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The integration of augmented and virtual reality in cell biology courses as a pedagogical innovation in the training of life and earth sciences teachers

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ABSTRACT
Teaching and learning using mobile devices such as tablets and smartphones has become a trend. Learners can use mixed reality technologies including augmented reality (AR) and virtual reality (VR) which are promising tools for science education. Augmented reality allows the user to see a combination of the real world and virtual objects, while virtual reality generates a virtual environment in which the user feels like in the real world. Several studies have focused on the contribution of AR/VR in different fields of education and have shown that this technology positively affects learners' motivation, promotes their self-learning, and can improve their academic performance. Our study was designed to investigate the contribution of activities integrating augmented and virtual reality in cell biology courses, on the learning and motivation of Moroccan pre-service teachers of life and earth sciences. We adopted a semi-experimental approach using a pre-test and a post-test with two groups. The pre-service teachers in the experimental group (n= 30) took the courses using AR/VR materials and tools, while the pre-service teachers in the control group (n=30) took the same courses using only traditional tools and materials. The results of the pre-test and post-test showed a statistically significant difference in the post-test in favour of the pre-service teachers of the experimental group who, in addition to the improvement in their test scores, expressed high motivation during the different training courses.

Keywords:augmented reality, virtual reality, cell biology, pre-service teachers, life and earth sciences.

1- INTRODUCTION

Teaching and learning using mobile devices such as smartphones and tablets have become a trend, and as an alternative to slideshows or textbooks, teachers and learners can use virtual reality (VR) and augmented reality (AR) technologies, which are promising potential tools for science education and could, both motivate autonomous learning and improve learning performance (Zhou et al., 2020). Several researchers have investigated the impact of augmented and virtual reality in education for almost two decades in different fields and with different variables in several studies, which have shown that augmented and virtual reality technology positively affects learners' motivation, promotes their self-learning, and can have a positive effect on their academic achievements (Ibáñez et al., 2014; Giasiranis & Sofos, 2016; Jamali, 2017; Chien et al., 2019; Safadel & White, 2019; Yilmaz & Batdi, 2021).

Understanding the nature of cells and cellular processes in the life of organisms is essential for learning biology. However, cells are too complex, diverse, and generally invisible to the human eye (Thompson et al., 2020). In this way, biological studies can find in AR/VR technology a useful tool to promote the learning of different cellular phenomena, and to visualize the different living elements at the macro and microscopic scales. It is therefore necessary for future biology teachers to be familiar with new technologies such as augmented reality and virtual reality and to be trained in the use of these technologies in order to be able to design and apply educational practices with students, and to take advantage of their benefits (Sáez-López et al., 2020).

In the Moroccan educational system, biological studies in high schools are taught in life and earth sciences courses. Before taking on the responsibility of teaching in classrooms, the pre-service teachers of life and earth sciences who have obtained a bachelor's degree or an equivalent university diploma in life and earth sciences, must take part in a one-year professional training course in teaching at a Regional Centre of Education and Training Professions (RCETP). During this training, the pre-service teachers take, among other courses, a 30-hour course called “Reinforcementofthe basic education” (RBE), to fill gaps in their basic knowledge of cellular and molecular biology (Moroccan Ministry of National Education, 2019). In this course, pre-service teachers are

trained to develop professional skills (knowledge and abilities) related to the teaching of various cell biology subjects in the high schools.
Studies in many countries have shown that pre-service teachers share misconceptions about some cell biology concepts with high school and university students(Dikmenli, 2010; Oztas, 2014; Hasni et al., 2016; Suwono et al., 2019; Assimi et al., 2022). In many cases, teachers' classroom practices are the source of students' misconceptions(Yates & Marek, 2014), therefore it is necessary to use innovative methods in the professional training of pre-service teachers(Assimi et al., 2022). In this study we aim to evaluate the effects of activities integrating augmented and virtual reality in the cell biology course, which is part of the RBE course, on the learning and motivation of pre-service teachers of life and earth sciences (LES) in training at the RCETP. To do this, we aim to answer the following question: What are the effects of activities integrating augmented and virtual reality on the learning of contents related to cell biology, among pre-service teachers of life and earth sciences?

2- THEORETICAL FRAMEWORK

Augmented reality (AR) is a technology that allows users to see a combination of the real world and virtual objects (Azuma, 1997), these virtual objects then seem to coexist in the same space as real world objects(Azuma et al., 2001). Virtual reality (VR) is a virtual and interactive digital environment in which the user feels like in the real world (Nasharuddin et al., 2021). Virtual reality uses technology to provide audio-visual and haptic information to the user, generating an immersive experience (Goddard et al., 2018).
Different AR technologies have different characteristics in cost, accessibility, and usability ineducational environments. The most preferred technology is the mobile devices(Akçayır et al., 2016).Recent studies show that access to AR technology has become easier with mobile devices that have become simpler, portable and interactive (Akçayır & Akçayır, 2017; Hwang et al., 2012).In 1968 Ivan Sutherland invented an AR system, and in 1974, Myron Krueger developed a system of projectors and cameras to project computer graphics on screen. Later, in the 1990s, the word "Augmented Reality" was the first commonly used term created by Thomas Caudell(Roopa et al., 2021). AR was first introduced as a training tool for airline and air force pilots in the 1990s (Caudell & Mizell, 1992).
Nowadays, augmented and virtual reality (AR/VR) has emerged as one of the newest visualization technologies in educational environments (Erbas & Demirer, 2019; Zhou et al., 2020). It is used at all school levels, from pre-school to high school (Chiang et al., 2014; Kerawalla et al., 2006)until university level (Ferrer-Torregrosa et al., 2015). Several AR/VR technologies have been introduced in education(Zhou et al., 2020)for their visualization functions to represent and show abstract or invisible content. Studies on AR/VR in education started in 2003 (Erbas & Demirer, 2019). Science, humanities, and the arts are the areas of education where AR/VR has been most applied, while health and wellness, education (teacher training), and agriculture are the least explored areas of research(Bacca et al., 2014).AR/VR tools are oriented for use in the classroom, in the laboratory, and as a course supplement. Most studies on AR/VR have targeted learners from preschool to high school as well as university students(Akçayır & Akçayır, 2017). However, early childhood education and professional training are potential groups to explore the uses of AR/VR (Bacca et al., 2014).
Several researchers have studied the effect of augmented and virtual reality in education for almost two decades in different fields, and have shown that this technology improves the development of learners' skills and positive attitudes (Liu et al., 2009; Boyle et al., 2012; Rahman et al., 2020), positively affects their motivation, promotes self-learning and can have a positive effect on their academic achievement (Ibáñez et al., 2014; Chang et al., 2015; Ferrer-Torregrosa et al., 2015; Lu & Liu, 2015; Giasiranis & Sofos, 2016; Jamali, 2017; Chien et al., 2019; Safadel & White, 2019; Yilmaz & Batdi, 2021).Methods using AR/VR can help learners gain a better understanding of their learning content (Yoon et al., 2012)and are judged more satisfying than traditional courses (Chen & Tsai, 2012; Muñoz-Cristóbal et al., 2015). AR/VR can make education more entertaining (Ibáñez et al., 2014; Lu & Liu, 2015)and can increase the interest in learning (Zhang et al., 2014). AR/VR technology promotes interaction between learners and between learners and learning materials, facilitating learning by practice(Hsiao et al., 2012; Kamarainen et al., 2013).However, there are some disadvantages of the use of AR/VR in education such as the distractive nature of this new technology, caused by the large amount of data that is displayed in the visual field of the learner, which can overload his perception and his nervous system, which can negatively influence his psychological component(Grinshkun et al., 2021).The limitations of AR/VR are mainly: difficulties in keeping information layered, giving too much attention to virtual information, and the fact that AR/VR is considered an intrusive technology(Bacca et al., 2014).

3- RESEARCH METHODOLOGY

3-1- Approach and participants

To evaluate the effect of using augmented and virtual reality (AR/VR) technology on learning and motivation, we adopted a quasi-experimental approach, with an experimental group (class 1) and a control group (class 2) and using a pre-test and a post-test. Participants are assigned to two classes by administration of the RCETP. In the literature related to our topic, most studies considered medium-sized research samples (between 30 and 200 participants), and used mixed assessment methods (Bacca et al., 2014). In our study, we targeted Moroccan pre-service teachers of life and earth sciences (LES) in training at Tangier RCETP (Class of 2022). One of the two classes was randomly assigned to the experimental group, while the other class was assigned to the control group. The participants in the study were 60 in total, with 30 participants in each group. Table 1 presents the characteristics of the two groups.

Table 1: Characteristics of the control and experimental groups

		Control group	Experimental group
Headcount		30	30
Sex	Male	40%	30%
	Female	60%	70%
Age	21-25 years	86.7%	56.7%
	26-30 years	3.3%	43.3%
Year of graduation	2014 to 2018	40%	56.7%
	2019 to 2021	60%	43.3%
Bachelor's degree specialization	Life Sciences	66.7%	70%
	Earth Sciences	6.7%	0%
	Education of Life and earth science	17.7%	30%

Based on the data in Table 1, there are no significant differences between the two groups about gender and age. However, most of the pre-service teachers had completed their university studies in life sciences or education, while the proportion of pre-service teachers who had a bachelor's degree in earth sciences was only 6.7% in the control group, while it was 0% in the experimental group. It is worth noting that the bachelor's degree in education of life and earth sciences is a program of education provided in the École Normale Supérieure, dedicated to prepare students to enter a teacher training centre to become a Life and Earth Sciences teacher. During this program, students take the similar biology and geology courses as students in science faculties, in addition to some additional modules in education sciences and didactics.

3-2- Research design

3-2-1- Duration of the experiment and themes studied

The experiment took place during the second semester of the 2021/2022 training year between April and June 2022, over a period of ten weeks of training. It concerned the course of RBE devoted to cellular and molecular biology. This 30-hour course includes three learning areas: the cell, structural and functional unit of life; genetic information: support, nature and expression and genetic engineering. The knowledge and goals targeted by this course are listed in the appendix. To elaborate this table, we have based our work on the syllabus of the Cellular and Molecular Biology course developed by the Moroccan Ministry of National Education (Moroccan Ministry of National Education, 2022).

3-2-2-Setting up the pre-test and the post-test

To implement the testing tool, we took the following steps:

- Construction of the conceptual framework of the test based on the cell biology program taught at the RCETP in the RBE course, and which aims to provide pre-service teachers of life and earth sciences with the knowledge and skills required to master the contents of cell biology, with a perspective of being able to teach them to high-school learners.
- Identification of the main concepts: The cell biology curriculum in the Moroccan secondary cycle includes contents shared between cell organization and different cell phenomena. We have identified the main concepts of cell biology that previous studies(Assimi et al., 2022), have shown to be misconceived by pre-service teachers, which are: cell, gene, nerve impulse, hormone and immune response.
- Design of the pre-test and post-test: At the beginning, we prepared an evaluation tool as a test with thirty items, the content of each of them refers to the cell biology concepts previously mentioned. Once these preparations completed, three experts checked the whole test: a biology teacher at the RCETP of Tetouan and two biology teachers at the RCETP of Tangier, one of whom had the responsibility of teaching the RBE course. Based on the experts' feedback, the necessary adjustments were made, and we kept twenty-six items scored out of twenty. The test is organized in two parts:
- The first part, scored out of ten points, is made up of twenty multiple-choice questions and aims to evaluate the mastery of knowledge related to theconcepts of cell biology that are the subject of our study. The

questions, each scored on 0.5 points, were distributed as follows: 12 questions for cell concept, 1 question for gene, 4 questions for nerve impulse, 1 question for hormone and 2 questions for immune response concept.

- The second part, scored out of ten points, includes 6 short answer questions on the same topics as the first part, and aims to evaluate the ability to exploit knowledge through analysis, synthesis and putting knowledge in relations to explain cellular phenomena. The questions were distributed as follows: five questions for the cell concept (three scored out of 0.5 points and two scored out of 1 point), five questions scored out of 0.5 points for gene, two questions scored out of 1 point for hormone and one question scored out of 2 points for immune response concept.

Table 2 lists the main cell biology concepts used as knowledge areas to develop the test items. The whole test is added as appendix 2

Table 2: Evaluation tool specification

Main Cell Biology Concepts (Knowledge Area)	Skills area								Total Scores	
	Part 1: Knowledge restitution				Part 2: Knowledge exploitation					
	Question count	Question Score	Score (/10)	%	Question count	Question Score	Score (/10)	%	Score (/20)	%
Cell	12	0.5	6	60%	3 2	0.5 1	3.5	35%	9.5	47.5%
Gene	1	0.5	0.5	5%	5	0.5	2.5	25%	3	15%
Nerve flow	4	0.5	2	20%	0	0	0	0%	2	10%
Hormone	1	0.5	0.5	5%	2	1	2	20%	2.5	12.5%
Immune response	2	0.5	1	10%	1	2	2	20%	3	15%

- Reliability verification of the assessment tool: A pilot sample of ten pre-service teachers of life sciences completed the test questions to verify its reliability. Calculation of Cronbach's alpha (Cronbach, 1951)showed a value of $\alpha = 0.805$ which is a good indicator of the test's reliability.
- Distribution of the assessment tool: Our assessment tool which served as both a pre-test and post-test distributed to pre-service teachers in both groups,in digital format using Google Forms, and they answered the questions in class using their smartphones. We chose this method for the ease and speed of response collection it offers.

3-2-3- Conduct of training activities

The training activities in cell biology in the RBE course was provided by a biology teacher at the RCETP of Tangier who followed as agreed, a classical method based on lectures and directed activities with the control group, and in parallel he integrated activities using augmented and virtual reality technology in the experimental group. These activities were conducted in two ways:

- Using the Merge cube and two smartphone applications: Merge explorer and Merge Object Viewer. It is a paper cube with symbols that can be recognized by the applications mentioned. These applications use the smartphone's camera to generate, from their databases, a 3D image of objects related to several topics, some of which concern cell biology. The generated 3D images can be manipulated by changing the position of the merge cube in space.
- Using VR headsets and digital cell biology resources available on YouTube in VR format. The scientific validity of the selected digital resources was verified by two of the previously mentioned experts, and then a list of valid resources was prepared for consultation in classes and as a supplementary course material.

The Merges cubes and VR headsets were made available to the pre-service teachers in the classroom, and the activities were conducted in groups of six, to allow the pre-service teachers in the experimental group to work collaboratively during the course sequences that include augmented and virtual reality activities.

3-3- Data collection and analysis

The data collected were analysed using two software programs: Microsoft Excel 365 and IBM SPSS Statistics 23. The pre-test and post-test results were analysed using the student's t test for independent samples. This test is used to compare the mean values of two groups (Cohen, 1988). In this test, we made two hypotheses:

- The null hypothesis (H0): the means of the two groups do not show any difference.
- The alternative hypothesis (H1): the two means show a difference.

The null hypothesis is rejected when the significance level (p-value) is under 0.05 (the commonly chosen alpha value). It is necessary to note that the use of this test requires the verification of certain conditions:

- Independence of the two groups: this condition is verified in our study where the two groups studied are different; an experimental group and a control group.
- Normal distribution of the data: this condition is verified using the Shapiro-Wilk test (Shapiro & Wilk, 1965) according to which the data come from a normally distributed population if the p-value is higher than the chosen alpha level (α = 0 ,05).
- Data homogeneity (data with equal variances). The variances are considered homogeneous, if the Levene test p-value is greater than the chosen alpha level.

4- RESULTS AND DISCUSSION

4-1- Pre-test results

Table 3 shows the statistics of pre-test results for the two groups.

Table 3: Descriptive statistics for the pre-test scores

	Control group	Experimental group
Headcount	30	30
Mean (m)	8.97	9.54
Minimum	3.00	3.75
Maximum	12.00	13.50
Standard deviation (σ)	2.07	2.22
Median	9.12	10.25
Mode	9.00	10.50
Variance (v)	4.31	4.94

From the data in Table 3, the average score obtained in the pre-test in the experimental group is m = 9.54 out of 20 with a standard deviation σ = 2.22, while the average score obtained in the control group is m = 8.97 out of 20 with σ = 2.07. The two averages are very close with a difference of 0.57 points and are under the acceptable average of ten (10), although most of the pre-service teachers in both groups have university degrees in the life sciences.

Table 4 shows the normality test of the distribution of the pre-test values in both groups, verified using the Shapiro-Wilk test, while Table 5 shows the t-test for independent samples.

Table 4: Normality test for the pre-test in both groups

Group	Shapiro-Wilk		
	Statistics	ddl	Signification
Experimental group	0.956	30	0.241
Control group	0.943	30	0.110

The scores obtained are normally distributed for both groups as the p-values are higher than 0.05.

Table 5: t-test of independent samples in pre-test

	Levene's test for equality of variances		t-test for equality of means				
	F	Sig.	t	ddl	Sig (bilateral)	Mean difference	Standard error difference
Hypothesis of equal variances	0.482	0.490	1.035	58	0.305	0.57500	0.55564

The results in Table 5 show that the p-value of Levene's test, p = 0.490, is over 0.05, which suggests that the variances of the two groups are homogeneous and that their difference could be explained by random sampling of the two groups' members. On the other hand, the p-value obtained in the t-test, p = 0.305 is over 0.05. This shows the absence of a significant difference between the means of the two groups, and the null hypothesis cannot be rejected.

No significant difference between the two groups was detected in the pre-test since the two groups are balanced. The scores of the majority of the pre-service teachers in both groups were close to the average of 10 out of 20, which reflects an intermediate level of these pre-service teachers and the existence of gaps in their basic biology knowledge that need to be filled during their qualifying training at the RCTEP.

4-2- Post-test results

Table 6 shows the statistics of the post-test results for both groups.

Table 6: Descriptive statistics for the post-test scores

	Control group	Experimental group
Headcount	30	30
Mean (m)	**10.02**	**11.92**
Minimum	4.50	5.50
Maximum	15.00	17.00
Standard deviation (σ)	2.55	3.03
Median	10.38	12.50
Mode	10.50	11.50
Variance (v)	6.49	9.20

From the results in Table 6, the mean score obtained in the post-test in the experimental group is $m = 11.92$ out of 20 with standard deviation $\sigma = 3.03$, while the mean score obtained in the control group is $m = 10.02$ out of 20 with $\sigma = 2.55$. The difference between the two means is 1.90 points.

Table 7 presents the normality test of the distribution of the post-test values obtained in the two groups, verified using the Shapiro-Wilk test, and Table 8 presents the t-test for independent samples.

Table 7: Normality test for the post-test in both groups

Group	Shapiro-Wilk		
	Statistics	ddl	Signification
Experimental group	0.963	30	0.369
Control group	0.960	30	0.314

Table 8: t-test of independent samples in post-test

	Levene's test for equality of variances		t-test for equality of means				
	F	Sig.	t	ddl	Sig (bilateral)	Mean difference	Standard error difference
Hypothesis of equal variances	1.628	0.207	2.627	58	0.011	1.90000	0.72321

The findings in Table 8 show, on the one hand, that the p-value of Levene's test ($p = 0.207$) is over 0.05, which means that the variances of the two groups are homogeneous, and on the other hand, the p-value obtained from the t-test ($p = 0.011$) is under 0.05. This shows the existence of a statistically significant difference between the two groups' means, and the null hypothesis can be rejected. This difference shows an improvement in the scores of the experimental group members compared to the control group members after the training sessions of the RBE course. This improvement could be due to the integration of activities using augmented and virtual reality technologies in the training sessions at the RCETP among the pre-service teachers in the experimental group, while those in the control group took the same course using conventional methods. It is worth noting that the pre-service teachers in the experimental group, on the one hand, expressed great motivation towards the use of AR/VR technology in the training sessions, and stated that learning with this technology was enjoyable. On the other hand, the pre-service teachers expressed a willingness to integrate this method into their classroom practices with their future students. We can therefore conclude that the integration of AR/VR technology in the learning activities of cell biology content improves learning and reinforces the motivation of pre-service teachers by allowing pleasant teaching. Our results are in line with those of several researchers who have studied the impact of augmented and virtual reality in education and have shown that this technology positively affects student motivation, promotes self-learning, can improve academic performance in several areas and can make boring teaching more entertaining(Ibáñez et al., 2014; Chang et al., 2015; Ferrer-Torregrosa et al., 2015; Lu & Liu, 2015; Giasiranis & Sofos, 2016; Jamali, 2017; Chien et al., 2019; Safadel & White, 2019; Yilmaz & Batdi, 2021).

4-3- Results based on knowledge areas and the learning gain

The means of the pre-test and post-test scores in each knowledge area, for the experimental and control groups, were used to calculate the learning gain of the different concepts studied for both groups. The normalized gain is calculated to assess the improvement in learners' understanding of scientific concepts and explanations (Hake, 2002). The formula for measuring the normalized learning gain score (N-gain) is as follows:

$$N - gain = \frac{\text{Posttest score} - Pretest\ score}{Ideal\ score - Pretest\ score}$$

The results of the normalized learning gain calculation are interpreted (Hake, 2002)as presented in Table 9.

Table 9: Interpretation of N-gain score

N-gain score	Criteria
0.0≤N-gain<0.3	Low
0.3≤N-gain<0.7	Medium
N-gain>0.7	High

Table 10 shows the different scores means in each knowledge area, as well as the learning gain for both groups.

Table 10: Score means and learning gain in each knowledge area

knowledge area		Cell	Gene	Nerve flow	Hormone	Immune response
Ideal score		9.5	3	3	2.5	3
Experimental group	Pre-test score	5.64	1.64	0.94	0.35	0.99
	Post-test score	6.33	2.25	1.02	1.01	1.32
	N-gain	0.2	0.4	0.1	0.3	0.2
	Interpretation	Low	Medium	Low	Medium	Low
Control group	Pre-test score	5.17	1.41	0.82	0.70	0.88
	Post-test score	5.70	1.65	0.97	0.82	0.89
	N-gain	0.1	0.2	0.1	0.1	0.0
	interpretation	Low	Low	Low	Low	Low

The results obtained show that the learning gain ranged from medium to low for the pre-service teachers in the experimental group, while it was low for the pre-service teachers in the control group in the five knowledge areas studied. These results confirm that the integration of activities using augmented and virtual reality technology in the cell biology training courses resulted in a slight improvement in the pre-service teachers' learning of the concepts studied in the experimental group compared to the control group. This slight improvement can be explained by the fascination effect that occurred following the integration of a new technology into teaching practices (Papadoudi-Ros, 2000), which leads some pre-service teachers to focus more on the way the technology used works and its playfulness(Picard-Gallart, 2019), instead of focusing on the scientific content presented. This effect could be overcome once the augmented and virtual reality technology becomes a common practice in classrooms for both teachers and learners. It is therefore recommended to be aware that technology is only a tool, and to take this into consideration before integrating new tools or technologies in teaching, ensuring a detailed presentation of the tool used beforehand in order to satisfy the learners' curiosity on the technical side before focusing on the scientific content.It is worth to point out in the same sense that the use of smartphones to consult the different AR/VR contents can be difficult for some pre-service teachers (Pombo & Marques, 2019) or may be a distraction where they are more likely to use mobile devices for purposes other than learning or alternate between learning and other distraction-inducing activities (Picard-Gallart, 2019; France et al., 2021; Criollo-C et al., 2022) and may decrease the learning gain. In our study like most other studies using AR/VR we aimed to ease learning and make self-learning more engaging. However, proper adoption of these technologies needs to be encouraged for both learners and teachers. Teachers in classrooms may feel challenged by their level of digital literacy as they need to master how to use the tool, and how to integrate it into teaching-learning activities (Buentello-Montoya et al., 2021), Hence the importance of initiating pre-service teachers to the use of new technologies such as AR/VR, even if not all learners and teachers can afford devices that implement AR/VR technology (Grinshkun et al., 2021).

5- CONCLUSION

Many studies have shown an improvement in the academic performance of learners in different disciplines because of the use of augmented and virtual reality technology in the classroom. This prompted us to investigate if the integration of augmented and virtual reality in cell biology training among Moroccan pre-service teachers of life and earth sciences, could have a positive effect on the learning of the main cell biology concepts, and on the motivation of the pre-service teachers. In fact, by adopting a semi-experimental approach, we found an improvement in the learning of the main concepts of cell biology in the experimental group with which we used augmented and virtual reality technology during the training sessions, compared to the control group with which we used classical teaching methods. In addition, the pre-service teachers in the experimental group expressed high motivation during the training sessions using augmented and virtual reality technology and expressed a willingness to use this technology with their future students because of the benefits it offers. Augmented and virtual reality technology certainly offers several benefits to teachers and learners, such as developing learners' skills and positive attitudes, motivation toward learning and improving academic performance, but it also has disadvantages and limitations such as the distracting nature of this technology, and the difficulties of maintaining the different information overlaid. It is still for teachers to choose the right content, time, and method to integrate this technology into their classroom practices. It is at this level that the role of the professional training of pre-service teachers in RCETP comes to provide them with the necessary didactic tools for the good planning and management of learning activities and the different technological tools allowing them to be up to date with the innovations in the education field in general and in cell biology education in particular.

REFERENCES

1. 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
2. Akçayır, M., Akçayır, G., Pektaş, H. M., & Ocak, M. A. (2016). Augmented reality in science laboratories : The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories. Computers in Human Behavior, 57, 334-342. https://doi.org/10.1016/j.chb.2015.12.054
3. Assimi, E., Janati Idrissi, R., Zerhane, R., & Boubih, S. (2022). The use of a three-tier diagnostic test to investigate conceptions related to cell biology concepts among pre-service teachers of life and earth sciences. Journal of Biological Education, 1-28. https://doi.org/10.1080/00219266.2022.2134175
4. Azuma, R., Baillot, 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
5. 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
6. 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
7. 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
8. Buentello-Montoya, D. A., Lomelí-Plascencia, M. G., & Medina-Herrera, L. M. (2021). The role of reality enhancing technologies in teaching and learning of mathematics. Computers & Electrical Engineering, 94, 107287. https://doi.org/10.1016/j.compeleceng.2021.107287
9. 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, 659-669 https://doi.org/10.1109/HICSS.1992.183317
10. Chang, Y.-L., Hou, H.-T., Pan, C.-Y., Sung, Y.-T., & Chang, K.-E. (2015). Apply an Augmented Reality in a Mobile Guidance to Increase Sense of Place for Heritage Places. Journal of Educational Technology & Society, 18(2), 166-178. https://www.jstor.org/stable/jeductechsoci.18.2.166

11. 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
12. 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.
13. 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
14. Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed). L. Erlbaum Associates. http://www.gbv.de/dms/bowker/toc/9780805802832.pdf
15. Criollo-C, S., Altamirano-Suarez, E., Jaramillo-Villacís, L., Vidal-Pacheco, K., Guerrero-Arias, A., & Luján-Mora, S. (2022). Sustainable Teaching and Learning through a Mobile Application : A Case Study. Sustainability (Switzerland), 14(11).. https://doi.org/10.3390/su14116663
16. Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. Psychometrika, 16, 297-334. https://doi.org/10.1007/BF02310555
17. Dikmenli, M. (2010). Misconceptions of cell division held by student teachers in biology : A drawing analysis. Scientific Research and Essays, 5(2), 235-247.
18. 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
19. 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/
20. France, D., Lee, R., Maclachlan, J., & McPhee, S. R. (2021). Should you be using mobile technologies in teaching? Applying a pedagogical framework. Journal of Geography in Higher Education, 45(2), 221-237.. https://doi.org/10.1080/03098265.2020.1773417
21. Giasiranis, 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), https://doi.org/10.4236/ce.2016.79134
22. Goddard, T. D., Brilliant, A. A., Skillman, T. L., Vergenz, S., Tyrwhitt-Drake, J., Meng, E. C., & Ferrin, T. E. (2018). Molecular Visualization on the Holodeck. Journal of Molecular Biology, 430(21), 3982-3996. https://doi.org/10.1016/j.jmb.2018.06.040
23. 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
24. Hake, R. R. (2002). Relationship of individual student normalized learning gains in mechanics with gender, high-school physics, and pretest scores on mathematics and spatial visualization. Physics education research conference, 8(1), 1-14.
25. Hasni, A., Roy, P., & Dumais, N. (2016). The Teaching and Learning of Diffusion and Osmosis : What Can We Learn from Analysis of Classroom Practices? A Case Study. Eurasia Journal of Mathematics, Science and Technology Education, 12(6), 1507-1531. https://doi.org/10.12973/eurasia.2016.1242a
26. 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
27. 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), https://doi.org/10.14742/ajet.825
28. 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

29. Jamali, S. S. (2017). An investigation of mobile augmented reality-based learning features in cognitive and affective environments [Phd, Murdoch University]. In Jamali, Siti S. <https://researchrepository.murdoch.edu.au/view/author/Jamali, Siti.html> (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/
30. 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
31. 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
32. 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.
33. 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
34. Moroccan Ministry of National Education. (2019). Descriptif du concours d’accès au CRMRF-SVT. 5-6.
35. Moroccan Ministry of National Education. (2022). Syllabus de Biologie cellulaire et moléculaire.
36. 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
37. Nasharuddin, N. A., Khalid, N. A., & Hussin, M. (2021). InCell VR : A Virtual Reality-based Application on Human Cell Division for Mobile Learning. International Journal of Interactive Mobile Technologies, 15(2), 55-71. https://doi.org/10.3991/ijim.v15i02.18049
38. Oztas, F. (2014). How do High School Students Know Diffusion and Osmosis? High School Students’ Difficulties in Understanding Diffusion & Osmosis. Procedia - Social and Behavioral Sciences, 116, 3679-3682. https://doi.org/10.1016/j.sbspro.2014.01.822
39. Papadoudi-Ros, H. (2000). Chapitre II - Technologies de communication et changements en éducation. In Technologies et Éducation (p. 153-204). Presses Universitaires de France. https://www.cairn.info/technologies-et-education--9782130500452-p-153.htm
40. Picard-Gallart, A. G. (2019). L’intégration des technologies numériques à l’École : Discours et pratiques en tension : étude d’une expérimentation « tablettes » en collège [Phdthesis, Université Bourgogne Franche-Comté]. https://theses.hal.science/tel-02887170
41. Pombo, L., & Marques, M. M. (2019). Educational mobile augmented reality edupark game : Does it improve students learning? 19-26. https://doi.org/10.33965/ml2019_201903l003
42. 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. Haviluddin, & C. K. On (Éds.), Computational Science and Technology (p. 491-499). Springer. https://doi.org/10.1007/978-981-15-0058-9_47
43. Roopa, D., Prabha, R., & Senthil, G. A. (2021). Revolutionizing education system with interactive augmented reality for quality education. Materials Today: Proceedings, 46, 3860-3863. https://doi.org/10.1016/j.matpr.2021.02.294
44. 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). https://doi.org/10.3390/educsci10020026
45. 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
46. Shapiro, S. S., & Wilk, M. B. (1965). An Analysis of Variance Test for Normality (Complete Samples). Biometrika, 52(3/4), 591-611. https://doi.org/10.2307/2333709

47. Suwono, H., Prasetyo, T. I., Lestari, U., Lukiati, B., Fachrunnisa, R., Kusairi, S., Saefi, M., Fauzi, A., & Atho'Illah, M. F. (2019). Cell Biology Diagnostic Test (CBD-Test) portrays pre-service teacher misconceptions about biology cell. Journal of Biological Education. https://doi.org/10.1080/00219266.2019.1643765
48. Thompson, M., Wang, A., Bilgin, C. U., Anteneh, M., Roy, D., Tan, P., & Eberhart, R. (2020). Influence of virtual reality on high school students' conceptions of cells. Journal of Universal Computer Science, 26(8), 929-946.
49. Yates, T. B., & Marek, E. A. (2014). Teachers teaching misconceptions : A study of factors contributing to high school biology students' acquisition of biological evolution-related misconceptions. Evolution: Education and Outreach, 7(1), 7. https://doi.org/10.1186/s12052-014-0007-2
50. Yilmaz, Z. A., & Batdi, V. (2021). Meta-Analysis of the Use of Augmented Reality Applications in Science Teaching. Journal of Science Learning, 4(3), https://doi.org/10.17509/jsl.v4i3.30570
51. 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
52. Zhang, J., Sung, Y.-T., Hou, H.-T., & Chang, K.-E. (2014). The development and evaluation of an augmented reality-based armillary sphere for astronomical observation instruction. Computers & Education, 73, 178-188. https://doi.org/10.1016/j.compedu.2014.01.003
53. 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

Appendix 1

Knowledge and goals targeted by the reinforcement of the basic training (RBE) course in cell and molecular biology
Course Goals: • Know how to use the cell study techniques. • Distinguish between the organization of a eukaryotic cell and a prokaryotic cell. • Describe the ultra-structure of the different organelles and cell membranes. • Explain cellular exchanges. • Identify the different phases of mitosis. • Explain the replication of the DNA molecule. • To appropriate the stages of expression of genetic material. • To appropriate the principle and steps of transgenesis and its interest. • Integrate ICT in the teaching of cellular and molecular biology.
Course content: I- The cell, structural and functional unit of the living beings • Structural organization of a prokaryotic cell and a eukaryotic cell • Ultra-structure of the different cytoplasmic organelles and of the membrane system, (Nucleus, mitochondria, chloroplast, plasma membrane, endoplasmic reticulum, Golgi apparatus) • Exchanges of substances between cells and the external environment (Membrane permeability, Membrane transporters). • Functional adaptations of certain tissues (muscle cells, glandular cells, nerve cells, etc.) • Cell division (mitosis) II- Genetic information: support, nature, and expression • Nature and structure of genetic material • DNA replication in eukaryotes • Transcription and regulation of gene expression in eukaryotes • Translation III- Genetic engineering • Principle and tools • Steps of transgenesis • Biotechnological applications of genetic engineering