



INNOVATION IN PROFESSIONAL PRE-SERVICE TEACHER TRAINING USING AUGMENTED AND VIRTUAL REALITY

ASSIMI Essadiq^{1*}, ZERHANE Rajae¹, BOUBIH Said^{1,2}, EN-NHILI Larbi¹, Rachid JANATI IDRISSE¹

¹ :ERIPDS¹, Ecole Normale Supérieure, Abdelmalek ESSAADI University, Tetouan, Morocco.

² : Institut Supérieur des Professions Infirmières et Techniques de la Santé, Tétouan

ARTICLE INFO

Keywords:

Augmented reality, Virtual reality,
Teaching-learning, Scientific
awakening, pre-service teachers.

ABSTRACT

This study investigates into the effects of incorporating augmented and virtual reality (AR/VR) activities into biology courses on the learning and motivation of primary cycle pre-service teachers at the Regional Centre for Education and Training Professions (RCETP). The primary aim of our study is to ease the transfer of skills by familiarizing pre-service teachers with AR/VR technology in life sciences learning activities, aiming to equip them for integrating these technologies into their future classroom responsibilities.

We administered a questionnaire survey to pre-service teachers, including twenty items rated on a Likert scale ranging from "Totally agree" to "Totally disagree." The objective was to gauge the extent to which respondents aligned with the provided statements. Survey results show a noteworthy level of enthusiasm and motivation observed during the training sessions. A considerable majority of pre-service teachers perceived the usefulness of augmented and virtual reality technology in education, and expressed their intent to incorporate augmented reality activities into life sciences courses as they start their professional careers. These findings highlight the positive and promising impact of using augmented and virtual reality in education. Moreover, they suggest that integrating AR/VR technology opens exciting new possibilities for future teachers.

INTRODUCTION

In the present era, it is crucial to emphasize the significant influence that the increasing prevalence of mobile devices like smartphones and tablets is exerting on educational approaches. Rather than being confined to traditional methods such as slide shows or conventional textbooks, learners now have the opportunity to leverage the advantages offered by virtual reality (VR) and augmented reality (AR) technologies. Numerous studies have consistently demonstrated that the integration of augmented and virtual reality technology positively affects learner motivation, fosters self-directed learning, and has the potential to enhance academic performance across various domains (Y.-C. Chen, 2006; Chien et al., 2019; Giasiranis & Sofos, 2016; Ibáñez et al., 2014;

Jamali, 2017; Safadel & White, 2019; Z. A. Yilmaz & Batdi, 2021).

In the field of science education, it is crucial for learners to understand different biological phenomena. Within this pedagogical context, augmented reality (AR) and virtual reality (VR) technologies emerge as promising instruments, offering a solution to enhance the comprehension of biological phenomena and facilitate the visualization of living entities across both macro and microscopic scales. Consequently, it becomes imperative for pre-service teachers to acquire proficiency in the utilization of these innovative technologies, namely AR and VR, and develop the requisite skills for their seamless integration into pedagogical practices. Through acquiring proficiency in the utilization of

¹ ERIPDS : Equipe de recherche en ingénierie pédagogique et didactique des sciences

* Corresponding author : assimi.sad@gmail.com

these technologies, pre-service educators will be empowered to conceptualize and execute compelling pedagogical interventions, thereby fully capitalizing on the potential benefits these technologies afford in the domain of science education (Sáez-López et al., 2020).

In the framework of the Moroccan education system, scientific awakening activities are systematically integrated into the primary education cycle, encompassing a spectrum of biological phenomena. Preparing for their instructional roles within classrooms, pre-service teachers, holding a bachelor's degree or an equivalent university diploma, undergo a comprehensive one-year professional training program at one of the Regional Centres for Education and Training Professions (RCETP). During this training period, pre-service teachers learn about biological content through dedicated modules, notably the "Reinforcing Basic Training" and "Didactical Production," each comprising 15 hours of instructional engagement. The aim of these modules is to develop the requisite professional skills, incorporating both theoretical knowledge and practical experience, which are indispensable for future teachers to proficiently convey diverse scientific subjects within the primary school level.

One of the innovations we have introduced in the professional training of future teachers is the integration of augmented and virtual reality technology into the training sessions within the modules of reinforcing basic training and didactical production. The use of this technology, eased through mobile devices (smartphones and tablets), took the form of practical workshops, involving the visualization of diverse content related to the primary school biology curriculum. Participants practiced how to integrate these technological tools into sessions of scientific awakening courses, anticipating their future use in classrooms with their students. The feedback from the prospective teachers following these sessions was positive, prompting us to investigate the extent to which these training sessions were beneficial and to what degree they

convinced the future teachers to adopt this technology in the classroom.

This research aims to answer two main questions concerning pre-service primary school teachers, following their participation in training courses at the RCETP on the use of AR/VR in science education.

- Firstly, how useful do pre-service primary school teachers perceive AR/VR to be in teaching and learning activities?
- Secondly, do they plan to adopt this technology in their classroom practices?

To answer these questions, two main hypotheses have been proposed:

- The first hypothesis (H1) postulates that pre-service teachers have clearly perceived the usefulness of AR/VR in teaching-learning activities following their training at the RCETP.
- The second hypothesis (H2) puts forward the idea that pre-service teachers intend to integrate AR/VR technology into their classroom teaching practices.

By testing these hypotheses, we will be able to better understand how future teachers perceive and plan the use of AR/VR as a potentially enriching tool for the scientific awakening of primary school learners.

THEORETICAL FRAMEWORK

Augmented reality (AR) is a technology that allows users to superimpose virtual objects on the real world, creating an experience where virtual objects appear to coexist with real ones (R. Azuma et al., 2001; R. T. Azuma, 1997). Similarly, virtual reality (VR) offers an interactive digital environment in which the user feels immersed in a virtual world like the real world. The various augmented reality (AR) technologies differ in terms of cost, accessibility, and usability in educational contexts. Recent studies show that access to augmented reality has become easier thanks to mobile devices, which have become easier, more portable and more interactive. (Akçayır & Akçayır, 2017; Hwang et al., 2012).

AR was initially introduced as a training tool for airline and air force pilots in the nineties (Caudell & Mizell, 1992). Augmented and virtual reality (AR/VR) is currently one of the most recent

visualisation technologies in educational environments (Erbas & Demirer, 2019; Zhou et al., 2020). It can be used at all school levels, from pre-school to high school (Chiang et al., 2014; Kerawalla et al., 2006) as well as at university level (Ferrer-Torregrosa et al., 2015). Several AR/VR technologies have been applied in the field of education (Zhou et al., 2020) because of their visualisation capabilities, which make abstract or invisible content tangible and visible. Studies on the use of AR/VR in education began in 2003 (Erbas & Demirer, 2019). Sciences, humanities and arts are the educational fields where AR/VR has been most used. The majority of studies on AR/VR have focused on primary and secondary school learners, as well as university students (Akçayır & Akçayır, 2017).

Over the last two decades, many researchers have studied the effects of the use of augmented and virtual reality (AR/VR) in the education field. Their findings show that this technology improves skills development and promotes positive attitudes among learners (Boyle et al., 2012; Liu et al., 2009; Rahman et al., 2020). It also has a positive impact on their motivation, encourages self-learning and can improve academic performance (Chien et al., 2019; Jamali, 2017; Safadel & White, 2019; Z. A. Yilmaz & Batdi, 2021). AR/VR methods help learners to better understand their learning content (Yoon et al., 2012), are perceived as more satisfactory than traditional teaching approaches (C.-M. Chen & Tsai, 2012; Muñoz-Cristóbal et al., 2015), and makes teaching more entertaining (Ibáñez et al., 2014; Lu & Liu, 2015). This technology also facilitates interaction between learners and between learners and learning materials (Hsiao et al., 2012; Kamarainen et al., 2013). However, there are some disadvantages to using AR/VR in education. The distracting nature of this technology can have a negative impact on their psychological well-being (Grinshkun et al., 2021). The limitations of AR/VR mainly include the difficulty of maintaining superimposed information, the excessive attention paid to virtual information and the perceived intrusiveness of the technology (Bacca et al., 2014).

METHODOLOGY

To investigate the intention of pre-service teachers to incorporate augmented and virtual reality (AR/VR) technology into their teaching practices, we executed a comprehensive questionnaire survey including twenty items. Participants were asked to evaluate these items using a Likert scale, ranging from "Totally agree" to "Totally disagree." The primary objective was to gauge the extent to which respondents concurred with the statements presented.

The questionnaire items were systematically categorized into two distinct variables: the perceived usefulness of AR/VR technology in the context of science teaching (comprising 10 items) and the inclination to integrate this technology into their classroom activities (comprising another 10 items). This dual-variable approach aimed to provide a nuanced understanding of the participants' perspectives on both the utility of AR/VR in science education and their intention to incorporate these technologies into their future teaching practices.

The survey was conducted among 85 pre-service teachers specializing in primary school education. These individuals were undergoing training at the Regional Center for Teacher Training and Pedagogical Support (RCTEP) of Benslimane during the academic year 2022. By focusing on this specific group of primary school pre-service teachers, our study aimed to capture insights into the perceptions and intentions of educators in the early stages of their professional development.

Using this methodological approach, we were able to collect significant data on the attitudes and intentions of pre-service teachers towards the use of AR/VR technology in their teaching. This research therefore offers a valuable overview of the perspectives for integrating these new educational technologies in the context of primary cycle teachers training.

Table 1: Statistics on respondents (Nb= 85)

Categorical variables		Percentage (%)
Gender	Female	91.8
	Male	8.2
Age	21-25	64.7
	26-30	35.3
Bachelor's degree speciality	Sciences	41.1
	Literature	8.2
	Economics / Law	50.3

The data presented in Table 1 highlights a notable gender disparity among pre-service teachers, with a higher representation of females compared to males. Furthermore, a significant portion of these individuals hold bachelor's degrees in science, economics, or law, while only 8.2% have a background in literature.

To ensure the reliability of the test instrument, a pilot sample of 10 pre-service teachers was engaged to respond to the test questions. The results of the Cronbach's alpha calculation (Cronbach, 1951), as depicted in Table 2, reveal a robust reliability with a value of $\alpha = 0.746$ for the first part of the test and $\alpha = 0.818$ for the second part. These elevated alpha values indicate that the test questions consistently measure the same characteristic or skill in the participants. This high level of reliability enhances the validity of the study's results, suggesting that the data obtained accurately reflects the intended aspects being measured. This contributes to the overall robustness and credibility of the study's findings.

Table 2: Reliability statistics of the survey

Cronbach's Alpha	Part 1: Perceived usefulness	Value	0,746
		Number of elements	10
	Part 2: Adoption intention	Value	0,818
		Number of elements	10
	Total number of items		20

The survey was directly conducted with pre-service teachers upon the completion of training sessions that incorporated augmented reality (AR) and virtual

reality (VR) technology into two specific modules: one focused on reinforcing fundamental science training and the other on didactical production. These instructional modules were structured as practical workshops, in which, pre-service teachers used the "Merge Cube" and applications like "Object Viewer" on their smartphones in addition to the "Anatomy 4D" application with its code's pages (Figure 3), to visualize diverse content related to the scientific awakening school programs across various levels of primary education. Specifically, the lessons covered the anatomy and physiology of multiple systems of the human body, such as the cardiovascular system, the nervous system, the respiratory system, the urinary system, and the reproductive system. Instead of using only two-dimensional materials, by using AR/VR technology, pre-service teachers had the opportunity to explore three-dimensional models in an interactive and immersive experience. This allowed observers to simultaneously examine the anatomy of each system and understand the relationships between different systems, supplying a comprehensive view of the anatomical and functional complementarity of biological systems.

To ensure a comprehensive understanding of the effectiveness of these innovative teaching tools, data collection and analysis were conducted through various software applications. Initially, Google Forms was employed for the collection of responses from the participants. Subsequently, MS Excel 365 was used for the management and processing of the gathered data. For a more in-depth statistical

analysis, SPSS 23 was employed, enabling a rigorous examination of the collected data. This methodological approach aimed to derive meaningful insights into the impact of AR/VR

technology integration on the training of prospective science teachers.



Figure 1: The merge cube

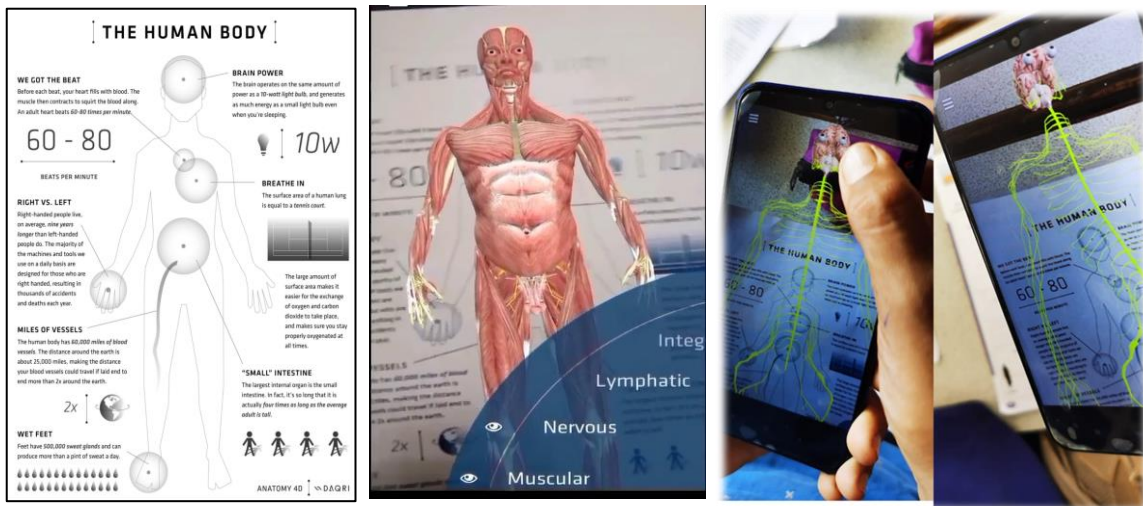


Figure 2: Example of resources displayed in the Object Viewer application using the merge cube

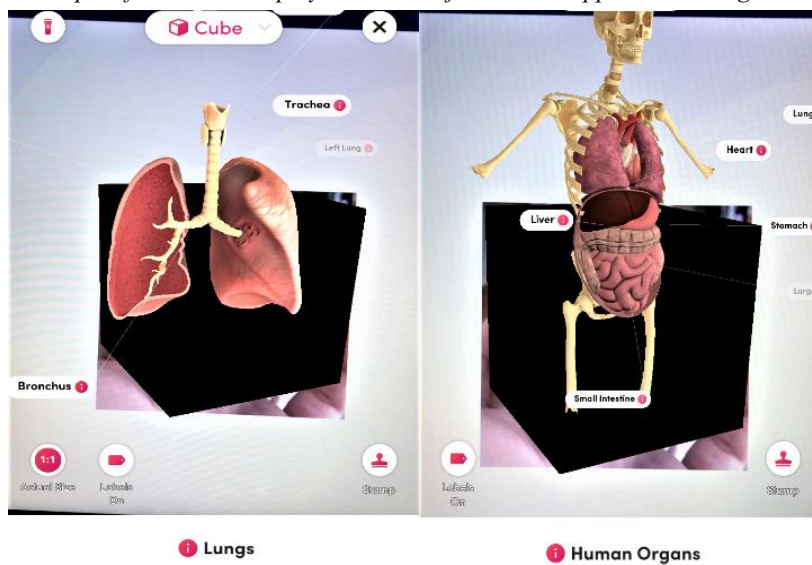


Figure 3: Example of code's pages used with mobile devices and resources visualized in the Anatomy 4D application.

In summary, the data collection process was conducted in a practical and interactive way during the training workshops, highlighting the benefits of AR/VR technology in science learning. The responses collected were then processed using right IT tools to obtain meaningful statistical analyses.

RESULTS AND DISCUSSION

1. The perceived usefulness of using AR/VR in the classroom

Table 3: Categorization results for items in the "Perceived usefulness of AR/VR" variable

Items	5	4	3	2	1	μ	s	Ranking	Category
1	63,5%	34,1%	2,4%	0%	0%	4,61	0,54	3	High
2	57,6%	36,5%	5,9%	0%	0%	4,52	0,61	4	High
3	54,1%	40,0%	5,9%	0%	0%	4,48	0,61	5	High
4	22,4%	42,4%	20,0%	8,2%	7,1%	3,65	1,13	10	Medium
5	71,8%	25,9%	2,4%	0%	0%	4,69	0,51	1	High
6	64,7%	34,1%	1,2%	0%	0%	4,64	0,51	2	High
7	30,6%	42,4%	21,2%	5,9%	0%	3,98	0,87	9	High
8	44,7%	38,8%	14,1%	2,4%	0%	4,26	0,79	8	High
9	45,9%	42,4%	8,2%	2,4%	1,2%	4,29	0,81	7	High
10	45,9%	43,5%	9,4%	1,2%	0%	4,34	0,70	6	High
All items						4,34	0,45	High	
5: Totally agree; 4: Agree; 3: Neutral; 2: Disagree; 1: Totally disagree; μ : Average; s: Standard deviation									

Table 4: Results of the univariate ANOVA according to categorical variables for the "Perceived usefulness of AR/VR" variable

Categorical variables	Sum of squares	ddl	Mean square	F	Sig.
Age	5,810	17	0,342	1,124	0,352
Gender	1,750	17	0,103	1,475	0,131
Bachelor's degree speciality	378,855	17	22,286	1,335	0,199
Year of graduation	62,422	17	3,672	0,891	0,587

From Table 3, it can be seen that only item 4 (AR/VR technology takes account of individual differences between learners) had average scores in the "medium" category, while all the other items were in the "high" category. This shows that the pre-service teachers expressed a high degree of agreement with the proposals made in the questionnaire. It is therefore clear that the pre-service teachers perceived the usefulness of using AR/VR technology in their classroom

The results of the pre-service teachers' responses to the items relating to the perceived usefulness of AR/VR technology are presented in Table 3. To facilitate the reading of results, we adopted the characterization method proposed by Le Poulter (1986), cited by Boubih (2022), which classifies the average scores into three categories:

- Low: scores between 1 and 2,33.
- Medium: scores between 2,34 and 3,67.
- High: scores between 3,68 and 5

teaching practices. These findings are in accordance with those of M. Yilmaz & Simsek (2023)), indicating that pre-service teachers perceive these technologies as effective for teaching subjects requiring visual support, such as organs, cells, and ecosystems. Moreover, our conclusions align with those of Du et al. (2022), demonstrating that pre-service teachers' intention to consistently adopt VR technology is influenced by factors such as the perceived utility

of this technology in their classroom practices. In a similar vein, future teachers acknowledge the importance of integrating augmented reality (AR) and virtual reality (VR) technologies into their classroom teaching, as highlighted by Taggart et al. (2023). These prospective educators express favorable opinions regarding the use of augmented reality applications in the learning process, identifying various benefits such as teaching effectiveness, facilitation of the educational process, capturing students' attention, concretization of abstract concepts, enhancement of imagination and creativity, increased student engagement and motivation, as well as cost and time savings (Atalay, 2022).

Analysis of the ANOVA results, as shown in Table 4, reveals that the significance level is higher than the used reference value, which is $\alpha = 0.05$. This shows that the respondents' answers

2. Intention to adopt AR/VR in the classroom

The results of the pre-service teachers' responses to the items relating to their intention to adopt AR/VR technology are presented in Table 5. To make the

were not affected by the various categorical variables studied. This shows that the respondents' answers were not affected by the different categorical variables studied. Furthermore, it suggests that the training received by pre-service teachers at the RCTEP convinced them of the usefulness of using AR/VR technology in the classroom, regardless of factors such as age, gender, year of graduation or bachelor's degree specialty. In summary, the results of Table 3 and Table 4 show that the pre-service teachers expressed strong agreement regarding the usefulness of using AR/VR technology in their classroom teaching practices, and that this positive perception was not influenced by the categorical variables studied. This reinforces the idea that the training received at the RCTEP succeeded in convincing pre-service teachers of the benefits of integrating AR/VR into their teaching.

results easier to read, we have adopted the same characterization method used previously.

Table 5: Categorization results for items in the "Intention to adopt AR/VR in pedagogical practices" variable

Items	5	4	3	2	1	μ	s	Ranking	Category
11	51,8%	40,0%	8,2%	0%	0%	4,44	0,64	2	High
12	58,8%	36,5%	2,4%	0%	2,4%	4,49	0,77	1	High
13	34,1%	41,2%	15,3%	8,2%	1,2%	3,99	0,97	9	High
14	28,2%	52,9%	16,5%	2,4%	0%	4,07	0,74	8	High
15	48,2%	38,8%	10,6%	2,4%	0%	4,33	0,76	7	High
16	55,3%	30,6%	10,6%	3,5%	0%	4,38	0,82	5	High
17	52,9%	38,8%	4,7%	3,5%	0%	4,41	0,74	3	High
18	35,3%	38,8%	16,5%	8,2%	1,2%	3,99	0,98	10	High
19	55,3%	30,6%	10,6%	3,5%	0%	4,38	0,82	6	High
20	52,9%	38,8%	4,7%	3,5%	0%	4,41	0,74	4	High
All items						4,28	0,44	High	
5: Totally agree; 4: Agree; 3: Neutral; 2: Disagree; 1: Totally disagree; μ : Average; s: Standard deviation									

Table 6: Results of the univariate ANOVA according to categorical variables for the "Intention to adopt AR/VR in pedagogical practices" variable

Categorical variables	Sum of squares	ddl	Mean square	F	Sig.
Age	7,348	16	0,459	1,657	0,077
Gender	0,950	16	0,059	0,737	0,747
Bachelor's degree speciality	444,712	16	27,795	1,795	0,050
Year of graduation	99,426	16	6,214	1,767	0,055

The results presented in Table 5 show that the average scores for all the items were in the "high" category, reflecting the high degree of agreement expressed by the pre-service teachers with the proposals made in the second part of the questionnaire. These results therefore suggest that the pre-service teachers expressed a strong intention to adopt AR/VR technology in their classroom teaching practices.

These findings are consistent with previous research, demonstrating that pre-service teachers have shown a positive enthusiasm for incorporating augmented and virtual reality systems into their classrooms (Dutta et al., 2022). Likewise, there is a positive trend among teachers in training to integrate augmented reality (AR) systems into their future teaching, suggesting that initial training that emphasizes the integration of virtual reality (VR) and AR technologies into pedagogical practices has proven to be advantageous (Oberdörfer et al., 2021). Table 6 shows that the results of the analysis of variance (ANOVA) have a level of significance higher than the commonly used reference value ($\alpha = 0.05$), for the categorical variables 'Age', 'Sex' and 'Year of graduation'. This shows that these variables did not have a significant influence on participants' responses. Regarding the categorical variable "bachelor's degree speciality", the results of the ANOVA show a level of significance equal to 0.05, which suggests that this variable had a statistically significant influence on the responses of the pre-service teachers. This observation can be explained by the reticence of some pre-service teachers to integrate AR/VR technology into their classroom practices, due to their worry that they will not fully master this technology. This reticence is particularly present among pre-service teachers whose university

training focused on specialties other than science, such as economics, law, and literature, even though the training they received at the RCTEP convinced them of the usefulness of this technology. This observation has previously been mentioned in previous studies, which revealed that some future teachers show a reluctance to integrate augmented reality (AR) and virtual reality (VR) technologies into their classroom teaching practices. Although these teachers recognize the potential of these technologies for the teaching and learning process, they may lack experience in their use (Cooper et al., 2019; Figueroa Flores & Huffman, 2020; Taggart et al., 2023).

The results obtained from the two tables converge towards the conclusion that pre-service teachers express a strong intention to adopt AR/VR technology in their classroom teaching practices, while certain categorical variables, such as degree specialty, have been identified as factors that may influence this intention.

The results obtained confirm hypothesis H1, showing that the vast majority of respondents fully perceived the usefulness of integrating activities using AR/VR after they had experienced it during training sessions at the RCTEP. The benefits of AR/VR were widely perceived, particularly in terms of clarifying content, making it possible to learn in 'real' situations, making abstract concepts more concrete, improving students' motivation to learn, as well as enhancing enjoyment of learning and improving long-term retention of information. Similarly, hypothesis H2 was confirmed, as the majority of respondents are considering adopting AR/VR technology in their classroom practices. They recognize its usefulness for both students and teachers, its potential in a variety of subjects, its complementary role to the traditional textbook, as

well as the fact that it does not require very advanced training or expensive equipment.

These findings highlight the growing importance of AR/VR as a valuable educational tool, capable of significantly enhancing the learning experience and enriching teaching practices. Teachers are therefore

CONCLUSION

Technological advances have revolutionized the way we learn and teach, offering unprecedented opportunities to improve the effectiveness and relevance of our teaching practices. In this context, pre-service teachers have an important role to play in the adoption and application of educational innovations such as AR/VR in the classroom. They must therefore be encouraged and supported to familiarize them with the latest technologies and innovative educational approaches. Ongoing training and professional development should include modules on digital tools, e-learning platforms and technology-based teaching methods. However, it is important to keep in mind that adopting new

technologies does not mean abandoning traditional methods. The key is to find the right balance between traditional approaches and innovative practices. Traditional methods provide stability, human interaction and timeless educational values, while innovative methods offer interactivity, personalization and adaptation to learners' needs. Finally, future education relies on the harmonious integration of new technologies, supporting teachers in their mission to provide quality education. The synergy between traditional methods and innovative approaches will create an enriching educational environment, preparing learners to face the modern world successfully.

REFERENCES

- Akçayır, M., & Akçayır, G, 2017, Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, 20, 1-11. <https://doi.org/10.1016/j.edurev.2016.11.002>
- Atalay, N, 2022, Augmented Reality Experiences of Preservice Classroom Teachers in Science Teaching. *International Technology and Education Journal*, 6(1). <http://itejournal.com/>
- Azuma, R., Bailiot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B, 2001, Recent advances in augmented reality. *IEEE Computer Graphics and Applications*, 21(6), 34-47. <https://doi.org/10.1109/38.963459>
- Azuma, R. T, 1997, A Survey of Augmented Reality. *Presence: Teleoperators and Virtual Environments*, 6(4), 355-385. <https://doi.org/10.1162/pres.1997.6.4.355>
- Bacca, J., Baldiris, S., Fabregat, R., Graf, S., & Kinshuk, 2014, Augmented Reality Trends in Education: A Systematic Review of Research and Applications. *Journal of Educational Technology & Society*, 17(4), 133-149.
- <https://www.jstor.org/stable/jeductechsoci.17.4.133>
- Boubih, S, 2022, *La classe inversée, potentialités pour le développement de l'enseignement hybride. Conception et évaluation*. Abdelmalek Essaadi university, Tétouan.
- Boyle, E. A., Connolly, T. M., Hainey, T., & Boyle, J. M, 2012, Engagement in digital entertainment games: A systematic review. *Computers in Human Behavior*, 28(3), 771-780. <https://doi.org/10.1016/j.chb.2011.11.020>
- Caudell, T. P., & Mizell, D. W, 1992, Augmented reality: An application of heads-up display technology to manual manufacturing processes. *Proceedings of the Twenty-Fifth Hawaii International Conference on System Sciences*, ii, 659-669 vol.2. <https://doi.org/10.1109/HICSS.1992.183317>
- Chen, C.-M., & Tsai, Y.-N, 2012, Interactive augmented reality system for enhancing library instruction in elementary schools. *Computers & Education*, 59(2), 638-652. <https://doi.org/10.1016/j.compedu.2012.03.001>

- Chen, Y.-C., 2006, A study of comparing the use of augmented reality and physical models in chemistry education. *Proceedings of the 2006 ACM international conference on Virtual reality continuum and its applications*, 369-372. <https://doi.org/10.1145/1128923.1128990>
- Chiang, T. H. C., Yang, S. J. H., & Hwang, G.-J., 2014, An Augmented Reality-Based Mobile Learning System to Improve Students' Learning Achievements and Motivations in Natural Science Inquiry Activities. *Educational Technology & Society*, 17(4), 352-365.
- Chien, Y. C., Su, Y. N., Wu, T. T., & Huang, Y. M., 2019, Enhancing students' botanical learning by using augmented reality. *Universal Access in the Information Society*, 18(2), 231-241. <https://doi.org/10.1007/s10209-017-0590-4>
- Cooper, G., Park, H., Nasr, Z., Thong, L. P., & Johnson, R., 2019, Using virtual reality in the classroom: Preservice teachers' perceptions of its use as a teaching and learning tool. *Educational Media International*, 56, 1-13. <https://doi.org/10.1080/09523987.2019.1583461>
- Cronbach, L. J., 1951, Coefficient alpha and the internal structure of tests. *Psychometrika*, 16, 297-334. <https://doi.org/10.1007/BF02310555>
- Du, W., Liang, R., & Liu, D., 2022, Factors Influencing School Teachers' Continuous Usage Intention of Using VR Technology for Classroom Teaching. *SAGE Open*, 12(3), 21582440221114325. <https://doi.org/10.1177/21582440221114325>
- Dutta, R., Mantri, A., & Singh, G., 2022, Assess Teachers' Attitude Towards Mobile Augmented Reality Systems for Teaching Digital Electronics Course. *ECS Transactions*, 107(1), 7631. <https://doi.org/10.1149/10701.7631ecst>
- Erbas, C., & Demirer, V., 2019, The effects of augmented reality on students' academic achievement and motivation in a biology course. *Journal of Computer Assisted Learning*, 35(3), 450-458. <https://doi.org/10.1111/jcal.12350>
- Ferrer-Torregrosa, J., Torralba, J., Jimenez, M. A., García, S., & Barcia, J. M., 2015, ARBOOK: Development and Assessment of a Tool Based on Augmented Reality for Anatomy. *Journal of Science Education and Technology*, 24(1), 119-124. <https://www.learntechlib.org/p/152432/>
- Figuroa Flores, J., & Huffman, L., 2020, Integrating AR and VR in Teacher Education: What Pre-service Teachers Perceive. *Frontiers in Education Technology*. <https://doi.org/10.22158/fet.v3n4p5>
- Giasirani, S., & Sofos, L., 2016, Production and Evaluation of Educational Material Using Augmented Reality for Teaching the Module of "Representation of the Information on Computers" in Junior High School. *Creative Education*, 7(9), Article 9. <https://doi.org/10.4236/ce.2016.79134>
- Grinshkun, A. V., Perevozchikova, M. S., Razova, E. V., & Khlobystova, I. Y., 2021, Using Methods and Means of the Augmented Reality Technology when Training Future Teachers of the Digital School. *European Journal of Contemporary Education*, 10(2), 358-374. Scopus. <https://doi.org/10.13187/ejced.2021.2.358>
- Hsiao, K.-F., Chen, N.-S., & Huang, S.-Y., 2012, Learning while exercising for science education in augmented reality among adolescents. *Interactive Learning Environments*, 20(4), 331-349. <https://doi.org/10.1080/10494820.2010.486682>
- Hwang, G.-J., Tsai, C.-C., Chu, H.-C., Kinshuk, K., & Chen, C.-Y., 2012, A context-aware ubiquitous learning approach to conducting scientific inquiry activities in a science park. *Australasian Journal of Educational Technology*, 28(5), Article 5. <https://doi.org/10.14742/ajet.825>
- Ibáñez, M. B., Di Serio, Á., Villarán, D., & Delgado Kloos, C., 2014, Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness. *Computers & Education*, 71, 1-13. <https://doi.org/10.1016/j.compedu.2013.09.004>
- Jamali, S. S., 2017, *An investigation of mobile augmented reality-based learning features in cognitive and affective environments*. PhD thesis, Murdoch University. <https://researchrepository.murdoch.edu.au/id/eprint/36809/>
- Kamarainen, A. M., Metcalf, S., Grotzer, T., Browne, A., Mazzuca, D., Tutwiler, M. S., & Dede, C., 2013, EcoMOBILE: Integrating augmented reality and probeware with environmental education field trips. *Computers & Education*, 68, 545-556. <https://doi.org/10.1016/j.compedu.2013.02.018>
- Kerawalla, L., Luckin, R., Seljeflot, S., & Woolard, A., 2006, "Making it real": Exploring the potential of augmented reality for teaching primary school science. *Virtual Reality*, 10(3), 163-174. <https://doi.org/10.1007/s10055-006-0036-4>

- Liu, T.-C., Peng, H., Wu, W.-H., & Lin, M.-S, 2009, The Effects of Mobile Natural-Science Learning Based on the 5E Learning Cycle: A Case Study. *Educational Technology & Society*, 12(4), 344-358.
- Lu, S.-J., & Liu, Y.-C, 2015, Integrating augmented reality technology to enhance children's learning in marine education. *Environmental Education Research*, 21(4), 525-541. <https://doi.org/10.1080/13504622.2014.911247>
- Muñoz-Cristóbal, J. A., Jorrín-Abellán, I. M., Asensio-Pérez, J. I., Martínez-Monés, A., Prieto, L. P., & Dimitriadis, Y, 2015, Supporting Teacher Orchestration in Ubiquitous Learning Environments: A Study in Primary Education. *IEEE Transactions on Learning Technologies*, 8(1), 83-97. <https://doi.org/10.1109/TLT.2014.2370634>
- Oberdörfer, S., Birnstiel, S., Latoschik, M. E., & Grafe, S, 2021, Mutual Benefits: Interdisciplinary Education of Pre-Service Teachers and HCI Students in VR/AR Learning Environment Design. *Frontiers in Education*, 6. <https://www.frontiersin.org/articles/10.3389/educ.2021.693012>
- Rahman, M. A., Ling, L. S., & Yin, O. S, 2020, Augmented Reality for Learning Calculus: A Research Framework of Interactive Learning System. In R. Alfred, Y. Lim, H. Havaluddin, & C. K. On (Éds.), *Computational Science and Technology* (p. 491-499). Springer. https://doi.org/10.1007/978-981-15-0058-9_47
- Sáez-López, J. M., Cózar-Gutiérrez, R., González-Calero, J. A., & Carrasco, C. J. G, 2020, Augmented reality in higher education: An evaluation program in initial teacher training. *Education Sciences*, 10(2). Scopus. <https://doi.org/10.3390/educsci10020026>
- Safadel, P., & White, D. (2019). Facilitating Molecular Biology Teaching by Using Augmented Reality (AR) and Protein Data Bank (PDB). *TechTrends*, 63(2), 188-193. <https://doi.org/10.1007/s11528-018-0343-0>
- Taggart, S., Roulston, S., Brown, M., Donlon, E., Cowan, P., Farrell, R., & Campbell, A, 2023, Virtual and augmented reality and pre-service teachers: Makers from muggles? *Australasian Journal of Educational Technology*, 39(3), Article 3. <https://doi.org/10.14742/ajet.8610>
- Yilmaz, M., & Simsek, M. C, 2023, The Use of Virtual Reality, Augmented Reality, and the Metaverse in Education: The Views of Preservice Biology and Mathematics Teachers. *MIER Journal of Educational Studies Trends and Practices*, 64-80. <https://doi.org/10.52634/mier/2023/v13/i1/2422>
- Yilmaz, Z. A., & Batdi, V, 2021, Meta-Analysis of the Use of Augmented Reality Applications in Science Teaching. *Journal of Science Learning*, 4(3), Article 3. <https://doi.org/10.17509/jsl.v4i3.30570>
- Yoon, S. A., Elinich, K., Wang, J., Steinmeier, C., & Tucker, S, 2012, Using augmented reality and knowledge-building scaffolds to improve learning in a science museum. *International Journal of Computer-Supported Collaborative Learning*, 7(4), 519-541. <https://doi.org/10.1007/s11412-012-9156-x>
- Zhou, X., Tang, L., Lin, D., & Han, W, 2020, Virtual & augmented reality for biological microscope in experiment education. *Virtual Reality & Intelligent Hardware*, 2(4), 316-329. <https://doi.org/10.1016/j.vrih.2020.07.004>