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Perceptions on the use of mixed reality in mobile environments in secondary education

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Abstract

Purpose – The beliefs about this subject of $N = 223$ secondary education teachers were collected through an ex post facto research method using a descriptive and correlational design and a 27-item questionnaire.
Design/methodology/approach – The arrival of online learning, in this case m-learning, to secondary education, has made educators in this stage incorporate digital resources, such as Smartphones or mixed reality (MR), to their classroom methodologies. The present study describes the results obtained in the project design, implementation and evaluation of MR materials in learning environments (PID2019-108933GB-I00). The starting general objective is to determine the perception of Compulsory Education teachers-in-training from the areas of Experimental Sciences, Engineering and Architecture, and Health Sciences, on the use of MR as a teaching tool under the m-learning modality.
Findings – The main conclusion obtained was that neither sex nor age had an influence on the use of MR in the classroom, and its use was determined by elements associated with the classroom methodology, such as collaborative work and attention to diversity, which took place in the education center.
Research limitations/implications – The main obstacle found when conducting the research was being able to access the general population of teachers-in-training in the aforementioned Master's program.
Originality/value – The value of the article lies in publicizing the knowledge that secondary school teachers have of MR and giving clues to create training actions that encourage its incorporation into the classroom methodology.

Keywords Teachers, M-Learning, Mixed reality, Secondary education
Paper type Research paper

Introduction or theoretical framework

Technology is changing society in general and the ways of teaching, with its use becoming an everyday necessity. The processes, that is, the teaching methodologies that are designed and modified according to the present idiosyncrasies, are different aspects that affect the act of teaching.

In this new reality, the use of screens and mobile devices such as Tables and Smartphones is ubiquitous, and these devices, when combined with mixed reality (MR), virtual reality (VR) and augmented reality (AR), provide users with experiences which change the manner in which they work and become educated (Pellas *et al.*, 2018).

Also, the use of innovative technologies is increasing, technologies such as AR, VR, MR, 3D printing and the use of smartphones. These are becoming very well-known, and they can be used inside the classroom. Each of these technologies has their own characteristics which makes them beneficial for their use in teaching, as pointed out by Birt *et al.* (2018):

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(1) AR tries to augment the digital world with real objects, providing users with the possibility of establishing a relationship between the real world and fictional objects.

(2) VR introduces users into the virtual world, in which there is nothing from the real world.

(3) Mobile phones provide the possibility of using VR and AR when devices that are within reach of most individuals are utilized.

(4) 3D printing allows the replication of objects designed digitally, which take shape in the real world.

MR consists of a combination between VR, AR and the real world (Carre *et al.*, 2022). It is also important to indicate that the concepts of AR and MR are frequently utilized to refer to technologies that combine the real and artificial worlds, to change the perception of the users (Leonard and Fitzgerald, 2018).

The differences between VR and AR should be explained, as they both consist of visual simulations, differentiating themselves from completely virtual environments, in important aspects from the theoretical and educational point of view. Therefore, VR consists of establishing completely fictional environments, which provide users the possibility of interacting with the space created. In this way, in general, the interaction with the real world is reduced or even eliminated. Also, VR technologies were mainly created for the world of videogames, becoming tools that could be economically affordable as they can be connected to mobile device screens (Leonard and Fitzgerald, 2018).

MR is having a great impact in different areas associated with marketing, artificial intelligence, as well as artificial vision. In the words of Kerdvibulvech (2022), it is understood as an enchanting experience in an environment in which a mixture is produced within the real world, through the incorporation of virtual scenes. Also, it is understood as a tool that transforms 3D technology to 4D. Thus, it can be utilized in many other areas, from health sciences (Adhikari *et al.*, 2021) to architecture or construction (Hegazy *et al.*, 2021), and even education (Marín and Vega, 2022).

In the last thirty years, constant attempts have been made to incorporate MR into different areas, such as education, medicine and industry, among other fields. In spite of this, the everyday use of MR is very low, and it is mainly used in leisure-related applications, such social networks, or television (Gattullo *et al.*, 2022).

Smartphones and mobile devices are presenting different innovations that allow students, through their phones, to access information on the internet, as well as videos and email, to collaborate on a project and to access documents from their classes that are provided through the Internet. Thus, researchers have named learning through the use of mobile devices as mobile learning (from here on, m-learning), as technology and mobile devices help or facilitate learning (Nikolopoulou, 2021).

However, according to Romero *et al.* (2020), some of the reasons why the putting into practice of m-learning within teaching is not very frequent, mainly include the perceptions of the educators or their resistance against changing the learning method, the feeling of the lack of usefulness of learning through mobile devices or the distractions that could appear when using technology. These authors determined that if mobile learning is introduced in an adequate and controlled manner, with specific schedules of use, it is possible to counteract the distraction of the students. Also, they point out that the main problems found in educators were their resistance against changing their teaching methodology, as they perceive the ICT as tools with little usefulness.

Likewise, MR is being associated to m-learning, a way of learning through the use of mobile devices, as shown in the study by Birt *et al.* (2018), in which the students had to use mobile devices to acquire knowledge. On the one hand, VR was used to develop interactive learning experiences in the virtual world, as 3D objects could be observed, and on the other hand, they used mobile phones to learn through AR, as it is a simple way of learning, as pointed out by the students, mainly due to its ease of use, aside from being a good complement to VR. Also, AR provides a rhythm of learning that is adapted to the students. Lastly, an aspect that should be pointed out is that students acquire abilities when using mobile devices, for using simulation tools. Therefore, simulation through mobile devices or MR improves the competences and skills of students.

As for secondary education, Bano *et al.* (2018) analyzed learning approaches through mobile devices, providing results on the use of different mobile applications and technologies. These authors recognized learning through mobile devices as a learning approach that is garnering popularity in secondary education, mainly in science and mathematics.

Thus, in the secondary education stage, many studies have been conducted in which MR was utilized within teaching-learning processes. A study by Lindgren *et al.* (2016a, b) used a sample of secondary school students, and within it mobile devices were utilized for simulations of movements that were habitual for students, such as running and walking. From this, while they learned in a self-informed manner, they also enjoyed the experience, as they had to be actively involved in the tasks, making easier the knowledge they interpreted as difficult, while at the same time, showing a better attitude for learning.

Therefore, the advancement of technology has led to the implementation of technology such as MR in learning. At the same time, MR can be linked with m-learning when using mobile devices to combine the real and fictitious worlds. More specifically, in secondary education, MR is being utilized together with learning, through m-learning.

Starting with the above, and under the auspices of the R&D + I project *Design, implementation and evaluation of Mixed Reality materials in learning environments* (PID2019-108933GB-I00), the starting general objective is to determine the perception of Compulsory Education teachers-in-training from the areas of Experimental Sciences, Engineering and Architecture, and Health Sciences, on the use of MR as a teaching tool under the m-learning modality.

Method

The present study was conducted through an ex post facto research method, through the use of a descriptive and correlational design. This study was covered by the R&D + I project *Design, implementation and evaluation of Mixed Reality materials in learning environments* (PID2019-108933GB-I00), granted by the Ministry of Science and Innovation of Spain. The main objective is the creation of MR materials and their posterior implementation with Secondary Compulsory Education students.

Starting with the general objective described above, the following working hypotheses were postulated:

(1) Women are more prone to use MR in the teaching-learning process with m-learning.

(2) Age is not a determining element for the use of MR for education in the Secondary Education Stage through m-learning.

(3) The educators from the macro area of Experimental Sciences feel more positive toward the use of MR in the teaching-learning process in the m-learning format.

Instrument

A questionnaire composed of 39 items was utilized to collect information. These were distributed into two large blocks. The first three questions referred to the sociodemographic variables of the participants. These were: sex, age and macro area (Experimental Sciences, Engineering and Architecture, and Health Sciences). The other 36 questions referred to MR. The responses used a Likert-type scale, where (1) corresponded to complete disagreement; (2) disagreement, (3) indifferent, (4) agree and (5) completely agree (Matas, 2018).

To determine the reliability and validity of the instrument, a Cronbach's alpha test was performed with the entire questionnaire, with a resulting value of 0.842, which is very high (Mateo, 2012; López-Roldán and Fachelli, 2016). Once each item removed one by one, the reliability of the instrument remained the same, with values ranging from 0.850 to 0.832.

For the validity of the instrument, an exploratory factorial analysis was performed (from here on, EFA) (Grant and Fabrigar, 2011), which provided three factors. The analysis used an unweighted least squares extraction (ULS) and an oblimin rotation with Kaiser normalization, which revealed 37% of the variance explained. Considering that 13 items had to be removed from the questionnaire, as they did not obtain the minimum load of 0.30 (Morales, 2011; Mavrou, 2015) in none of the factors generated, we considered that this factorial structure could be assumed given that the Kaiser–Meyer–Olkin (KMO) value obtained was 0.829, that is, acceptable, along with a significant Bartlett's sphericity test (X^2 (300) = 2286.762 and $p < 0.001$).

Nevertheless, given that the sample size was not very large, and that the variables studied decreased to 24, the test was re-done with the Factor Analysis (v.11) software, considering the scores from statistical tests associated to this procedure, as pointed out by Freiberg *et al.* (2013), through the unweighted least squares (ULS) method with promin and varimax rotation and Kaiser normalization. In this case, Pearson's correlations were used (KMO = 0.844; Bartlett's sphericity test: X^2 = 2408.1; gl; 630; sig<0.01), for a recommended distribution of three factors, with a total variance explained of 41.96%. The values of the statistics tests, within a 95% confidence interval, were: CFI = 0.978; BIC = 1505.385; GFI = 0.953; AGFI = 0.944; RMSR = 0.0678.

Ultimately, this instrument comprises two blocks, the first containing the three sociodemographic variables, and the second with the 24 items that are distributed in three dimensions (see Table 1).

Once the dimensions of the questionnaire were obtained, a reliability test was once again performed, which provided a value of 0.867, which again indicated a high reliability (Mateo, 2012; López-Roldán and Fachelli, 2016) (see Table 2).

Participants

The participants in this study were secondary school teachers-in-training during academic year 2021–2022, who were enrolled in the Teacher training in Secondary Education Masters program, at the University of Cordoba (Spain). For this, a non-probabilistic, convenience sampling method was used (Otzen and Manterola, 2017), for $N = 223$. Of these, 54.7% were men and 45.3% women. Considering the distribution according to age (see Figure 1), the mean age was 29.25 years old (SD = 6.655).

As for the macro area of reference, the sample of participants was distributed in the following manner: 56.5% belonged to the area of Engineering and Architecture, 39% to Experimental Sciences and 4.5% to Health Sciences.

Results

The descriptive study of the three dimensions determined by the EFA (see Table 3) indicates that for dimension 1, which referred to the *Methodology in the classroom*, the participants were in agreement with the statements that stated that MR promotes the reading comprehension of the texts utilized in the class (*f.* = 35.4%; $M = 3.26$; SD = 1.025); the development of key competences (*f.* = 56.5%; $M = 3.87$; SD = 0.716); favors personal

	Factors 1	2	3
1. The use of MR promotes the reading comprehension of texts associated with the class in which it is employed	0.676		
2. The use of MR will favor the critical spirit of the students	0.638		
3. The use of MR will make the didactic methodology used in the classroom to lead to the development of key competences	0.583		
4. The use of MR promotes the oral expression associated to the class in which it is employed	0.577		
5. The use of MR promotes the development of the capacity to dialogue and express oneself in public, associated to the class in which it is employed	0.571		
6. The use of MR promotes education in values	0.552		
7. The use of MR will favor the personal initiative of students	0.551		
8. The use of MR will make it so that the methodology used in the classroom is more specific to the objectives in the class in which it is employed	0.497		
9. The use of MR will favor the creativity of the students	0.427		
10. The use of MR will favor the capacity of students to communicate what was learned	0.417		
11. The use of MR will help in the resolution of problems associated to the class in which it is employed	0.385		
12. The use of MR will help in the performing of high complexity tasks associated to real situations or as contextualized as possible, associated to the class in which it is employed	0.338		
13. The use of MR can be used by individuals with hearing difficulties		0.679	
14. The use of MR can be used by individuals with motor difficulties		0.640	
15. The use of MR can be used with individuals who have specific educational needs		0.583	
16. The use of MR can be used by individuals with psychological difficulties		0.525	
17. The use of MR can be used by gifted individuals		0.513	
18. The use of MR can promote the cross-sectional teaching of contents		0.311	
19. The use of MR allows cooperative work between students			−0.940
20. The use of MR allows collaborative work between students			−0.899
21. The use of MR allows group work between students			−0.875
22. The use of MR will make the didactic methodology used in the classroom to be more participative			−0.343
23. The use of MR can promote multicultural education			−0.307
24. The use of MR can promote intercultural education			−0.303

Table 1.
Exploratory factorial analysis

Dimension	Alpha value
Didactics methodology	0.823
Attention to diversity	0.836
Classroom work	0.746

Table 2.
Cronbach's alpha according to dimension

initiative (*f.* = 67.3%; *M* = 4.01; SD = 0.637); (*f.* = 54.3%; *M* = 3.67; SD = 0.702) and the creativity of students (*f.* = 48.9%; *M* = 4.21; SD = 0.767) as well as their capacity to communicate what was learned (*f.* = 54.3%; *M* = 3.78; SD = 0.793); helps in the resolution of problems associated to the class in which it is utilized (*f.* = 62.3%; *M* = 3.91; SD = 0.750) and the performing of more complex tasks associated to real situations or as contextualized as possible (*f.* = 52.5%; *M* = 4.24; SD = 0.699). It is significant to point out that the students were indifferent in elements such as the critical spirit of the students (*f.* = 39.5%; *M* = 3.36; SD = 0.879); the oral expression associated with the class in which it is used (*f.* = 39.9%;

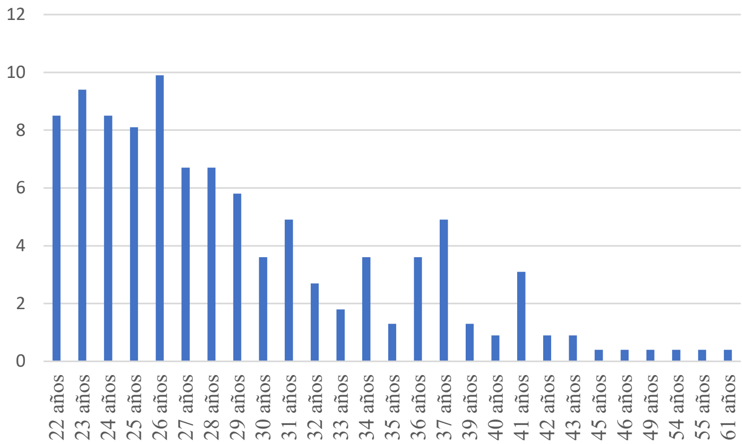

Figure 1.
Distribution of the sample according to age

		Dimension 1	Dimension 2	Dimension 3
N	Valid	223	223	223
	Lost	0	0	0
Asymmetry		−0.064	−0.394	−0.599
Standard error of asymmetry		0.163	0.163	0.163
Kurtosis		0.581	−0.121	0.640
Standard error of kurtosis		0.324	0.324	0.324

Table 3.
Descriptive study of the dimensions

M = 3.18; SD = 0.903); develops the capacity of dialogue and public expression (*f.* = 41.3%; *M* = 3.27; SD = 0.925); promotes education in values (*f.* = 45.7%; *M* = 3.30; SD = 0.802).

As for dimension 2 (*Attention to diversity*), the participants were completely in agreement when indicating that it could be utilized by gifted students (*f.* = 59.2%; *M* = 4.57; SD = 0.548). Also, they were in agreement in that MR used in m-learning can be utilized with special needs students (*f.* = 45.7%; *M* = 3.30; SD = 0.802), more specifically, with hearing (*f.* = 51.6%; *M* = 4.31; SD = 0.644) and motor difficulties (*f.* = 56.1%; *M* = 4; SD = 0.846), and they also indicate that it could promote the cross-sectional learning of contents (*f.* = 52.9%; *M* = 4.19; SD = 0.717).

With respect to the third dimension (*Work in the classroom*), which is related to the work of the professor with the students, the students were in agreement in that MR allows cooperative (*f.* = 52.5%; *M* = 4.24; SD = 0.738) collaborative (*f.* = 51.6%; *M* = 4.22; SD = 0.744), and group (*f.* = 52.5%; *M* = 4.21; SD = 0.743) work; also pointing out that work in the classroom will be more participative (*f.* = 46.6%; *M* = 4.23; SD = 0.757). Lastly, they were in agreement in that MR could promote intercultural (*f.* = 50.7%; *M* = 4.02; SD = 0.750) and multicultural (*f.* = 48%; *M* = 4.06; SD = 0.757) education.

To verify if the variable gender (Hypothesis 1: *Women are more prone to use MR in the teaching-learning process with m-learning*) has an influence on the use of MR in the education of secondary school students, a Student's *t*-test for independent samples was performed. The results indicated that the hypothesis must be rejected, as significant differences were not found between the dimensions considering the variable sex.

To verify if Hypothesis 2 (*Age is not a determining element for the use of MR for education in the Secondary Education Stage through m-learning*) could be accepted or not, an ANOVA was performed, which results indicated the non-existence of statistically significant differences in the dimension proposed by the EFA. Thus, this hypothesis could be accepted.

With respect to the third hypothesis (*The educators from the macro area of Experimental Sciences are more positive towards the use of MR in the teaching-learning process in the m-learning format*), the results reached indicated that it had to be rejected, given the lack of statistically significant differences considering the macro area as the selection variable.

Also, a correlational study was performed between the three dimensions, with a correlation between them observed with a high level of significance ($p < 0.01$) (see Table 4).

Considering the previous correlational study, and with the intention of explaining how the three dimensions found in the EFA relate to each other, a stepwise multiple linear regression was performed between them (see Table 5), presupposing that dimension 3 (Work in the classroom) is the dependent variable, with the independent variables being dimension 1, dimension 2, sex, age and degree. The results showed a corrected coefficient of determination of $R^2 = 0.336$, and a Durbin–Watson value of 2.0, with $F(3, 219) = 38.529$ and $p < 0.001$ with n.s. = 0.05. These values show the interdependence of the residues, and that the explanatory variables have a joint and linear influence on dimension 3. Nevertheless, the variables from the model selected, Dimension 3 = 1.2 + 0.5 Dimension 1 + 0.34 Dimension 2−0.01Age, only explained 34% of this dimension, work in the classroom.

As for the predictor variables introduced into the model, it was observed that sex and degree were eliminated, while dimension 1 ($t = 7.588$ and $p < 0.001$), dimension 2 ($t = 5.108$ and $p < 0.001$) and age ($t = -2.286$ and $p = 0.023$) were maintained, all of which were significant for explaining dimension 3.

The multicollinearity of the model, as observed through the VIF and tolerance values, was adequate, as indicated by Vilà *et al.* (2019), given that the values of the former were higher than 1, and the second higher than 0.10.

To discover if the variables extracted had some effect if they were considered selection variables, a stepwise linear regression was performed, with the moderating variables being degree and sex. The former (degree) was not found in any model, and the parameters for the second are shown in Table 6.

For men, the explanatory model for dimension 3 excluded age with respect to the variables that explained the general model, $F(2,119) = 30.744$, $p < 0.001$ (with n.s. = 0.05), given a corrected coefficient of determination $R^2 = 0.330$ and a Durbin–Watson value of 2.0; with the equation being Dimension 3 = 0.84 + 0.48 Dimension 1+0.37 Dimension 2; where dimension 1 intervenes with $t = 5.470$ and $p < 0.001$, and dimension 2 with $t = 4.304$ and $p < 0.001$.

On the other hand, for women, the equation of the model is Dimension 3 = 1.6 + 0.52 Dimension 1 + 0.32 Dimension 2 – 0.02 Age, that is, the model is similar to the general one,

Table 4.
Correlations according to dimensions

		Dimension 1	Dimension 2	Dimension
Dimension 1	Pearson's correlation	1		
	Sig. (two-tailed)			
	N	223		
Dimension 2	Pearson correlation	0.252**	1	
	Sig. (two-tailed)	0.000		
	N	223	223	
Dimension 3	Pearson correlation	0.491**	0.404**	1
	Sig. (two-tailed)	0.000	0.000	
	N	223	223	223

$F(3,97) = 18.760$ and $p < 0.001$(with n.s. = 0.05), given a corrected coefficient of determination $R^2 = 0.348$ and a Durbin–Watson value of 2.0; for dimension 1, being $t = 5.015$ and $p < 0.001$; and for dimension 2, $t = 3.092$ and $p = 0.003$; and for age, $t = -3.096$ and $p = 0.003$.

In light of these results, it can be concluded that according to sex, women are closer to the general model that explains dimension 3, Work in the classroom, with a percentage that was even higher than that of the general model (35% women as compared to 34% general), while for the men, age was not a variable that explained dimension 3 (Work in the classroom), beyond the other two dimensions, with a finding of 33%.

Discussion

The immersion of emerging technologies in modern teaching cannot be questioned, as shown in studies by Garay *et al.* (2017), Cabero and Marín (2018), de Morais *et al.* (2021), to cite a few. These studies highlight their importance in teaching and learning processes, and the importance of MR utilized as a resource for the development of learning with the m-modality, given that the combination of a networked society, knowledge and education of subjects leads to changes in the views, beliefs and ways of understanding and educating (Marín-Díaz *et al.*, 2022a). This is why, as pointed out by Marín and Cabero (2018), it is necessary to know the perception of teachers on technologies or digital resources in general, as this opinion will make their presence in the classroom to be real or not. Ultimately, online learning associated with MR has led to the inclusion of a new point of view that is associated to how its inclusion in the classroom methodology is perceived by educators (Miller, 2017; Marín and Cabero (2018)). More specifically, in education stages such as secondary education, it necessary to determine this perspective, given that it tends to be the initial contact with learning using the

	Constant	Dimension 1	Dimension 2	Age
B	1.192	0.504	0.338	−0.011
S.E	0.361	0.066	0.066	0.005
Beta		0.427	0.290	−0.126
T	3.297	7.588	5.108	−2.286
Sig.	0.001	0.000	0.000	0.023
Zero order		0.491	0.404	−0.150
Partial *R*		0.456	0.326	−0.153
Semipartial *R*		0.415	0.279	−0.125
Tolerance		0.943	0.930	0.982
VIF		1.060	1.076	1.019

Table 5. Multiple linear regression for work in the classroom

	Men			Women			
	Constant	Dimension 1	Dimension 2	Constant	Dimension 1	Dimension 2	Age
B	0.835	0.483	0.370	1.558	0.522	0.315	−0.023
S.E	0.427	0.088	0.086	0.572	0.104	0.102	0.007
Beta		0.417	0.328		0.416	0.258	−0.251
T	1.955	5.470	4.304	2.725	5.015	3.092	−3.096
Sig.	0.050	0.000	0.000	0.008	0.000	0.003	0.003
Zero order		0.488	0.418		0.480	0.375	−0.282
Partial *R*		0.488	0.367		0.454	0.299	−0.300
Semi-partial *R*		0.407	0.320		0.405	0.250	−0.250
Tolerance		0.953	0.953		0.947	0.940	0.992
VIF		1.049	1.049		1.055	1.063	1.008

Table 6. Multiple linear regression for work in the classroom according to gender

m-learning format (Loreto-Echevarri *et al.*, 2021). In this sense, the research conducted with teachers-in-training in this stage of education has implied that educators must become aware of the presence of an element such as MR, which has come to stay (Marín-Díaz *et al.*, 2022b), as well as the online teaching models (Marín-Díaz *et al.*, 2022c).

If we consider the hypotheses designed for the present study, we must indicate that as opposed to studies by Marín-Díaz *et al.* (2022b, c), Matome and Jantjies (2019), and Tang *et al.* (2018), in this case, the sex variable did not show differences in the beliefs associated to the use of MR in the areas of Experimental Sciences, Architecture and Engineering, or Health Sciences. It is important to point out that we believe that the prior training received by the educators in these areas of knowledge, have been or could have been associated with the use of this technology. On the other hand, these results also coincide with those obtained by Bursztyn *et al.* (2017), so that we can conclude that sex does not determine the use of MR in learning with the m-learning format.

Focusing our attention on the second hypothesis (*Age is not a determining element for the use of MR for education in the Secondary Education Stage through m-learning*), we observe that the variable age does not determine the use MR as a resource in m-learning in this stage of education, but it explains the work in the classroom, along with the didactic methodology, and attention to diversity, in a general manner (Huang *et al.*, 2016), and more specifically for women.

On the other hand, the third hypothesis (*The educators from the macro area of Experimental Sciences are more positive towards the use of MR in the teaching-learning process in the m-learning format*) is somewhat marked by the first hypothesis. Thus, we can conclude that belonging to a specific macro-area does not determine the use of MR as a teaching resource, as opposed to the data obtained by Marín-Díaz *et al.* (2022b, c).

To conclude, if we highlight the general objective of the present study, we could consider that the work in the classroom with MR is explained, considering the didactic methodology in line with the results obtained by Rossler *et al.* (2020) and attention to diversity (Araiza-Alba *et al.*, 2021). More specifically, the participating teachers-in-training believed that this methodology was associated to promoting the collaborative and cooperative work of the students through the use of MR in the m-learning format diversity (Araiza-Alba *et al.*, 2021), which could promote the skills needed for the resolution of problems associated to the classes in which it is utilized (Araiza-Alba *et al.*, 2021; Marín-Díaz *et al.*, 2022b, c), and as result, will help them to performs the tasks that given their complexity, could be associated to situations that are as real as possible (Elmqaddem, 2019; Mena-Vargas *et al.*, 2019).

Lastly, with respect to this objective, referring to attention to diversity, it is worth noting that the results obtained in the present study are a continuation to those from Magallanes *et al.* (2021) and Huang *et al.*, (2016), so that it can be concluded that on this subject, the use of MR online with both gifted students and those with a hearing disability could be highly beneficial for their process of education. And that as pointed out by Araiza-Alba *et al.* (2021), the students with special education needs can improve their learning process through the use of MR in m-learning environments.

Limitations

The main obstacle found when conducting the research was being able to access the general population of teachers-in-training in the aforementioned Master's program.

References

Adhikari, R., Kydonaki, C., Lawrie, J., O'Reilly, M., Ballantyne, B., Whitehorn, J. and Paterson, Ruth (2021), "A mixed-methods feasibility study to assess the acceptability and applicability of immersive virtual reality sepsis game as an adjunct to nursing education", *Nurse Education Today*, Vol. 103, 104944, doi: 10.1016/j.nedt.2021.104944.

Araiza-Alba, P., Keane, T., Chen, W.S. and Swinbu, J.K. (2021), "Immersive virtual reality as a tool to learn problem-solving skills", *Computer and Education*, Vol. 164, 10421, doi: 10.1016/j.compedu.2020.104121.

Bano, M., Zowghi, D., Kearney, M., Schuck, S. and Aubusson, P.J. (2018), "Mobile learning for science and mathematics school education: a systematic review of empirical evidence", *Computers and Education*, Vol. 121, pp. 30-58, doi: 10.1016/j.compedu.2018.02.006.

Birt, J., Stromberga, Z., Cowling, M. and Moro, C. (2018), "Mobile mixed reality for experiential learning and simulation in medical and health sciences education", *Information*, Vol. 9 No. 2, p. 31. doi: 10.3390/info9020031.

Bursztyn, N., Shelton, B., Walker, A. and Pederson, J. (2017), "Increasing undergraduate interest to learn geoscience with GPS-based augmented reality field trips on students' own smartphone", *GSA Today*, Vol. 27 No. 5, pp. 4-11, doi: 10.1130/GSATG304A.1 .

Cabero, J. and Marín, V. (2018), "Blended learning y realidad aumentada: experiencias de diseño docente", *RIED, Revista Iberoamericana de Educación a Distancia*, Vol. 21 No. 1, pp. 57-74. doi: 10.5944/ried.21.1.18719.

Carre, A.L., Dubois, A., Partarakis, N., Zabulis, X., Patsiouras, N., Mantinaki, E., Zidianakis, E., Cadi, N., Baka, E., Thalmann, N.M., Makrygiannis, D., Glushkova, A. and Manitsaris, S. (2022), "Mixed-reality demonstration and training of glassblowing", *Heritage*, Vol. 5 No. 1, pp. 103-128, doi: 10.3390/heritage5010006.

de Morais, E., Andrade, F.G., Heredia, H. and Fiuza, L.M. (2021), "Dominios y dificultades digitales de los estudiantes del curso de Pedagogía de la Universidad Estatal de Ceará (Brasil) a través de la educación a distancia", *EDMETIC*, Vol. 10 No. 1, pp. 40-57, doi: 10.21071/edmetic.v10i1.12950.

Elmqaddem, N. (2019), "Augmented reality and Virtual reality in education. Myth or reality?", *i-jet*, Vol. 14 No. 3, pp. 234-242, doi: 10.39991/ijet.v14i03.9289.

Freiberg, A., Stover, J., de la Iglesia, G. and Fernández, M. (2013), "Correlaciones policóricas y tetracóricas en estudios factoriales exploratorios y confirmatorios", *Ciencias Psicológicas*, Vol. 7 No. 2, pp. 151-164, doi: 10.22235/cp.v7i1.1057.

Garay, U., Tejada, E. and Castaño, C. (2017), "Percepciones del alumnado hacia el aprendizaje mediante objetos educativos enriquecidos con realidad aumentada", *EDMETIC*, Vol. 6 No. 1, pp. 145-164, doi: 10.21071/edmetic.v6i1.5812.

Gattullo, M., Laviola, E., Boccaccio, A., Evangelista, A., Fiorentino, M., Manghisi, V.M. and Uva, A.E. (2022), "Design of a mixed reality application for STEM distance education laboratories", *Computers*, Vol. 11 No. 4, pp. 1-24, doi: 10.3390/computers11040050.

Grant, N. and Fabrigar, L. (2011), "Exploratory factor analysis", in Salkind, N.J. (Ed.), *Encyclopedia of Measurement and Statistics*, SAGE Publications, Thousand Oaks, CA, pp. 459-465.

Hegazy, M., Ichiriyama, K., Yasufuku, K. and Abe, H. (2021), "Comparing daylight brightness perception in real and immersive virtual environments using perceptual light maps", *Automation in Construction*, Vol. 131, 103898, doi: 10.1016/j.autcon.2021.103898.

Huang, T.C., Chen, C.C. and Chou, Y.W. (2016), "Animating eco-education: to see, feel, and discover in an augmented reality-based experiential learning environment", *Computer and Education*, Vol. 96, pp. 72-82, doi: 10.1016/j.compedu.2016.02.008.

Kerdvibulvech, C. (2022), "Geo-Based mixed reality gaming market analysis", *Human Behavior and Emerging Technologies*, pp. 1-9, doi: 10.1155/2022/1139475.

Leonard, S.N. and Fitzgerald, R.N. (2018), "Holographic learning: a mixed reality trial of Microsoft HoloLens in an Australian secondary school", *Research in Learning Technology*, Vol. 26, doi: 25304/rlt.v26.2160.

Lindgren, R., Tscholl, M., Wang, S. and Johnson, E. (2016a), "Enhancing learning and engagement through embodied interaction within a mixed reality simulation", *Computers and Education*, Vol. 95, pp. 174-187, doi: 10.1016/j.compedu.2016.01.001.

Lindgren, R., Tscholl, M., Wang, S. and Johnson, E. (2016b), "Mobile mixed reality for experiential learning and simulation in medical and health sciences education", *Information*, Vol. 9 No. 2, pp. 1-14, doi: 10.3390/info9020031.

López-Roldán, P. and Fachelli, S. (2016), *Metodología de la investigación social cuantitativa*, UAB, Barcelona.

Loreto-Echevarri, G., Marín-Ochoa, B. and Sánchez-García, O. (2021), "Capacidades de los docentes para la incorporación de estrategias m-learning en sus procesos de enseñanza y aprendizaje. Estudio de un caso colombiano", *Pedagogía y Sociología de la Educación*, Vol. 16 No. 1, pp. 220-232, doi: 10.18041/2382-3240/saber.2021v16n1.75291.

Magallanes, J.S., Rodríguez, Q.J., Carpio, Á.M. and López, M.R. (2021), "Simulación y realidad virtual aplicada a la educación", *RECIAMUC*, Vol. 5 No. 2, pp. 101-110, doi: 10.26820/reciamuc/5.

Marín, V. and Vega, E. (2022), "La formación del docente de enseñanza secundaria en torno a la realidad mixta en ámbitos inclusivos", in Sánchez-Rivas, E., Colomo-Magaña, E., Ruiz-Palmero, J. and Gómez-García, M. (Eds), *La tecnología educativa como eje vertebrador de la innovación*, Octaedro, Barcelona, pp. 73-85.

Marín-Díaz, V., Sampedro, B. and Figueroa, J. (2022a), "Augmented reality in the secondary education classroom: teachers' visions", *Contemporary Educational Technology*, Vol. 14 No. 2, ep348. doi: 10.30935/cedtech/11523.

Marín-Díaz, V., Sampedro, B.E. and Vega, E. (2022b), "La realidad virtual y aumentada en el aula de secundaria", *Campus Virtuales*, Vol. 11 No. 1, pp. 225-236. doi: 10.54988/cv.2022.1.1030.

Marín-Díaz, V., Sampedro-Requena, B.E. and Vega-Gea, E. (2022c), "Visiones del profesorado en torno a la Realidad Aumentada en la Enseñanza Secundaria", *Teknokultura. Revista de Cultura Digital y Movimientos Sociales*, Vol. 19 No. 2, pp. 25-36. doi: 10.5209/TEKN.77853.

Matas, A. (2018), "Diseño del formato de escalas tipo Likert: un estado de la cuestión", *Revista Electrónica de Investigación Educativa*, Vol. 20 No. 1, pp. 38-47.

Mateo, J. (2012), *La investigación ex post-facto. En R. Bisquerra (coord.), Metodología de investigación educativa*, La Muralla, Madrid, pp. 195-229.

Matome, T.J. and Jantjies, M.E. (2019), "Student perceptions of virtual reality in higher education", *16th International Conference on Cognition and Exploratory Learning in Digital Age (CELDA 2019)*, pp. 92-100, available at: https://eric.ed.gov/?id=ED608662.

Mavrou, I. (2015), "Análisis factorial exploratorio. Cuestiones conceptuales y metodológicas", *Revista Nebrija de Lingüística Aplicada a la Enseñanza de Lenguas*, Vol. 19, pp. 71-80, doi: 10.26378/rnlael019283.

MenaVargas, Y.A., Millán-Rojas, E.E. and Sánchez-Castillo (2019), "Application of augmented reality as a means of interdisciplinary learning", *Scientia et Technica*, Vol. 24 No. 3, pp. 472-482.

Miller, R. (2017), "How digital technologies are transforming aerospace and defense", available at: https://www.ey.com/en_gl/aerospace-defense/how-digital-technologies-are-transforming-aerospace-and-defense.

Morales, P. (2011), "El Análisis Factorial en la construcción e interpretación de tests, escalas y cuestionarios", available at: http://www.upcomillas.es/personal/peter/investigacion/AnalisisFactorial.pdf.

Nikolopoulou, K. (2021), "Mobile devices and mobile learning in Greek secondary education: policy, empirical findings and implications", in Marcus, A. and Hourigan, T. (Eds), *Handbook for Online Learning Contexts: Digital, Mobile and Open*, Springer, Cham, pp. 67-80, doi: 10.1007/978-3-030-67349-9_6.

Otzen, T. and Manterola, C. (2017), "Técnicas de muestreo sobre una población a estudio", *International Journal of Morphology*, Vol. 35 No. 1, pp. 227-232, doi: 10.4067/S0717-95022017000100037.

Pellas, N., Fotaris, P., Kazanidis, I. and Wells, D. (2018), "Augmenting the learning experience in primary and secondary school education: a systematic review of recent trends in augmented reality game-based learning", *Virtual Reality*, Vol. 23, pp. 329-346, doi: 10.1007/s10055-018-0347-2.

Romero, J.M., Aznar, I., Hinojo, F.J. and Gómez, G. (2020), "Mobile learning in higher education: structural equation model for good teaching practices", *IEEE Access*, Vol. 8, pp. 91761-91769, doi: 10.1109/ACCESS.2020.299496.

Rossler, K.L., Sankaranarayanan, G. and Hurutado, M.H. (2020), "Developing an immersive virtual reality medication administration scenario using the nominal group technique", *Nurse Education Today*, Vol. 56, 10391, doi: 10.1016/j.nepr.2021.103191.

Tang, Y., Au, K. and Leung, Y. (2018), "Comprehending products with mixed reality: geometric relationships and creativity", *International Journal of Engineering Business Management*, Vol. 10, pp. 1-12, doi: 10.1177/1847979018809599.

Vilà, R., Torrado, M. and Reguant, M. (2019), "Análisis de regresión lineal múltiple con SPSS: un ejemplo práctico", *REIRE. Revista d'Innovació i Recerca en Educació*, Vol. 12 No. 2, pp. 1-10, doi: 10.1344/reire2019.12.222704.

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