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INNOVATIVE APPROACH FOR TEACHING AND LEARNING SCIENCES THROUGH AUGMENTED REALITY

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Abstract- Our study aimed to evaluate how the integration of augmented reality (AR) technology into science learning courses at the primary and secondary school levels can impact student learning. We conducted this research during the 2023 school year in three primary schools in the Casablanca-Settat region and one college in the Tangier-Tetouan Al Houceima region. Eight novice teachers collaborated on action research projects. The study population consisted of students from various primary and secondary school classes. We adopted a semi-experimental methodological approach, dividing students into experimental and control groups. Before introducing AR into the teaching process, a pre-test was administered to all groups to assess their initial level of knowledge. Subsequently, lesson sessions were organized, with the experimental groups using AR technology while the control groups followed conventional teaching methods. The study findings demonstrated a notable enhancement in both student motivation and performance in the experimental groups compared to their peers in the control groups. Additionally, the participating teachers expressed great interest in this innovative pedagogical practice and felt the usefulness of pedagogical innovation in their professional careers. These results clearly demonstrate that integrating augmented reality into biology teaching has a positive impact on student learning.

Keywords: Pedagogical Innovation, Augmented Reality, Sciences Education, Primary Education, Secondary Education.

1. INTRODUCTION

Placing the learner at the center of educational reforms in Morocco is a key priority. The strategic vision for education from 2015-2030 aims to simplify and diversify curricula, programs, and teaching methods. The goal is to focus on the intellectual development of learners, promote research and innovation, and encourage initiative and autonomy. Pedagogical innovation through the integration of new technologies, various teaching methods, and interactive materials is crucial in the evolution of education. These approaches aim to make courses more engaging, motivate students, and encourage active participation. Augmented reality is a promising solution, especially for novice teachers, due to its flexibility, contextual integration, responsiveness, feedback, and ability to motivate learners.

In the Moroccan context, scientific awakening sessions during the primary cycle cultivate students' curiosity from an early age, laying the foundations for a deeper understanding of scientific principles related to physics, geology, and biology. In the secondary cycle, life and earth sciences courses are built upon the primary cycle, allowing students to deepen their scientific knowledge. The professional training of future teachers plays a crucial role in successfully implementing innovative educational approaches. According to official documents from the Moroccan Ministry of Education, pre-service teachers undergo several training modules, that provide them with scientific knowledge and teach them how to integrate technologies and teaching methods into their practices. After their assignment, novice teachers gain a deep understanding of the practical challenges of pedagogical innovations through action-research projects.

In this study, we mentored eight novice teachers as they incorporated augmented reality technology into science awareness sessions in the primary cycle, as well as life and earth sciences classes in the secondary cycle. These teachers previously received training to integrate augmented reality technology in biology teaching during their professional training. Our study is designed to answer the following question: What are the potential consequences of using augmented reality (AR) technology in science learning sessions on student performance and learning conditions?

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To address this question, we formulated two hypotheses:

- H0: There is no notable disparity in academic performance between students who utilized AR technology and those who employed traditional learning methods.
- H1: The introduction of AR technology has a significant positive impact on students' academic performance compared to those who used conventional learning methods.

2. THEORICAL FRAMEWORK

Nowadays, teachers use innovative technology tools like augmented reality (AR) and virtual reality (VR) in the field of science education. The AR is a technology that combines the real world with virtual objects [1]. These virtual objects appear to coexist in the same space as real-world objects [2]. The VR, on the other hand, is a digital and interactive virtual environment that allows users to experience the real world [3]. The origins of this technology can be traced back to Ivan Sutherland, who designed an augmented reality device in 1968. In the 90s, the term "Augmented Reality" was popularized by Thomas Caudell and David Mizell, becoming the first commonly used term [4]. Currently, AR and VR are utilized at all levels of education, from preschool to high school [5], and even in universities. Research on AR/VR in education began in 2003 [6], primarily focusing on the sciences, humanities, and arts. However, areas such as health, teacher training, and agriculture have not been extensively explored [7]. The AR and VR applications are designed for use in classrooms, laboratories, and as complementary resources for courses.

Numerous studies have shown that integrating AR and VR technology into education has significant benefits for learners and teachers. Research conducted by Lu and Liu [8] has demonstrated that the use of AR/VR technology helps improve learning outcomes. Additionally, according to Chiang, et al. [9], this technology has the potential to enhance learner motivation and create a dynamic and engaging learning environment. Studies by Kamarainen, et al. [10] also highlight the role of AR/VR technology in enhancing learners' comprehension by providing a more immersive and contextualized learning experience. Findings from Wojciechowski and Cellary [11] emphasize that AR/VR technology enriches the learning experience and makes important pedagogical contributions. Similarly, Ibanez, et al. [12] highlight the ability of AR/VR technology to enhance learners' enjoyment of the learning process. Liu and Tsai [13] underline how this technology can increase learner engagement. Finally, Huang, et al. [14] outline the potential of AR/VR technology in providing students with collaborative opportunities, thus enhancing the social aspects of learning.

Like any technological tool, integrating augmented reality into teaching presents substantial challenges, as several studies have shown. Some learners may face difficulties using AR, which can hinder their learning experience, as noted by Munoz Cristobal, et al., [15].

Furthermore, adopting AR requires a significant investment of time, as indicated by the findings of Gavish, et al., [16]. Technical issues, as highlighted by Chang, et al., [17], add another dimension of complexity. Moreover, AR can lead to cognitive overload for users, disrupting their perception and nervous system, which could have a negative impact on their psychological well-being [18]. Finally, AR's ability to distract students' attention, as pointed out by Chiang, et al., [9], represents another potential challenge to its successful integration into the educational context. These multiple obstacles underscore the need for a thoughtful approach and strategic problem-solving to maximize the pedagogical benefits of AR while minimizing its inherent challenges.

3. METHODOLOGY

Two first-year Moroccan middle school teachers from the Larache provincial directorate, along with six first-year Moroccan primary school teachers from the Mediouna provincial directorate, willingly participated in this study. Their objective was to complete their final dissertations on the integration of augmented reality technology into life science teaching. During this study, the teachers worked in pairs under our supervision. A total of 432 students in ten classes were included in the AR experimentation in this study. The students belonged to two school cycles: 148 students in four classes in the 1st year of middle school (1AC), and 275 students in a pair of classes in the third year of primary school (3AP) and four classes in the sixth year of the same school level (6AP). Table 1 provides data on the study participants and the themes studied.

Table 1. Data on study participants and themes studied

Teachers (Pairs)	Establishment	Teaching levels	Headcount		Themes studied
			Exp Grp	Ctrl Grp	
M1	Al Qolla Middle School (Larache)	1AC	60	88	The cell
P1	El Farabi Primary School (Casablanca)	6AP	30	30	The nervous system
P2	El Farabi Primary School (Casablanca)	6AP	30	30	The nervous system
P3	Touria Chaoui Primary School (Casablanca)	3AP	42	46	The respiratory system
M1: Pair of middle school teachers; P1, P2, P3: Pairs of primary school teachers. Exp Grp: Experimental group; Ctrl Grp: Control group					

We set up pre- and post-tests with participating teachers at the beginning of the study. The tests were tailored to the classes and grade levels for which the teachers were responsible. The themes studied were based on the official distribution of lessons in the science curriculum for primary school classes and the life and earth sciences curriculum for middle school students. The study lasted three months, with different durations of teaching-learning activities depending on the school level and lesson allocation. During this period, two groups of students received different teaching-learning activities.

The primary cycle students received science awareness courses, while the middle school cycle students received life and earth sciences courses. These courses were allocated two hours per week. The control group was taught using conventional methods, while the experimental group was taught using Augmented Reality. The experimental group used Merge Cube combined with smartphones equipped with the Object Viewer application, as well as the Anatomy 4D application combined with corresponding printed symbols on sheets. To promote collaboration and due to limited availability of mobile devices in the classroom, students worked in groups of three or four. The one-hour lessons followed the official pedagogical guidelines of the Moroccan Ministry of Education.

We analyzed the collected data using Microsoft Excel 365 and IBM SPSS Statistics 23. The Shapiro-Wilk test was used to check the normality of the data distribution for the pre- and post-assessment scores. For data with a normal distribution, we used the t-test for independent samples (Student's t-test), and for data that did not follow a normal distribution, we used the Mann-Whitney U-test. These assessments were employed to evaluate and match the average results of the two groups. In these tests, we made two hypotheses: The null hypothesis, denoted as H0, posited that there was no meaningful divergence in means between the two groups. and the alternative hypothesis (H1) stated that the means differed. Null hypothesis is rejected when the level of significance (p-value) is below 0.05, which is the commonly chosen alpha value.

4. RESULT

4.1. Results for Middle School Students

For the pair of middle school teachers (M1), we employed the Shapiro-Wilk test to assess the normality of the obtained score distributions in the pretest and post-test for the two student groups. The test showed a significance value exceeding 0.05 for both the pre- and post-test, indicating that the results of the experimental and control groups follow a normal distribution. We employed the student's t-test for two independent samples in order to make a comparison between the means of the two groups. The t-test results are shown in Tables 2 and 3.

Table 1. *t*-Test for independent samples in the pre-assessment phase

	Levene's test for equality of variances		t-test for equality of means				
	F	Sig	*t*	*ddl*	Sig. (bilateral)	Mean difference	Std error difference
HEV	3.72	0.056	-1.91	146	0.057	-0.813	0.424
HUV			-1.83	108.19	0.069	-0.813	0.442
HEV: Hypothesis of Equal Variances; HUV: Hypothesis of Unequal Variances							

The pre-test, Levene's test, resulted in a significance value of 0.056, which is slightly above the conventional threshold of 0.05. This indicates that we should take into account the equality of variances. However, the subsequent t-test showed a p-value of 0.57, indicating that at the beginning of the study, there was no statistical difference observed between the experimental and control groups. This suggests that the initial scores were similar and that the groups were comparable at the start.

Table 2. The t-Test for independent samples in post-assessment phase

	Levene's test for equality of variances		t-test for equality of means				
	F	Sig.	*t*	*ddl*	Sig. (bilateral)	Mean difference	Std error difference
HEV	6.39	0.013	-2.79	146	0.006	-1.446	0.518
HUV			-2.64	102,56	0.009	-1.446	0.546
HEV: Hypothesis of Equal Variances; HUV: Hypothesis of Unequal Variances							

In the post-assessment phase, Levene's test detected a significant difference in variances ($p = 0.013$), prompting consideration of unequal variances for the t-test. This test, shows p-value=0.009, further emphasized the importance of this difference and indicated a statistically significant distinction in the post-test scores between the experimental and control groups. These results highlight the significance of considering both Levene's test and the t-test, especially when variances may affect the interpretation of group differences.

Figure 1 visually presents the pre- and post-assessment means for both groups. It shows a parallel starting point with relatively low initial means: 6.2/20 for the experimental group and 5.4/20 for the control group. However, the post-test results reveal a substantial improvement in both groups. The experimental group achieved an average score of 13.12/20, while the control group achieved 11.7/20. The enhanced performance in both groups emphasizes the effectiveness of the instructional interventions. Importantly, the improvement in the experimental group exceeded that of the control group, reaffirming the beneficial effect of the implemented strategies by using AR technology in teaching and learning. This notable enhancement in performance suggests that teaching methods using AR technology significantly contributed to the observed gains in scores, supporting the conclusion drawn from the statistical analyses. These findings not only validate the success of the intervention but also highlight the potential for pedagogical innovations to lead to meaningful improvements in student outcomes.

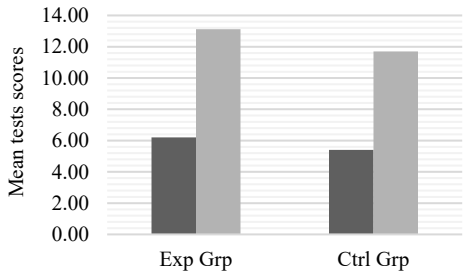

Figure 1. Mean test scores obtained by students of pair M1

4.2. Results for Primary School Students

Before selecting the appropriate statistical test, it is essential to check the normality of the score distributions. For this purpose, the Shapiro-Wilk test was used, which is a common choice for assessing the normality of small samples. The results for the three pairs of teachers are shown in Table 4.

Table 3. Results of the normality test

Pairs	Group	Test	Test statistic	p-value	Interpretation
P1	Experimental	Pre-test	0.9351	0.0673	Normal
		Post-test	0.5893	5.42×10^{-8}	Non-normal
	Control	Pre-test	0.8970	0.0071	Non-normal
		Post-test	0.8673	0.0015	Non-normal
P3	Experimental	Pre-test	0.9252	0.0368	Non-normal
		Post-test	0.8497	0.0006	Non-normal
	Control	Pre-test	0.8478	0.0006	Non-normal
		Post-test	0.9303	0.0499	Non-normal
P3	Experimental	Pre-test	0.899	7.75×10^{-4}	Non-normal
		Post-test	0.826	7.57×10^{-6}	Non-normal
	Control	Pre-test	0.8478	1.46×10^{-4}	Non-normal
		Post-test	0.9303	8.60×10^{-7}	Non-normal

Given that the normality of the distributions was not observed, except for the pre-test's results of the experimental group of pair P1, the decision was made to opt for the *U* test of Mann-Whitney. We selected this non parametric test for a comparison of the means of the two groups. The non-conformity with the normal distribution in most cases led to the use of this adapted statistical approach to evaluate the differences between the groups, enabling a reliable analysis despite the lack of normality in the data distribution [19]. Table 5 shows the results of U-test for the three pairs.

Table 4. Results of Mann-Whitney *U* test

Pair	Test	U-statistics	p-value	Interpretation
P1	Pre-test	487.5	0.5686	No significant difference
	Post-test	849.0	1.68×10^{-9}	Significant difference
P2	Pre-test	562.5	0.0919	No significant difference
	Post-test	830.0	1.37×10^{-9}	Significant difference
P3	Pre-test	1000.5	0.772	No significant difference
	Post-test	1665.0	2.92×10^{-9}	Significant difference

Figure 2 shows the mean scores of the students in the various groups belonging to the classes of the three pairs of novice teachers who took part in the pre- and post-test assessments.

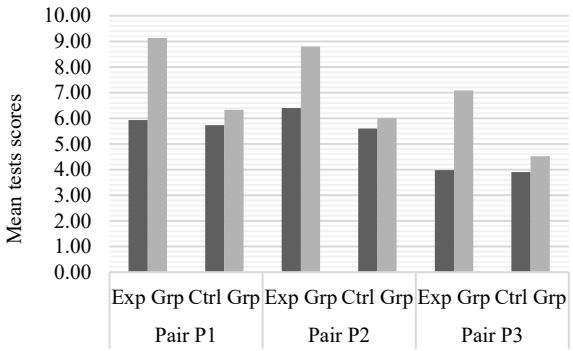

Figure 2. Mean test scores for students of the three pairs P1, P2 and P3

These findings indicate that the instructional interventions implemented in the experimental groups had a significant impact on student performance across all three pairs of teachers. The initial similarities in mean scores at the beginning of the study ensure a fair comparison between the two groups. The posterior test averages for the experimental groups show a substantial increase, demonstrating the effectiveness of the intervention strategies used. In pair P1, there was a remarkable improvement from an initial mean of 5.93/10 to a post-test mean of 9.13/10. Similarly, in pair P2, students in the experimental group experienced a significant increase from 6.40/10 to 8.80/10. Pair P3 also showed significant progress, with averages rising from 3.98/10 to 7.09/10. These results highlight the positive influence of the experimental teaching methods on student learning outcomes. The observed improvements in the experimental groups demonstrate the potential of these interventions to enhance students' understanding and mastery of the subject matter. The comparison with the control groups further emphasizes the unique contribution of the experimental teaching approaches in promoting academic achievement.

This study not only reinforces the importance of innovative teaching methods but also provides valuable insights for educators and policymakers seeking to improve overall classroom outcomes. The substantial improvements seen in the experimental groups using AR technology in learning suggest that a thoughtful and targeted approach to instruction can yield significant benefits, potentially transforming the educational experience for students.

5. DISCUSSION

The results of experimentation with augmented reality technology in life and earth sciences lessons for middle school students are significant. Initially, in the pre-test, the statistical analyses carried out to compare the performance of the intervention and reference groups showed that there no statistically notable variation was noted between the performance of the two groups. This suggests that the groups were equivalent and started from the same starting point. The post-assessment (post-test) showed significant variations in results, indicating a statistically notable difference between the performance of the two groups when AR technology was integrated into teaching and learning activities. These results suggest that the use of augmented reality had a measurable impact on student performance compared to conventional teaching methods.

When examining the mean scores of pretests as well as post-test for the two groups, the results have changed considerably. The initial means, which were relatively similar between students in the two groups, showed a clear improvement at the post-test. This improvement was particularly marked for students in the experimental group, highlighting a substantial enhancement in their achievement if we compare them to the control group. These results strongly suggest that the use of augmented reality was beneficial for student learning.

The substantial improvement in the experimental group's performance, as compared to the control group, suggests that Augmented Reality (AR) has a positive effect on enhancing students' academic achievement in life and earth sciences. These results are in line with those of numerous researchers who have investigated the impact of augmented reality in the field of education and have demonstrated that this technology promotes the development of skills in learners, positively affects their motivation, and can have a positive effect on their academic results [5], [8], [12], [20-24].

For primary school students, the results obtained from different classes of the three pairs of teachers are significant in assessing the impact of this technology on student learning. These results highlight significant differences between the experimental and reference groups. This finding underlines the effectiveness of AR technology use in the classrooms of all three pairs, in favor of the experimental groups. Examination of pre- and post-test means for students in the various groups showed relatively similar initial means between students in the intervention and reference groups in the classes of the three pairs. However, a significant increase in post-test means was noted, especially in the experimental groups when we compare them to the control groups, demonstrating a net improvement in the performance of students in the experimental groups compared to those in the control groups, which is in line with the results of several previous studies [25-28].

It should be emphasized that the teachers who agreed to participate in this study were fully aware of the significance of integrating augmented reality technology into their teaching practices. They observed, as previously noted by Martin Gutierrez, et al. [29] and Pellas, et al. [30], an increase in motivation and a positive change in behavior among their students during class sessions. Furthermore, as highlighted by Mercier, et al. [31] they perceive that this experience provided them with a good opportunity to develop and enhance their professional competences. However, the inexperienced teachers encountered some difficulties, mainly due to a lack of material resources and practical teaching experience.

All these results point to a positive impact of teaching methods that implement innovative pedagogical approaches, such as the use of augmented reality, on students' educational progress. This clearly proves a distinct advantage of innovative pedagogical approaches over conventional methods. They clearly show that integrating augmented reality into primary and middle school life science education has a positive impact on student learning, paving the way for a new era of more dynamic and engaging educational methods. These findings align with Ameziane, et al. [32] who indicate that it is essential to integrate Information and Communication Technologies for Education into programs and curricula, and to establish technological standards in reference frameworks for assessing learners.

6. CONCLUSION

The use of augmented reality technology in the classroom was crucial for assessing its impact on learners and learning conditions. Significant findings emerged in life science courses when employing this technology. Post-assessments across student groups indicated a distinct statistical improvement in performance, favoring the experimental groups over the control groups. Mean analyses showed a significant shift in results, with noticeable enhancements in performance, particularly within the experimental groups during post-tests. This substantial progress compared to the control groups strongly suggests the beneficial impact of augmented reality on students' learning, significantly boosting their academic performance. Despite encountering some hardware difficulties, novice teachers in this study observed heightened motivation and positive behavioral changes in students during teaching-learning sessions. The teachers recognized the experience as an opportunity to enhance their professional skills. Although these experiments were conducted in a limited number of Moroccan schools, they yield noteworthy results regarding the positive impact of integrating new technologies into teaching-learning activities. This is especially crucial in a context where learners use mobile devices for entertainment, emphasizing the need to redirect their focus toward applications that enhance their educational journey.

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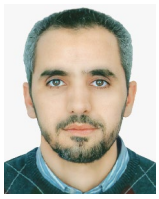
BIOGRAPHIES



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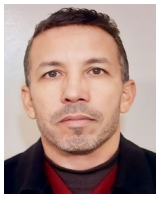
Scientific Publications: 5 Papers



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