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Research article

Effectiveness of augmented reality in learning about leg ulcer care: A quasi-experimental study in nursing students

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ABSTRACT

Background: Chronic wounds are a serious public health problem worldwide. Providing optimal treatment to patients suffering from leg ulcers is a priority for nursing. Therefore, nursing students need to acquire the necessary competencies to provide evidence-based care. Augmented Reality (AR) is an emerging technology in health science education which can help nursing students achieve these skills if it is promoted by both institutions and educationalists.

Objectives: To test the effectiveness of an AR-based methodology for teaching-learning aspects of the nursing curriculum (leg ulcer care), as well as to describe how AR influences different learning determinants of nursing students.

Design: A quasi-experimental study was carried out.

Participants/settings: The participants of the study were 137 s-year nursing students from the School of Nursing of the University of Santiago de Compostela (Spain) (average age = 21.59 years, 80.29 % females). Of them, 65 comprised the control group (Non-AR-based teaching) and 72 comprised the experimental group (AR-based teaching).

Methods: Pre-post tests were used to measure knowledge and skills about leg ulcer care in both groups. Additionally, two validated questionnaires were selected to identify the influence of AR on learning determinants in the experimental group. The study took place during the 2018/2019 academic year.

Results: Significantly higher scores (7.68 vs. 6.14) were found in the knowledge post-test in the experimental group ($p \leq 0.001$), while the pre-test did not show differences between groups (4.43 vs. 4.32). Also, nursing students indicated high scores in attention, autonomous learning, understanding and motivation to carry out learning objectives using AR.

Conclusions: AR is a tool that improves performance related to the specific aspects of the nursing academic curriculum (leg ulcer care), while encouraging positive attitudes towards the teaching-learning process. These findings reinforce the need to include innovative methodologies in nursing classrooms.

1. Introduction

Chronic wounds are a serious and highly prevalent public health problem worldwide, with leg ulcers being the most common example (Martinengo et al., 2019). These ulcers cause high morbidity and affect the physical, mental and social spheres of the individual, decreasing quality of life and generating high costs for health systems (Gethin et al., 2020; González de la Torre et al., 2017). This situation requires special attention since it is estimated that the appearance of leg ulcers will continue on an upward trend in the coming decades associated with the increase in life expectancy and the quality of health care (Franks et al., 2016; Gethin et al., 2020).

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It is clear that the provision of inappropriate care or management could seriously harm both the patient and the health system (Redmond et al., 2020). Nurses, due to their role and competences, must be trained in the management of leg ulcers, including diagnosis, prevention, and treatment (Wang et al., 2018). Therefore, it is essential to acquire the appropriate knowledge and skills to care for this type of wound, and this should begin during undergraduate training (Redmond et al., 2020). It is the responsibility of nurse educationalists to enable students' acquisition of competencies to deal with leg ulcers. To this end, innovative learning strategies are useful (Redmond et al., 2018). Information and communication technologies (ICT) have been increasingly used in teaching in recent years, and augmented reality (AR) is becoming especially popular among educationalists (Alexander et al., 2019).

2. Background

AR is an emerging technology that is beginning to be used in health science education due to its advantages in the teaching-learning process (Rodríguez-Abad et al., 2021). Thus, nursing science is a very interesting area for application (Ingrassia et al., 2020; Wüller et al., 2019). AR is a variation of virtual reality that enriches the real world with digital content in real time through different technological media such as smartphones, tablets or smartglasses (Mendez et al., 2020). In this way, unlike virtual reality, AR does not replace reality, but rather integrates it into the virtual experience (Mendez et al., 2020).

To use AR in the educational environment, four resources are necessary. 1) An electronic device with a camera. 2) Software capable of integrating virtual content into the real world. 3) A "trigger" that can run AR content, which is often a QR code but can also be an image or object. 4) A server to store the virtual information you want to project in the real world (Blázquez, 2017).

As a didactic tool, AR improves the teaching-learning process since it promotes active learning centered on the student (Küçük et al., 2016), enables the acquisition of competences (Rochlen et al., 2017) and increases realism in simulation rooms (Vaughn et al., 2016). It can also be implemented in the classroom without any additional costs, as it is possible to interact with digital content through widely used mobile devices (Rodríguez-Abad et al., 2021). Recent studies confirm the positive influence of an AR-based teaching methodology on the academic performance of students or the achievement of teaching objectives (Bork et al., 2019; Henssen et al., 2020; Jamali et al., 2015). Likewise, numerous technical and pedagogical advantages have been found in a recent systematic review, such as autonomous learning or understanding, which facilitate the acquisition of knowledge and skills (Rodríguez-Abad et al., 2021). Regarding motivation, recent investigations prove that this methodology increases the degree of this characteristic of learning (Khan et al., 2019; Kugelmann et al., 2018). This last feature is particularly relevant since increasing students' motivation is currently a great challenge for educationalists (Díaz-Agea et al., 2021); and is also decisive in the academic performance of health sciences students (Wu et al., 2020).

Despite this technology's great potential and its growing use in health science education in recent years (Rodríguez-Abad et al., 2021), experiences with AR are still limited. This is due to the many challenges that it means for teachers and institutions to develop AR (Mendez et al., 2020), hence the need for more research (Moro et al., 2021; Rochlen et al., 2017). Furthermore, there are few studies that focus on the different elements of the teaching-learning process of specific nursing areas. It is therefore necessary to provide a specific insight into this scientific field (Wüller et al., 2019).

This study therefore contributes to addressing the gap in the literature regarding specific aspects of the impact of AR on the learning experience in nursing education. Consequently, the objectives were: (1) to test the effectiveness of an AR-based methodology for teaching-learning aspects of the nursing curriculum (leg ulcer care) compared to a traditional teaching method, and (2) to describe the influence of using AR on the attention, autonomous learning, understanding and motivation of nursing students.

3. Methods

3.1. Design and participants

A quasi-experimental study design was carried out in the School of Nursing at the University of Santiago de Compostela (North-west Spain). To ensure adequate and clear data reporting, the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) Statement was used (Des Jarlais et al., 2004).

The study was performed during the 2018/2019 academic year. Eligible participants were undergraduate nursing students[2] who complied with the following criteria: (1) They had to be enrolled in the "Clinical Nursing I" course which is taken in the second year (third and fourth semesters) and (2) They had to provide previous informed consent. Participants were recruited among the students of the course in which the researchers were involved, so no sampling procedure was utilized.

No participant declined to be enrolled. Of the total, 53 % ($n = 72$) comprised the experimental group (AR-based teaching methods) and 47 % ($n = 65$) made up the control group (Non-AR-based traditional teaching methods). Both groups were randomly selected among class groups previously established by the School. All participants completed the lesson and associated study.

Subsequently, we found no significant differences between these groups based on gender distribution and average grade of the student record.

3.2. The AR project

The AR experience was conducted during a 3-h interactive session (practical) structured in four learning stations. Each group was divided into work teams of 5 students and spent 40 min at each station. The last 20 min were used to students to actively participate by answering questions and giving feedback about the session with the nurse educationalists. Students of the experimental group carried out the AR experience (HP Reveal® and Aumentaty Creator®) using their own electronic devices (smartphones or tablets) while the control group used traditional notes:

- Station 1: "Introduction to leg ulcers" consisted of the nurse educationalists' notes about leg ulcer care. The control group obtained this information on paper (traditional notes) while the experimental group accessed the digital content through QR codes that served as a link to the multimedia presentations stored in the institution's cloud.
- Station 2: "Ankle brachial index" consisted of performing this diagnostic test on one of the members of the work team. To perform the test and interpret the information, the control group had traditional notes, while the experimental group accessed multimedia content and infographics through QR codes.
- Station 3: "Dressings" consisted of a presentation of the main products used in moist wound healing for the prevention and treatment of leg ulcers. The control group had the printed version of the wound dressings catalogue which is available in the regional health system. In addition, they also had a multimedia presentation by the nurse educationalist. In the case of the experimental group, they had real wound dressings which acted as AR triggers (Fig. 1) that led to associated digital content (multimedia presentations, images, videos, animations, and 3D models made on free AR platforms).
- Station 4: "Lower limb compression therapy" where the students learned how to make an adequate compression bandage for each case

[2] This Nursing degree is framed within the European Higher Education Area: http://www.ehea.info/.

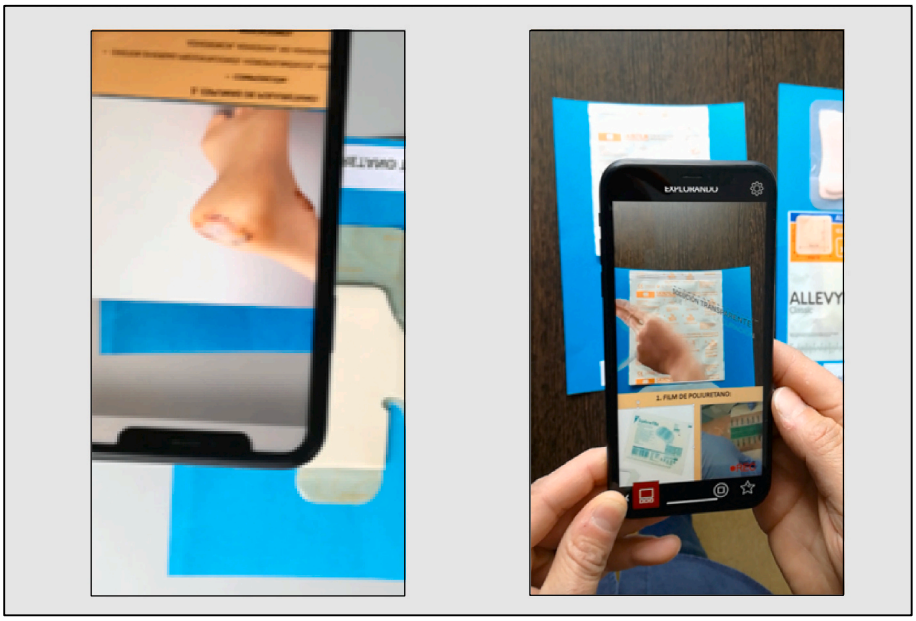

Fig. 1. Screenshots showing digital content through Augmented Reality.

given to them by the nurse educationalist. For this, the students in the control group used traditional notes and images, while the experimental group accessed AR content through different triggers such as a compression bandage.

3.3. Evaluative tools

To achieve the proposed objectives different evaluative tools were distributed during the interactive class, and each took around 10 min to complete. Fig. 2 shows a diagram of the instruments used in each group. The tools and how they were distributed are explained below.

- Ad hoc knowledge and skills test on nursing care about leg ulcers. This consisted of 10 multiple choice questions, each one could be assessed with a 0 (incorrect answer) or a with a 1 (correct answer). Therefore, the participants could obtain a score from 0 to 10 points in this test. This assessment tool was evaluated and agreed upon by a group of 5 experts in chronic wounds and 2 experts in pedagogy. In addition, a pilot test was carried out with third-year students who had already taken the course to check that the tool was easily understood and appropriately worded. The instrument was distributed to all participants (experimental and control groups) before (pre-test) and after (post-test) the interactive session. The participants were also clearly informed that their answers would not be used to evaluate them in the course.
- Validated questionnaire by Ferrer-Torregrosa et al. (2016). This questionnaire was adapted to this experience and allowed us to measure the learning perceptions of the experimental group. The questionnaire consisted of the following dimensions: attention and motivation, autonomous work and comprehension. These dimensions are related to the use of a teaching methodology based on AR, as well as the learning expectations of the students with the use of these tools. Items were assessed on a Likert-type scale from 1-never to 4-always, whereas the dimensions scores were obtained using the average of the related items. Cronbach's alpha index with the sample of the present study revealed a good internal consistency (0.89). The instrument was distributed to the AR group at the end of the interactive session.
- Validated "Instructional Material Motivational Survey" (IMMS) questionnaire (Cook et al., 2009; Keller, 2010) and adapted by Barroso et al. (2016) to measure the degree of influence generated by the interaction with AR-based teaching content on motivation towards learning. The questionnaire applied to the experimental group was made up of four dimensions based on the "ARCS" model: Attention, Relevance, Confidence and Satisfaction. Items were assessed on a Likert-type scale from 1-maximum disagreement to 7-maximum agreement, whereas the dimensions scores were obtained using the average of the related items. Negative statements were reverse coded, so a higher score indicates greater disagreement. Cronbach's alpha index with the sample of the present study revealed an adequate internal consistency (0.76). The instrument was distributed to the AR group at the end of the interactive session.

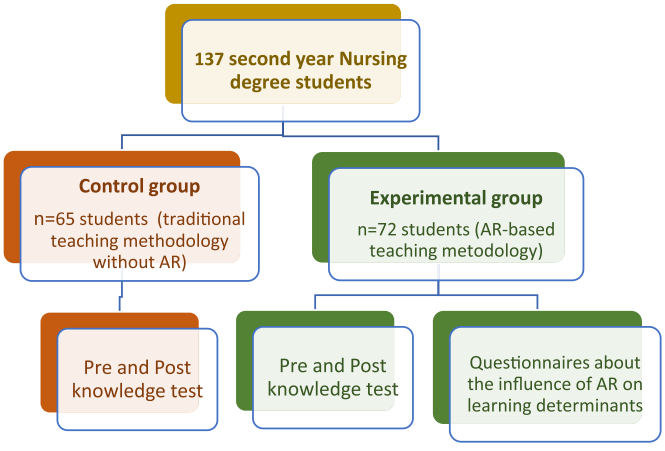

Fig. 2. Distribution of the research participants showing the measurement instruments used in control and experimental groups.

3.4. Data analysis

Data were analyzed using Statistical Package for the Social Sciences (SPSS) 25.0 for Mac (IBM Inc.) and R (R Core Team, 2019a) using the libraries foreign (R Core Team, 2019b) and WRS2 (Mair and Wilcox, 2020). Results were expressed as percentages for categorical variables and as mean (M) and standard deviation (SD) or median (M_e) and first

and third quartiles in brackets for continuous variables, respectively, depending on whether (or not) they showed a normal distribution. Moreover, to test the internal consistency or reliability of the questionnaires, Cronbach's alpha index was obtained. After verifying that assumption of normality was violated using the Kolmogorov-Smirnov test, a robust mixed ANOVA with a between-subjects factor, Group (Experimental vs Control Group), and a within-subject factor, Test (Pre vs Post-test) was conducted to evaluate differences in the knowledge and skills test about leg ulcer care between the control and experimental groups. When significant effects were obtained, multiple pairwise comparisons were carried out using Mann-Whitney *U* tests, adjusting the significance value with the Holm-Bonferroni method (Holm, 1979). *p* values <0.05 were considered significant. Finally, non-parametrical correlations (Spearman rho) were carried out to contrast the relationship between the IMMS (dimensions and total score) and performance in the final knowledge and skills test.

3.5. Ethical considerations

The study protocol received full ethical approval by the Bioethics Committee of the University of Santiago de Compostela (reference 190708). At the beginning of the experience, the students were informed of the method, purpose, and research team, and were assured that the results or participation in the experience would not affect their course grade. After that, students voluntarily agreed to participate in the study and subsequently they signed the written informed consent, following the current European and national regulations on data protection. To reduce power differences between the educationalist and students, a member of the research team other than the educationalist of the course was responsible for collecting the informed consents and data.

4. Results

4.1. Sample and group characteristics

The sample consisted of a total of 137 undergraduate nursing students, of whom 110 (80.29 %) were females and 27 (19.81 %) males. The average age was 21.59 years (SD = 4.09).

To reinforce the findings, control variables were used to ensure homogeneity between control and experimental groups, and therefore rule out any potential effects of differences in academic performance between each student in said groups. To this end, the average grade of the student record at the time of the study, the final grade of the course "Clinical Nursing I", the grade attained in a practical case about leg ulcers, and the grade obtained in a previous test of other topics in the course not related to leg ulcer care were used. The median grade of all the students' records was 7.33 out of 10 [7.02–7.65] with a minimum of 6.15 and a maximum of 8.54 points. None of these control variables varied depending on the Group factor, so obtained results could be attributed to the use of AR (Table 1).

4.2. Effect of an AR-based teaching methodology on performance in the knowledge and skills test

The results related to this objective were obtained after the statistical analysis of the data provided by the initial (pre-test) and final knowledge and skills test (post-test) issued to both groups (control and experimental).

The robust ANOVA (group × test) showed a significant effect of the Group factor ($F(df1 = 1; df2 = 73.51) = 7.37$; $p = 0.01$), since the participants of the experimental group obtained better scores in the knowledge and skills test (M = 6.08; SD = 2.26) than the control group (M = 5.23; SD = 2.38). The ANOVA also showed a significant effect of the Moment factor in both groups ($F(df1 = 1; df2 = 75.11) = 180.20$; $p \leq 0.001$). The scores were better after the learning experience, that is, the subsequent scores (M = 6.95; SD = 2.03) with respect to those prior to practice (M = 4.40; SD = 1.92). Finally, the ANOVA showed a significant effect of the interaction between both factors ($F(df1 = 1; df2 = 75.11) = 11.14$; $p = 0.001$). The multiple comparisons by pairs adjusted to Bonferroni indicated no differences between groups in the knowledge and skills pre-test (U = 2258.50; $p = 0.722$) (control group M = 4.32; SD = 2.11) (experimental group M = 4.47; SD = 1.74). However, in the post-test the participants of the experimental group (M = 7.68; SD = 1.43) manifested a higher score (U = 1401.00; $p \leq 0.001$) than those of the control group (M = 6.14; SD = 2.29).

4.3. Influence of AR on learning determinants in the experimental group

4.3.1. Ferrer-Torregrosa et al. (2016) questionnaire

Participants rated their learning experience using the Ferrer-Torregrosa et al. (2016) questionnaire. Learning experience was rated highly across all dimensions. In particular, the dimension that showed the highest score was "Attention and motivation" (M = 3.27; SD = 0.41), followed by "Autonomous work" (M = 3.12; SD = 0.62) and "Comprehension" (M = 3.00; SD = 0.54) (see Table 2):

- "Attention and motivation" dimension: the students perceived that the teaching methodology with AR helped them to improve fundamental aspects of the learning process, mainly attention and motivation. The highest average rating score was for the statement "It helps me to see/to imagine very clearly what I am being explained" (M_e = 4.00 [3.00–4.00]).
- "Autonomous learning" dimension: the students agreed that the use of AR-based technological tools for teaching purposes stimulates active learning and autonomous work (M_e = 3.00 [3.00–4.00]), allowing access to teaching materials anywhere and at any time (M_e = 3.00 [2.00–4.00]).
- "Comprehension" dimension: in general, the students stated that the teaching methodology with AR facilitates the understanding of the subject. They particularly perceived that this AR-based methodology helped them to identify how to apply basic care in relation to the prevention, diagnosis, and care of leg ulcers (M_e = 3.00 [2.00–4.00]), and was the statement with the highest score.

Table 1
Medians (Me) and first and third quartiles [Q1-Q3] of each of the control variables, showing no significant differences between groups.

	Total participants (n = 137)		Groups				Statistical contrast
			Control (n = 65)		Experimental (n = 72)		
	Me	[Q1-Q3]	Me	[Q1-Q3]	Me	[Q1-Q3]	p
Average grade of the student record at the time of the study	7.33	[7.02–7.65]	7.34	[7.06–7.69]	7.30	[6.98–7.63]	0.414
Final grade of the course "Clinical Nursing I"	6.50	[4.20–5.80]	6.60	[4.40–6.05]	6.45	[4.13–5.68]	0.844
Grade of a previous test on other topics of the course	4.90	[5.00–7.10]	5.10	[4.70–7.20]	4.70	[6.45–6.98]	0.117
Grade obtained in a practical case about leg ulcers	7.00	[6.00–8.00]	7.00	[6.00–8.00]	7.00	[6.00–8.00]	0.721

Medians (Me) and quartiles [Q1-Q3]. Grade range from 0 to 10 points. Statistical contrasts using Mann-Whitney *U* test.

Table 2
Means (standard deviation) of each of the dimensions and frequencies, medians [first and third quartiles] of each item of the Ferrer-Torregrosa et al. (2016) questionnaire that measures the attention and motivation, autonomous work and comprehension ($n = 72$).

		M	SD	Item	Likert scale (%)					
					1 – Never	2	3	4-Always	Me	[Q1-Q3]
FERRER-TORREGROSA et al. (2016) QUESTIONNAIRE DIMENSIONS	ATTENTION AND MOTIVATION	3.27	0.41	It helps me to fix my attention	00.00	07.14	57.14	35.71	03.00	[3.00–4.00]
				It helps me to retain the contents	02.86	07.14	64.29	24.29	03.00	[3.00–3.50]
				It motivates me to learn	01.42	04.29	52.86	38.58	03.00	[3.00–4.00]
				It makes possible studying in different ways avoiding in this way feeling frustration	00.00	04.29	45.71	48.58	03.00	[3.00–4.00]
				It helps me to see/to imagine very clearly what I am being explained	00.00	02.86	34.29	62.86	04.00	[3.00–4.00]
				It helps me to understand nursing care for leg ulcers	00.00	02.86	48.57	47.14	03.00	[3.00–4.00]
				It helps me to understand the course without excessive explanations from the professor	00.00	20.00	42.86	37.14	03.00	[3.00–4.00]
				It helps me to revise at home	02.86	30.00	44.29	13.00	03.00	[2.00–3.00]
	AUTONOMOUS WORK	3.12	0.62	Active learning stimulates me	02.86	05.71	52.86	38.57	03.00	[3.00–4.00]
				It strengthens my autonomous learning	02.86	11.43	52.86	32.86	03.00	[3.00–4.00]
				It would allow me to repeat by myself, outside the university, the activities made in class	02.86	31.43	35.71	27.14	03.00	[2.00–4.00]
	COMPREHENSION	3.00	0.54	It helps me to recognize the etiology of leg ulcers	01.42	22.86	51.43	21.43	03.00	[2.25–3.00]
				It has allowed me to learn to guide the treatment of choice	01.42	20.00	55.71	22.86	03.00	[3.00–3.00]
				I am able to recognize the signs and symptoms of infection and take action	01.42	28.57	51.43	15.71	03.00	[2.00–3.00]
				I have improved my ability to select the most appropriate dressing based on the characteristics of the ulcer	02.86	22.86	52.86	20.00	03.00	[2.00–3.00]
				I have improved my ability to visualize the placement of the different dressings	04.29	15.71	51.43	27.14	03.00	[3.00–4-00]
				It has helped me to know how to apply basic care for leg ulcers (prevention, diagnosis, and care)	01.42	10.00	61.43	25.71	03.00	[3.00–4.00]

Means (M), standard deviation (SD) of each of the dimensions and medians (Me) and quartiles [Q1-Q3] of items that compose them. All items were valued on a Likert-type scale rated from 1-never to 4-always.

4.3.2. *IMMS questionnaire*

The results of IMMS questionnaire adapted to use with AR reported a high experience rating related to motivation. Thus, all dimensions showed an average score >5 out of 7. Table 3 provides the students' ratings of the AR attributes, being the attention dimension the most relevant for them (M = 5.93; SD = 0.66).

- "Attention" dimension: the included digital content was entertaining (M_e = 6.00 [6.00–7.00]) and attractive (M_e = 7.00 [6.00–7.00]). Both the quality and quantity of the AR-materials used and the way the information was organized helped them keep their attention on the lesson (M_e = 6.00 [5.00–7.00]). Also, the use of AR aroused their curiosity (M_e = 6.00 [5.00–7.00]) and allowed them to learn surprising aspects about this technology (M_e = 5.00 [4.00–6.00]).
- "Confidence" dimension: The information contained in the AR-materials increased the students' expectations of being successful in the development of the lesson, since they could really understand the material (M_e = 7.00 [6.00–7.00]) and the good organization helped them learn topics (M_e = 6.00 [5.00–7.00]). Despite this, some students had the impression that it would not be easy for them when they saw the lesson for the first time (M_e = 4.00 [3.00–5.00]).
- "Relevance" dimension: they strongly agreed that the topic was relevant to their knowledge needs (M_e = 7.00 [6.00–7.00]) and it would be useful in their professional performance (M_e = 7.00 [6.00–7.00]). However, participants considered that the relationship between the topic and their previous knowledge could be clearer (M_e = 5.00 [4.00–6.00]).
- "Satisfaction" dimension: the students expressed their well-being by achieving an effective understanding of leg ulcers. They stated that they found the lesson pleasant to work on and that it was well designed (M_e = 6.00 [6.00–7.00]). They agreed that completing the lesson generated a sense of accomplishment (M_e = 6.00 [5.00–6.00]) and that they would like to know more about leg ulcers (M_e = 5.00 [5.00–6.00]).

5. Discussion

This study addresses the effectiveness of AR-based teaching methods in knowledge and skills about leg ulcer care as well as the influence of AR on the teaching-learning process among nursing undergraduates. Therefore, this project complements the little current evidence of the benefits of this innovative technology and the opportunities it might bring to nursing education.

Our research shows that, although both groups benefited from interactive activity (better score in post than in pre-test), the use of AR significantly improved the acquisition of knowledge in the highly specific and relevant topic of nursing that is leg ulcer care. Several recent studies focused on learning human anatomy have shown greater knowledge acquisition associated to the use of AR compared to traditional teaching methods. In some of these investigations, such differences were statistically significant (Barmaki et al., 2019; Bork et al.,

Table 3
Means (standard deviation) of each of the dimensions and frequencies, medians [first and third quartiles] of each item of the Instructional Material Motivational Survey (IMMS) questionnaire that measures the Attention, Relevance, Confidence, and Satisfaction (ARCS) motivational model ($n = 72$).

		M	SD	Item	Likert scale (%)								
					1-absolutely disagree	2	3	4	5	6	7- absolutely agree	Me	[Q1-Q3]
IMMS QUESTIONNAIRE DIMENSIONS	ATTENTION	5.93	0.66	There was something interesting at the beginning of this lesson that got my attention	00.00	00.00	01.42	12.86	20.00	44.29	21.43	6.00	[5.00–6.00]
				This AR-technology is eye-catching	00.00	01.42	02.86	08.57	18.57	30.00	38.57	6.00	[5.00–7.00]
				The quality of the AR material helped to hold my attention	00.00	00.00	00.00	11.43	17.14	35.71	35.71	6.00	[5.00–7.00]
				This material is so abstract that it was hard to keep my attention on it §	44.29	32.86	14.29	08.57	00.00	00.00	00.00	6.00	[6.00–7.00]
				The images, videos and notes of this lesson look dry and unappealing §	42.86	37.14	17.14	01.42	00.00	01.42	00.00	6.00	[6.00–7.00]
				The way the information is arranged using this technology helped keep my attention	00.00	01.42	01.42	05.71	17.00	47.14	27.14	6.00	[5.00–7.00]
				The information discovered through experience stimulated my curiosity	00.00	00.00	00.00	08.57	22.86	54.29	14.29	6.00	[5.00–7.00]
				The amount of repetition in this activity caused me to get bored sometimes §	31.43	41.43	12.86	08.57	04.29	01.42	00.00	6.00	[5.00–7.00]
				I learned some things about AR that were surprising or unexpected	00.00	01.42	12.86	17.14	22.86	35.71	10.00	5.00	[4.00–6.00]
				The variety of audiovisual material helped keep my attention on the lesson.	00.00	00.00	01.42	07.14	22.86	35.71	32.86	6.00	[5.00–7.00]
				The audiovisual material is boring §	54.29	35.71	04.29	05.71	00.00	00.00	00.00	7.00	[6.00–7.00]
				There is so much content that it is irritating §	64.29	21.43	08.57	02.86	01.42	01.42	00.00	7.00	[6.00–7.00]
	CONFIDENCE	5.28	0.67	When I first looked at this lesson, I had the impression that it would be easy for me	02.86	14.29	25.71	27.14	20.00	08.57	02.86	4.00	[3.00–5.00]
				This material was more difficult to understand than I would like for it to be §	20.00	47.14	11.49	15.71	04.29	01.42	00.00	6.00	[5.00–6.00]
				After reading the introductory information, I felt confident that I knew what I was supposed to learn from this lesson	00.00	04.86	08.57	17.14	24.29	41.49	04.29	5.00	[4.00–6.00]
				The information was so much that it was difficult for me to remember the important points §	11.43	34.29	12.86	21.43	14.29	04.29	01.42	5.00	[4.00–6.00]
				As I worked on this lesson, I was confident that I could learn the content	00.00	00.00	01.42	10.00	27.14	47.14	14.29	6.00	[5.00–6.00]
				It was difficult to discover the digital information associated with the real image §	32.86	38.57	11.43	07.14	07.14	02.86	00.00	6.00	[5.00–7.00]
				After working on this lesson for a while, I was confident that I would be able to pass a test on it	01.42	01.42	07.14	31.43	37.14	14.29	01.42	5.00	[4.00–5.00]
				I could not really understand quite a bit of the material in this lesson §	65.86	32.86	02.86	00.00	00.00	00.00	01.42	7.00	[6.00–7.00]
				The good organization of the content helped me be confident that I would learn this topic	00.00	00.00	01.42	11.43	18.57	40.00	28.57	6.00	[5.00–7.00]
	RELEVANCE	5.86	0.49	It is clear to me how the content of this material is related to things I already know	01.42	05.71	07.14	20.00	31.42	28.57	05.71	5.00	[4.00–6.00]
				There were no images, videos or texts that showed me how this material is related to things that I already know §	60.00	24.29	05.71	04.29	02.86	02.86	00.00	7.00	[6.00–7.00]
				Completing this lesson successfully was important to me	00.00	00.00	04.29	08.57	27.14	40.00	20.00	6.00	[5.00–6.00]
				The content of this material is relevant to my interests	00.00	01.42	00.00	07.14	10.00	41.43	40.00	6.00	[6.00–7.00]
				There are explanations or examples of how people use the knowledge in this lesson	00.00	02.86	08.57	22.86	14.29	32.86	18.57	6.00	[4.00–6.00]
				The content and audio-visual material in this lesson convey the impression that its content is worth knowing	00.00	00.00	01.42	08.57	18.57	50.00	21.43	6.00	[5.00–6.00]
				This lesson was not relevant to my needs because I already knew most of it §	71.43	22.86	05.71	00.00	00.00	00.00	00.00	7.00	[6.00–7.00]

(*continued on next page*)

Table 3 (*continued*)

	M	SD	Item	Likert scale (%) 1-absolutely disagree	2	3	4	5	6	7- absolutely agree	Me	[Q1-Q3]
			I could relate the content of this lesson to things I have seen, done, or thought about in my own life	00.00	00.00	02.86	07.14	22.86	48.33	25.70	6.00	[5.00–7.00]
			The content of this lesson will be useful to me	00.00	01.42	00.00	00.00	08.57	31.43	58.57	7.00	[6.00–7.00]
SATISFACTION	5.57	0.57	Completing the exercises in this lesson gave me a satisfying feeling of accomplishment	00.00	01.42	04.29	05.71	31.43	40.00	17.14	6.00	[5.00–6.00]
			I enjoyed this lesson so much that I would like to know more about this topic	00.00	01.42	04.29	14.29	38.57	25.71	15.71	5.00	[5.00–6.00]
			I really enjoyed studying this lesson	00.00	00.00	00.00	07.14	21.43	42.86	28.57	6.00	[5.00–7.00]
			The wording of feedback after the exercises, or of other comments in this lesson, helped me feel rewarded for my effort	00.00	02.86	04.29	27.14	31.42	25.71	08.57	5.00	[4.00–6.00]
			It felt good to successfully complete this lesson	00.00	00.00	04.29	12.86	28.57	45.71	08.57	6.00	[5.00–6.00]
			It was a pleasure to work on such a well-designed lesson	00.00	00.00	01.42	04.29	11.43	35.71	47.14	6.00	[6.00–7.00]

Means (M), standard deviation (SD) of each of the dimensions and medians (Me) and quartiles [Q1-Q3] of items that compose them. All items were valued on a Likert-type scale rated from 1-maximum disagreement to 7-maximum agreement. §Negative statements were reverse coded, so a higher score indicates greater disagreement.

2019; Jamali et al., 2015), whereas in others they were not (Henssen et al., 2020; Nørgård et al., 2019).

Participants indicated a high degree of agreement that AR contributes to maintaining their attention on the curricular objectives, creating immersive and interactive learning environments allowing visualizations that would not otherwise be possible. In addition, an innovative methodology is provided that avoids the feeling of frustration, in line with the studies by Henssen et al. (2020) and Khan et al. (2019) in health science students. Our students also considered that the quantity and organization of the session was appropriate, a fact that must be considered when designing them. This is relevant since an excessive and disorganized amount of information causes a negative impact on learning objectives and motivation (Cheng, 2017).

The students declared that AR made it easier to understand leg ulcer management. Thus, the virtual information with which AR enriches the real world enabled the understanding of abstract phenomena that are difficult to understand in the real world, as indicated by Khan et al. (2019). Previous studies with similar objectives have focused predominantly on anatomy aspects (Henssen et al., 2020). However, our evidence seems to indicate that the three-dimensional vision provided by AR also allows for a better understanding of topics directly related to nursing care such as leg ulcers.

Motivation is a substantial component which influences learning, and preserving it is a huge challenge in nursing studies (Díaz-Agea et al., 2021). To increase motivation, teaching objectives must be relevant, and students need to feel competent to learn (Covington, 2000). In this regard, we obtained positive research scores in the dimensions of motivation. Some studies have been able to compare the motivation of different groups of students, showing different results. While there are authors who have not observed significant differences between the group using AR and the control group (Henssen et al., 2020; Nørgård et al., 2019), others have (Cabero-Almenara and Roig-Vila, 2019; Kugelmann et al., 2018; Vaughn et al., 2016). Given the results of our study, future research could delve into this specific aspect of learning among different nursing students from other contexts and academic years. Nevertheless, it seems logical to think that students who use AR show more motivation than those instructed using traditional teaching methods.

The incredibly widespread use that university students make of electronic devices promotes a more flexible and autonomous learning, being able to access content at any time and place (Jamali et al., 2015). A methodological change is taking place in higher education, where ICT and active methodologies take on a leading role (Küçük et al., 2016; Vaughn et al., 2016). Considering this and in agreement with recent systematic reviews (Rodríguez-Abad et al., 2021; Wüller et al., 2019), it is necessary to increase this type of research to reinforce the use of evidence-based methodologies in nursing studies. In this vein, AR can be used by educationalists to guide undergraduate students in their self-learning (Moro and McLean, 2017), creating interactive spaces with different learning rhythms, which are currently minimally developed (Ferrer-Torregrosa et al., 2016; Mendez et al., 2020).

5.1. *Limitations and strengths*

Our research might have limitations that should be considered. The sample selection was intentional and in a single center, since the AR project was linked to a specific course and subject matter. Therefore, a larger and more heterogeneous sample would be necessary to generalize these findings.

The questionnaires used in this research had been previously validated and showed good internal consistency, although it is necessary to develop more evaluative tools specifically aimed to evaluate nursing students' skills using AR. Unlike previous studies which studied aspects of the curriculum common to different health sciences professions, our investigation focuses on developing AR-based teaching material in nursing specific topics (leg ulcer care). This is highly relevant not only

for undergraduates but also for the continuous training of nursing professionals. This AR project and associated evidence might contribute to implement ICT in the nursing learning environment and shed light on the lack of knowledge about the use of AR in nursing education (Mendez et al., 2020).

6. Conclusions

This study shows that AR improves both knowledge, skills and students' perceptions and expectations towards the teaching-learning process, influencing it in a multidimensional way (attention, autonomous learning, understanding and motivation). These positive findings highlight the importance of developing innovative teaching strategies in nursing classrooms, making it necessary to promote the challenge of education focused on the student with the support and benefits of ICT. It is essential to carry out more learning experiences and studies on the subject to both reinforce our findings and continue to provide knowledge to this little-studied field, promoting the evidence-based use of AR as an effective learning tool in nursing education.

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Ethical approval

The study was approved by the Bioethics Committee of the University of Santiago de Compostela to ensure participant and student rights.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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