Technology, Knowledge and Learning (2023) 28:1443–1459
https://doi.org/10.1007/s10758-023-09671-9

ORIIGINAL RESEARCH

Attitudes Towards the Development of Good Practices with Augmented Reality in Secondary Education Teachers in Spain

José-Antonio Marín-Marín[1] · **Jesús López-Belmonte**[1] · **Santiago Pozo-Sánchez**[1,2] · **Antonio-José Moreno-Guerrero**[1]

Accepted: 7 April 2023 / Published online: 28 August 2023

Abstract
The attitude of the teaching staff is positioned as a fundamental aspect for the development of good training practices. These good practices are essential when applied within an innovative techno-pedagogical methodology: augmented reality in education. The objectives of this study are to analyze the development of good teaching practices with augmented reality and to discover the factors that influence their quality. A descriptive and correlational design has been carried out. A total of 1490 Spanish Secondary Education teachers have participated. The instrument used was the adaptation to the Spanish context of the questionnaire of the Attitude Scale of Augmented Reality Applications. The results reveal that teachers show a positive attitude towards the use of augmented reality. As for the aspects that influence the good attitude of teachers are age, the number of devices teachers use, the time they dedicate to technological resources and teaching experience. However, ICT training is what determines a direct influence on the attitude of teachers, as well as satisfaction with reliability.

Keywords Augmented reality · Teacher attitudes · Good practices · Secondary education · Educational innovation · Techno-pedagogical methodologies

1 Introduction

In the last twenty years, technological advances have radically changed people's habits. These natural changes have also been reflected in existing approaches to teaching that, increasingly, have been supported by this technology. Among the different technologies that are open source to support training processes is augmented reality (AR). This technology (data) finds its beginnings in the mid-20th century (Grubert et al., 2017), although that

✉ Santiago Pozo-Sánchez
santiagopozo@ugr.es

[1] Department of Didactics and School Organization, University of Granada, Granada, Spain

[2] Department of Didactics of Musical, Plastic and Corporal Expression, University of Granada, Granada, Spain

name was not coined until 1992, when researchers Tom Caudell and David Mizell (Arth et al., 2015) proposed it to Boeing as a system to help their customers used to assemble complex wire harnesses; They defined it as the superposition of virtual materials made by computer and images of the real world (Arth et al., 2015). In this sense, AR can be defined as a technique that links digital information with the real world by placing digital content such as text, images, audio and video generated by computer in the image of the real world that individuals see around them (Köse & Güner-Yildiz, 2021). In this way, AR makes it possible to perfectly superimpose the user's physical environment and computer-generated digital content to turn it into a unique and coherent perception, and allows the user to interact with it simultaneously (Bower et al., 2014; Grubert et al., 2017; Wiederhold, 2019). This technology works in parallel with the information provided by the physical world and uses technology to improve or mask the users' perception of the reality that surrounds them.

Recent technological advances have led to a wide availability of relatively affordable technology that can be very easily adapted, modified and customized by designers and researchers (Wiederhold, 2019). These new technologies, easy to use and carry in your pocket, combined with the same advances in body sensors or other sensors such as GPS, accelerometer, gyroscope or compass, allow an exponential advance in widespread use. In this sense, in the last ten years the integration of AR systems in mobile devices has been facilitated, allowing the increase in the number of AR applications (Soltani & Morice, 2020). In the case of its application in the educational field, numerous studies have revealed that this technology has immense potential to improve learning and teaching (Billinghurst & Duenser, 2012; Cai et al., 2021; Conley et al., 2020; Dunleavy et al., 2009; Garzón and Acevedo, 2019; Jesionkowska et al., 2020; Johnson et al., 2011; Wang, 2017). Furthermore, studies reveal how it has been used in the hope of increasing knowledge retention by students (Huang et al., 2019); as a strategy to encourage participants to be active and interact with other participants (Finco et al., 2017); powerful and effective means to visualize the microscopic world so that students can observe the composition of different subjects live (Cai et al., 2014); visualize abstract concepts in general (Cai et al., 2016; Dunleavy et al., 2009); as a learning material in the education of people with special needs (Köse & Güner-Yildiz 2021); and it can even help students memorize factual historical information more effectively (Lim & Lim, 2020).

In addition to the advantages of visualization, AR is presented as a powerful technology in offering educational experiences in general and in innovative learning models (Cai et al., 2021). An example of this is the potential that this technology can have to improve motivation, performance and the ability to explore the contents on the part of the student (Chiang et al., 2014). In terms of peer interaction, AR technology supports student cooperative learning and allows students to immerse themselves more deeply in the research process (Chen et al., 2020; Wang et al., 2014). In this way, AR has proven to be a powerful and emerging tool within educational technology, with the possibility of being revolutionary in challenging what is seen as the integration of technology in the classroom and in all subjects.

This evidence has been contrasted with various meta-analysis studies in which the effect of the sample was measured and in all of them it was greater than 0.50 (Garzón et al., 2019; Ozdemir et al., 2018; Tekedere & Göke, 2016), concluding that AR applications have a positive impact on learning. Along the same lines, another more recent meta-analysis carried out on 64 documents related to AR and education (Garzón & Acevedo, 2019), identified that AR has a medium effect (0.68) in improving student learning, although states that more than 93% of the studies corresponded to relatively short experimental interventions

with AR in education, lasting less than one month. This raised to the authors the possibility that the positive impact of AR on education could be due to the novelty effect (Lim & Lim, 2020; Wang et al., 2014).

The diversity of subjects in which you can benefit from the possibilities offered by AR is wide. Research shows how AR has been applied to simulate behavior as an innovative technique for learning ethics and, specifically, to improve moral vision (Sari et al., 2021); the teaching of history (Lim & Lim, 2020); language learning (Uiphanit et al., 2020); digital literacy (Severini et al., 2019); learning mathematics (Aldon & Raffin, 2019); or learning biology (Fuchsová et al., 2019). This takes place at all stages of education, from preschool to college.

In contrast, some research has also pointed out negative aspects of the use of AR in educational contexts (Avila-Garzon et al., 2021; Kazanidis et al., 2021; Turhan et al., 2022):

- Economic cost: The use of augmented reality in education can be expensive, since it requires specialized devices and applications that may not be available to all students or educational institutions.
- Accessibility: To use augmented reality, it is necessary to have access to a compatible mobile device and an Internet connection. This can be an obstacle for those who do not have access to these resources.
- Connectivity issues: Augmented reality often requires a high-speed internet connection, which can be a problem in some school settings.
- Hardware and Software Requirements: Augmented reality may require specialized hardware and software, which can be challenging for some schools or educational institutions.
- Distracting: Although augmented reality can be a useful tool to enrich learning, it can also be distracting for some students. It is important to set clear limits and rules for the use of augmented reality in the classroom to avoid unnecessary distractions.
- Technology Dependence: The use of AR can cause students to become overly dependent on technology and can limit their ability to learn independently.
- Lack of content: Although there is an increasing amount of augmented reality content available, there is still a lack of quality, relevant content for learning.
- Lack of training: Many teachers may not be familiar with augmented reality and may need training to know how to use it effectively in the classroom.

As can be seen, the vast majority of research on AR and education is directed to the study of the implications of AR on student learning and the benefits or limitations it can offer. On the contrary, studies on the training and perception of teachers are scarce. There is an interesting study on the Professional Development of Teachers (PDT) program, in the context of the European Union project, on Animated Laboratories within STEM Education (Science, Technology, Engineering, Mathematics) (Lasica et al., 2020). This study aims to familiarize teachers with the potential of AR Technology to improve teaching and learning processes in STEM lower secondary education. The PDT program offers teacher training in information and communication technologies (ICT) according to the principles of the TPACK (Technological Pedagogical and Content Knowledge) model (Bustamante, 2019) of teaching technological competence. Among the results of this study, it should be noted that all the teachers who participated in the PDT program had heard of innovative technologies, such as virtual reality, AR and mixed reality, but did not know how to apply them in the educational process. In addition, 20% of teachers expressed feelings of anxiety and insecurity due to the high rate of development of technology, whose evolution is so fast

that it prevents maintaining an adequate level of training, even among the most innovative teachers. At the end of the PDT program, the faculty stated that AR is a promising technology that could have additional value for their students in the future, provided that more educational content relevant to the curriculum is available and that teachers receive training in high quality on AR-based pedagogical approaches.

On the other hand, the study by Sáez-López et al. (2020) on initial teacher training highlights the difficulty of its correct application and the essential need for initial training that avoids the barriers and difficulties that would arise from an erroneous pedagogical application. In addition, it highlights the advantages of AR in the development of creativity, collaboration, innovation, motivation, participation and student interest. Along the same lines, (Ashley-Welbeck & Vlachopoulos, 2020), in the interviews conducted with teachers who participated in a program on technology training and AR, conclude that the ability of teachers to integrate the content of the application in the didactic units is one of the possible limitations, together with the need to be familiar with technology to be effective for teaching. Likewise, as with all technologies, the use of AR in the classroom is not only limited to the student, but is highly dependent on the willingness and skills of teachers to use it effectively.

For all the above, we understand that the original contribution of this research is to address as a central issue the attitudinal predisposition of secondary school teachers to carry out good practices with RA and the incident factors in its development. The use of techno-pedagogy as an innovative resource for teaching and learning processes is a reality, and its benefits have been widely studied in the scientific literature. However, the analyzes focused on the potential of didactic resources and teaching methodologies sometimes do not contemplate all the agents involved in the learning process. The attitude of teachers, on occasions, is not analyzed in a quantitative way in order to draw generalizable conclusions that allow delimiting the state of the question regarding the use of RA and its good practices. Delimiting the factors that affect good teaching practices regarding the use of an innovative resource such as RA is essential to guide the continuous training actions of teachers and continue advancing in the field of methodological pedagogical innovation.

1.1 Objectives and Research Questions

In the scientific literature, AR is positioned as an educational technology of great projection in learning spaces (López-Belmonte et al., 2019). Its potential lies in the benefits it provides in training actions and that science has been demonstrating in its trajectory as a technology applied to the field of education (Cai et al., 2021; Conley et al., 2020; Jesionkowska et al., 2020). In this sense, research has mostly focused on verifying its effectiveness as a technological resource for the improvement of various psychosocial and educational indicators in student populations (Garzón & Acevedo, 2019). On the other hand, there is a gap in research on the skills that teachers need to develop good training practices with AR. Based on this approach, the objectives formulated for this study are: (a) Analyze the attitudinal predisposition of secondary school teachers to carry out good practices with AR; (b) Verify the incident factors in the attitudes of teachers for the development of good practices with AR.

The following Research Questions (RQ) are derived from these objectives to conduct the study.

- RQ1: What is the proportion of secondary teachers with skills to develop good practices with AR?
- RQ2: What are the sociodemographic factors that determine the necessary skills for the development of good teaching practices with AR?
- RQ3: How do the interactions of the constructs influence the attitudes required for the realization of good teaching practices with AR?

2 Materials and Methods

2.1 Research Design and data Analysis

To carry out this study, a quantitative research methodology has been carried out, through a design with a descriptive and correlational approach. For a correct development of the research, the methodological precepts of the experts in this field of knowledge were taken into account (Hernández et al., 2014).

The data analysis process was carried out with the IBM SPSS and IBM SPSS Amos programs, version 24. The mean scores and standard deviations of the participants were delimited according to each of the established socio-demographic factors. Before carrying out the following analyses, the assumptions of linearity, independence, normality, homoscedasticity, residual analysis and non-collinearity were analyzed, complying with the appropriate values to perform the parametric tests. Likewise, with the t test for independent samples and the ANOVA test the possible resulting significance between factors was analyzed. In addition, to determine the influence of the factors analyzed in the development of good teaching practices, two Path analyzsis were carried out. First, the hypothesis of multivariate normality was tested according to the Mardia coefficient (Mardia, 1970). Similarly, different goodness-of-fit indices were taken to confirm the adequacy of the two models (Byrne, 2013).

2.2 Participants

A total of 1490 Spanish Secondary Education teachers participated in the study. Access to this sample has been provided by the database of the Ministry of Education and Vocational Training (https://cutt.ly/2f9NGV1). A sample of 42.6% men and the rest women was configured. Other sociodemographic data are listed in Table 1.

2.3 Instrument

For data collection, the adaptation to the Spanish context of the Augmented Reality Applications Attitude Scale (ARAAS) questionnaire (Díaz-Noguera et al., 2017) has been used. It is a tool designed and validated to determine the teachers' attitudes towards carrying out training practices through AR. This instrument is structured in three dimensions and has a total of 23 items (1-Relevance = 9 items; 2-Satisfaction = 9 items; Reliability = 5 items). The questionnaire follows a 5-point Likert scale response format (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree). The Spanish version of the ARAAS has adequate psychometric properties. It presents a high global reliability of the instrument (Cronbach's alpha = 0.923), as well as in its various dimensions (Relevance: $\alpha = 0.795$; Satisfaction: $\alpha = 0.854$; Reliability: $\alpha = 0.794$). Likewise, the

Table 1 Sociodemographic data of the participants

Variables	n	%
Age		
20–35	460	30.9
36–50	685	46
51–65	287	19.3
+65	58	3.9
ICT use		
Yes	982	65.9
No	508	34.1
The use of AR is appropriate		
Yes	1121	75.2
No	369	24.8
Number of devices		
0	17	1.1
1–4	490	32.9
5–10	741	49.7
+10	242	16.2
ICT training		
0–1 course	594	39.9
2–5 courses	713	47.9
More than 5 courses	183	12.3
Time use of technology		
1–2 h	607	40.7
3–4 h	487	32.7
5–6 h	235	15.8
+6 h	161	10.8
Teaching experience		
1–10	170	11.4
11–20	508	34.1
21–30	303	20.3
+31	509	34.2

Kaiser-Meyer-Olkin test yielded relevant values overall (KMO = 0.908) and the Bartlett test of sphericity reflected an adequate score ($\chi 2 = 1621.667$; $df = 253$; $p < .000$). In short, after carrying out the corresponding exploratory and confirmatory factor analysis, this instrument is postulated as a valid tool to collect data on the state of the matter in a Spanish context. Specifically for this research, 8 variables of a sociodemographic nature were added (gender, age, use of ICT, adequate use of AR, number of devices, ICT training, time of use of technology and teaching experience). Therefore the questionnaire finally used is made up of 23 items, distributed in three dimensions: relevance (RE), satisfaction (SA) and reliability (REA).

2.4 Procedure

To deploy a study of magnitude and generalizable, the entire Spanish geography was taken into consideration. Specifically, a convenience sampling was applied in the different regions of Spain. The participating educational centers were chosen based on their availability and collaboration to carry out the different actions involved in a study. For this, contact was made with the various institutions and management teams that comprise them. They were informed about the objectives of the investigation and permission was obtained to carry out the investigative deployment. The data was collected using the Google Forms application. All the participants were aware of the study objectives and agreed to participate in the research through informed consent.

3 Results

The positive attitude of Secondary Education teachers in the application and development of AR in the teaching and learning processes was recorded in 40.13% of the cases (n = 598). This is determined given that this number of teachers obtained a score above 75% in the instrument used for this study. These scores are above 82.25, out of a total of 115 points. This shows that there is a high number of teachers with an appropriate attitude for the use of AR in pedagogical processes. Table 2 shows the means achieved in the various sociodemographic variables. In addition, it is reflected if there are significant differences in each of these variables.

There were no statistically significant differences in gender ($p = .158$). In this case, the mean of men is slightly higher (M = 98.36) than that of women (M = 97.50). Statistical significance does occur in age ($p = .000$), with the mean of subjects over 65 years (M = 102.86) higher than that of the rest of the age groups. In the use of ICT, no statistically significant differences were observed ($p = .216$), with the mean of teachers who use ICT slightly higher than those who do not use them in teaching and learning processes. Likewise, no statistical significance is reported among the subjects who postulate the use of AR as an adequate resource for the pedagogical act. In this case, the average of those who think positive is slightly higher than those who do not consider it adequate. On the other hand, the number of devices shows significant differences ($p = .026$), being those teachers who have between one and four devices the ones that show the highest mean (M = 98.99) with respect to the rest. On the contrary, the completion of training courses related to the use of ICT does not show a significant relationship. In this case, the teachers who have taken between two and five courses on ICT show a higher average compared to the rest (M = 98.18). However, the time that teachers spend in the use of technological devices in their day-to-day life is significant ($p = .001$), with the average of those who use technological resources being between one and two hours higher than the rest (M = 99.02). Finally, the teaching experience is also significant, with the average of those teachers with less than ten years of experience being higher than the rest (M = 100.51).

In order to establish the structural equation models (SEM), specifically the path analysis models, the goodness indices of the statistical analysis have been identified (Table 3). The calculation of the Mardia coefficients indicates that both model 1 (Mardia: 2749) and model 2 (Mardia: 5473) present values lower than 288. This indicates that the values are adequate (Bollen, 1989). Next, the model's fit indices were identified in order to identify

Table 2 Descriptive statistical data and differences between groups

	n	M	SD	p
Gender				
Man	257	98.36	7.77	0.158
Woman	341	97.50	7.11	
Age				
20–35	194	98.36	8.11	0.000
36–50	254	97.23	7.06	
51–65	92	95.46	6.49	
+65	58	102.86	5.02	
ICT use				
Yes	395	98.14	7.48	0.216
No	203	97.34	7.25	
The use of AR is appropriate				
Yes	470	98.06	7.37	0.222
No	128	97.16	7.50	
Number of devices				
0	7	94.00	6.11	0.026
1–4	204	98.99	7.52	
5–10	293	97.54	7.37	
+10	94	96.75	7.08	
ICT training				
0–1 course	225	97.72	7.62	0.480
2–5 courses	296	98.18	7.22	
More than 5 courses	77	97.09	7.46	
Time use of technology				
1–2 h	307	99.02	7.74	0.001
3–4 h	180	96.53	6.87	
5–6 h	66	97.16	6.67	
+6 h	45	96.40	7.07	
Teaching experience				
1–10	81	100.51	9.36	0.001
11–20	229	97.78	7.27	
21–30	124	96.26	6.68	
+31	164	97.90	7.31	

n = sample; M = mean; SD = standard deviation; p = p value

whether both models were adequate or not. In both cases, after several adjustments, they were considered adequate, complying with all the established assumptions (Byrne, 2013).

In the first statistical model of path analysis, the influence of all sociodemographic variables on the attitudes of teachers regarding the use of AR in the teaching and learning processes is analyzed. The results obtained indicate that only ICT training shows a significant relationship with respect to the attitude of teachers in the use of AR. In the rest of the established connections, no significant relationship is observed (Table 4).

The first model (path 1) shows the relationships established between the sociodemographic variables and the attitudes of teachers regarding the use of AR in the teaching and

Table 3 Goodness and fit indices of the analysis models

Fit index	Obtained value		Expected value
	Path 1	Path 2	
χ^2	81.032	125.110	
df	28	45	
χ^2/df	2.894	2.78	≤3
GFI	0.920	0.925	0.90–1
AGFI	0.901	0.907	0.90–1
RMR	0.086	0.075	Closest to 0
RMSEA	0.049	0.047	<0.05
CFI	0.921	0.925	0.90–1
NFI	0.919	0.913	0.90–1
NNFI	0.928	0.916	0.90–1

GFI = Goodness of fit index; AGFI = Weighted fit index; RMR = Root mean square residual index; RMSEA = Root mean square error of approximation; CFI = Comparative fit index; NFI = Normalized fit index; NNFI = Non-normalized index of fit

Table 4 Path analysis model parameters 1

Association between variables	RW	SE	CR	p	SRW
AUAR ← Gender	−0.051	0.028	−1.819	0.069	−0.076
AUAR ← Age	0.038	0.020	1.921	0.055	0.092
AUAR ← ICT use	−0.020	0.034	−0.589	0.556	−0.026
AUAR ← AR use	−0.029	0.036	−0.797	0.426	−0.034
AUAR ← Technological devices	−0.022	0.015	−1.467	0.142	−0.065
AUAR ← ICT training	−0.053	0.018	−2.864	0.004	−0.132
AUAR ← ICT usage time	−0.009	0.022	−0.408	0.683	−0.017
AUAR ← Teaching experience	−0.028	0.025	−1.134	0.257	−0.053

AUAR = Attitudes in the use of augmented reality; RW = Regression weighting; SE = Standard error; CR = Critical radio; SRW = Standardized regression values; ***$p < .001$ = significance relationship

learning processes. In this case, attitudes about the use of AR were located in the central zone, showing the influence that sociodemographic variables exert on it. As can be seen in Fig. 1, only the training of teachers in the use of ICT has an influence on the attitude of these professionals in the use of AR. The rest of the variables have no influence whatsoever. In this case, the established distribution explains 10.3% of the model.

In the second statistical model of path analysis, the dimensions that make up the instrument used are analyzed in a more sectional way, as well as the influence of the various sociodemographic variables. Before establishing the present model, reflected in Fig. 2, other combinations and structures were established, the one shown being the only one that presented adequate indicators of goodness. The variables gender, number of ICT devices, training and time of ICT use were related to RE. In this way, these variables reflect being incident factors in the perceived relevance of good practices for the use of AR. Sociodemographic variables, the use of AR and use of ICT in training

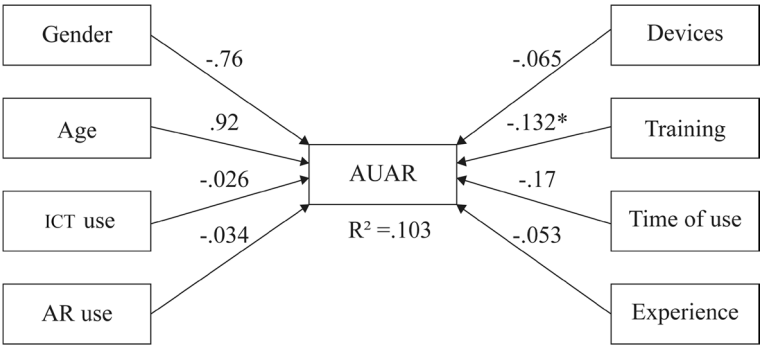

Fig. 1 SEM of the path analysis model 1. *Significant at $p < .001$

processes have also been found as determining factors to determine the degree of teacher satisfaction (SA) with regard to the development of good practices for the use of AR. A highly significant correlation has also been found between the SA and REA dimensions, which reflects that the greater the satisfaction in the use of AR in teaching practice, the greater the level of reliability regarding the use of this technology in the classroom. Continuing with the REA dimension, it shows a significant correlation with sociodemographics, age and teaching experience, which is why they are verified as incident factors in teacher reliability when using AR as a pedagogical resource. Finally, a relationship with a lesser degree of significance has been verified between the gender of teachers and the ER dimension, understanding that their gender can be a determining factor for the perceived relevance of good practices for the use of AR. The present model shows the combination established for teachers to show an adequate attitude for the use of AR in the teaching and learning processes (Table 5).

The second model (path 2) shows the main construct established, after applying the statistical tests in the dimensions RE, SA and REA. Through this construct, the

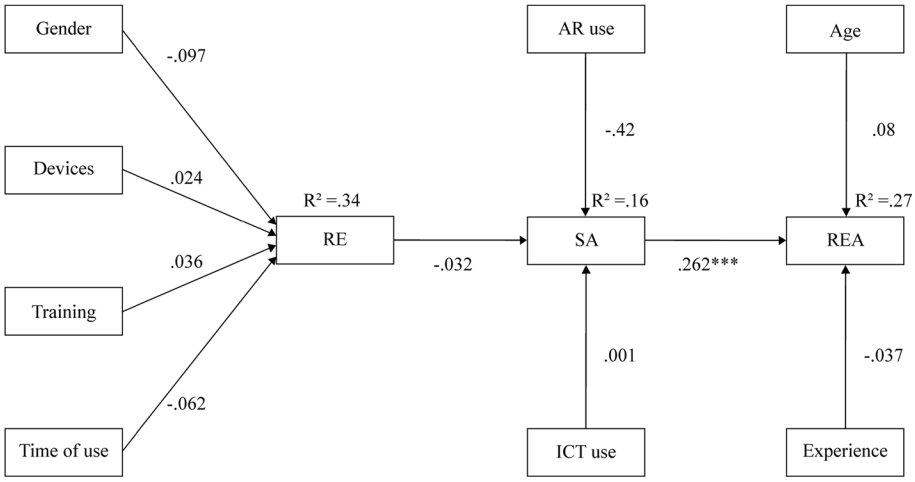

Fig. 2 SEM of the path analysis 2 model. *** Significant at $p < .001$

Table 5 Path analysis model parameters 2

Association between variables	RW	SE	CR	*p*	SRW
RE ← Gender	−0.121	0.052	−2.307	0.021	−0.097
RE ← Technological devices	0.023	0.044	0.535	0.593	0.024
RE ← Training	0.034	0.040	0.853	0.394	0.036
RE ← ICT usage time	−0.046	0.033	−1.383	0.167	−0.062
SA ← AR use	−0.044	0.045	−0.976	0.329	−0.042
SA ← ICT use	0.001	0.042	0.026	0.980	0.001
SA ← RE	−0.022	0.028	−0.762	0.446	−0.032
REA ← Age	0.056	0.031	1.828	0.068	0.080
REA ← Experience	−0.021	0.025	−0.873	0.383	−0.037
REA ← SA	0.354	0.055	6.458	***	0.262

RE = Relevance; SA = Satisfaction; REA = Reliability; RW = Regression weighting; SE = Standard error; CR = Critical radio; SRW = Standardized regression values; ***$p < .001$ = Significance relationship

connection established between the various sociodemographic variables with respect to the various dimensions is shown, showing the influence they generate on the set of different dimensions. This model shows the direction of the factors that influence the attitude of teachers in the application of AR in the teaching and learning processes. In this case, a very significant relationship of the SA dimension over REA is shown, which reveals how the set of dimensions and sociodemographic variables exert a medium force of association on REA (Fig. 2).

4 Discussion

AR as an educational technology has led to various improvements in teaching and learning processes (Chen et al., 2020; Huang et al., 2019). This has been verified in the scientific literature as presented in this work. On the other hand, it is not only important to know what this technology contributes in the training aspect, but it is also important to determine the attitudes of the teachers who use it and put it into practice in learning spaces. For this reason, this study has tried to carry out an analysis of the training actions with AR of Spanish teachers who teach in Secondary Education and the factors that determine their quality.

In the research carried out, it is observed that only 40.13% of teachers have adequate attitudes to be able to apply pedagogical methods through the use of AR. This is in relation to what is established by other lines of research (Ashley-Welbeck & Vlachopoulos, 2020; Lasica et al., 2020).

The various statistical analysis applied show that there are only statistically significant differences in relation to age, the number of devices that teachers use in their day by day life, the time they dedicate on a daily basis to technological resources and the teaching experience. In this case, the best attitudes were recorded by teachers over 65 years of age, by teachers who have an approximate number of 1 to 4 devices, by teachers with less than 10 years of experience and by teachers who dedicate a daily shift 1–2 h. In other words, these aspects are considered significant in the use of AR in teaching and learning processes. Other investigations such as those by Heintz et al. (2021) and Marín-Díaz et al.

(2022) contemplate age and experience as determining factors for the optimal use of RA, however, they establish lower values of age and experience as the most determining factors.

The contrast between the years of the teachers and the teaching experience is remarkable. In this case, it can be indicated that sociodemographic variables such as gender, the use of ICT, the assessment of the use of AR in pedagogical processes and training on the use of ICT are not elements that influence teachers to when presenting good attitudes in the use of AR. These results are those obtained after applying them individually between the variables of good attitude about the use of AR and each of the sociodemographic variables. In contrast, the analysis carried out by Pozo-Sánchez et al. (2020) consider gender and the frequency of ICT use as incident factors in the level of digital competence of teachers and -consequently- consider these variables as determinants for the potential use of AR technologies. Other studies that directly analyze the teaching characteristics for the use of AR determine that gender and the frequency of ICT use directly affect the positive assessment of AR as a techno-pedagogical resource (Castaño-Calle et al., 2022; Heintz et al., 2021).

But what happens when they are analyzed as a whole? In this case, bearing in mind the first path analysis carried out, it is seen that there is a direct influence in the formation of ICT on the attitudes of teachers for the use of AR. In other words, ICT training does affect the model as a whole. Other investigations have also revealed the importance of teacher techno-pedagogical training for the optimal implementation of RA-mediated methodologies, highlighting a higher frequency of use in those teachers with a higher level of digital competence (Fuentes et al., 2019; Sáez- Lopez et al., 2020).

In the second path analysis carried out, each of the study dimensions was analyzed in relation to the sociodemographic dimensions. In this case, the model presented is the result of various combinations, being in this case the most representative model. As can be seen, there is a very significant influence between the SA dimension and the REA dimension. In the rest of the connections, there is only a significant influence between gender and RE. In all other connections, there is no significant influence. That is to say, the influence of SA on REA generates an important effect in the fact of presenting a good attitude for the application of AR in the teaching and learning processes. This correlation has also been verified by other investigations that have analyzed the incidence of satisfaction and reliability perceived by teachers in the use of AR in educational contexts (Ibili et al., 2019; Mystakidis et al., 2021).

5 Conclusions

It can be concluded that less than half of the teachers who teach students between 12 and 16 years of age, that is, in the Secondary Education stage of the Spanish context, show a positive attitude towards the development and application of the AR in the teaching and learning processes. There are aspects that influence the good attitude of teachers, such as age, the number of devices teachers use in their day-to-day life, the time they dedicate on a daily basis to technological resources and the teaching experience. But in the data set, it is ICT training that exerts a direct influence on the good attitude of teachers. Furthermore, the SA dimension exerts a very significant influence on REA. These elements are, according to the study presented, influential when it comes to showing a good attitude to the use of AR in the teaching and learning processes.

The prospective of this research focuses on equating the advances of educational technology to the reality of the teaching attitude in the context of secondary education. The

constant evolution of techno-pedagogical resources is sometimes not accompanied by investigative support that highlights the importance of the teaching attitude towards the use, training and perception of innovative resources, analyzing in this research the specific case of AR.

On the one hand, it shows to the scientific community all the influencing aspects in achieving a positive attitude of the Secondary Education teachers towards the performance of instructional practices with AR. Likewise, this work seeks to reflect to the different educational organizations and institutions the abilities, skills and certain aspects that can influence the achievement and maintenance of adequate levels of positive attitude towards the use of AR technology in the teaching and learning processes.

As a future line of research, derived from this study, it is intended to analyze the attitudes of teachers towards the use of AR in other educational stages of the Spanish context such as Early Childhood Education, Primary Education, Baccalaureate and Higher Education. All this to establish a comparison between the attitudes reflected by teachers in the different educational stages that make up the Spanish educational system. Also, it is intended to analyze good practices with AR through the teaching, by the participating teachers, of a didactic unit using this technology. All this to follow the path already started in previous studies (Moreno-Guerrero et al., 2021). On the other hand, it is intended to deepen the analysis of the incident factors in the good practices for the use of RA, trying to respond to the implicit situation derived from each of the contextual situations. In this way, it will be possible to know with a greater degree of concretion the intrinsic peculiarities of teacher training in techno-pedagogy, the time of use of technology in the teaching and learning processes, the causes derived from the appropriate use of AR in the classroom and the various possible correlations derived from the exhaustive study of the sociodemographic variables treated in this research.

5.1 Limitations

This study has reported a number of limitations. The first focuses on the type of sampling carried out, which, being intentional and therefore not probabilistic, the results obtained in this work must be interpreted with caution since they are typical of a certain context. Therefore, the generalization of these findings to other regions is conditioned.

Another limitation of this study is related to the dichotomous choice (Yes/No) in variable 4: "the use of RA is appropriate". The researchers consider in the research design that a closed choice would make it easier to focus the research objective. We understand that not knowing how to use the AR is explicitly included in the answer "no". Despite the above, a future line of research is born from this limitation that allows us to verify the intrinsic factors in the use of RA from multiple perspectives focused on the intention of use and the intention of continuous training in this regard.

We also found a limitation in the search for a high participation in the study sample, since it implied an arduous and continuous work to achieve a considerable sample size, as well as for the various participants to fill in the data collection instrument. In addition, another of the reported limitations of this work is that no experience was applied to the teachers to assess their good practices with AR. That is, the data was collected through the perception of the participants, on previous experiences in their professional career or from their previous knowledge.

5.2 Implications of the Study

The present study leads to various implications of a theoretical and practical nature. The theoretical implications are focused on the body of knowledge that is generated after the completion of this work and that contributes to establish and expand the theoretical bases on everything concerning the use of AR in training processes, related to the attitude of teachers. The results obtained allow us to offer, both to the scientific community and to the teaching community, those aspects that influence the acquisition and reflection of an adequate attitude of education professionals to carry out effective instructional practices through AR technology. In the region where the research is carried out, there are not many studies where this construct is analyzed. Therefore, this work increases the existing literature on this state of the art in a Spanish context.

As for the practical implications derived from this study, there are several. In the first place, the findings presented allow the development of action plans to improve the competence of teachers. That is, the design and implementation of training plans that allow influencing and improving those most deficient aspects of the teaching staff. All this linked to teaching performance through innovative actions with AR in learning spaces. In the same way, as it has been revealed that variables are the most decisive for the achievement of positive attitudes in the development of practices with AR, educational institutions, private training centers, as well as any organization linked to the educational field can develop plans and training courses that promote the development of such conditioning factors to achieve positive attitudes. Today, teachers can guide and personalize their continuous training. All this will favor the inclusion and projection of this technology in the field of education, as well as the development of good training practices.

Author Contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by José-Antonio Marín-Marín, Antonio-José Moreno Guerrero, Santiago Pozo-Sánchez and Jesús López-Belmonte. The first draft of the manuscript was written by José-Antonio Marín-Marín and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding Funding for open access publishing: University of Granada/CBUA. This work was supported by I + D + i Project OTRI-University of Granada with financing code number 4995: Services related to the pilot phase of the evaluation of educational programs. The research was carried out within the EducaTech XXI Research Group (SEG-666) of the University of Granada.

Declarations

Conflict of interest The researchers declare that they have no conflict of interest. The results of the research have not led to conflicts of interest.

Informed consent The researchers have the informed consent of the participants. The subjects have voluntarily confirmed their decision to participate in the research after having been duly informed of all relevant aspects.

Ethical approval The research has followed the relevant ethical guidelines for conducting research with human participants in Educational Sciences.

References

Aldon, G., & Raffin, C. (2019). Mathematics Learning and Augmented reality in a virtual school. *Augmented Reality in Educational Settings*, 123–146. https://doi.org/10.1163/9789004408845_006.

Arth, C., Grasset, R., Gruber, L., Langlotz, T., Mulloni, A., & Wagner, D. (2015). *The history of mobile augmented reality*. Retrieved from http://arxiv.org/abs/1505.01319.

Ashley-Welbeck, A., & Vlachopoulos, D. (2020). Teachers' perceptions on using augmented reality for Language Learning in primary years Programme (PYP) education. *International Journal of Emerging Technologies In Learning (IJET)*, *15*(12), 116. https://doi.org/10.3991/ijet.v15i12.13499.

Avila-Garzon, C., Bacca-Acosta, J., Duarte, J., & Betancourt, J. (2021). Augmented reality in education: An overview of twenty-five years of Research. *Contemporary Educational Technology*, *13*(3), 1–29. https://doi.org/10.30935/cedtech/10865.

Billinghurst, M., & Duenser, A. (2012). Augmented reality in the Classroom. *Computer*, *45*(7), 56–63. https://doi.org/10.1109/mc.2012.111.

Bollen, K. A. (1989). *Structural equations with latent variables*. Wiley. https://doi.org/10.1002/9781118619179.

Bower, M., Howe, C., McCredie, N., Robinson, A., & Grover, D. (2014). Augmented reality in education—cases, places and potentials. *Educational Media International*, *51*(1), 1–15. https://doi.org/10.1080/09523987.2014.889400.

Bustamante, C. (2019). TPACK-based professional development on web 2.0 for spanish teachers: A case study. *Computer Assisted Language Learning*, *33*(4), 327–352. https://doi.org/10.1080/09588221.2018.1564333.

Byrne, B. M. (2013). *Structural equation modeling With AMOS: Basic concepts, applications, and programming, second edition multivariate applications series*. Taylor & Francis.

Cai, S., Wang, X., & Chiang, F. (2014). A case study of augmented reality simulation system application in a chemistry course. *Computers In Human Behavior*, *37*, 31–40. https://doi.org/10.1016/j.chb.2014.04.018.

Cai, S., Chiang, F., Sun, Y., Lin, C., & Lee, J. (2016). Applications of augmented reality-based natural interactive learning in magnetic field instruction. *Interactive Learning Environments*, *25*(6), 778–791. https://doi.org/10.1080/10494820.2016.1181094.

Cai, S., Liu, C., Wang, T., Liu, E., & Liang, J. (2020). Effects of learning physics using augmented reality on students' self-efficacy and conceptions of learning. *British Journal of Educational Technology*. https://doi.org/10.1111/bjet.13020.

Castaño-Calle, R., Jiménez-Vivas, A., Poy-Castro, R., Calvo-Álvarez, M. I., & Jenaro, C. (2022). Perceived benefits of future teachers on the usefulness of virtual and augmented reality in the teaching-learning process. *Education Sciences*, *12*(12), 1–11. https://doi.org/10.3390/educsci12120855.

Chen, C., Yang, C., Huang, K., & Yao, K. (2020). Augmented reality and competition in robotics education: Effects on 21st century competencies, group collaboration and learning motivation. *Journal Of Computer Assisted Learning*. https://doi.org/10.1111/jcal.12469.

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. *Journal of Educational Technology & Society, 17*(4), 352–365. Retrieved November 10, 2020, from http://www.jstor.org/stable/jeductechsoci.17.4.352.

Conley, Q., Atkinson, R., Nguyen, F., & Nelson, B. (2020). MantarayAR: Leveraging augmented reality to teach probability and sampling. *Computers & Education*, *153*, 103895. https://doi.org/10.1016/j.compedu.2020.103895.

Díaz-Noguera, M. D., Toledo-Morales, P., & Hervás-Gómez, C. (2017). Augmented reality applications attitude scale (ARAAS): Diagnosing the attitudes of future teachers. *The New Educational Review*, *50*(4), 215–226. https://doi.org/10.15804/tner.2017.50.4.17.

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology*, *18*(1), 7–22. https://doi.org/10.1007/s10956-008-9119-1.

Finco, M. D., Rocha, R. S., Fão, R. W., & Santos, F. (2017). Pokémon GO: A healthy game for all. In *European Conference on Games Based Learning* (pp. 165–172). Academic Conferences International Limited.

Fuchsová, M., Adamková, M., & Lapšanská, M. (2019). Uses of augmented reality in Biology Education. *Augmented Reality In Educational Settings*, 168–194. https://doi.org/10.1163/9789004408845_008.

Fuentes, A., López-Belmonte, J., & Pozo-Sánchez, S. (2019). Análisis de la Competencia Digital Docente: Factor clave en el Desempeño de Pedagogías activas con Realidad Aumentada. *REICE Revista Iberoamericana sobre Calidad Eficacia y Cambio en Educación*, *17*(2), 27–42. https://doi.org/10.15366/reice2019.17.2.002.

Garzón, J., & Acevedo, J. (2019). Meta-analysis of the impact of augmented reality on students' learning gains. *Educational Research Review, 27*, 244–260. https://doi.org/10.1016/j.edurev.2019a.04.001.

Garzón, J., Pavón, J., & Baldiris, S. (2019). Systematic review and meta-analysis of augmented reality in educational settings. *Virtual Reality*, *23*(4), 447–459. https://doi.org/10.1007/s10055-019-00379-9.

Grubert, J., Langlotz, T., Zollmann, S., & Regenbrecht, H. (2017). Towards pervasive augmented reality: Context-awareness in augmented reality. *IEEE Transactions on Visualization and Computer Graphics*, *23*(6), 1706–1724. https://doi.org/10.1109/TVCG.2016.2543720.

Heintz, M., Law, E. L. C., & Andrade, P. (2021). Augmented Reality as Educational Tool: Perceptions, Challenges, and Requirements from Teachers. In *European Conference on Technology Enhanced Learning* (pp. 315–319). Springer. https://doi.org/10.1007/978-3-030-86436-1_27.

Hernández, R., Fernández, C., & Baptista, M. P. (2014). *Metodología de la Investigación*. McGraw Hill.

Huang, K., Ball, C., Francis, J., Ratan, R., Boumis, J., & Fordham, J. (2019). Augmented versus virtual reality in education: An exploratory study examining science knowledge retention when using augmented reality/virtual reality mobile applications. *Cyberpsychology Behavior and Social Networking*, *22*(2), 105–110. https://doi.org/10.1089/cyber.2018.0150.

Ibili, E., Resnyansky, D., & Billinghurst, M. (2019). Applying the technology acceptance model to understand maths teachers' perceptions towards an augmented reality tutoring system. *Education and Information Technologies*, *24*(5), 2653–2675. https://doi.org/10.1007/s10639-019-09925-z.

Jesionkowska, J., Wild, F., & Deval, Y. (2020). Active learning augmented reality for STEAM education—A case study. *Education Sciences*, *10*(8), 198. https://doi.org/10.3390/educsci10080198.

Johnson, L., Smith, R., Willis, H., Levine, A., & Haywood, K. (2012). *NMC horizon report: 2011 Edition*. The New Media Consortium.

Kazanidis, I., Pellas, N., & Christopoulos, A. (2021). A learning analytics conceptual framework for augmented reality-supported educational case studies. *Multimodal Technologies and Interaction*, *5*(3), 1–16. https://doi.org/10.3390/mti5030009.

Köse, H., & Güner-Yildiz, N. (2020). Augmented reality (AR) as a learning material in special needs education. *Education and Information Technologies*. https://doi.org/10.1007/s10639-020-10326-w.

Lasica, I., Meletiou-Mavrotheris, M., & Katzis, K. (2020). Augmented reality in lower secondary education: A teacher Professional Development Program in Cyprus and Greece. *Education Sciences*, *10*(4), 121. https://doi.org/10.3390/educsci10040121.

Lim, K., & Lim, R. (2020). Semiotics, memory and augmented reality: History education with learner-generated augmentation. *British Journal of Educational Technology*, *51*(3), 673–691. https://doi.org/10.1111/bjet.12904.

López-Belmonte, J., Moreno-Guerrero, A. J., López, J. A., & Pozo, S. (2019). Analysis of the productive, structural, and dynamic development of augmented reality in higher education research on the web of science. *Applied Sciences*, *9*(24), 1–21. https://doi.org/10.3390/app9245306.

Mardia, K. V. (1970). Measures of multivariate skewness and kurtosis with applications. *Biometrika*, *57*, 519–530. https://doi.org/10.1093/biomet/57.3.519.

Marín-Díaz, V., Sampedro, B., & Figueroa, J. (2022). Augmented reality in the secondary education classroom: Teachers' visions. *Contemporary Educational Technology*, *14*(2), 1–16. https://doi.org/10.30935/cedtech/11523.

Mystakidis, S., Fragkaki, M., & Filippousis, G. (2021). Ready teacher one: Virtual and augmented reality online professional development for K-12 school teachers. *Computers*, *10*(10), 1–16. https://doi.org/10.3390/computers10100134.

Ozdemir, M., Sahin, C., Arcagok, S., & Demir, M. (2018). The effect of augmented reality applications in the learning process: A meta analysis study. *Eurasian Journal of Educational Research*, *18*, 1–22. https://doi.org/10.14689/ejer.2018.74.9.

Pozo-Sánchez, S., López-Belmonte, J., Fernández-Cruz, M., & López-Núñez, J. A. (2020). Análisis correlacional de los factores incidentes en el nivel de competencia digital del profesorado. *Revista Electrónica Interuniversitaria de Formación del Profesorado*, *23*(1), 143–159. https://doi.org/10.6018/reifop.396741.

Sáez-López, J. M., Cózar-Gutiérrez, R., González-Calero, J. A., & Gómez, C. J. (2020). Augmented reality in higher education: An evaluation program in initial teacher training. *Education Sciences*, *10*(2), 1–12. https://doi.org/10.3390/educsci10020026.

Sari, R., Sholihin, M., Yuniarti, N., Purnama, I., & Hermawan, H. (2020). Does behavior simulation based on augmented reality improve moral imagination? *Education and Information Technologies*. https://doi.org/10.1007/s10639-020-10263-8.

Severini, E., Lehotayova, B., & Csandova, E. (2019). Uses of augmented reality in pre-primary education. *Augmented Reality In Educational Settings*, 3–23. https://doi.org/10.1163/9789004408845_001.

Soltani, P., & Morice, A. (2020). Augmented reality tools for sports education and training. *Computers & Education*, *155*, 103923. https://doi.org/10.1016/j.compedu.2020.103923.

Tekedere, H., & Göke, H. (2016). Examining the effectiveness of augmented reality applications in education: A meta-analysis. *International Journal of Environmental and Science Education*, *11*(16), 9469–9481.

Turhan, M. E., Metin, M., & Çevik, E. E. (2022). A content analysis of studies published in the field of augmented reality in education. *Journal of Educational Technology and Online Learning*, *5*(1), 243–262. https://doi.org/10.31681/jetol.925340.

Uiphanit, T., Unekontee, J., Wattanaprapa, N., Jankaweekool, P., & Rakbumrung, W. (2020). Using augmented reality (AR) for enhancing chinese vocabulary learning. *International Journal of Emerging Technologies In Learning (IJET)*, *15*(17), 268. https://doi.org/10.3991/ijet.v15i17.15161.

Wang, H., Duh, H., Li, N., Lin, T., & Tsai, C. (2014). An investigation of University students' collaborative inquiry learning behaviors in an augmented reality simulation and a traditional simulation. *Journal of Science Education and Technology*, *23*(5), 682–691. https://doi.org/10.1007/s10956-014-9494-8.

Wang, M., Callaghan, V., Bernhardt, J., White, K., & Peña-Rios, A. (2017). Augmented reality in education and training: Pedagogical approaches and illustrative case studies. *Journal of Ambient Intelligence and Humanized Computing*, *9*(5), 1391–1402. https://doi.org/10.1007/s12652-017-0547-8.

Wiederhold, M. D. (2019). Augmented reality: Poised for impact. *Cyberpsychology Behavior and Social Networking*, *22*(2), 103–104. https://doi.org/10.1089/cyber.2019.29140.mdw.