Exploring the Viability of Augmented Reality as a Supplementary Material for Learning Cell Biology and Photosynthesis for Grade 12 Students

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Abstract: Augmented reality (AR) is one of the many emerging digital technologies that specializes in gaming, medicine, entertainment, and education. AR-assisted technologies have undergone studies and were claimed to provide a better learning experience for students and lecturers who integrate its features in modern-day classrooms. An example is Google Expeditions, a cost-effective and accessible alternative; however, further research may be needed on such applications, especially when used solely as a supplement. This study assesses AR's effects on Grade 12 students' academic performance and motivation when used as a supplemental learning material for cell biology and photosynthesis. Assessment scores between those who used augmented reality and those who did not reveal a greater improvement in academic performance of the former group. Furthermore, students reported through the Instructional Materials Motivation Survey (IMMS) that they were motivated by the AR tours used during the experiment. These findings point to the potential benefit of integrating AR-based supplementary materials to promote student learning and motivation.

Key Words: augmented reality; academic performance; motivation; cell biology; photosynthesis

1. INTRODUCTION

Digital technology, which refers to all types of electronic devices, equipment, and applications, has been integrated into various schools as educational technologies to facilitate learning and education. These include educational software, learning platforms, and more recently, augmented reality (AR) and virtual reality (Lo & Miller, 2020).

AR-assisted technologies not only give students a new perspective on learning but teachers as well. They provide a platform for experiential learning where students are partially immersed in a physical environment layered with digital elements, allowing them to view objects and models for better visualization and interactive experiences (Shapovalov et al., 2018). A meta-analysis conducted by Radu (2014) attributed AR to increased content understanding, long-term memory retention, improved physical task performance, improved collaboration, and increased student motivation.

One example of AR technologies is Google Expeditions, a platform that aims to bring both AR and VR to educational institutions. It contains a freely accessible catalog of "tours" that discuss a wide range of topics from various subjects. Though head-mounted devices are required for VR tours, AR tours simply require a smartphone with a camera.

Although numerous studies have reported the benefit of using AR in students' learning, the majority of these experiments utilize dedicated equipment and feature the full-time use of AR. Limited studies regarding more cost-effective and accessible applications such as Google Expeditions are found in literature. In this paper, we describe our experiment in assessing the impact of Google Expeditions on students' academic performance and motivation when used as supplementary material in learning about *cell biology* and *photosynthesis* in Grade 12 General Biology 1 class. We compare the assessment scores of students who used augmented reality as a supplement with those who solely relied on traditional learning methods. We also quantify learner motivation and share feedback from students on their perception of the use of AR technology to motivate them in their study.

2. RELATED WORK

Google Expeditions is a free immersive education app that features various AR and VR environments known as "tours." The app contains

1000 VR tours and 100 AR tours (Google, n.d.), allowing teachers and students alike to use their mobile devices to bring three-dimensional (3D) objects into life by virtually exploring different worlds through the different VR/AR tours.

Cell biology is the study of cells' structure and functions, focusing on both a cell's general properties and a specialized cell's unique features (Pentimalli & Giordano, 2017). It is one of the topics covered in the *General Biology 1* course mandated by the Department of Education. Four related AR tours were identified as relevant by University biology professors, namely tours about plant cells, the type of cells, cell organelles, and photosynthesis. Google Expeditions presents these as static 3D cross-sectional or complete models of particular cell types, organelles, or components. The *Photosynthesis* tour presents similar models of agents involved, including molecular models of some substances.

3. METHODOLOGY

This study adopted a quantitative approach to measure academic performance and a mixed qualitative-quantitative approach to elicit learner's motivation.

3.1. Participants

Fifty-five participants from two sections of Grade 12 Science, Technology, Engineering, and Mathematics (STEM) students to comprise the experimental and the control groups, respectively, gave their consent to participate in the study. Both sections have the same professor who was assigned to teach their General Biology 1 class. The experimental or AR group consisted of 33 students, while the control or non-AR group consisted of 22 students.

3.2. Procedure

Prior to the experiment proper, a *Learner Profile Questionnaire* was given to all participants to gather demographic information such as age, gender, and general average. A pre-test was then administered to both groups in order to assess their existing knowledge about cells and photosynthesis. It consisted of 15 multiple choice questions about cell types, cell structure, cell organelles, and photosynthesis sourced from various existing resources. Both the pre-test and post-test questionnaires were validated by biology professors of the university.

For both the AR and non-AR groups, the class professor conducted synchronous lectures and delivered the same content using the same visual aids. After 3 weeks, both groups were given a supplementary refresher class—in contrast with earlier lectures, the AR group was taught with a live screencast of Google Expeditions instead of traditional lecture materials. A post-test was answered by the two groups after two (2) days. As recommended by a University biology coordinator, paraphrased versions of the 15 items of the pre-test comprised the post-test.

For the AR group, a revised version of the *Instructional Materials Motivation Survey* (IMMS) by Keller (2010) was given prior to the post-test. The survey is composed of thirty-six 5 point Likert-scale items created by the author with reference to his ARCS model for learner motivation; the model and survey comprises four subscales: *attention*, *relevance*, *confidence*, and *satisfaction*. These were used to quantify participant motivation during the use of the AR application. To support the numerical data, six (6) open-ended questions were added at the end of the questionnaire to solicit qualitative feedback.

3.3. Data Analysis

To determine academic performance, results from the pre-test and post-test questionnaires were compared by calculating the percent changes of the mean scores. A higher positive percent change indicates a greater improvement between pre-test and post-test scores. The number of individual participants who garnered positive, negative, and no changes to their test scores was also displayed using a cluster analysis table. To further assess the statistical significance of one group's improvement compared to the other, an independent samples *t*-test between their respective score changes was conducted through the statistical software Jamovi. Assumptions such as normality and homogeneity of variances were tested to determine the type of *t*-test used.

Data from the IMMS, on the other hand, were analyzed by computing the mean score and standard deviation for each ARCS subscale and its items; a value closer to 5 corresponds to a higher level of motivation. The descriptive statistics of each subscale and their highest-scoring and lowest-scoring items are presented. Responses from the open-ended questions were also associated with the appropriate subscale and used to support the yielded results.

4. RESULTS AND DISCUSSION

Out of 33 participants, 19 from the AR group were able to attend the supplementary refresher class. Along with 20 out of 22 participants from the non-AR group, they were able to complete all data collection instruments. In this section, we present our findings and corresponding analyses of the data gathered from the pre-test, post-test, and IMMS.

4.1. Academic Performance

Comparison of the scores of the AR group and non-AR group is presented in Table 1. The percent change represents the improvement of students' scores after the lesson was taught to the students. Based on Table 1, the average score that the AR group improved by 22.11% while the non-AR group gained only a 5.84% elevation in score. A cluster analysis of the positive, negative, and neutral changes of each students' scores is also presented in the table.

The AR group had the most number of positive changes in scores (13 students or 68%) while the non-AR group had 10 students (50%). In terms of negative change, the AR group only had three students (16%), while the non-AR group had nine (45%). Only three students (16%) from the AR group and one student (5%) from the non-AR group had no change in scores.

Table 1. Comparison of academic performance per group

	Average			Frequency		
Group	Pre-test Score	Post-test Score	% Change	Negative Change	No Change	Positive Change
AR (n = 19)	9.63	11.11	22.11%	3	3	13
No AR (n = 20)	10.85	11.10	5.84%	9	1	10

Table 2 presents the results of the independent samples *t*-test for the mean score change (i.e., post-test score minus pre-test score) between both groups. Data were successfully tested for normality and homogeneity of variances. According to Student's *t*-test, $t(37.0) = 1.92$, $p < 0.05$ (one-tailed), the AR group had a statistically significant greater score change compared to the non-AR group. On average, the AR group's post-test score was 1.47 greater than their pre-test score, while the non-AR group's score only increased by 0.25.

Table 2. Independent samples *t*-test

		Statistic	df	p
Score Change	Student's *t*	1.92	37.0	0.031

Note: H_a AR > No AR

4.2. Motivation

Descriptive statistics for each motivation subscale of the IMMS are presented in Table 3. All four motivation subscales yielded a mean above 3.5, indicating that, on average, the AR group found it *moderately true* that the Google Expeditions induced motivation. Descriptive statistics for the highest-rated and lowest-rated items per subscale are presented in the table.

Among all the motivation subscales, the *attention* criterion obtained the highest mean (M = 3.88) and least-dispersed data (SD = 0.53). This implies that Google Expeditions did best in capturing the interest and prompting the curiosity of the participants. As seen in Table 2, the highest-scoring item (M = 4.45, SD = 0.59) referred to *attention* as well. Several participants affirmed this with comments such as, *"It was cool and refreshing because it's new,"* and *"I was amazed when our teacher showed us the cell through a camera."*

Relevance obtained the lowest overall mean, indicating that Google Expeditions was least compatible or connected to the learners' goals. For instance, some participants commented that the application was *"unnecessary as all the information and content may have been presented in a textbook"* and *"no different to other reading materials that had pictures."*

Table 3. Descriptive statistics for IMMS subscales and their highest-rated and lowest-rated items

IMMS Subscale	M	SD
Attention	**3.88**	**0.53**
15. The AR application is interesting and appealing.	4.45	0.59
28. The variety of the lessons in the AR application helped keep my attention on the lessons.	3.27	1.11
Relevance	**3.60**	**0.71**
6. It is clear to me how the content in the AR application is related to things I already know.	4.05	1.00
16. The content in the AR application is relevant to my interests.	3.18	0.98
Confidence	**3.63**	**0.50**
34. I could understand quite a bit of the material in the AR application.	4.18	0.72
25. After using the AR application for a while, I was confident that I would be able to pass a test on the material.	3.09	1.14
Satisfaction	**3.64**	**0.90**
36. It was a pleasure to use such a well-designed AR application.	3.95	1.00
5. Completing the exercises in the lessons after using the AR application gave me a satisfying feeling of accomplishment.	3.27	1.16

Nonetheless, the application was shown to have increased the participants' *confidence* or expectations of successfully understanding the lesson, as seen in item no. 34 (M = 4.18, SD = 0.72). Participants have noted that AR could *"make the learning of students easier"* and that the visualizations make the biology lesson *"comprehensible."*

In terms of *satisfaction*, participants moderately agree that Google Expeditions was well-designed (M = 3.95, SD = 1.00). The said criterion received the most-dispersed results (M = 3.64, SD = 0.90). Related comments from the participants vary positively and negatively, from *"It has everything I need"* to *"Using Google Expeditions currently sucks. If we give it more time to develop into a more robust application, then it could be worthwhile to use the tech."*

5. CONCLUSION AND RECOMMENDATIONS

Based on the findings presented, this study shows that AR as a supplementary tool has a positive effect on student academic performance and motivation. The group who used AR achieved greater improvement in their test score, reflecting better academic performance. Meanwhile, the resulting statistics on the motivation subscales which include attention, relevance, confidence, and satisfaction indicate that AR induced the learning motivation of those who have used it. With these promising results along with other existing studies, it can be established that implementation of AR as a supplementary material is certainly viable and has a big potential in revolutionizing the learning experience of students.

Findings reported in this study can serve as a foundation for future research needed in the development of more effective strategies and learning methods that will optimize AR in the educational field. The use of other AR applications can be explored to determine the best fit for various purposes, and the research sample size can be expanded to cover more diverse study groups. The length of time using the AR application can also be extended to capture more conclusive results, and instead of merely finding out whether the AR group was motivated, the motivation of both groups can also be compared.

Despite many pointing out AR's advantages, its application in the educational arena is still at its infancy stage. There remains a lot more to discover and learn about next-generation AR technologies and how they will transform the future of learning.

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