An Interuniversity Competition for Medical Students to Learn Radiology in the Second Life Metaverse

Teodoro Rudolphi-Solero, MD, PhD[a], Rocío Lorenzo-Álvarez, MD, PhD[b], Dolores Domínguez-Pinos, MD, PhD[c], Miguel José Ruiz-Gómez, PhD[c], Francisco Sendra-Portero, MD, PhD[d]

Abstract

Purpose: The aim of this study was to evaluate an interuniversity competition online to learn radiology held in a 3-D virtual world, the Second Life metaverse, by analyzing the results of the game and students' perceptions.

Methods: Medical students voluntarily participated in teams of four, for 6 weeks, successively covering radiologic anatomy and radiologic semiology of the chest, abdomen, and musculoskeletal. Each week, participants had 4.5 days to study self-learning presentations and 2.5 days to complete an individual multiple-choice test and a team task, the results of which determined the game's ranking. Participants were asked to complete a cognitive-load test, a perception questionnaire, and a postexposure knowledge test.

Results: The competition was repeated for 2 years (editions), in 2020 and 2021. Seventy-five of 102 teams (73.5%) registered completed the game; 76% of them included third-year students. The average percentage of correct answers in the individual tests and team tasks was 74.2 ± 15.1 and 71.6 ± 14.7 respectively, without significant differences between both competitions. In general, the experience was valued positively (scores >8 on a 10-point scale). A lower perception score was found in 2021 among students from universities other than the organizing university, showing a positive correlation with the in-game score.

Conclusions: An interuniversity competition in the Second Life metaverse for undergraduate learning radiology is feasible and reproducible. Participating medical students considered it interesting and useful and also identified this activity during the 2 years of the coronavirus disease 2019 pandemic as a playful learning and social interaction experience.

Key Words: Radiology education, medical students, metaverse, game-based learning, team-based learning

J Am Coll Radiol 2024;21:812-821.

INTRODUCTION

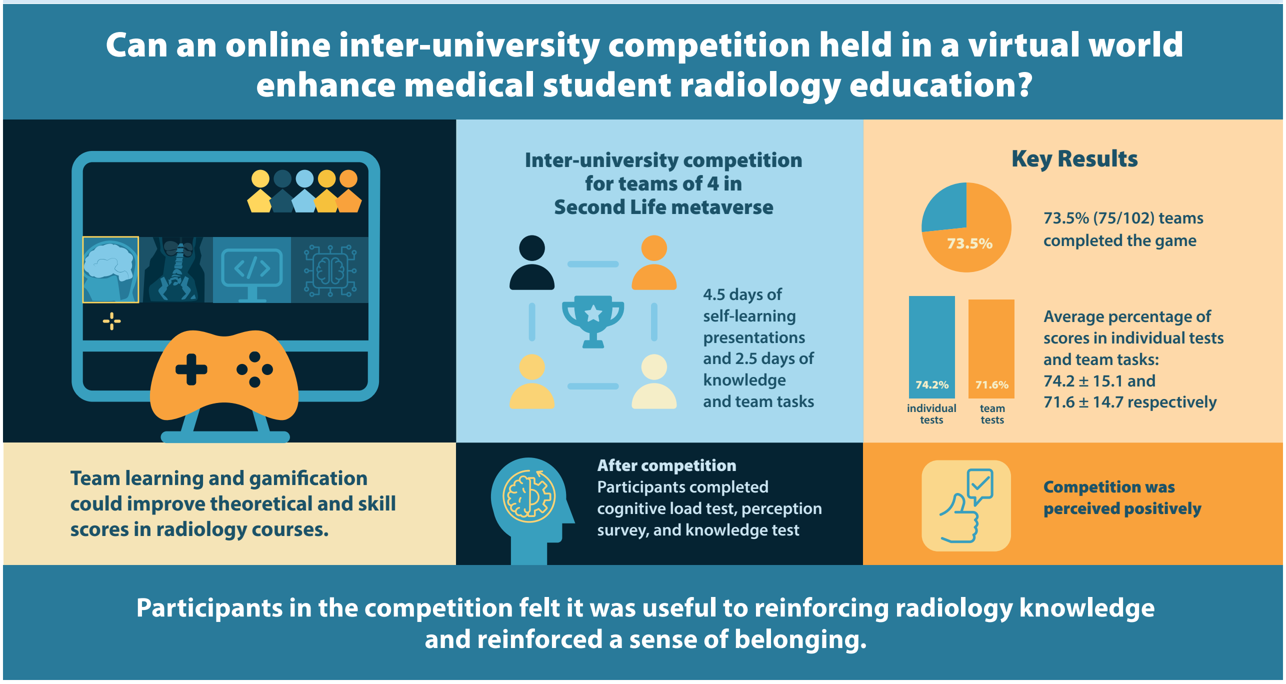
Collaborative learning is crucial in higher education and provides vital dynamics in undergraduate medical education [1,2]. Competition and collaboration have a positive effect on learning by increasing students' motivation [3,4]. Team-based initiatives have been penetrating the online teaching of undergraduate health care students [5], especially after the coronavirus disease 2019 (COVID-19) pandemic lockdown [6]. Team learning could improve theoretical and skill scores in radiology courses and encourage students to learn by themselves, increasing their interest in learning, team cooperation ability, and interpersonal communication skills [7].

Gamification applies playful design elements to non-playful contexts, such as learning and health [8,9], and offers

[a]Department of Radiology and Physical Medicine, Faculty of Medicine, University of Málaga, Málaga, Spain.
[b]Critical Care and Emergency Service, Hospital de la Axarquía, Velez-Malaga, Spain.
[c]Department of Radiology and Physical Medicine, Faculty of Medicine, University of Málaga, Málaga, Spain.
[d]Director, Department of Radiology and Physical Medicine, Faculty of Medicine, University of Málaga, Málaga, Spain.
Corresponding author and reprints: Francisco Sendra-Portero, Department of Radiology and Physical Medicine, Faculty of Medicine, University of Málaga, Bulevar Luis Pasteur, 29071 Málaga, Spain; e-mail: sendra@uma.es.
Follow these authors via X: Teodoro Rudolphi-Solero @TeoRudSol, Rocío Lorenzo-Álvarez @estrellitadluz, Francisco Sendra-Portero @Pakosendra
This work was partially supported by the Educational Innovation Projects of the University of Malaga (PIE19-217 and PIE22-045). Funding for open-access charge was provided by Universidad de Málaga/CBUA. The authors state that they have no conflict of interest related to the material discussed in this article. The authors are non-partner/non-partnership track employees.

1546-1440/24/$36.00 ■ https://doi.org/10.1016/j.jacr.2023.09.012

Visual Abstract



JACR VISUAL ABSTRACT

immersive attractive experiences to get specific objectives and learning results [10]. Gamification can play an important role as a complement to radiology education, adaptable to the level and learning objectives of both undergraduate and postgraduate students [11]. Its development can take place in the classroom and other real-life settings but also through online formats that facilitate remote access and user management, including the metaverse [11], whose teaching potential needs to be explored [12]. The metaverse, a computer-generated virtual universe, introduced first in the novel *Snow Crash* [13], is currently technologically feasible and has a great potential for social interaction, content creation and sharing, and new educational experiences in augmented reality, lifelogging, mirror worlds, and virtual worlds [12]. Virtual worlds are environments reproduced in the computer screen, where users can join, move, communicate, and interact through self-representations called avatars [14]. Second Life (SL), created in 2003, is the virtual world most used by health care educators [15-17]. Users can access SL freely through a computer application in which they can communicate with others through written chat, voice calls, or notecards (sendable text files stored in the receiving avatar's inventory). Previous educational applications of the SL metaverse in radiology include the creation of virtual learning environments with medical students, biomedical engineering students, family physicians, and radiology residents, addressing teaching objectives related to interpretive [18,19] and noninterpretive [20,21] skills.

League of Rays (LOR) is a competitive online game created in 2015 for medical students from a single university to learn radiology in the Medical Master Island, a virtual environment in SL that reproduces a university campus. Its educational objective is to provide a gamified complement to the formal teaching of radiologic anatomy and radiologic semiology. The first three competitions were individual [22,23], and later, the rules were modified to participate in teams of four students [24]. The aim of this study was to develop an interuniversity team-based competitive game in the SL metaverse, as a voluntary activity complementary to the formal education planned in each institution, and to evaluate the results of the game, the perceptions of the students, and possible differences among different subgroups of participants.

METHODS

The competition was repeated for 2 years (editions) with identical rules and structure, from February 20 to April 1, 2020, and from March 8 to April 25, 2021. Two months before each competition, 57 radiology professors from 31 universities were contacted by email, through personal contacts of the organizers at the National Society of Radiology and the National Association of University Professors of Radiology. The project and its background were explained to them as a method of reinforcing basic

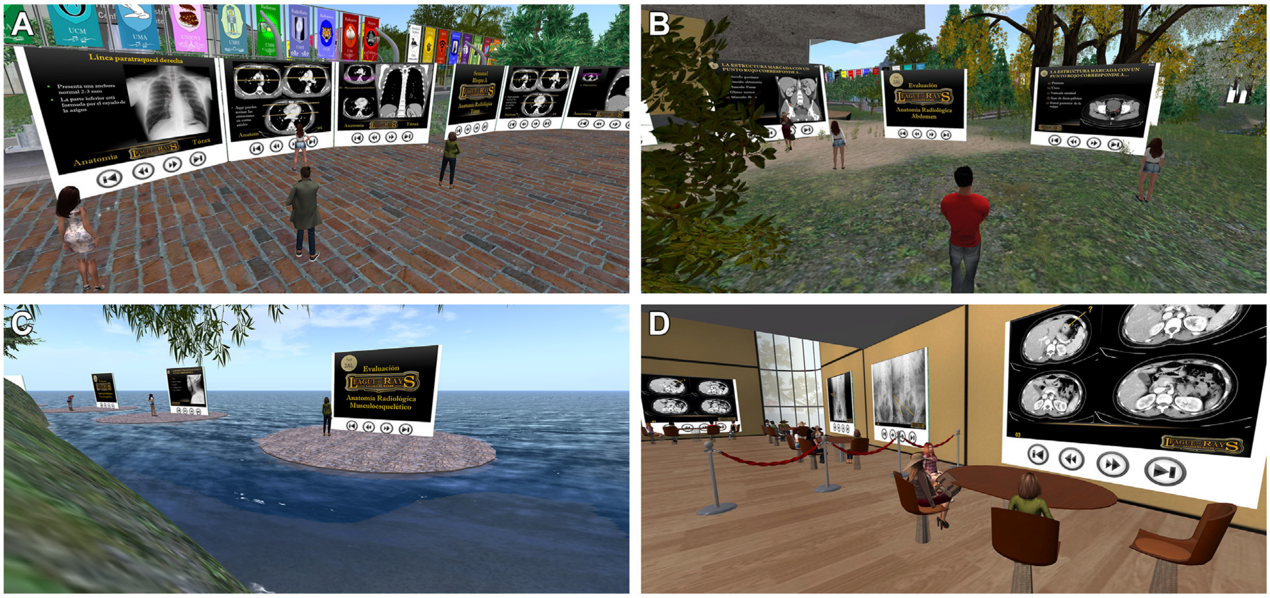


Fig. 1. Screenshot during various scenes from the game League of Rays. (A) Several avatars in the central esplanade of the island, in front of the set of three panels with educational content. (B) Participants looking in the gardens for the assigned individual test. (C) Avatars on floating platforms, performing individual tests. (D) Avatars solving team tasks.

knowledge of anatomy and radiologic semiology. They were asked to invite those students who were studying radiology in that academic year to participate voluntarily. The students had to form four-person teams and send an email to the organization, indicating the university of origin, the name of the team, a logo and a representative color and designating a captain. Applicants received a guide on the use of SL and access to the virtual location (see Appendix 1).

Structure and Rules of the Game

The competition had six weekly thematic blocks, covering radiologic anatomy and semiology of the thorax, abdomen, and musculoskeletal system. The participants had 4.5 days to study weekly didactic contents displayed on sets of three panels with 50-slide presentations, arranged in the central esplanade of the island. The learning panels were then removed, and a 2.5-day testing period began (Fig. 1). The participants had to answer weekly individual test of 15 multiple-choice questions displayed on new slide panels, sending a notecard to the organization's avatar. Twelve test variants were created from a bank of 30 questions for each weekly block (180 questions in total). Participants were required to complete weekly team tasks. Those of anatomy consisted of correctly identifying anatomic structures in 20 radiologic images, and those of semiology, called "normal or pathologic" (N/P), consisted of correctly identifying 12 normal images and giving the correct diagnosis in 8 pathologic images in a set of 20. Participants were unaware of the N/P ratio. The captain had to send a notecard with the team's response. Each incorrect answer subtracted 0.25 points. The sum of points from the four individual tests was normalized to 10 points and the points from the team tasks as well, so the maximum weekly score was 20 points (see Appendix 2 for some examples of questions). All the contents of the game were elaborated and analyzed by professors of the organizing university (ORGU) in previous intrauniversity competitions [22-24].

Leaderboards were published after each stage, categorized according to radiologic densities: metal, calcium, water, fat, and air. Teams were eliminated if they did not submit results 2 weeks in a row or if they voluntarily left the game. The three winning teams in each edition received prizes consisting of radiology books and T-shirts.

Evaluation

After the third week, the participants were surveyed about the cognitive load, using a notecard, answering how much mental effort it cost them to manage SL, view the educational presentations, and performing the weekly tests, on a 9-point Likert-type scale developed by Paas and van Merriënboer [25]. Fifteen days after finishing the game, a synchronous wrap-up meeting was held in SL to summarize the development of the game, during which the 180 questions of the individual tests were reviewed, using 60 questions (10 randomized per week) to do a postexposure knowledge test.

Participants were asked to complete an anonymous perception questionnaire, slightly modified from previous studies [22-24] (see Appendix 3), consisting of 25 items to be answered on a 5-point Likert-type scale (7 about the virtual world, 8 about the game, 4 about the educational

Table 1. Correct answers in individual tests and team tasks during the interuniversity competition

	Individual Tests*			Team Tasks†		
	2020	2021	P	2020	2021	P
Anatomy	79.7 ± 18.6	79.4 ± 17.4	0.801	64.3 ± 22.5	69.4 ± 17.6	0.044
Stage 1: thoracic anatomy	66.3 ± 18.3	69.3 ± 17.2	0.120	57.1 ± 21.7	67.1 ± 15.8	0.013
Stage 2: abdominal anatomy	86.3 ± 15.7	80.4 ± 15.0	0.002	77.5 ± 15.1	74.3 ± 15.0	0.348
Stage 3: MSK anatomy	88.3 ± 12.3	89.4 ± 13.3	0.467	59.4 ± 24.3	66.6 ± 20.8	0.152
Semiology	70.0 ± 20.8	72.9 ± 19.0	0.034	71.5 ± 19.6	76.4 ± 16.1	0.048
Stage 4: thoracic semiology	67.3 ± 22.4	69.7 ± 21.0	0.337	62.8 ± 20.0	69.7 ± 18.3	0.125
Stage 5: abdominal semiology	74.1 ± 20.3	79.2 ± 17.5	0.024	75.5 ± 17.2	81.0 ± 13.7	0.139
Stage 6: MSK semiology	68.6 ± 18.9	70.1 ± 16.5	0.480	77.0 ± 18.7	78.9 ± 13.6	0.630
Total	75.2 ± 20.2	76.5 ± 18.4	0.148	67.7 ± 21.5	72.5 ± 17.3	0.007

Note: Data are expressed as mean ± SD. MSK = musculoskeletal.
*Percentage calculated on 15 questions of each test.
†Percentage calculated on 20 questions of each task. The calculations include all the tests and tasks received at each stage.

presentations, and 6 about the tests) and 12 items to score between 1 and 10 points. Finally, there were two spaces for open comments on the impact of the COVID-19 lockdown on their participation and for any additional comments. In both editions the same didactic contents, tests and questionnaires were maintained. The data from the questionnaires were anonymized in accordance with current data protection laws. This study received the approval of the ethics committee of experimentation of the University of Malaga (decision number 138-2022-H, January 18, 2023).

Data Analysis

Data were organized in an Excel 365 spreadsheet (Microsoft) and statistically analyzed using SPSS version 24 (IBM). The numeric results of the game are considered continuous variables and those of the questionnaires ordinal variables, which are presented as mean ± SD. The Mann-Whitney *U* test and Student's *t* test were applied to compare ordinal and continuous variables, respectively. The correlation between the finalist teams scores and the average of their perception questionnaires answers was analyzed using the Pearson correlation coefficient (>30 teams) or Spearman correlation coefficient (<30 teams). Statistical signification was established at $P < .05$. Open comments were classified through collaborative systematic coding by group consensus agreement (T.R.-S., R.L.-A., and F.S.-P.) on the basis of their content [26]. Comments about the impact of COVID-19 were classified using single-layer coding and additional open comments in two hierarchical layers.

RESULTS

Development of the Game

Three hundred students from 20 universities of 408 registered in both editions finished the competition, 128 from the ORGU and 172 form other universities (OTHU). As radiology is taught in different years, depending on the university, they were distributed as follows: 228 (76%) from the third year, 36 (12%) from the fifth year, 20 (7%) from the fourth year, and 16 (5%) from the second year. Twenty-eight teams finished the game in 2020 and 47 in 2021 (Supplementary Material, Fig. S1). The lowest proportion of correct answers was found in thoracic anatomy and semiology (Table 1). The winning teams, both including third-year students, reached 105.96 and 109.59 points in 2020 and 2021, respectively. The finalist teams exceeded 50% of the maximum score in 2020 and 2021, by 79% and 87%, respectively. The descriptive statistics of their results is shown in the Supplementary Material (Table S1). No significant differences were found between 2020 and 2021 teams. Although the second-year and fourth-year teams obtained lower average results, they did not show significant differences because of the small number of teams from courses other than third.

Ninety-five participants (57.9%) answered the cognitive-load questionnaire in 2020 and 84 (51.2%) in 2021. On a Likert-type scale ranging from 1 to 9, the mental effort required was considered low to moderate (3.6 ± 1.8 and 3.7 ± 2.0) to manage SL, moderate (4.3 ± 1.8 and 4.3 ± 2.0) to read the educational presentations, and moderate to high (6.1 ± 1.3 and 6.3 ± 1.4) to conduct the weekly tests. There were no significant differences between both editions.

At the end of the experience, 50.9% (2020) and 39.4% (2021), respectively, of the finalists attended the closing meeting. In the postexposure test, correct answers decreased by 11% in 2020 and 16% in 2021 compared with correct answers in individual tests during the game. A moderate to low positive correlation was found between the game score and the postexposure test (Pearson correlation coefficients of 0.316 and 0.288).

Table 2. Student perceptions of different aspects of the experience on a 5-point Likert-type scale*

Perceptions	2020†	2021‡	P§
About Second Life			
The island environment seemed attractive to you	4.5 ± 0.8	4.2 ± 0.9	.034
You move through Second Life with ease, without problems	3.9 ± 1.0	3.6 ± 1.1	.027
The tasks of creating and managing your avatar were easy	3.9 ± 1.1	3.4 ± 1.2	.001
Your computer meets the requirements to work in Second Life without problems	4.2 ± 1.1	3.7 ± 1.3	.002
Your Internet connection allows you to work in Second Life without problems	4.2 ± 1.0	3.9 ± 1.2	.082
Learning radiology in Second Life seems interesting to you	4.7 ± 0.5	4.4 ± 0.9	.012
Contact with your peers in Second Life is beneficial for your training	4.4 ± 0.9	4.2 ± 1.0	.141
About League of Rays			
The design of the competition seemed correct to you	4.5 ± 0.7	4.3 ± 0.9	.107
The information about the competition was adequate	4.7 ± 0.5	4.5 ± 0.7	.027
The contents seemed appropriate for your training as a doctor	4.7 ± 0.5	4.5 ± 0.7	.019
The contents were too difficult for your current level of knowledge	3.0 ± 1.0	2.9 ± 1.1	.705
You think that playing in competitive environments you learn better	4.2 ± 0.8	4.1 ± 1.0	.614
You worked as a team on this experience	4.8 ± 0.6	4.7 ± 0.7	.859
Your participation in the competition was very active	4.6 ± 0.6	4.3 ± 0.9	.019
You would participate in another experience in Second Life in future courses	4.5 ± 0.8	4.0 ± 1.1	.003
Presentations of the different stages			
The contents of the presentations were interesting	4.5 ± 0.6	4.2 ± 0.9	.026
The presentations were adequate to the educational objectives	4.3 ± 0.7	4.2 ± 0.9	.605
The extension of the contents was adequate	4.3 ± 0.7	4.0 ± 0.9	.012
I was able to follow the presentations with ease	4.2 ± 0.8	4.0 ± 1.0	.314
Evaluations of the different stages			
The evaluations were interesting	4.4 ± 0.6	4.3 ± 0.8	.475
The questions were appropriate to the educational objectives	4.3 ± 0.8	4.1 ± 0.8	.070
The response through notecards was adequate	4.5 ± 0.6	4.4 ± 0.8	.415
I was able to do the assessments with ease	4.0 ± 0.9	3.8 ± 1.0	.174
I did the individual tests as a team, with the help of my classmates	3.9 ± 1.2	3.7 ± 1.3	.439
We carry out the team tasks working together	4.7 ± 0.9	4.7 ± 0.7	.477

Note: Data are expressed as mean ± SD.
*Scale anchors: 1 = totally disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, and 5 = totally agree.
†Number of participants who responded to the questionnaire in 2020: n = 93 (83%).
‡Number of participants who responded to the questionnaire in 2021: n = 160 (85.1%).
§*P* value for the comparison of means using the Mann-Whitney *U* test.

Evaluation of the Experience

Ninety-three participants (83.0%) took the perception questionnaire in 2020 and 158 (84.0%) in 2021. There was less agreement in 2021 than in 2020, significantly, for 9 of 15 statements on the 5-point Likert-type scale about SL and LOR (Table 2). The participants agreed that learning in SL was interesting and that the island environment was attractive. They also agreed that they worked as a team, that playing in competitive environments is better for learning, and that the design of the competition was correct, the information adequate and the content appropriate. The least agreement was found in the ease of moving in SL and creating and managing the avatar. It should be noted that 72% to 74% of the participants agreed that they performed the individual tests together with their team.

The assessment of 1 to 10 points was very positive, with mean values greater than 8 points for all items, except for connectivity to SL in 2021 (Fig. 2). The project organization and the teacher received the highest marks. The items with the lowest score were the evaluations of the N/P tests and the connectivity to SL. Participants gave significantly lower scores in 2021 than in 2020 on 8 of the 12 items evaluated.

In 2020, only four of the items to be answered with 1 to 10 points showed significant differences between ORGU and OTHU students, although OTHU participants gave scores greater than 8 points on all items (Supplementary Material, Fig. S2). However, in 2021, OTHU participants scored significantly lower on all items, with four items less than 8 points: global

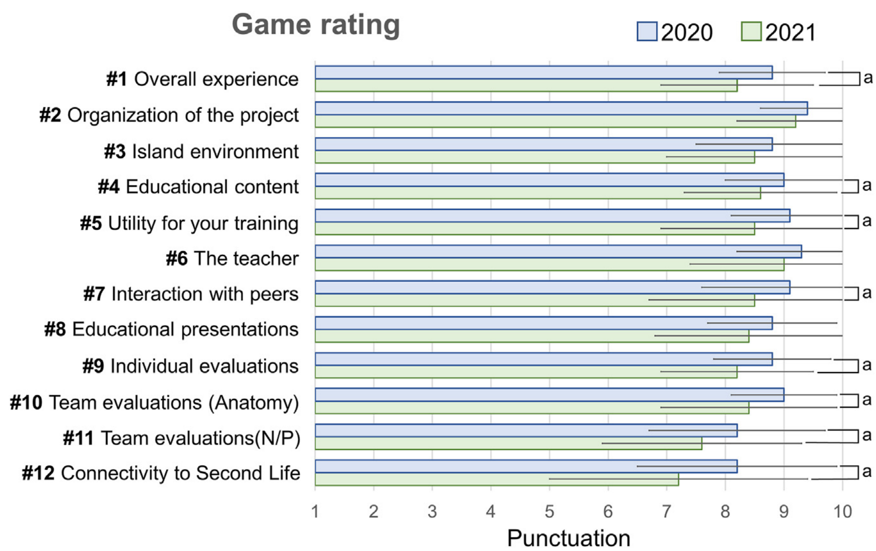


Fig. 2. Bar chart showing the mean of the rating from 1 to 10 points of 12 aspects of the experience. Error bars represent the standard deviation. a = significant differences between the two editions; N/P = normal or pathologic.

experience (7.9 ± 1.4), individual evaluations (7.2 ± 1.4), team tasks N/P (7.1 ± 1.9), and connectivity to SL (6.6 ± 2.5). To check whether these differences of opinion were related to the in-game score, a comparison was made by successively eliminating the OTHU teams with the lowest score (Fig. 3). As can be seen, the probability of error (*P*) increases as the teams with the lowest scores are eliminated until the significant differences disappear. The correlation matrices confirmed this relationship, showing significant correlations between the questionnaire score and experience ratings in the OTHU 2021 group, and no correlation in the OTHU 2020 group and the ORGU groups in both editions (Supplementary Material, Fig. S3).

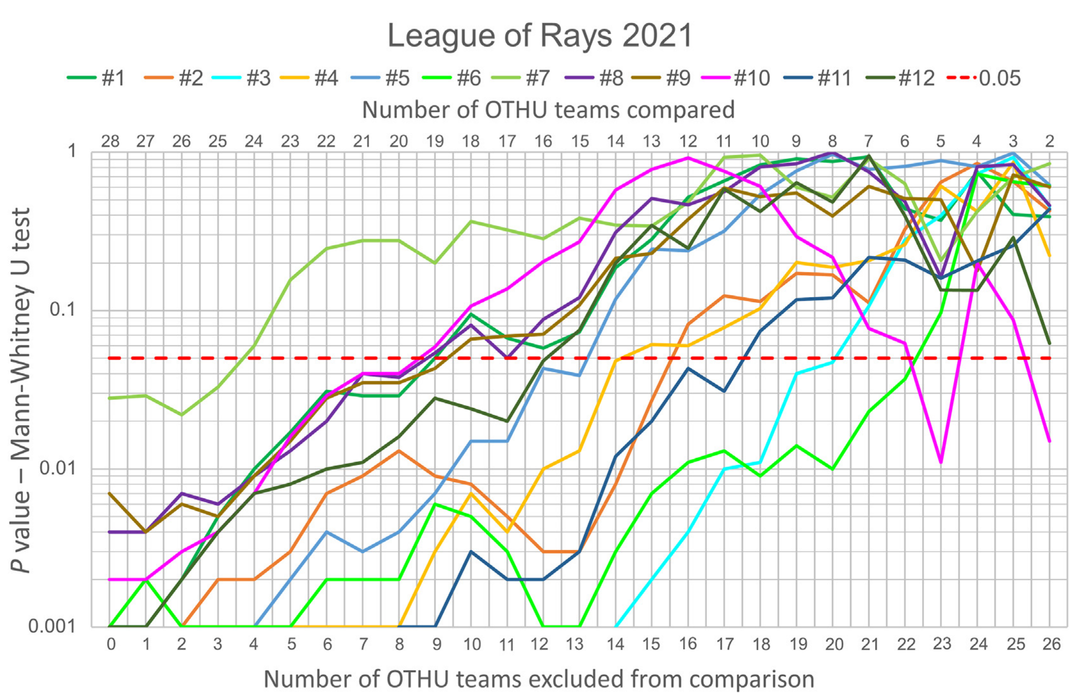


Fig. 3. Line graph that expresses the values of statistical significance and their modification as the teams with the lowest scores from other universities (OTHU) are progressively eliminated when comparing them with the teams of the organizing university. Global rating questions 1 to 10 points. The dashed line marks the Mann-Whitney *U* test level of statistical significance (*P* = .05).

Table 3. Thematic codification of the open-ended additional comments included in the questionnaire

Codes and Subcodes	Frequency 2020 (n = 58)	2021 (n = 95)	Both (n = 153)
Positive	50 (86.2)	81 (85.2)	131 (85.6)
Appreciation: Additionally expressed with terms such as I liked, interesting, attractive, gratifying, enjoyable, positive, very cool, fantastic.	40 (69.0)	66 (69.5)	106 (69.3)
Usefulness: Indicating that the experience was useful for learning, profitable, helpful, formative.	30 (51.7)	50 (52.6)	80 (52.3)
Fun: Playful, entertaining, expressing that you learn by playing.	12 (20.7)	12 (12.6)	24 (15.7)
Innovation: Also expressed with terms such as new, original, unusual, surprising, creative, different.	3 (5.2)	2 (2.1)	5 (3.3)
Contact between students: Highlighting the benefit of virtual contact between participants.	2 (3.4)	3 (3.1)	5 (3.3)
Negative	35 (60.3)	42 (44.2)	77 (50.3)
Informatic requirements: Expressing technical problems to run SL properly because of the computer or the Internet connection.	11 (19.0)	13 (13.7)	24 (15.7)
Cognitive load (LOR): Indicating that he difficulty of the game was high, even stressful.	8 (13.8)	16 (16.8)	24 (15.7)
Cognitive load (SL): Referring to a high difficulty of operating in SL. They feel that they are not used to or do not handle the interface well.	5 (8.6)	7 (7.4)	12 (7.8)
Presentations: They indicate that educational presentations should have more information, or are not of good quality.	6 (10.3)	5 (5.3)	11 (7.2)
Individual TEST: They indicate that the individual tests were too long or did not fit with the learning presentations.	0 (0.0)	3 (3.1)	3 (2.0)
N/P team tasks: They felt that these team tasks were too long or repetitive.	2 (3.4)	1 (1.0)	3 (2.0)
Information: They pointed out lack of sufficient information about the game.	2 (3.4)	1 (1.0)	3 (2.0)
Organization: The students sent a complaint to the organization and did not feel they were responded to.	1 (1.7)	4 (4.2)	5 (3.3)
Suggestions	20 (34.5)	21 (22.1)	41 (26.8)
Correct answers: Students would like to know the correct answers to the tests during the game.	5 (8.6)	6 (6.3)	11 (7.2)
New initiatives: They proposed other ways to use the SL platform to learn.	3 (5.2)	6 (6.3)	9 (5.9)
New topics: They proposed to include more cases in the game, with more modalities, such as ultrasound, breast imaging, etc.	6 (10.3)	2 (2.1)	8 (5.2)
New game rules: Participants suggested including new rules for the game.	5 (.6)	2 (2.1)	7 (4.6)
Schedule: Modifications to the current game calendar, shortening the experience or doing it in different months.	1 (1.7)	4 (4.2)	5 (3.3)
Alternative platform: They proposed using a platform other than SL to run the game, such as the Moodle Virtual Campus.	0 (0.0)	1 (1.0)	1 (0.6)
N/P team tasks: The student proposed to attach clinical information to solve the cases.	1 (0.0)	0 (0.0)	1 (0.6)
Teamwork	11 (19.0)	14 (14.7)	25 (16.3)
Positive. The students indicated that they liked spending time with their team and working together.	11 (19.0)	13 (13.7)	24 (15.7)
Negative. The student indicated collaboration problems with other team members.	0 (0.0)	1 (1.0)	1 (0.6)

Note: The percentages of codes found in the open comments of the participants is provided in parentheses. LOR = League of Rays; N/P = normal or pathologic; SL = Second Life,

Qualitative Data

One hundred eighty-six students commented on the impact of COVID-19 on their participation. Comments were classified into 6 thematic codes; 42% reported no impact, 30% noted benefits of maintaining relationship with classmates during home confinement, and 29% indicated that they participated more because of confinement and reduced academic activities (Supplementary Material, Table S2). One hundred fifty-three participants provided additional open comments. The first-layer codification resulted in 131 positive comments, 77 negative, 41 suggestions, and 25 comments about teamwork. The coding of the second layer and the respective explanations are shown in Table 3.

DISCUSSION

Previous studies showed that participation in LOR improves radiology learning in the medium term compared with students who did not participate in it [22], that the experience is less accepted when participation is mandatory [23], and that it can be adapted easily to team participation [24]. The aim of this study was to verify how LOR works beyond the local scope of a single university. In two consecutive years, 300 students completed these interuniversity competitions to learn radiology, the first ever held in the metaverse, to our knowledge. According to the curricula of the different medical schools in this country, radiology subject is taught mainly in the third year. In this study, the number of second-, fourth-, and fifth-year participants is too low to establish statistical differences in game results. The hit average in the game tests was high (Supplementary Material, Table S1), which means that a significant percentage of students learned during the game. The results of the game also show some strengths and weaknesses of the radiology education of the participants. For example, the worst results were obtained in radiology and thoracic semiology, as it is an anatomic region that is especially difficult to interpret.

Cognitive load is defined as the mental effort to perform a learning task. It can be affected by the intellectual complexity of the task (intrinsic cognitive load) and the organization and presentation of information (extraneous cognitive load) [27]. In radiology education, the cognitive load depends on what is intended to be learned, how much is intended to be learned, how the data are presented to the learner, and whether the information is new to the learner [28]. The use of virtual worlds in education can increase the extraneous cognitive load, if the student requires excessive effort to learn to use the technology [29]. The cognitive load to manage SL remained at moderate to low averages. However, reading educational content and taking weekly tests required a moderate and moderate to high cognitive load, respectively. On the one hand, game design measures such as self-management of time to read and respond, and careful organization of images and text contributed to reducing extraneous cognitive load [28]. However, understanding anatomic structures and relationships requires considerable intrinsic cognitive load [30-32].

The aim of this study was to establish work synergies through competition while learning radiology, fostering team collaboration. Teamwork can develop areas such as collaboration, communication, time management, and sharing of technological systems [33]. The sense of belonging to a team is an important factor in creating work dynamics and making members feel accepted. The identity of the team is determined by the degree of identification with its organization [34,35]. In addition, competition with other teams from the same country can be very motivating, as other educational competitions with medical students developed in China [36], the United States [37], and Canada [38] have shown. The nature of voluntary participation in the study can prevent students from becoming disinterested in teamwork [39]. The creation of teams according to their preferences generally avoids negative team environments and maintains motivation [40].

The participants highly valued the competition and stated that they learned during the game, admitting that it was very useful to reinforce their knowledge of radiology. The positive opinions of the OTHU students demonstrate the reproducibility of the experience without a direct academic link with the game organizers, ruling out proximity bias [41]. But the lack of this link also favors abandoning the game or having a different perception depending on the outcome of the game. The students gave lower scores in the perception questionnaires in 2021 than in 2020, mainly because of a lower assessment of the OTHU students in the 2021 edition, which was correlated with game scores. The theory of social comparison could negatively affect losing teams [42], which can cause them to abandon the game, or equally, it can explain their worse opinion about the game in 2021. The differences in perception of the students of OTHU in 2021 compared with 2020 may be because 69% more OTHU teams completed the game in 2021 (27 vs 16), and these were two different phases of the pandemic: total confinement with great uncertainty in 2020 and restricted circulation with blended teaching and some social adaptation in 2021.

The COVID-19 pandemic accelerated the application of new technologies in learning [43], caused stress for medical students [44], and reduced doctor-student contact

[45]. In 2020, LOR seemed to fit well into student schedules during lockdown. In 2021, learning was organized with limited hospital internships, few face-to-face teachings, and many online activities. This habit of using 2-D online teaching resources made activities in 3-D environments, such as SL, perceived as different and fun, with more sense of presence and student engagement with learning [46]. Nearly a third of the participants found team play helpful in maintaining virtual relationships and relieving pandemic-related stress.

One of the limitations of this study, expressed by 8% of the participants, was the technical problems in running SL, due to poor Internet connection or insufficient computing capacity. Another limitation was time, as a larger number of participants need more time to organize the game. Although the contents are reused in each edition, the organization must provide information to the participants, create news about the game, resolve doubts, correct weekly tests, and so on. The next edition of LOR aims to increase social interaction between participants from different universities, modifying the rules to promote agreements and strategies among them. Another future development could be to adapt the contents for an interhospital competition for radiology residents, which would provide interesting data on the educational impact of gamification in SL during residency.

CONCLUSIONS

Competitive games in the metaverse virtual worlds such as SL are a valuable tool for learning radiology. This inter-university competition was feasible, reproducible, and considered by the participants interesting and useful for learning. Participants identified this activity as a playful experience of learning and social interaction during the COVID-19 pandemic.

TAKE-HOME POINTS

- A competition for teams of medical students to learn radiology conducted in the metaverse is highly valued by the participants, who recognize that it is very useful to reinforce their knowledge of radiology.
- The participation of students from different universities demonstrates the reproducibility of the experience, rules out proximity biases, and encourages the personal stimulation of students and collaborative action among teachers.
- Universities and medical schools can provide a sense of belonging to team members, an important factor in creating work dynamics, and an additional motivating element in the learning competition.
- Participants found team play useful for maintaining virtual relationships and identified this activity as a playful learning and social interaction experience during the COVID-19 pandemic.

ACKNOWLEDGMENTS

The authors acknowledge the students for their voluntary participation in this project and the radiology professors of the participating universities for their collaboration in disseminating this project among their students. The authors also thank Blanca Pantoja Merelo for her help with the English writing of this report.

ADDITIONAL RESOURCES

Additional resources can be found online at: https://doi.org/10.1016/j.jacr.2023.09.012.

REFERENCES

1. Huitt TW, Killins A, Brooks SW. Team-based learning in the gross anatomy laboratory improves academic performance and students' attitudes toward teamwork. Anat Sci Educ 2015;8:95-103.
2. Burgess A, Roberts C, Ayton T, Mellis C. Implementation of modified team-based learning within a problem-based learning medical curriculum: a focus group study. BMC Med Educ 2018;18:74.
3. Sánchez E. Competition and collaboration for game-based learning: a case study. In: Wouters P, van Oostendorp H, eds. Instructional techniques to facilitate learning and motivation of serious games. New York: Springer; 2017:161-84.
4. Van Gaalen AEJ, Jaarsma ADC, Georgiadis JR. Medical students' perceptions of play and learning: qualitative study with focus groups and thematic analysis. JMIR Serious Games 2021;9:e25637.
5. Dearnley C, Rhodes C, Roberts P, Williams P, Prenton S. Team based learning in nursing and midwifery higher education; a systematic review of the evidence for change. Nurse Educ Today 2018;60:75-83.
6. Gaber DA, Shehata MH, Amin HAA. Online team-based learning sessions as interactive methodologies during the pandemic. Med Educ 2020;54:666-7.
7. Bingjie L, Chunyi Y, Haoyan L, Qing C, Xuelei M. Impact of team-based learning versus lecture-based learning on Chinese radiology education: a scoping review and meta-analysis. SAGE Open 2022:12.
8. Brigham TJ. An introduction to gamification: adding game elements for engagement. Med Ref Serv Q 2015;34:471-80.
9. Seaborn K, Fels DI. Gamification in theory and action: a survey. Int J Hum Comput Interface 2015;74:14-31.
10. Rutledge C, Walsh CM, Swinger N, et al. Gamification in action: theoretical and practical considerations for medical educators. Acad Med 2018;93:1014-20.
11. Aguado-Linares P, Sendra-Portero F. Gamification: basic concepts and applications in radiology. Radiologia 2023;65:122-32.
12. Kye B, Han N, Kim E, Park Y, Jo S. Educational applications of metaverse: possibilities and limitations. J Educ Eval Health Prof 2021;18:32.
13. Stephenson N. Snow crash. New York: Bantam; 1992.
14. Richardson A, Hazzard M, Challman SD, Morgenstein AM, Brueckner JK. A "Second Life" for gross anatomy: applications for multiuser virtual environments in teaching the anatomical sciences. Anat Sci Educ 2011;4:39-43.

15. Warburton S. Second life in higher education: assessing the potential for and the barriers to deploying virtual worlds in learning and teaching. Br J Educ Technol 2009;40:414-26.
16. Potkonjak V, Gardner M, Callaghan V, et al. Virtual laboratories for education in science, technology, and engineering: a review. Comput Educ 2016;95:309-27.
17. Gong W. Education and three-dimensional virtual worlds: a critical review and analysis of applying second life in higher education. Master's thesis, University of British Columbia, 2018.
18. Lorenzo-Alvarez R, Rudolphi-Solero T, Ruiz-Gomez MJ, Sendra-Portero F. Medical student education for abdominal radiographs in a 3D virtual classroom versus traditional classroom: a randomized controlled trial. AJR Am J Roentgenol 2019;213:644-50.
19. Lorenzo-Alvarez R, Ruiz-Gomez MJ, Sendra-Portero F. Medical students' and family physicians' attitudes and perceptions toward radiology learning in the second life virtual world. AJR Am J Roentgenol 2019;212:1295-302.
20. Pino-Postigo A, Domínguez-Pinos D, Lorenzo-Alvarez R, Pavía-Molina J, Ruiz-Gómez MJ, Sendra-Portero F. Improving oral presentation skills for radiology residents through clinical session meetings in the virtual world second life. Int J Environ Res Public Health 2023;20:4738.
21. Lozano-Durán A, Rudolphi-Solero T, Nava-Baro E, Ruiz-Gómez MJ, Sendra-Portero F. Training scientific communication skills on medical imaging within the virtual world second life: perception of biomedical engineering students. Int J Environ Res Public Health 2023;20:1697.
22. Lorenzo-Álvarez R, Rudolphi-Solero T, Ruiz-Gómez MJ, Sendra-Portero F. Game-based learning in virtual worlds: a multiuser online game for medical undergraduate radiology education within Second Life. Anat Sci Educ 2020;13:602-17.
23. Rudolphi-Solero T, Lorenzo-Álvarez R, Ruiz-Gómez MJ, Sendra-Portero F. Impact of compulsory participation of medical students in a multiuser online game to learn radiological anatomy and radiological signs within the virtual world Second Life. Anat Sci Educ 2021;15:1-14.
24. Rudolphi-Solero T, Jiménez-Zayas A, Lorenzo-Álvarez R, Domínguez-Pinos D, Ruiz-Gómez MJ, Sendra-Portero F. A team-based competition for undergraduate medical students to learn radiology within the virtual world Second Life. Insights Imaging 2021;12:89.
25. Paas F, van Merriënboer JJG. Instructional control of cognitive load in the training of complex cognitive tasks. Educ Psychol Rev 1994;6:51-71.
26. Saldaña J, ed. The coding manual for qualitative researchers (2nd ed). Thousand Oaks, CA: Sage; 2013.
27. Sweller J. Cognitive load theory, learning difficulty, and instructional design. Learn Instruct 1994;4:295-312.
28. Lewis PJ. Brain friendly teaching—reducing learner's cognitive load. Acad Radiol 2016;23:877-80.
29. Van Nuland SE, Rogers KA. E-learning, dual-task, and cognitive load: the anatomy of a failed experiment. Anat Sci Educ 2016;9:186-96.
30. Garg AX, Norman GR, Eva KW, Spero L, Sharan S. Is there any real virtue of virtual reality? The minor role of multiple orientations in learning anatomy from computers. Acad Med 2002;77:S97-9.
31. Seixas-Mikelus SA, Adal A, Kesavadas T, et al. Can image-based virtual reality help teach anatomy? J Endourol 2010;24:629-34.
32. Moxham BJ, Shaw H, Crowson R, Plaisant O. The future of clinical anatomy. Eur J Anat 2011;15:29-46.
33. Hoag A, Baldwin T. Using case method and experts in inter-university electronic learning teams. J Educ Techno Soc 2000;3:337-48.
34. Sedgwick MG, Yonge O. "We're it," "we're a team," "we're family" means a sense of belonging. Rural Remote Health 2008;8:1021.
35. Mesmer-Magnus JR, Asencio R, Seely PW, DeChurch LA. How organizational identify affects team functioning: the identity instrument hypothesis. J Manage 2015;44:1530-50.
36. Jiang G, Chen H, Wang Q, et al. National Clinical Skills Competition: an effective simulation-based method to improve undergraduate medical education in China. Med Educ Online 2016;21:29889.
37. Goodman MJ, Kurylo CM, Zhou DW, Peso P, Liang S, Baynes K. A national medical student diagnostic radiology competition initiative: survey and outcomes of the RadiOlympics. Acad Radiol 2023;30:2741-8.
38. Bouthillier M, Canil A, Cheng BYC, Lebel K, Dobson JL. Inaugural Pan-Canadian RADGames: results from a successful approach to radiology education for medical students. Acad Radiol 2022;30:113-21.
39. Hoag AM, Jayakar KP, Erickson K. The role of trust in virtual and interpersonal environments: implications for team learning & case method pedagogies. J Mass Commun Educ 2002;57:370-83.
40. Triviño A, de la Rubia E, Moreno FA, López-Martínez FJ, Sánchez-Martínez JJ. Implementing a competitive learning framework in chemical engineering degree in Spain and its applicability on an inter-university scenario. In: 2014 IEEE Frontiers in Education Conference (FIE) Proceedings 22nd-25th October 2014.
41. Johanson M. Hybrid work: How "proximity bias" can lead to favouritism. BBC Work Life 9th August 2021. Available at: https://www.bbc.com/worklife/article/20210804-hybrid-work-how-proximity-bias-can-lead-to-favouritism. Accessed April 18, 2022.
42. Van Gaalen AE, Brouwer J, Schonrock-Adema J, Bouwkamp-Timmer T, Jaarsma AD, Georgiadis JR. Gamification of health professions education: a systematic review. Adv Health Sci Educ 2021;26:683-711.
43. Awan OA. Virtual radiology readouts after the coronavirus disease (COVID-19) pandemic. AJR Am J Roentgenol 2021;217:765-6.
44. O'Byrne L, Gavin B, McNicholas F. Medical students and COVID-19: the need for pandemic preparedness. J Med Ethics 2020;46:623-6.
45. Byrnes YM, Civantos AM, Go BC, McWilliams TL, Rajasekaran K. Effect of the COVID-19 pandemic on medical student career perceptions: a national survey study. Med Educ Online 2020;25:1798088.
46. Ravaei S, Alonso-Martinez JM, Jimenez-Zayas A, Sendra-Portero F. Reflections about learning radiology inside the multi-user immersive environment Second Life® during confinement by COVID-19. Proceedings 2020;54:9.