but for the average schools, more so for the public education system, this becomes a huge and daunting challenge. The use of mobile augmented reality in the classroom opens a whole new way of learning as it provides relevant and immersive experiences especially on topics that are “difficult” to learn or those requiring specialized laboratories/equipment and materials. As 4D combines augmented reality and other technologies, it creates an interactive and digitally manipulable world that can drive and transform the way students learn. Elements 4D is specifically designed for the chemistry classroom. It is a set of interactive blocks that helps students learn the Periodic Table by showing how elements combine into new chemical substances, what the reactions look like, and the resulting chemical equation.

Theoretical framework

For this study, the theoretical framework is comprised of a learning theory and an augmented reality technology.

Learning theory

David Kolb’s theory on experiential learning is utilized as basis for designing the learning activity and worksheet. The underlying principle of Kolb’s four-stage model is a simple description of the learning cycle which shows how experience is translated through reflection into concepts, which in turn are used as guides for active experimentation and the choice of new experiences. Kolb (1984) refers to these four stages as: concrete experience (CE), reflective observation (RO), abstract conceptualization (AC) and active experimentation (AE). They follow each other in a cycle (which may be entered at any point, but the stages should be followed in sequence):
Kolb suggests that it is important to systematically take and engage the learner around each stage of the learning cycle, ensuring that effective links are made between each stage. He argues that learning (or at least retention) is enhanced as more of the learning stages are used.

**Augmented reality technology**

Augmented reality (AR) uses technology that integrates 3-dimensional virtual objects generated digitally by computer imagery into a real-time environment. Computer-generated information, whether these be images, audio, video, and touch or haptic sensations can be spatially overlaid on 3D objects and the real world (by using a video camera), thus, rendering the visual images as real and allowing the learner to interact with the virtual world in real-time. Modern AR applications are seen as emerging technologies that can make learning more immersive and realistic.

The mobile AR application used for this study is a free-to-download app by DAQRI called Elements 4D. A downloadable set of paper blocks (Figure 2) includes thirty-six elements that can be viewed (Figure 3) and combined, if the chemicals react to one another (Figure 4), using the mobile AR app. Each side of the paper block contains one element and also serves as the “marker” for the AR app visualization. The AR app also shows the physical properties of element such as appearance, texture, color as well as the chemical properties such as atomic number and mass. Equations of resulting chemical reactions are also shown when two elements are successfully combined.
Statement of the Problem

To further investigate the effectiveness of a mobile augmented reality (AR) application in chemistry learning, the following research questions were addressed:

1. Is there a statistically significant improvement in students’ post-test scores after using the AR tool?
2. What types of learners based on their characteristics (i.e. gender and learning achievement) benefited more from the use of the AR tool?

Significance of the study

This study aims to benefit science teachers, especially those exploring the use of mobile augmented reality technology, as a learning tool in teaching difficult science concepts that require experimentation and exploration in laboratories. It also seeks to establish the fundamental link between learning theories and technology integration which would provide guidance for educators and information technologists alike. Lastly, this study hopes to shed light for decision-makers or policy-makers in the academe as far as the use of technology in science classrooms is concerned.

Related Literature

**Integrating technology to science teaching and learning**

There is an increasing expectation for teachers to integrate technology into their practice. In a study by Chittleborough (2014), the results showed that technological knowledge enhanced the fundamental pedagogical knowledge necessary for teaching chemistry content as supported by the TPACK and SAMR frameworks on technology integration. This means that as teachers integrate technology into their practice, they also improve their teaching competencies. The paper concludes that teacher education courses...
should include technological skills that complement the
technologies available in schools, and introduce new
technologies that keep up with the changing culture
of using technology in schools. In their book, Roblyer
and Doering (2013) gave an exhaustive list of emerging
trends in tools and applications like augmented reality
systems and gesture-based computing in educational
technology integration.

Augmented reality and science teaching and learning

There have been various studies done on the use
of AR in the field of science teaching and learning. In a study by Crandall, et. al. (2015), the researchers
reported on the development and beta-testing of an
augmented reality (AR) game that focuses on basic
enzyme kinetics to senior level students in a food
chemistry course. The researchers used the learning
objectives of one of the most difficult topics in food
chemistry, enzyme kinetics, to test this concept. The
results showed unanimous preference from participants
in favor of using the game-based learning as opposed to
the standard lecture format on enzyme kinetics.

In a similar study by Yoon, Anderson, Lin and
Elinich (2017), the researchers sought to prove that
students acquire a more accurate understanding of the
Bernoulli’s principle, a challenging science concept,
by interacting with an augmented reality (AR) device.
An experimental research design was adopted in this
study and it was conducted at a science museum in the
US. Collectively, the results suggest that the digital
augmentation had a positive effect on students’ content
knowledge. The results showed that students in the
AR condition demonstrated significantly greater gains
in knowledge over students in the non-AR condition.
Through interview responses, findings point that the
AR provides greater ability to visualize details and
hidden information to help students learn the science
concept. The researchers have shown in this study that
AR not only supports learning of science content but
can also support learning of very challenging science
content during brief periods of exploration.

In a recent paper by Liou, Yang, Chen and Tamg
(2017), the researchers compared the influence of the
2D image-based virtual reality (VR) and augmented
reality (AR) in an inquiry-based astronomy course.
The results revealed that the students in the AR group
performed significantly better than those in the VR
group. Accordingly, these findings point to the AR
technology as a beneficial tool for students to learn a
moon phase course.

While AR is considered as an “emerging” technology,
its usefulness in making difficult and challenging
science concepts easier to teach and learn have been
supported by these prior studies.

Augmented reality and experiential learning

A common weakness in the practice of technology
integration is the lack, or sometimes absence, of
learning theories from which it will be grounded. Some
of the previous studies cited cognitive load and situated
and constructivist learning as theories (Crandall et. al.,
2015; Liou, et. al., 2017).

In an article by Herrington, Reeves, and Oliver
(2007), the authors focused on immersive learning
(realistic creations of simulated environments) and
emphasized that the key element of immersive learning
is in the learning task itself. This supports the idea that
it is not the technologies that create the conditions for
immersive learning but the learning environment and
task. They concluded that while it is important to select
appropriate technologies, the responsibility for learning
should always move back to the learner. The learning
activities should allow the learner to reflect and decide
the steps and sub-steps in completing the task.
One significant paper that explored an augmented reality system based upon Kolb’s experiential learning theory was conducted by Huang (2015). In that study, the author developed e-commerce learning environments, enabling experiential learning, through an image-based augmented reality and a virtual reality. The learners were able to learn by doing, by experiencing and by reflecting. The author asserted that interaction with a simulated environment through the augmented reality learning can be a reasonable and viable substitute for the real-world experience.

2. Methodology

Design

As a pilot study to test the effectiveness on the use of an AR tool for chemistry learning, one group of students was chosen for this study. The group underwent the learning session using a worksheet designed after the principles of Kolb’s learning cycle and the AR app as a tool. It was implemented in a stand-alone in-class session for about one hour.

Setting and Population

The study was conducted in a public high school in Metro Manila. The participants were twenty-three senior high school students enrolled in a tech-voc program composed of 10 males and 13 females within the age group of 18-25.

Instruments

The following tools were used for the experiment:

- A chemistry pre- and post-test focusing on the topic of chemical reactions involving oxygen to measure learning gains
- A student worksheet reflective of Kolb’s learning stages to serve as an inquiry-based, learner-led activity

Data collection

All students were asked to answer a 10-item pre-test to assess their prior knowledge on the topic. For the experiment, the students used the worksheets, their own mobile phones with pre-installed Elements 4D application and the interactive paper blocks for the activity. A 10-item post-test was given at the end to measure “learning gains”.

Data analysis

The pre- and post-test scores of the students were analyzed to compute for the learning gains. The scores were summarized and analyzed, and a t-test was used to test for significance.
3. Results and Findings

To determine the effectiveness of a mobile augmented reality (AR) application in chemistry learning, the collected data are discussed following the identified research questions:

1. Is there a statistically significant improvement in students’ post-test scores after using the AR tool?

Test scores of the 23 students for both the pre- and post-tests were collected and results show positive learning gains for all, except one (1) student with a -1 learning gain. Overall, post-test scores are also higher than the pre-test scores. A t-test (Paired Two Sample for Means) was also used to further analyze the scores (significance level is $\alpha = 0.05$) and results show that there is a significant difference between the students’ scores after using the AR learning tool compared to those attained before the learning activity.

2. What types of learners based on their characteristics (i.e. gender and learning achievement) benefited more from the use of the AR tool?

For purposes of analyzing learning achievement, the students were categorized into three (3) groups based on their pre-test scores: low-achieving (L), mid-achieving (M) and high-achieving (H). Table 1 summarizes the results based on gender and learning achievement of the students:

<table>
<thead>
<tr>
<th>CATEGORIES</th>
<th>AVERAGE PRE-TEST SCORE</th>
<th>AVERAGE POST-TEST SCORE</th>
<th>AVERAGE LEARNING GAINS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>4.62</td>
<td>7.62</td>
<td>3.00</td>
</tr>
<tr>
<td>M</td>
<td>5.10</td>
<td>7.40</td>
<td>2.30</td>
</tr>
<tr>
<td>Learning Achievement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>6.38</td>
<td>8.50</td>
<td>2.13</td>
</tr>
<tr>
<td>M</td>
<td>4.43</td>
<td>7.71</td>
<td>3.29</td>
</tr>
<tr>
<td>L</td>
<td>3.63</td>
<td>6.38</td>
<td>2.75</td>
</tr>
</tbody>
</table>

Table 1. Average Pre- and Post-Test Scores based on Categories

Results show that there are positive learning gains across all categories considered. It also shows that female students attained higher learning gains compared to male students. As for learning achievement, mid-achieving students recorded the highest learning gains followed by the low-achieving group. To determine which types of learners based on these learner characteristics benefited more from the use of the mobile AR learning tool, a more detailed review of the results is shown on Table 2:
Results show that low-achieving female students posted the highest learning gains compared to other groups. On the other hand, low-achieving and high-achieving male students had similar (and the lowest) learning gains. Additionally, while high-achieving male students attained higher pre- and post-test scores on the average compared to their female counterparts, the high-achieving female students posted better learning gains compared to the high-achieving male students.

### Table 2. Average Pre- and Post-Test Scores based on Combined Categories

<table>
<thead>
<tr>
<th>CATEGORIES</th>
<th>AVERAGE PRE-TEST SCORE</th>
<th>AVERAGE POST-TEST SCORE</th>
<th>AVERAGE LEARNING GAINS</th>
</tr>
</thead>
<tbody>
<tr>
<td>FH</td>
<td>6.00</td>
<td>8.40</td>
<td>2.40</td>
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<tr>
<td>FM</td>
<td>4.33</td>
<td>7.67</td>
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</tr>
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<tr>
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</tr>
<tr>
<td>MM</td>
<td>4.50</td>
<td>7.75</td>
<td>3.25</td>
</tr>
<tr>
<td>ML</td>
<td>4.00</td>
<td>5.67</td>
<td>1.67</td>
</tr>
</tbody>
</table>

4. Conclusion and Future Work

This study is a pilot project that sought to investigate the effectiveness of the use of a mobile AR tool for chemistry learning. The results of the study reveal that post-test scores of the students after engaging in the learning activity using the mobile AR tool were higher on the average compared to their pre-test scores. Positive learning gains were also recorded across gender and learning achievement categories. The results further show that low-achieving female students benefited the most in using the mobile AR tool. These findings support the positive effect of the use of an AR tool in a science class that can enable students to conduct experiments and exploration without the need for physical laboratories or expensive equipment/materials. The results also point how AR technologies could help improve science learning among certain types of learners.

While the class activity designed for this study only covers a very specific topic on chemical reactions involving oxygen, it was designed using the principles of Kolb’s experiential learning theory – which balances the need for sound pedagogy in the attempt to test technology as a learning tool. The class activity was implemented as an inquiry-based and student-led learning session with the teacher only acting as an observer-facilitator. This further provides guidance on the design of learning activities that integrates the use of AR technologies.

This pilot project serves as groundwork for future studies involving the use of mobile AR tools for chemistry learning. Future iterations of this work
will include using an experimental design in the study to compare an experimental group using an AR tool and a control group using a non-AR tool. Other considerations that may guide future work is to include a user experience study to quantitatively determine the students’ reaction on the use of the AR tool. Students must also be provided with the same device to eliminate other external factors that might affect their use of the mobile AR app. Adding more class sessions that will enable the students to use the AR app for an extended length of time will also be helpful to address the possible “novelty effect” of the tool on learning achievement.

5. References


Elements 4D Chemistry Lessons and Interactive Blocks by DAQRI


Image sources: