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Submitted to: JMIR Medical Education
on: November 07, 2024

Table of Contents

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Abstract

Background: The integration of new technologies such as virtual worlds, clinical environments simulation, and case-based learning can contribute to improving the practical understanding of medical students, developing technical and communication skills, and promoting educational innovation.

Objective: This study aimed to design and develop a gamified learning experience on emergency radiology in the virtual world Second Life (SL), and to analyze the reproducibility of the experience, as well as the outcomes and students' perceptions.

Methods: The experience was integrated into a two-week radiology clerkship. Teams of 3-4 students reviewed seven clinical cases presented in virtual Objective Structured Clinical Examination (OSCE) stations and answered two randomly assigned cases. The students then discussed the cases in a synchronous virtual meeting and received a seminar on emergency radiology. Finally, they voluntarily completed a perception questionnaire, which included questions on a 1 to 5 Likert scale (from strongly disagree to strongly agree), assessment of the cognitive load of the game, 10-point rating of the experience, and open-ended comments.

Results: A total of 352 students participated in this study over two academic years: 182 in 2020-21 and 170 in 2021-22. The students demonstrated strong competence in team-based resolution of clinical cases, with mean scores (± standard deviation) of 7.36 ± 1.35 in 2020-21 and 8.41 ± 0.99 in 2021-22 (P < .001). The highest cognitive load was observed in avatar editing and OSCE case-solving, with median values of 7 (95% CI = 0.20) and 6 (95% CI = 0.19), respectively, and significantly lower values recorded in 2021-22 (P = .047 and P < .001, respectively). The perception questionnaire had a 90.6% response rate. The students rated the experience highly, with average scores exceeding 8.0 out of 10 across various aspects. Notably, the highest-rated aspects were the teaching staff (9.13±1.15), OSCE cases (8.60±1.31), project organization (8.42±1.67), OSCE rooms (8.36±1.62). The lowest rated aspect was the connectivity to Internet (6.68±2.53). Despite the positive scores, all aspects were rated significantly lower in 2021-22 compared to 2020-21 (P-values ranging from < .001 to .028).

Conclusions: This study shows that a game-based learning experience in the SL virtual world, featuring virtual OSCE stations and team-based activities, is feasible and reproducible within a radiology clerkship. By combining asynchronous activities with synchronous group meetings in a playful context, this experience fosters clinical reasoning and teamwork, providing educational value that students highly appreciate. Expanding the use of OSCE stations in 3D virtual environments could further benefit education in radiology and other medical fields.

(JMIR Preprints 07/11/2024:68518)
DOI: https://doi.org/10.2196/preprints.68518

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Keywords: Radiology Education, Medical Students, Computer Simulation, Virtual Worlds, Emergency radiology, Game-based learning, Case-based learning.

Introduction

Gamification is the use of game elements in non-game environments, such as in education. It is an alternative educational approach that promotes student motivation and participation in the learning process [1]. Game-based learning is a synonym or subcategory of educational games. It is often

referred to as digital games [2,3], which help students achieve learning objectives through immersive and engaging learning experiences. These game-based activities can be carried out in virtual worlds, providing effective and promising results with medical students [4,5], and their use in undergraduate learning is worth exploring.

Virtual worlds are computer-generated three-dimensional (3D) virtual spaces where people interact with each other remotely through representations of themselves called avatars. The concept of virtual worlds, along with others such as virtual reality, mirror worlds, and augmented reality, integrates into the concept of the metaverse [6], a virtual reality beyond reality, in a world expressed through digital media and the Internet. Clinical simulation environments have been developed in virtual worlds to train various skills, such as taking anamnesis on virtual patients [7], resolving clinical situations in a pneumology ward [4], training cardiopulmonary resuscitation [8], or communication skills with patients [9,10].

One of the most used virtual worlds as a teaching resource for health professionals is Second Life (SL) [11]. Its main advantages are the possibility of remote access, a significant sense of presence, ease of access, anonymity, the opportunity to develop public speaking and communication techniques, the ability to promote active learning, and being free of charge. Second Life is a digital platform that allows the design and recreation of various scenarios for training with clinical cases [12], in the style of a Structured Objective Clinical Examination (OSCE), where physical spaces, called stations, are used to reproduce clinical scenarios and situations to evaluate students' clinical skills in a standardized, reliable and objective way [13]. Second Life has proven to be a useful tool for teaching and learning Radiology in online activities, both synchronous and asynchronous [14] and for developing game-based learning on radiological anatomy [5]. However, to our knowledge, no game-based experiences have been carried out with radiology OSCE-like clinical scenarios in SL or other virtual worlds.

The objectives of this study were to design virtual OSCE stations in SL to develop a game-based learning experience on emergency radiology with sixth-year medical students (who are in their final year of medical school in our country) during a formal radiology clerkship, and to analyze the reproducibility of the experience, as well as the outcomes and students' perceptions.

Methods

Background and project design

Sixth-year medical students at our university complete a two-week radiology clerkship, consisting of four days of hospital practice, ten two-hour seminars on clinical radiology, and online learning activities. Each year, seven groups of 24-28 students successively complete the radiology clerkship between mid-October and early February. The educational purpose of the activity in this study, called "Rainbow-Game", was to provide students with reflective training on clinical situations involving medical emergencies mediated by the corresponding radiological procedures, in a playful and collaborative context, as part of the activities of the clerkship.

Each group was randomly divided into seven teams of 3-4 students named with the colors of the rainbow. On the first day of the clerkship, students were briefed on the details of this experience. They had to dress their avatar with shirts of their team's color and had nine days to visit, on demand, a virtual space with seven OSCE stations, with emergency radiology cases. As part of the game, teams had to send the professor original and imaginative SL screenshots showing their avatars dressed in the corresponding color. On the eighth day, two cases were randomly assigned to each

team, asking them to send the written answers using a SL internal message system (notecard). On the tenth, there was a two-hour meeting with the whole group in SL. First, the teams had to orally present the results of the assigned cases and discuss them with their peers. Subsequently, they received a one-hour seminar on emergency radiology, in which the professor presented 15 clinical cases, distributed equally among head, chest, and abdominal emergencies. At the end of the seminar, three exam cases were arranged, to be answered individually using a notecard. A 24-item checklist was used to correct answers uniformly (see Appendix 1). This activity was repeated during two academic years (2020-21 and 2021-22) with the same contents and organization.

Virtual scenarios

This study was conducted at the SL location named “The Medical Master Island”, designed with various academic buildings surrounded by trees and plants (Figure 1). Seven OSCE stations were designed with access from the same distributor, imitating a real OSCE. Each station had: a) an access door; b) a panel on the wall describing the clinical situation and the questions to be answered; c) a table with one or two monitors, showing the images of the case; and d) X-ray or computed tomography equipment to contextualize the place as a radiology room (Figure 1). To minimize repetitions, sixteen cases were used (Table 1), which were rotated for the seven groups (Table 2). An example case is shown in Figure 2. The group meeting was held in the main building's aula magna, which had monitors with images to discuss the cases and a panel of slides to present the seminar (Figure 1).

Table 1. Description of the 16 cases used in the Rainbow-Game.

Case	Image modality shown	Case description
1	Brain CT without iv contrast: 18 axial slices.	52-year-old man. Spontaneous intraparenchymal haemorrhage with a subarachnoid component.
2	Abdominal CT with iv contrast: 18 axial slices and 18 coronal slices.	39-year-old woman. Multiple renal lacerations with hemoperitoneum.
3	Chest X-ray: posteroanterior.	65-year-old woman. Complete opacification of the left hemithorax: atelectasis of left lung due to a bronchial carcinoma.
4	Brain CT without iv contrast: 18 axial slices.	79-year-old man. Acute ischemic lesion in the left cerebral hemisphere: MCA stroke with subfalcine herniation.
5	Abdominal Radiography: oblique.	73-year-old man. Large bowel dilatation with coffee bean sign: Acute sigmoid volvulus with pneumoperitoneum.
6	Abdominal CT with iv contrast: 18 axial slices.	55-year-old woman. Gallbladder distention, wall thickening, mucosal hyperenhancement and pericholecystic fat stranding: Acute cholecystitis.
7	Brain CT without iv contrast: 18 axial slices plus 18 in bone window.	40-year-old man. Parietal acute epidural hematoma with associated bone fracture.
8	Chest X-ray: posteroanterior.	59-year-old woman. Widening of mediastinum, wide aortic contour, tracheal deviation, aortic kinking: Acute aortic dissection.

9	Abdominal CT with iv contrast: 18 axial slices.	55-year-old man. Ruptured abdominal aortic aneurysm with hemoperitoneum.
10	Brain CT without iv contrast: 18 axial slices plus 18 in bone window.	58-year-old man. Frontal intraparenchymal hemorrhage, subdural hemorrhage and occipital skull fracture.
11	Chest X-ray: posteroanterior.	65-year-old man. Pulmonary consolidation without volume loss, air bronchogram and silhouette sign: Lobar pneumonia.
12	Abdominal CT with iv contrast: 18 axial slices.	60-year-old man. Colonic wall thickening, pericolic fat stranding in an area of sigmoid diverticulosis: Acute diverticulitis.
13	Chest X-ray: posteroanterior.	62-year-old man. Consolidations and ground-glass opacities bilateral, peripheral, and located in the lower fields: COVID-19 pneumonia.
14	Brain CT with and without iv contrast: two sets of 18 axial slices.	55-year-old woman. Single cortical lesion, round, well-demarcated with enhancement and perilesional vasogenic edema: Metastatic lesion.
15	Abdominal CT with iv contrast: 18 axial slices and 18 coronal slices.	49-year-old man. Large soft-tissue mass, with internal heterogeneity: Retroperitoneal sarcoma.
16	Chest X-ray: posteroanterior and lateral.	76-year-old man. Bone osteoblastic lesions: Metastasis due to prostate carcinoma.

Table 2. Assignment of cases to the OSCE stations across different groups.[a]

	Station1	Station2	Station3	Station4	Station5	Station6	Station7
Group 1	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Group 2	Case 8	Case 9	Case 10	Case 11	Case 12	Case 13	Case 14
Group 3	Case 15	Case 16	Case 1	Case 2	Case 3	Case 4	Case 5
Group 4	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12
Group 5	Case 13	Case 14	Case 15	Case 16	Case 1	Case 2	Case 3
Group 6	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Group 7	Case 11	Case 12	Case 13	Case 14	Case 15	Case 16	Case 1

[a]The same assignment was maintained for both years of the study.

Qualification of the participants

Each team was qualified based on three parameters, normalized to 10 points each: a) the written response to the two assigned cases, using a checklist for each case (40%); b) the originality and quality of the best screenshot submitted (20%); and c) the average of the individual points of the team to the three seminar questions (40%). Students were informed that their team's score on this compulsory online activity would have no impact on their clerkship's grades. However, as extrinsic motivation, the team with the highest score in each group received a bonus of one extra point in the final grade, up to 10 points.

Perception of the experience by the students

After the seminar, the students were asked to complete a questionnaire about the experience (see Appendix 2), which included: a) a dichotomous question about whether they knew SL before the experience; b) an assessment of 13 aspects of the game with a Likert scale of 1-5 (from totally disagree to totally agree); c) an assessment of the cognitive load of six aspects of the game, following

the 9-point scale proposed by Paas and Merriënboer [15]; d) a rating of up to 10 points on nine aspects of the game; and e) a space for open comments asking "anything else to add". The questionnaire contained questions constructed, worded, and validated in previous studies [5,14]. Submission of the questionnaire was voluntary, and participants gave their explicit consent when submitting it. This study received the approval of the ethics committee of experimentation at our university (decision number 141-2022-H. Approval date 18 January 2023).

Data Analysis

Descriptive statistics were performed using Microsoft Excel 2021 (Microsoft, Redmond, WA, USA) to characterize the population and subpopulations of participants, and the SPSS statistical package v24 (IBM Corporation, Armonk, NY, USA) was used for statistical analysis. A Mann-Whitney U test was used to compare the results of the questionnaire about the experience for both academic years. Unpaired two-sample t-tests were used to evaluate differences between groups and years in terms of the means of the global qualification of the project. Statistical significance was accepted at a probability of error of $P < .05$.

Open comments were analyzed using the systematic collaborative consensus coding by committee [16]. Comments related to aspects of the clerkship other than the Rainbow-Game were not considered. During two consensus meetings, a two-layer hierarchical coding was established, with three codes in the first layer (advantages, disadvantages, and suggestions) and different subcodes in the second layer.

Results

Outcome of the Rainbow-Game

Three hundred fifty-two students participated in this project, 182 in 2020-21 and 170 in 2021-22. The average rating (± standard deviation) up to 10 points of the teams in 2020-21 vs. 2021-22 was as follows: in OSCE cases, 7.36±1.35 vs. 8.41±0.99 ($p < 0.001$); screenshots taken in SL, 7.31±1.65 vs. 7.04±1.73 ($p = 0.439$); the seminar questions 4.98±0.83 vs. 4.41±1.07 ($p = 0.004$); and the final score of the experience, 6.40±0.86 vs. 6.54±0.77 ($p = 0.396$). Figure 3 shows the average score of the seven groups for each year in chronological order. There was no difference in the academic grade of the clerkship between the students of both years (7.68±0.44 vs. 7.79±0.43; $p = 0.192$).

The average score obtained in the 16 OSCE cases is shown in Figure 4. In five cases, the score obtained in 2021-22 was significantly higher than in 2020-21; there were no other significant differences. Considering both years, the easiest case was number 9, a ruptured abdominal aortic aneurysm with hemoperitoneum on CT (mean score 9.58±0.79), and the most difficult was number 16, osteoblastic bone metastases from prostate carcinoma in a chest X-ray (5.83±2.25).

Students´ perception

Three hundred and nineteen students (90.6%) submitted the perception questionnaire, 167 (91.8%) in 2020-21 and 152 (89.4%) in 2021-22. Only 38 (11.9%) stated that they did not know SL previously, the rest had participated in educational activities in SL during their third year. The results regarding cognitive load are summarized in Table 3. The task that required the greatest mental effort was editing and dressing the avatar, with an average score between rather high and high mental effort (median = 7; 95% CI = 0.20), followed by solving the cases proposed in the OSCE stations, with an average score between no mental effort and rather high mental effort (median = 6; 95% CI = 0.19). The rest of the tasks required from rather low to very low mental effort. There were no significant

differences in cognitive load between the two years except for the tasks of dressing the avatar, which required greater mental effort in 2021-22, and the resolution of OSCE cases, which required less mental effort in 2021-22.

Table 3. Results of the questionnaire about the cognitive load.[a]

How much mental effort does it cost you to develop the following tasks:	2020-21			2021-22			*P* [b]	Both years		
	Mean (std)	Median	95% IC	Mean (std)	Median	95% IC		Mean (std)	Median	95% IC
Moving around in Second Life	3.85 (2.25)	4	0.34	3.93 (2.25)	3	0.36	.354	3.89 (2.25)	3	0.25
Communicate by written chat	2.07 (1.52)	2	0.23	2.23 (1.69)	2	0.27	.272	2.15 (1.60)	2	0.18
Communicate by voice	2.67 (2.14)	2	0.33	2.99 (2.34)	2	0.37	.109	2.83 (2.24)	2	0.25
Edit and dress your avatar	6.62 (1.81)	7	0.28	6.90 (1.85)	7	0.29	.047	6.76 (1.83)	7	0.20
Solve the proposed cases in the OSCE-RX room	5.95 (1.71)	6	0.26	5.38 (1.73)	6	0.28	<.001	5.67 (1.74)	6	0.19
Follow the development of the seminar in Second Life	4.54 (2.26)	5	0.35	4.44 (1.92)	5	0.30	.328	4.49 (2.10)	5	0.23

[a]Likert scale from 1 to 9 according to: 1) Very, very low mental effort; 2) Very low mental effort; 3) Low mental effort; 4) Rather low mental effort; 5) Neither high nor low mental effort; 6) Rather high mental effort; 7) High mental effort; 8) Very high mental effort; and 9) Very, very high mental effort

[b] *P* is the probability of error of the Mann Whitney U test. Significant data for *P* <.05. std: standard deviation.

Overall, more than 95% of the respondents agreed or strongly agreed that the OSCE case selection was suitable for their training, the contents were appropriate, and that they worked as a team. Additionally, more than 79% found the environment of the OSCE rooms attractive, the competition design appropriate, and the information provided adequate (Figure 5). Between 49% and 56% agreed that learning radiology in SL is interesting and that playing and competing is a better way to learn. Twenty-two percent of students disagreed with the suitability of their computers, and 9% disagreed with the adequacy of their Internet connection for working in SL. Fifty-four percent of the 2021-22 students agreed that they had fun during the experience. There was significantly lower agreement in 2021-22 on eight of the 5-point Likert scale statements.

The participants rated the experience up to 10 points, with mean scores higher than 8 points in 7 of 9 items (Table 4). The lowest rating was given for connectivity to SL. All mean scores in 2021-22 were significantly lower than those in 2020-21.

One hundred forty-three questionnaires (44.8%) included open comments: 82 (49.1%) in 2020-21, and 61 (40.1%) in 2021-22. After the initial first-layer coding, 12 second-layer subcodes were found among the advantages, 8 among the disadvantages, and 9 among the suggestions, as shown in Table 5, along with the thematic description and frequency.

Table 4. Rating in a 0-10 points scale of various aspects of the experience. [a]

Items	2020-21	2021-22	*P* [b]	Both years
Overall experience	7.81±1.70	7.07±1.72	<.001	7.46±1.75
Organization of the project	8,88±1.45	7.92±1.75	<.001	8.42±1.67
Environment of the OSCE rooms	8.66±1.44	8.03±1.74	<.001	8.36±1.62
OSCE cases	8.75±1.35	8.43±1.25	.028	8.60±1.31
The virtual seminar	8.63±1.66	7.62±2.03	<.001	8.15±1.91
The teachers	9.30±1.17	8.93±1.10	.004	9.13±1.15
The utility for your training	8.52±1.59	7.56±1.98	<.001	8.06±1.85
Interaction with peers	8.55±1.65	7.73±1.99	<.001	8.16±1.86
Connectivity to Second Life	7.22±2.37	6.09±2.57	<.001	6.68±2.53

[a] Data are mean±standard deviation.

[b] *P* is the probability of error of the Student t-test for unpaired data. Significant data for *P*<.05.

Table 5. Thematic codification of the open comments included in the questionnaire.

Codes	Subcodes	2020-21	2021-22	Both
ADVANTAGES				
	APPRECIATION: With terms like I liked, interesting, attractive, gratifying, enjoyable, positive, very cool, fantastic.	30	19	49
	ACKNOWLEDGEMENT: Recognition, thanks to teachers for the effort, design and organization.	20	9	29
	DIDACTIC: Indicating that the experience is useful for learning, profitable, helpful, formative.	14	11	25
	PLAYFUL: Fun, entertaining, expressing that you learn by playing.	18	9	27
	INNOVATIVE: Also expressed with terms such as new, original, unusual, surprising, creative, different.	13	8	21
	TEAMWORK: Highlighting its importance, social contact, collaboration, coworking.	14	4	18
	CASES: Finding them interesting, of balanced difficulty, useful or of didactic value for active learning.	6	9	17
	SEMINAR. Emphasizing the interest in medical training, the educational value or the feeling of presence and dynamics as in the classroom.	11	4	15
	COVID: A good solution or adequate for the pandemic situation, which allows them to maintain social contact.	7	3	10
	T-SHIRT: Together with the picture contest, expressing that they liked it, thought it was a creative idea, or that it favors a good	3	1	4

	atmosphere.			
	GUIDELINES: Highlighting that they were good, useful or detailed.	4	-	4
	2D PLATFORMS: Preference over 2D platform platforms such as Zoom, Google Meet, Microsoft Teams, etc.	-	2	2
DISADVANTAGES				
	TECHNICAL PROBLEMS: Due to the computer or the Internet connection, the program does not run well.	22	20	42
	- Mild or occasional	15	15	30
	- Serious (prevents executing SL)	7	5	12
	- Of them, resolved	6	4	10
	SECOND LIFE: Running SL is complicated, even stressful. They feel that they are not used to it or that they do not handle the interface well. A learning curve is necessary	13	11	24
	DRESSING UP: The tasks of dressing the avatar are difficult and/or complicated, time consuming and not important to them.	8	9	17
	TIME: This activity becomes more complicated in the last year of the degree, in which there is a lot of occupation with other activities and tasks.	1	15	16
	FACE-TO-FACE: Preference for face-to-face seminars in the real world.	5	6	11
	CAMERA: Problems using the camera (avatar vision) and seeing the images properly.	6	4	10
	NOTECARDS: Problems sending notecards	-	2	2
	2D PLATTFORMS: Preference for 2D online platforms, such as Zoom, Google Meet, Microsoft Teams, etc.	1	1	2
SUGGESTIONS				
	VOLUNTARY: Proposal that these activities be voluntary, even on vacation.	-	7	7
	OTHER PLATFORMS: To be used as a resource when Second Life fails or there are connection problems.	3	1	4
	MORE CASES: Include more cases, with more modalities, such as ultrasound, breast imaging, etc.	2	1	3
	TRAINING SL: Provide training on handling SL in medical school, including tricks, handling avatars, etc.	2	2	4
	MODIFICATIONS: Slight modifications to the current experience related to scheduling, team building, or information	2	2	4
	SL PROPOSALS: New gamification proposals, learning strategies and radiology repositories. Even do all the clerkship seminars in SL.	4	-	4
	PATIENTS: Add virtual patients to OSCE stations	1	-	1
	COMPUTERS SL: Enable computers with the SL viewer in the Faculty of Medicine.	-	1	1
	UBIQUITY: Carry out the experience with	-	1	1

	professors and students from other universities.			

Discussion

Principal Results

Today's radiology students have different learning styles compared to previous generations, preferring to shift from the traditional lecture-based approach to more active learning methods that engage them more effectively [17]. This study presents a new educational experience for sixth-year medical students, conducted in SL during a two-week radiology clerkship and replicated over two academic years, which integrated various active learning components, such as case-based learning through virtual OSCE stations, team-based learning, competitive game-based learning, and synchronous virtual seminars.

Case-based learning connects theoretical knowledge with the clinical environment and encourages students to think like doctors. By reflecting on radiological images through clinical cases, students can appreciate the role of radiology in patient care [17]. The 24/7 availability of the content in SL enables the organization of asynchronous tasks, such as the 9-day period for evaluating OSCE cases in this study, adapting to students' study schedules, an essential factor for reflection and self-regulated learning [18]. Team-based learning is particularly suitable for visual topics like radiology, as it promotes and facilitates group discussion of complex, real-life radiological cases [19]. Teamwork dynamics are vital in undergraduate medical training, as they foster collaboration among students with varying levels of knowledge and experience [20,21].

Virtual world technologies, such as SL, make avatar-mediated student assessment in simulated 3D scenarios technically feasible to set up and run. This has been demonstrated in home accident scenarios in geriatric medicine [22], as well as in office or hospital settings [10], but has never been used to replicate scenarios for learning radiology. In this study, seven OSCE stations were developed to simulate clinical scenarios involving medical emergencies, providing students with a variety of cases. The environment created allowed students to work in groups remotely at significantly lower cost than a similar scenario in the real world.

The educational activity in this study includes a significant component of competitive team gamification, a cooperative learning technique that enhances students' motivation and focus on learning tasks [21], combining group rewards with individual responsibility [20]. According to self-determination theory, motivation has two components [23,24]: intrinsic motivation, defined as participation in an activity because it is found to be inherently interesting and enjoyable, and extrinsic motivation, where participation is driven by external factors such as rewards, promotions, or the avoidance of academic failure. Competition is a powerful extrinsic motivator; however, it is criticized for creating high-pressure environments that reduce intrinsic motivation and hinder optimal learning [25]. Previous studies have shown that multi-user competitive games developed in SL through asynchronous activities can enhance medical students' learning of basic radiological content, such as anatomy and semiology, and that students find these games highly beneficial for their training as physicians, both when competing individually [5,26] and in teams [27]. This study proposes a different approach to learning games, incorporating clinical content commonly found in medical practice, centered on case resolution through teamwork and supplemented by synchronous discussion and debate activities. In both courses, students recognized and appreciated the educational value of the Rainbow-Game experience.

Second Life is an appropriate environment to develop oral communication skills in clinical radiology through the presentation and discussion of content [28]. In this study, effective communication was forested through group discussion and reflection on the cases. The experience concluded with a seminar on emergency radiology to reinforce students' knowledge and clinical reasoning. Seminars conducted in SL provide a strong sense of co-presence and have an educational impact comparable to those held in person, as long as the same objectives, content, and script are maintained [29].

Emergency radiology is an essential part of the undergraduate medical curriculum, ensuring that students can recognize major radiological emergencies [30]. In this study, students delved into clinical reasoning on cases commonly found in hospital emergency settings, achieving good results on the cases assigned to each team, with differences mainly related to the difficulty of the cases (Figure 4). This provides a measure of student performance on clinical cases in the final year of medical school. In contrast, the seminar exam questions were scored poorly due to limited response time and possibly an excessive number of items on the assessment checklist (see Appendix 1). Students in 2021-22 performed better on the cases than those in 2020-21 and reported a lower cognitive load to solve them. This could indicate that they were better prepared for this type of tasks; however, they performed worse on the seminar questions, and there were no significant differences in the academic grades for the clerkship, so some leakage of results from one year to another cannot be ruled out.

In general, the students perceived the experience as innovative and appropriate for their training, and they valued the selected cases, design, and organization positively. They acknowledged working as a team and, in their comments, highlighted their appreciation for the experience and recognized its didactic and playful aspects. The main disadvantages noted were technical problems and tasks inherent to SL, such as dressing the avatar. Some students found the time dedicated to this activity excessive, particularly in the 2021-22 academic year, where perceptions were generally lower than in the previous year. This difference in perception may be attributed to the timing of both experiences during different phases of the COVID-19 pandemic. In the first semester of 2020-21, students faced a stressful situation with restricted in-person academic activities, where online solutions were seen as essential for teaching. One year later, teaching had partially normalized, with some precautions still in place, but there was a certain sense of fatigue from the overuse of online activities [31]. This may have contributed to a greater perception of workload among the students and, consequently, a lower appreciation of the learning experience.

Comparison with Prior Work

This type of learning experience may be less appealing to those who are not drawn to gamification and technology. In fact, it has been shown that mandatory participation in gamification activities in SL can lead to a lower perception and acceptance of the game by a proportion of students [26]. Mandatory activities contribute to the extrinsic motivation of medical students, but “imposed” gamification has a counterproductive effect, described as “mandatory fun” [32]. User acceptance of 3D virtual world technology is positively influenced by their perception of the ease of use, usefulness, enjoyment, and visual appeal of a virtual learning environment, which significantly impacts student satisfaction, learning outcomes, and retention [33,34]. Most participants in the Rainbow-Game found the experience interesting and suitable for learning, and more than half found it fun. However, some students may not have perceived sufficient reward in a compulsory learning game. Therefore, the option for the best team in each group to earn an additional point on their academic grade compensates for this by providing an extrinsic motivation.

Limitations

The main limitation of this experience, consistent with previous studies [14,29], was the presence of technical problems with the computers and the online connection needed to run SL correctly, as recognized in the open comments of 13% of the questionnaires. However, two-thirds of these issues were minor or occasional problems, and a third were resolved through simple solutions, such as borrowing a computer or using a cable connection. Since SL is developed as computer software, it requires suitable hardware that meets minimum requirements. Additionally, SL is an Internet-based technology with a client/server structure, which relies on stable Internet connectivity. Despite the significant increase in Internet access for higher education students, many still face restricted connectivity [34]. Another limitation to consider is that this study was conducted at a single institution. Although the experience has been replicated over two academic years, it would be valuable to see if it could be implemented elsewhere, which would require the cooperation of professors from other institutions and the inclusion of the project in the teaching guide for the corresponding courses.

Conclusions

This study demonstrates how a mandatory game-based learning experience in SL can be added to the formal teaching organization of a radiology clerkship. Training in case resolution, peer discussion, and attending a seminar on emergency radiology provides added value to the educational objectives of this clerkship in the final year of the degree. The design of the cases and OSCE stations, along with the positive perception of students, is another added value. The immediate continuation of this project, which has already been completed and is pending publication, involved the development of individual, synchronous radiology OSCEs conducted over a restricted period of several minutes per station, emulating face-to-face OSCEs, like those carried out at the end of the degree [35].

In conclusion, this study presents a game-based radiology learning experience conducted in the SL virtual world, integrating simulated case-based learning in virtual OSCE stations, team-based competitive learning, and synchronous group sessions. The experience, adapted to a radiology clerkship, is feasible and reproducible, promoting clinical reasoning and teamwork among students in a playful context that they recognize and value highly. Additionally, it is worth exploring the educational potential of OSCEs in 3D virtual environments for radiology and other medical disciplines.

Acknowledgements

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: Universidad de Málaga / CBUA. The authors also want to acknowledge the students who participated in this study and voluntarily sent the project assessment questionnaires.

Conflicts of Interest

None declared.

Abbreviations

3D: Three-dimensional
COVID-19: Coronavirus Disease-19
OSCE: Objective Structured Clinical Examination
SL: Second Life

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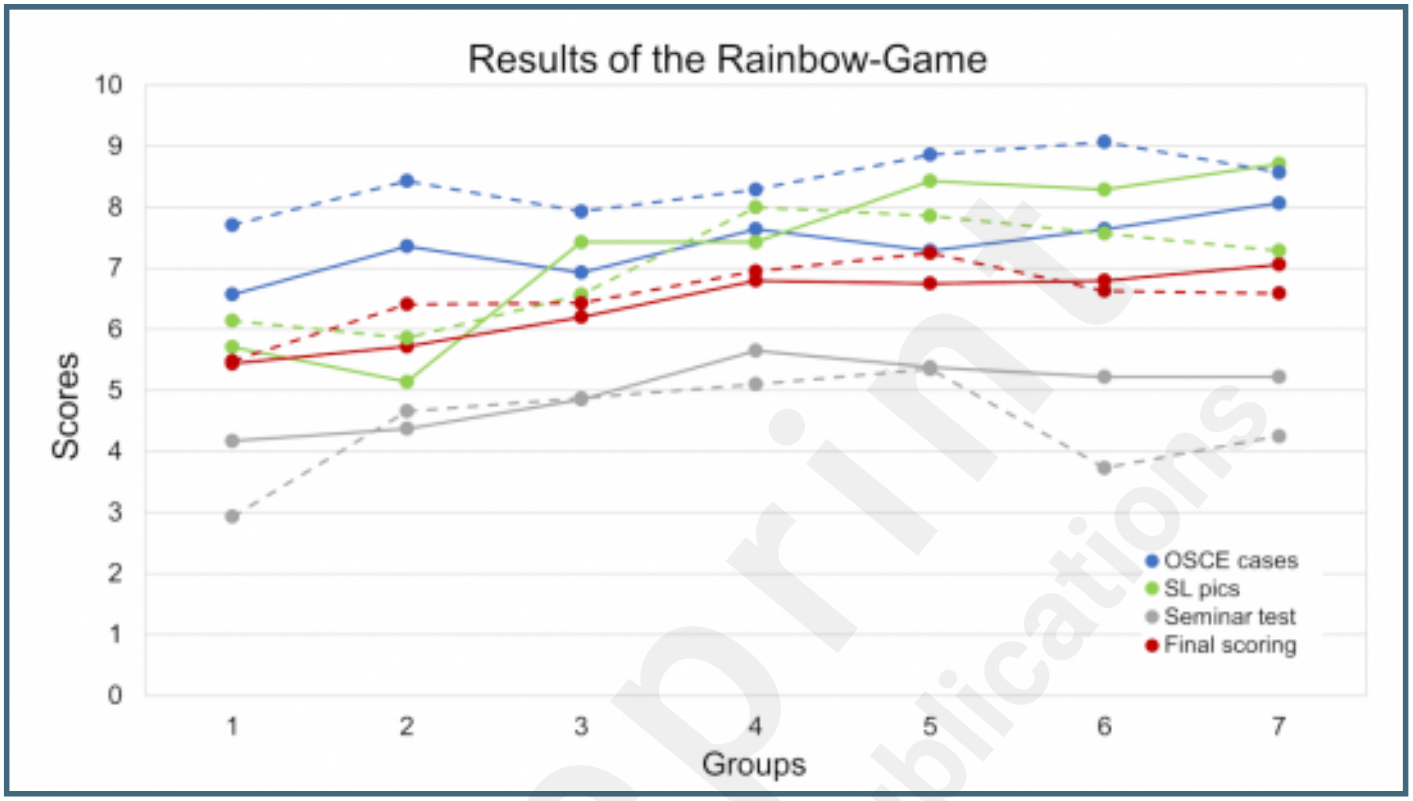
Supplementary Files

Figures

Various scenes during the Second Life virtual world experience. A: Aerial view of Medical Master Island with a flying avatar in the foreground. In the background, the main building, where the synchronous seminars were held, can be seen. B: Example of an OSCE station set up as a radiology room, with a team of students reviewing a head CT case. The description of the clinical situation and the tasks to be performed are displayed on the wall. C. Scene during a synchronous meeting with a student group, reviewing one of the OSCE cases. D: Screenshot submitted by a team of students as part of the competition.

A chest X-ray corresponding to case number 3 shows complete opacification of the left hemithorax due to atelectasis of the left lung caused by bronchial carcinoma. The clinical situation presented to the students is that of a 65-year-old woman who went to the emergency department due to progressive dyspnea occurring with minimal effort, reporting weight loss over the last month. Her personal history includes smoking and dyslipidemia. On examination, she is conscious, oriented, and cooperative, with mild respiratory retractions. Global hypoventilation in the left lung is noted. O2 saturation is 85%. She is afebrile. An imaging test is performed. Tasks to be carried out included describing as accurately as possible the imaging technique used and the pathological findings, establishing a differential diagnosis, and outlining the clinical approach to the suspected condition. Indicate what other tests would be required and why.

Scoring of the different components of the Rainbow-Game educational experience. The final scores were obtained by considering the percentage contribution of the OSCE cases (40%), the SL screenshots (20%), and the seminar test (40%). The points represent the mean values of the seven teams in each group. The solid line corresponds to the 2020-21 academic year, and the dashed line to 2021-22.



Bar chart with the average score obtained for each case over two consecutive years. Each year, 6 teams evaluated the cases, except for case 1, which was evaluated by 8 teams. Error bars represent the standard deviation. Statistically significant differences, with P < .05, are identified with the letter ‘a’.

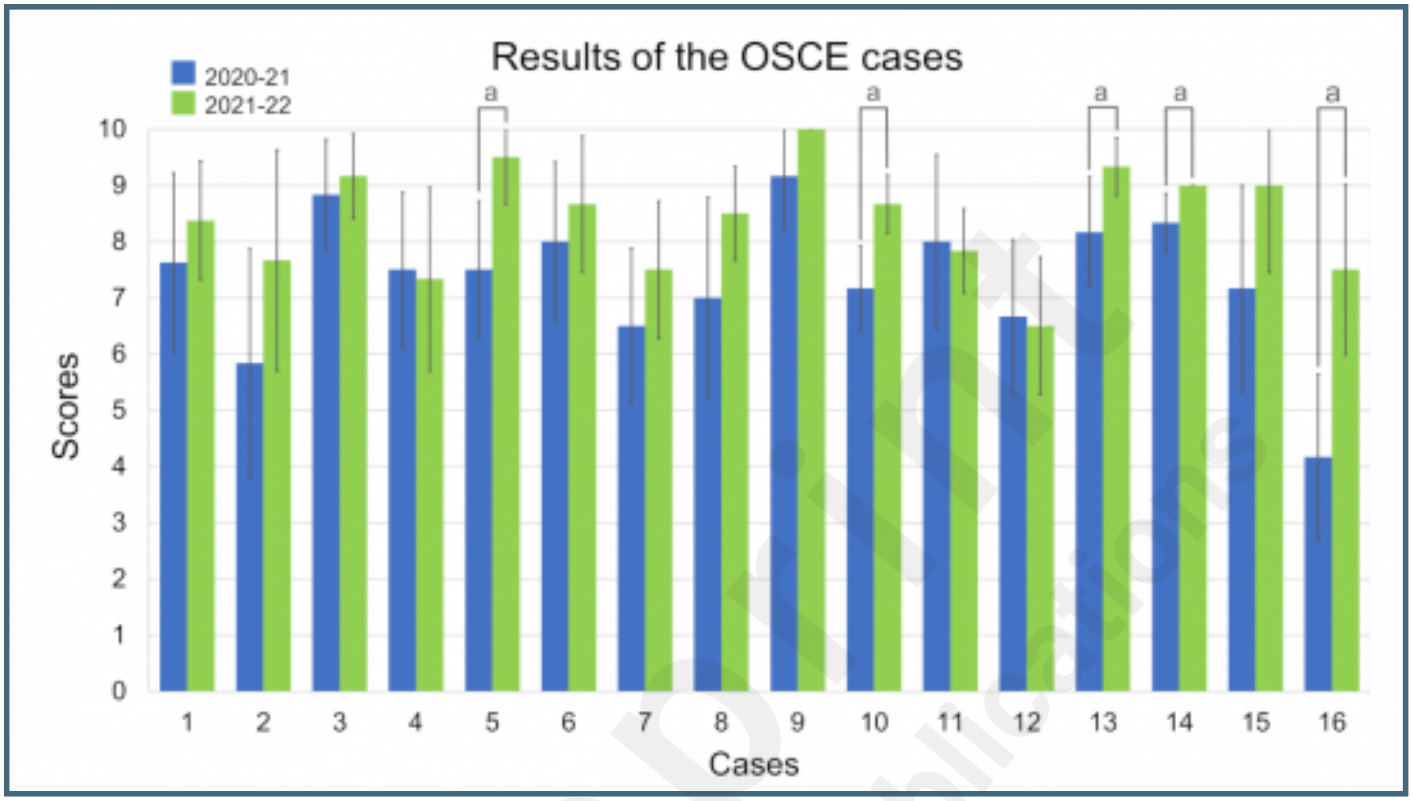
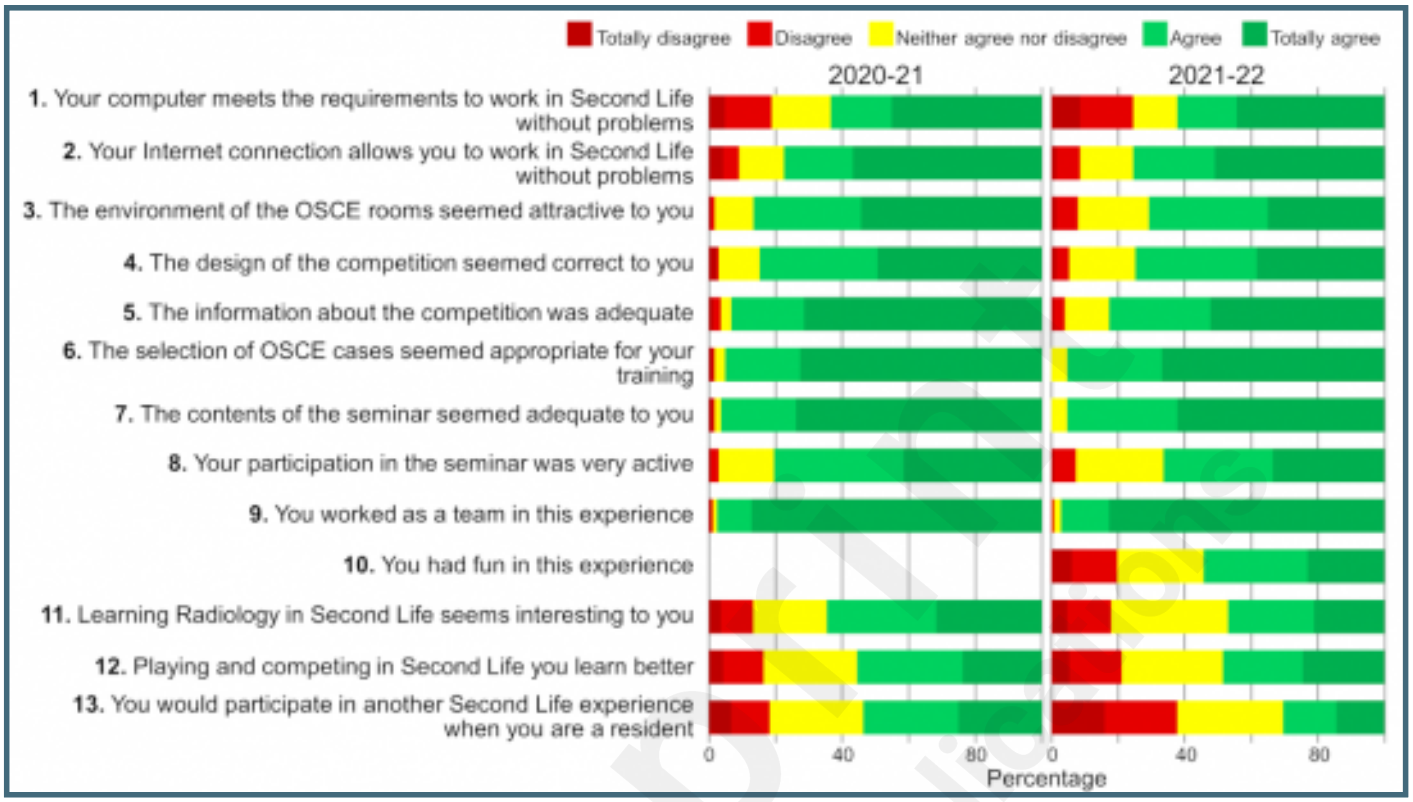


Diagram showing the degree of agreement, expressed as a percentage, reached each year in the responses to the experience evaluation questionnaire, which used a 1-5 Likert scale.



Multimedia Appendixes

Presentation of the seminar exam cases, and the checklist used for their correction.
URL: http://asset.jmir.pub/assets/8a17d846f6a9b94beaf9fbe81d2551fb.pdf

Perception questionnaire on the Rainbow-Game experience.
URL: http://asset.jmir.pub/assets/182d792d9b57b5d38011cb0b98389eaa.pdf