Augmented Reality In Physics Laboratories: The Impact Of The Use Of Augmented Reality In Physics Laboratories On Student Performance: Rectification PW Case

Ayaichi Laila[1]; Bouras Nihal[1]; Amaaz Aziz[2]; Mouradi Abderrahman[1]; El Kharrim Abderrahman[1]

[1]Energy, materials and computing physics research team, Abdelmalek Essaadi University, Tetouan, Morocco
[2]Computer science and university pedagogical engineering research team, Abdelmalek Essaadi University, Tetouan, Morocco

laila.ayaichi@etu.uae.ac.ma

Abstract . Recent studies emphasize a positive impact of learning with augmented reality (AR) systems in various instructional scenarios. This study investigated the effects of the use of AR technologies in science laboratories on university students' laboratory skills and attitudes towards laboratories. A quasi-experimental pre-test/post-test control group design was employed. The participants were 180 third-year university students in physics chemistry and first-year master in physics chemistry, aged 20–24 years old. They were assigned to either an experimental or a control group Qualitative and quantitative data collection tools were used. The experimental results obtained after the use of augmented reality in the rectification PW. Revealed that AR technology has significantly improved the development of laboratory skills of university students. AR technology has both improved students' experimental skills and helped them develop positive attitudes towards physics laboratories.

Keywords : Augmented reality , rectification PW , Laboratory skills , Attitude

1 Introduction

Pedagogical tools have proved effective in improving the learning and teaching environment in the classroom and have even changed the way we think about education. One such technology that is receiving increasing attention in educational research is augmented reality (AR)[1]. AR is a type of technology that adds an extra layer of virtual information to the real world[2]. It allows users to discover the real world with virtual objects superimposed on them via a computer or smartphone camera [3]. In the field of education, AR allows students to be fully immersed in a semi-virtual environment through their senses[4]. This technology offers exceptional pedagogical opportunities

M. Khaldi et al. (eds.), Proceedings of the E-Learning and Smart Engineering Systems (ELSES 2024), Atlantis Highlights in Social Sciences, Education and Humanities 36,
https://doi.org/10.2991/978-2-38476-408-2_65

for educational users, including mobility, visualisation, alternative perspectives, comparison/contrast of multiple perspectives and integration of multiple perspectives[5]. Thanks to a relevant formative assessment mechanism, AR-based learning considerably improves learners' learning and motivation and reduces their cognitive load[6]. for example, Bacca-Acosta, Baldiris, Fabregat, Graf and Kinshuk [7] observed that the most reported benefits of using AR in educational contexts were that students had better learning performance and increased motivation. Saltan et Arslan[8] found evidence that the use of AR improves academic performance, student engagement, student motivation and student satisfaction. Akçayır et Akçayır [9] have also found that PLAR helps to improve learning outcomes in educational contexts. Chiang et al[10] shows that the use of augmented reality in physics education improves professional skills (e.g. spatial visualisation skills, assembly skills) [10]

The integration of AR in physics laboratories aims to transcend the limitations inherent in traditional teaching methods by providing students with interactive tools to explore and experiment with complex scientific concepts[11]. This innovative approach represents a unique way of visualising abstract phenomena, making them more concrete and accessible, which could potentially enhance understanding of the fundamental principles of physics and generate greater interest in the subject among students [12]. In addition, AR reduces the time needed to visualise physical phenomena that are often invisible, thus improving the overall effectiveness of physics learning[13]. Compared with traditional teaching methods such as reading paper documents, PLAR stimulates students' motivation and interest in learning[14]. AR-based laboratory experiments allow students to develop deeper learning skills, significantly improving the quality of physics teaching[15].

The integration of AR into physics laboratories has significantly improved student performance, offering significant benefits in several key areas of learning [16]. Advances in AR technology have enhanced the visualisation of physical phenomena, optimised the efficiency of experiments and deepened our understanding of concepts [6]. Research has shown that the use of AR in practical physics work has not only led to an improvement in students' results, but also to a reduction in the time needed to carry out experiments [17], A recent study highlighted that AR applications in physics laboratory experiments have facilitated the development of learning skills in students, while enhancing the quality of teaching and providing enriching opportunities for analysis, discussion and evaluation [14]. Research has also shown that the use of AR in physics laboratories has significantly improved the success of learning and the preparation of experiments, guaranteeing a safer and more efficient learning process. [11]. The use of interactive 3D models of circuits and circuit components, made possible by AR, allowed students to visualise, manipulate and explore concepts in a more immersive and hands-on way [18]. In addition, studies have shown the positive impact of AR on students' motivation, skills and attitudes towards practical physics work, underlining its crucial role in improving the overall laboratory learning experience [19]. However, despite the promising results, certain gaps remain in the literature, notably the lack of comparison with traditional teaching methods and the absence of objective measures of the effectiveness of the AR experience. In this context, our article aims to fill these gaps by examining the impact of the use of AR in physics practical work, focusing specifically on the study of righting TP. By assessing the performance of university students, our research aspires to provide valuable insights to inform educational practitioners on the benefits and challenges of integrating AR into physics laboratories More specifically, the aims of this study are:

What is the impact of using augmented reality in physics laboratories on students' academic performance, particularly in terms of exam results, knowledge retention and the acquisition of experimental skills?

2 Research methodology

The methodology adopted in this study aims to examine the impact of the use of augmented reality on the performance of third-year undergraduate and first-year masters students in physics chemistry in practical physics sessions, with a particular focus on the case of straightening. The study sample is made up of 180 male and female students from the Ecole Normale Supérieure, selected at random to ensure a balanced representation of the two levels of study.
As part of this research, an experimental device was designed to evaluate the students' performance before and after the augmented reality intervention. This evaluation was carried out in two stages: firstly, a pre-test was administered before any augmented reality intervention, aimed at assessing the participants' level of understanding and competence in physics straightening. Then, after a period of intervention using AR in practical physics sessions, a post-test identical to the pre-test was carried out to measure any changes in the students' performance.

The experiment was carried out in several distinct stages to ensure a rigorous methodology and accurate assessment of the impact of augmented reality on student performance. Firstly, a preliminary experimental design phase was undertaken, during which the augmented reality tools were selected and integrated as part of the physics practical work sessions on straightening. The students were then randomly divided into two groups, an experimental group that took part in the physics practical sessions using augmented reality, and a control group that followed the sessions in the traditional way, without the use of augmented reality (see Figure 1).

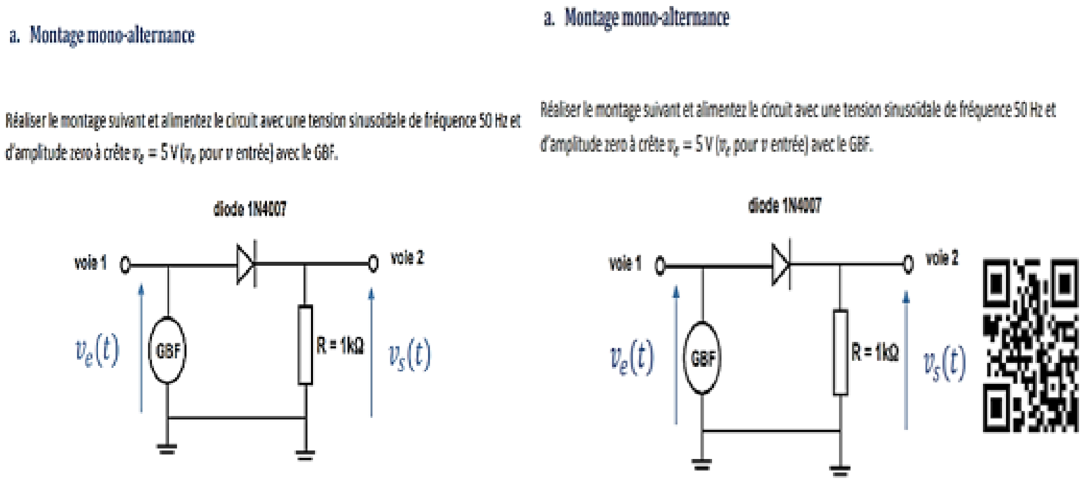

Fig. 1. Screenshot of the laboratory manuals for the experimental (left) and control (right) groups.

The main phase of the experiment involved the implementation of AR intervention in the physics practical sessions for the experimental group. During this time, students used AR devices to virtually manipulate electrical components and visualise rectification concepts in action. The sessions were designed to provide an immersive and interactive experience, allowing students to manipulate abstract concepts in a concrete way (see Figure 2). Through the perception of the marker label on the paper by a webcam or mobile device, augmented components (e.g. text, audio, video and links to additional materials and 3D objects) are produced by the AR

Fig. 2. screenshot of the procedure for accessing AR resources

As part of this study, AR application specially developed for practical physics sessions was used. This application was designed to be compatible with common mobile devices such as smartphones and tablets, allowing users to view virtual schematics of electrical circuits superimposed on real circuits. This feature provides an immediate, interactive experience for users. In addition, the application incorporates features such as automatic detection of electrical components and the ability to interact with them in real time. The addition of these further details about the AR technologies used in this study is intended to facilitate the replication and application of the methodology in other similar studies.

At the same time, the control group followed the practical sessions in the conventional way, using traditional teaching aids such as textbooks and practical demonstrations. Particular care was taken to ensure that the teaching conditions between the two groups remained as equitable as possible, with the exception of the use of AR in the experimental group.

The use of a pre-test and a post-test allows a direct comparison of students' performance before and after the AR intervention, thus providing significant quantitative data on the effectiveness of this learning method. This rigorous methodological approach will enable an in-depth evaluation of the impact of AR on students' physics skills, particularly in the specific context of recovery.

3 The Results

In this study, students' performance was assessed through a pre-test and a post-test, before and after the AR intervention, respectively. The results presented below (see Table 1) provide an in-depth overview of the differences observed between the experimental and control groups, as well as relevant statistical analyses, highlighting the implications of this innovative intervention on physics learning.

Table 1. ANOVA analysis of the pre-test results for the control and experimental groups

variable	groupe	N	Mean	SD	F	P
Pré-test	Groupe de contrôle	90	14,0207	1,17827	,000	,021
	Groupe expérimentale	90	14,0236	1,18817		

The results of the analysis of variance (ANOVA) for the pre-test indicate a striking similarity between the initial performance of the two groups before any AR intervention. The means of the control and experimental groups were very close, with similar standard deviations. Although the F-test showed a slight variation between the means of the two groups, the difference observed was minimal and not significant. These results suggest that the initial performance of the two groups was virtually identical before the intervention.

The impact of the augmented reality intervention on students' performance in the post-test is presented in the table below (see table 2), highlighting the differences between the control group and the experimental group.

Table 2. ANOVA analysis of post-test results for control and experimental groups

variable	groupe	N	Mean	SD	F	P
Post-test	Groupe de contrôle	90	14,0207	1,17827	839,749	,000
	Groupe expérimentale	90	19,3307	,79138		

The results of the analysis of variance (ANOVA) revealed a significant difference between the performance of the control and experimental groups after the AR intervention. The experimental group obtained a significantly higher mean score than the control group, indicating a positive effect of the intervention on students' performance in physics. The variation observed between the two groups was not due to chance, as suggested by the high F test, and the very low p-value confirms the significance of this difference.

4 Discussion and conclusion

In this study, the use of AR technology in practical physics work was tested to measure the effects on the performance of university students. The superior performance observed among students in the experimental group at the post-test clearly indicates the benefits of this intervention on their learning. AR offers a deeper immersion into abstract physical concepts, allowing students to visualise and manipulate virtual objects in three dimensions. This interactive approach encourages a more intuitive and concrete understanding of concepts, which can lead to improved performance. These results have also been predicted by studies in the literature [17], [20], [21] which highlights the potential of AR to enhance learning by providing realistic simulations and making it easier to understand complex concepts.

Furthermore, the similarity of initial performance between the two groups, as evidenced by the pre-test results, strengthens the internal validity of our study and confirms that the observed improvements are attributable to the RA intervention rather than to initial differences between the groups. This suggests that AR played a crucial role in improving the performance of students in the experimental group. However, despite these promising results, it is important to acknowledge the limitations of our study. The limited duration of the intervention and the small number of participating students may limit the generalisability of the results. In addition, external factors such as the students' level of familiarity with AR technology could have influenced the results.

Future research could deepen our understanding of the underlying mechanisms of AR learning. By exploring the different ways in which students interact with virtual environments and identifying the most effective learning strategies, we could maximise the impact of this technology on education. In addition, it would be interesting to study the long-term effect of using AR on students' performance and motivation to learn. In conclusion, our study shows that the integration of AR into practical physics work offers significant potential for improving student learning. The results of our analysis revealed superior performance among students in the experimental group, suggesting that the interactive immersion offered by AR can foster a deeper understanding of physics concepts and lead to higher academic achievement.

In addition, an in-depth analysis of student reactions to the use of AR could provide valuable insights into the psychological and emotional aspects of AR learning. Understanding how students perceive and react to this technology could help educators design more inclusive learning experiences and overcome potential barriers to its widespread adoption. By focusing on these aspects, future research could help shape more effective and meaningful use of AR in education, paving the way for major advances in educational technology.

References

[1] J. Grodotzki, B. T. Müller, et A. E. Tekkaya, « Introducing a general-purpose augmented reality platform for the use in engineering education », *Advances in Industrial and Manufacturing Engineering*, vol. 6, p. 100116, mai 2023, doi: 10.1016/j.aime.2023.100116.

[2] R. Permana, E. P. W. Mandala, et D. E. Putri, « Augmented Reality dengan Model Generate Target dalam Visualisasi Objek Digital pada Media Pembelajaran », *Majalah Ilmiah UPI YPTK*, p. 7-13, juin 2023, doi: 10.35134/jmi.v30i1.143.

[3] L. w. s. Loijens, D. Brohm, et N. Domurath, « 1. What is augmented reality? », in *Augmented reality for food marketers and consumers*, Wageningen Academic Publishers, 2016, p. 13-28. doi: 10.3920/978-90-8686-842-1_1.

[4] D. Kamińska *et al.*, « Augmented Reality: Current and New Trends in Education », *Electronics*, vol. 12, nº 16, Art. nº 16, janv. 2023, doi: 10.3390/electronics12163531.

[5] M. J. Rodríguez-Fórtiz, A. Fernández-López, T. Ruiz-López, C. Rodríguez-Domínguez, M. C.- Cuevas, et M. L. Rodríguez-Almendros, « Providing adaptations for Special Education Mobile Learning », *EAI Endorsed Transactions on Future Intelligent Educational Environments*, vol. 1, nº 1, sept. 2014, Consulté le: 5 avril 2024. [En ligne]. Disponible sur: https://eudl.eu/doi/10.4108/fiee.1.1.e4

[6] Y.-C. Chien, Y.-N. Su, T.-T. Wu, et Y.-M. Huang, « Enhancing students' botanical learning by using augmented reality », *Univ Access Inf Soc*, vol. 18, nº 2, p. 231-241, juin 2019, doi: 10.1007/s10209-017-0590-4.

[7] J. L. B. Acosta, S. M. B. Navarro, R. F. Gesa, et K. Kinshuk, « Framework for designing motivational augmented reality applications in vocational education and training », *Australasian Journal of Educational Technology*, vol. 35, nº 3, Art. nº 3, juin 2019, doi: 10.14742/ajet.4182.

[8] F. Saltan et Ö. Arslan, « The Use of Augmented Reality in Formal Education: A Scoping Review », *EURASIA J Math Sci Tech Ed*, vol. 13, nº 2, p. 503-520, déc. 2016, doi: 10.12973/eurasia.2017.00628a.

[9] M. Akçayır et G. Akçayır, « Advantages and challenges associated with augmented reality for education: A systematic review of the literature », *Educational Research Review*, vol. 20, p. 1-11, févr. 2017, doi: 10.1016/j.edurev.2016.11.002.

[10] F.-K. Chiang, X. Shang, et L. Qiao, « Augmented reality in vocational training: A systematic review of research and applications », *Computers in Human Behavior*, vol. 129, p. 107125, avr. 2022, doi: 10.1016/j.chb.2021.107125.

[11] J. Hallmann, C. Stechert, et S. I.-U. Ahmed, « SUPPORTING STUDENT LABORATORY EXPERIMENTS WITH AUGMENTED REALITY EXPERIENCE », *Proceedings of the Design Society*, vol. 3, p. 3235-3244, juill. 2023, doi: 10.1017/pds.2023.324.

[12] M. Freese, A. Teichrew, J. Winkelmann, R. Erb, M. Ullrich, et M. Tremmel, « Measuring teachers' competencies for a purposeful use of augmented reality experiments in physics lessons », *Frontiers in Education*, vol. 8, p. 1180266, juin 2023, doi: 10.3389/feduc.2023.1180266.

[13] A. D. Rahmat, H. Kuswanto, I. Wilujeng, et R. Perdana, « Implementation of mobile augmented reality on physics learning in junior high school students », *Journal of Education and e-Learning Research*, vol. 10, nº 2, p. 132-140, févr. 2023, doi: 10.20448/jeelr.v10i2.4474.

[14] B. S. Arymbekov, K. M. Turekhanova, D. D. Alipbayev, et Y. R. Tursanova, « DEVELOPMENT OF AUGMENTED REALITY APPLICATION FOR PHYSICS AND GEOPHYSICS LABORATORY », *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. XLVIII-5-W2-2023, p. 19-24, juin 2023, doi: 10.5194/isprs-archives-XLVIII-5-W2-2023-19-2023.

[15] Y. Chang, « PhysicsAR: Problem Set Reality », in *ACM SIGGRAPH 2023 Appy Hour*, in SIGGRAPH '23. New York, NY, USA: Association for Computing Machinery, juill. 2023, p. 1-2. doi: 10.1145/3588427.3595359.

[16] G. Iatraki et T. A. Mikropoulos, « Augmented Reality in Physics Education: Students with Intellectual Disabilities Inquire the Structure of Matter », *PRESENCE: Virtual and Augmented Reality*, vol. 31, p. 89-106, déc. 2022, doi: 10.1162/pres_a_00374.

[17] A. Laila, B. Nihal, A. Aziz, M. Abderrahman, et E. K. Abderrahman, « Exploring the possibilities of augmented reality in physics education », présenté à E-Learning and Smart Engineering Systems (ELSES 2023), Atlantis Press, févr. 2024, p. 480-489. doi: 10.2991/978-94-6463-360-3_45.

[18] K. Mukhtarkyzy, G. Abildinova, et O. Sayakov, « The Use of Augmented Reality for Teaching Kazakhstani Students Physics Lessons », *International Journal of Emerging Technologies in Learning (iJET)*, vol. 17, nº 12, p. 215-235, juin 2022.

[19] M. Akçayır, G. Akçayır, H. M. Pektaş, et M. A. Ocak, « Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories », *Computers in Human Behavior*, vol. 57, p. 334-342, avr. 2016, doi: 10.1016/j.chb.2015.12.054.

[20] R. Zatarain-Cabada, M. L. Barrón-Estrada, B. A. Cárdenas-Sainz, et M. E. Chavez-Echeagaray, « Experiences of web-based extended reality technologies for physics education », *Computer Applications in Engineering Education*, vol. 31, nº 1, p. 63-82, 2023, doi: 10.1002/cae.22571.

[21] S. Yu, Q. Liu, J. Ma, H. Le, et S. Ba, « Applying Augmented reality to enhance physics laboratory experience: does learning anxiety matter? », *Interactive Learning Environments*, vol. 31, nº 10, p. 6952-6967, déc. 2023, doi: 10.1080/10494820.2022.2057547.