

UPDATE IN RADIOLOGY

Gamification: Basic concepts and applications in radiology

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Received 30 August 2022; accepted 2 October 2022

KEYWORDS

Gamification;
Games;
Medical education;
Radiology;
Medical students;
Residents

Abstract Gamification is the use of elements from games in non-game environments, such as education. It is an alternative educational focus that promotes students' motivation and participation in the learning process. Gamification has proven effective in training health professionals and can play an important role in diagnostic radiology training, both at the undergraduate and postgraduate levels. Gamification activities can be carried out in real environments, such as classrooms or session rooms, but there are also interesting online modalities that favor remote access and user management. The possibilities of gamification in virtual worlds to teach undergraduate students radiology are very promising and deserve to be explored in training residents. This article aims to review general concepts in gamification and to present the main types of gamification used in medical training, pointing out its applications and advantages and disadvantages and emphasizing experiences in radiology education.

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PALABRAS CLAVE

Gamificación;
Juego;
Educación médica;
Radiología;
Estudiantes de
Medicina;
Residentes

Gamificación: conceptos básicos y aplicaciones en Radiología

Resumen La gamificación consiste en el empleo de elementos de los juegos en entornos no lúdicos, como la educación. Es un enfoque educativo alternativo que fomenta la motivación y la participación de los estudiantes en su proceso de aprendizaje. La gamificación ha demostrado eficacia en la formación de profesionales de la salud y un papel importante en la formación en radiodiagnóstico, tanto en pregrado como en posgrado. Las actividades de gamificación pueden realizarse en entornos reales, como aulas o salas de sesiones, pero existen interesantes modalidades online que favorecen el acceso remoto y la gestión de usuarios. Las posibilidades de

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gamificación en mundos virtuales para aprender radiología en pregrado son muy prometedoras y merecen ser exploradas con residentes. El objetivo de este artículo es revisar conceptos generales de gamificación y presentar los principales tipos empleados en formación médica, destacando sus aplicaciones, ventajas e inconvenientes y enfatizando experiencias educativas en radiología.

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Introduction

Games are an intrinsic part of learning and cognitive development during childhood¹, but interesting results have also been obtained when they have been applied in the adult world, specifically in terms of gamification². The term gamification was coined by computer programmer Nick Pelling in 2002, who defined it as the use of game elements and designs in non-game environments³, including contexts such as user interfaces, market research, business profits, and also education. It is worth mentioning some related concepts before focusing on the concept of gamification itself. Activities known as 'serious games', 'educational games' or 'learning games' are specifically designed to enhance learning in various educational and training environments, such as the military, government, different levels of education, business and health care². Game-based learning is considered to be synonymous with—or a sub-category of—serious games⁴ and often refers to digital games⁵, which help students achieve learning objectives through immersive and engaging learning experiences.

Gamification activities feature a set of game-like rules, rewards and achievements that, when coupled with cooperative competition, make for an overall more enriching experience. They have been used in a variety of fields such as education, social sciences, health and technology⁶. Their application in educational settings attracts a great deal of interest because they increase student engagement in learning, thanks to the fact that educational games are considered to be fun and intrinsically motivating^{7,8}. The aim of gamification is to enhance user participation and improve specific outcomes such as engagement, social interaction, productivity and learning⁹. The aim of this article is to review the main types of gamification used in medical training, with an emphasis on examples from radiology training. It will also highlight the main applications of this methodology and its advantages and disadvantages in the learning process.

Advantages and disadvantages of gamification

Due to its appealing nature, gamification helps increase motivation to perform tasks that may usually be thought of as tedious. Learning new concepts while having fun increases motivation, which is an essential aspect of the learning process¹⁰. Furthermore, gamification can

improve attendance and increase participation as it encourages teamwork, which in turn leads to students working together to achieve objectives, often surpassing expectations. A further advantage to the teamwork element is the promotion of group cohesion, given that this type of experience generates a sense of belonging to a group in which everyone helps each other to achieve common goals¹¹. Moreover, it develops relationships and communication skills which help broach problems from different perspectives.

Academic performance is also improved, thanks to the way gamification complements theoretical and practical classes. Gamification facilitates the understanding and long-term retention of educational content¹² and it also has the additional advantage of generating engagement with the work and exams set.

In terms of disadvantages, one of the main drawbacks of gamification can be the resources needed to implement it. A significant budget is required for the teaching material, due to the high production costs, and the cost of the corresponding maintenance and periodic updates.

As with any other educational activity, time has to be invested in content creation, in addition to the time spent on the activity and teacher supervision. It is also true that focusing too much on gamification aspects can distract students from the main objective, leading to lower academic performance.

If some students do not participate as much as others, they may drop out during the process. Similarly, students may become demotivated once the initial novelty has worn off. As in any game, excessive competitiveness or cheating can occur, contrary to the educational values of the game with the latter even potentially distorting the desired results.

Educational psychology theories applied to gamification

Werbach and Hunter¹³ describe three basic elements of gamification ([Fig. 1](#)): dynamics (such as emotions, narrative and game progression), mechanics (such as cooperation, competition and rewards), and components (such as points, leaderboards and levels). When combined, these elements can influence people's behaviour and boost motivation.

According to self-determination theory¹⁴, there are two kinds of motivation: extrinsic motivation, which is based on incentives or the expected consequences of an action,

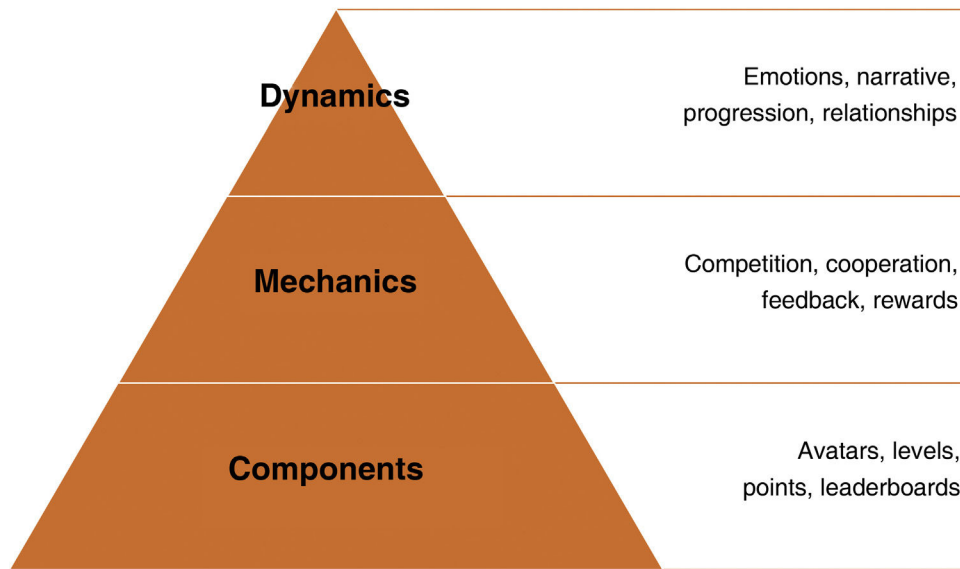


Figure 1 Pyramid of gamification elements. Dynamics: the 'big picture' aspects of the gamified system that have to be considered and integrated, but which are not directly included in the game. Mechanics: the basic processes that drive the action forward and generate player engagement. Components: the specific instantiations of the game mechanics and dynamics. Adapted from Werbach and Hunter¹³.

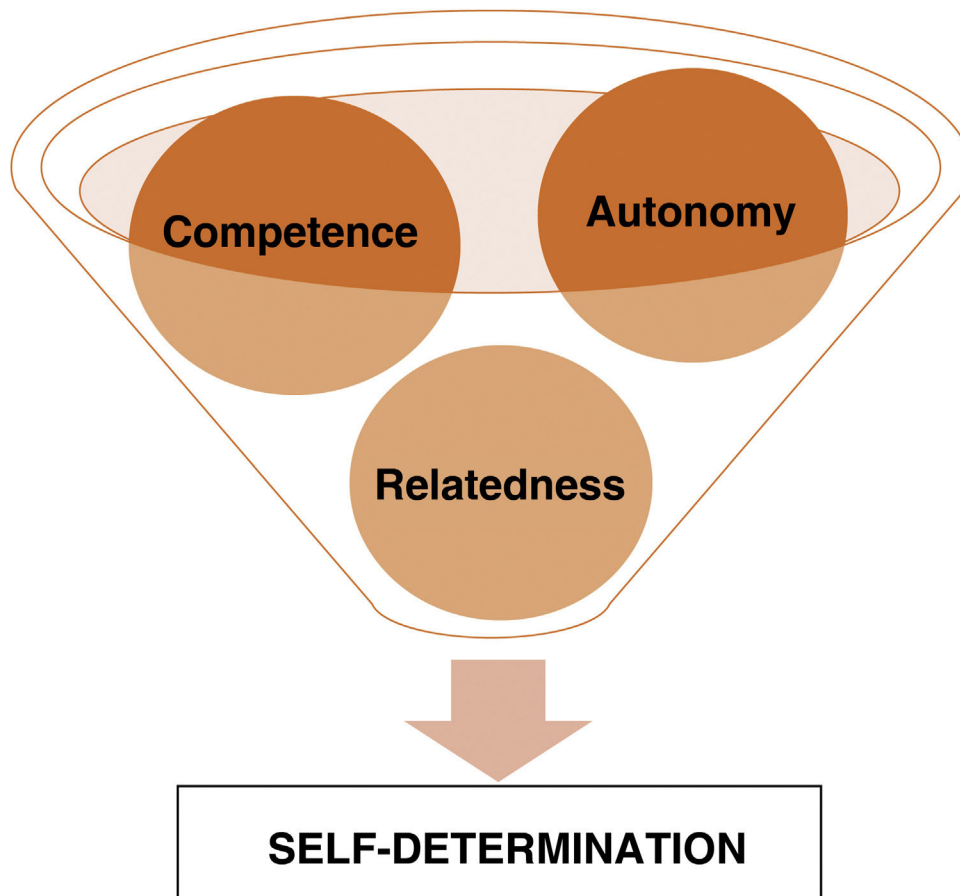


Figure 2 Self-determination theory according to Edward L. Deci and Richard Ryan. Competence: the experience of mastery and being efficient in one's activity. Autonomy: the feeling that one has choice and voluntarily endorses one's own behaviour. Relatedness: the need to feel a sense of connectedness and belonging to a group.

Table 1 Keys to incorporating gamification in medical education.

Make learning fun and engaging
Appeal to intrinsic and extrinsic motivation
Incorporate progression mechanics
Use a narrative structure
Make learning experiential
Develop effective feedback
Ensure sustainability and reproducibility
Use technology and devices
Repetition is essential for learning
Competition can enhance motivation
Focus on collaborative learning
Integrate different types of players

and intrinsic motivation, which is derived from accomplishing the action for its own sake. Both should be taken into consideration in gamified educational systems. Humans tend to seek out activities to satisfy their intrinsic motivational needs which include: competence—the ability to do something successfully or efficiently; autonomy—the feeling of being in control; and relatedness—a sense of connectedness to others¹⁴ (Fig. 2).

Motivation is associated with a number of concepts related to learning, such as engagement, effort, goals, concentration, self-efficacy, confidence, achievement and interest¹⁵. A better understanding of the motivational aspects of gamification will help us to improve the way we design gamified experiences that boost the motivation of our target student population and lead to desirable learning targets⁸ (Table 1).

Intrinsically motivated people (those with an internal motivation to learn) are usually more engaged, retain information better and are generally happier than extrinsically motivated people (those driven by external forces, such as pressure from team members or a desire to win a competition). In fact, in certain circumstances, extrinsic rewards and competition can be counterproductive and even diminish pre-existing intrinsic motivation¹⁶.

Gamification in medical training and radiology teaching

Gamification helps medical students learn a subject by motivating them to study and helping them remember what they have learned¹⁷. Fig. 3 shows the different kinds of gamification that can be applied in medical training. Some studies contend that gamification should be integrated into all medical curricula¹⁸. Today's medical students are more accustomed to using technology. Rather than passively receiving information, they tend to be more interactive in the learning process and they prefer to be actively involved. New technological advances, such as simulations, virtual worlds and augmented reality, have led to an unprecedented transformation in education. There seems to be a consensus in the literature that gamification is at least as effective as conventional teaching. However, several authors have also agreed that there is a need for further research to compare it with traditional teaching methods¹⁹. Different medical spe-

cialities have recently started to incorporate gamification into their own curricula, for example in otolaryngology²⁰ and general surgery²¹, as well as radiology²².

Gamification can be used to motivate postgraduate radiology trainees in their day-to-day training because it enables them to fit their study tasks into their busy schedules and because it allows them to monitor their learning progress. The simulation-based model of gamification provides opportunities to learn surgical techniques, while improving self-confidence and decision-making skills, for example, in thoracic surgery²³. It would be interesting to explore using this learning model for the various skills involved in interventional radiology.

Gamification in the classroom and other real-life scenarios

Games in the classroom break up the usual dynamics of these academic settings. Competition creates an incentive for learning through play, although excessive competitiveness or an obligation to play can be construed as a disadvantage and may cause some students to reject the activity²⁴. Both individual and team competitions can be proposed, with the latter having the advantage of stimulating collaboration^{25,26}. Presented below are various gamification models that are used in real-life environments.

Student response systems

The first student response systems used interactive remotes, known as clickers, which required a corresponding receiver system and dedicated software to gather the responses from the remotes. By developing questions and managing responses, they allow entertaining activities to take place in the classroom. They are useful for connecting up ideas, encouraging classroom participation and gathering data^{27,28}. Their prolonged use as a learning method in radiology studies is being explored by the PECORAD (Perceptions and Knowledge of Radiology) project which poses questions to medicine students on the speciality, the different subspecialties, diagnostic imaging and radiology anatomy^{29,30}.

More recently, digital educational applications such as Kahoot!^{®17,31} and Socrative^{®32} have been developed for mobile devices, thus eliminating the need to purchase clickers, receivers and connection software. Participants use a PIN to gain access to the application in real time and the questions can be projected in the classroom, with multiple answers displayed in various colours and formats. Points are awarded when you provide correct answers and bonus points are awarded if you answer quickly or if you get a streak of consecutive correct answers. At the end, your ranking is displayed in a leaderboard. The advantages of this kind of educational gamification are the simplicity of its use and the increased motivation for attendance and participation. The disadvantages include technical connectivity issues and reduced communication between students^{17,31,32}.

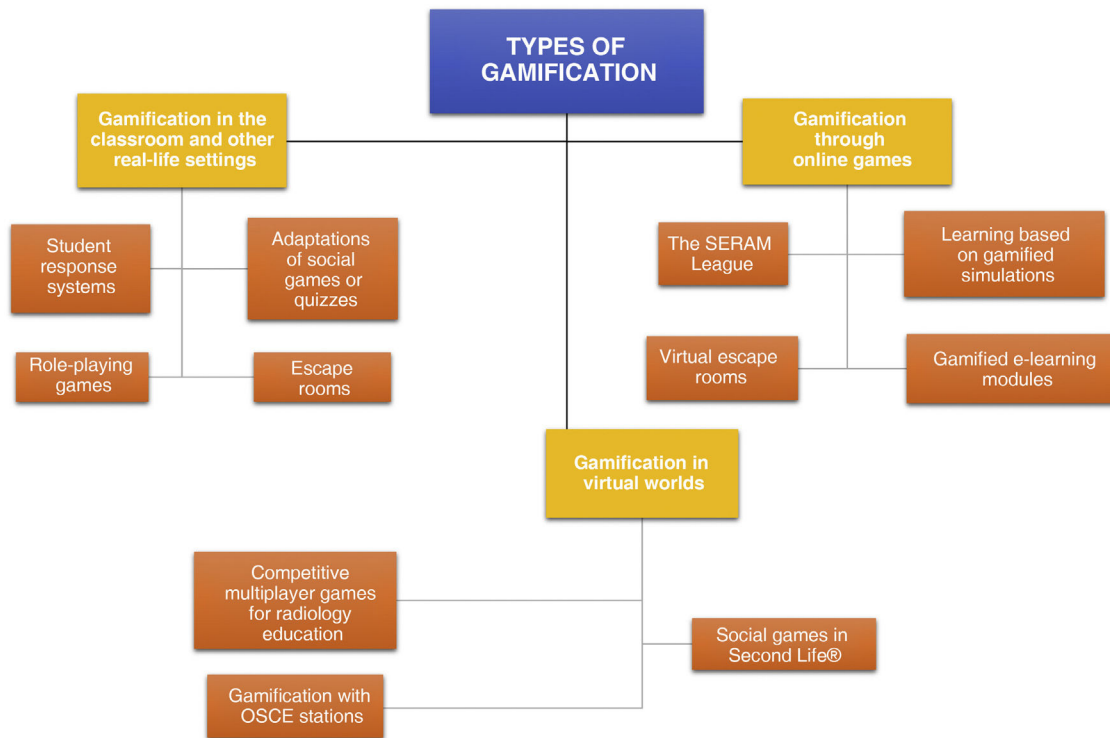


Figure 3 Vertical linear flowchart showing the classification of gamification types.
SERAM: Spanish Society of Medical Radiology; OSCE: Objective Structured Clinical Evaluation.

Adaptations of social games and quizzes

Famous quizzes and board games are social activities that can be adapted for gamification experiences in the classroom. They have the advantage that students usually know the basic rules of the game and this facilitates their incorporation. For example, adaptations of card games have been used in clinical simulations³³, bingo adaptations have been used for learning non-technical clinical skills³⁴ and adaptations of the TV quiz show 'Who Wants to be a Millionaire?' have been used to learn pharmacology³⁵. Indeed, a variety of quizzes can be adapted to higher educational settings, including the Spanish TV word game 'Pasapalabra®', 'Wheel of Fortune®' and 'Lingo®' among others³⁶. The well-known board game, Trivial Pursuit®, commonly adapted for team games in pubs and other entertainment venues, has been used as a teaching tool³⁷ in classrooms and more specifically, at student radiology conferences between 2015 and 2019 in Malaga, Barcelona, Madrid and Murcia. Trivial Pursuit®, as with many other similar board games, has a strong teamwork component where collaboration and game strategy are encouraged in addition to having fun.

Role-playing games

Role-playing games provide opportunities for exploring non-interpretative skills, in which participants take on different roles (such as patient, radiology trainee or specialist doctor). When used in university training programmes^{38,39}, they

provide students with valuable experiences that prepare them for challenging situations which can arise during their clinical placements. With role-playing games, these situations are reproduced in a safe environment before they are actually encountered in the real world⁴⁰. It would be very interesting and beneficial to incorporate these kinds of experiences into diagnostic imaging training, so that students (or radiology trainees) are made to address clinical situations from different perspectives such as the referring doctor, the radiologist, the patient or the patient's family member.

Escape rooms

An escape room is a physical space where several puzzles are set up in a "locked" room. In recent years, this kind of activity has been very successful in the leisure industry. Participants are encouraged to communicate and work as a team to solve the puzzles which will eventually allow them to "unlock" the room and escape. Several escape rooms have been designed for the gamification of various medical specialties^{41,42}.

In 2018, an escape room designed for radiology trainees was presented at the Radiological Society of North America (RSNA) conference⁴³. It was played by 144 radiology trainees from more than 10 different countries. The game consisted of four sets of puzzles that had to be solved in less than an hour. A qualitative evaluation was carried out for the skills, which were divided into participation, collaboration, creativity and critical thinking. The result was

very positive and the participants awarded it a high satisfaction score (4.85 out of 5 points). In another escape room designed to test medical undergraduates on paediatric radiology⁴⁴, 19 medical students from two universities had to complete a challenge in a maximum of 30 min, and tests were carried out before and after the activity to assess knowledge retention. Feedback on the escape room was remarkably positive (9.14 out of 10 points) and the increased knowledge retention was maintained for up to two weeks later.

Escape rooms encourage teamwork, critical thinking, creativity and the use of interpersonal communication skills. The flexibility and reproducibility of their design are two advantages for medical education settings. In addition, their difficulty level can be adjusted for different groups of participants.

Gamification through online games

The internet provides opportunities for many online gamification initiatives with advantages such as remote participation, the management of large numbers of participants, the gathering of data, and gaming events^{45,46}, in both synchronous and asynchronous contexts.

Learning based on gamified simulations

Medical simulations are an educational method that provide students with opportunities to rehearse clinical experiences or situations in a controlled environment that mimic real life as closely as possible^{47,48}. They can be used to train technical skills. For example, the SonoGames ultrasound simulator games were developed with a focus on the acquisition and interpretation of ultrasound images. The first edition was run in 2014 with 73 emergency medicine trainees who undertook a four-hour activity structured in three stages. Practical skills such as teamwork, decision-making and communication were taken into account⁴⁹. In the 2021 edition, a similar format was used with 30 radiology trainees. Overall, the results indicated that knowledge levels, motivation and the students' use of ultrasound technology improved thanks to the gamified simulation⁵⁰.

In another study on simulations in radiology education⁵¹, 20 emergency medicine trainees took part in a four-hour "boot camp" made up of three e-learning modules⁵²: RadTutorials—tutorials on strokes, cervical spine injuries, female pelvic ultrasounds and tubes and lines; RadGame—a game about thoracic imaging findings; and ICARUS, more specifically the simulation-based modules on obstructions in the small intestine⁵³. The experience was perceived to have had a positive impact on learning; it was rated as a valuable resource for the future; and participants said they would recommend it to other trainees.

Gamified e-learning modules

E-learning involves IT-based training that does not require the teacher and student to be in the same physical location at the same time. Several gamified online modules

have been designed for teaching radiology. One of the first examples was a breast radiology game developed in 2002 with a web-based design⁵⁴. Forty-two fourth-year medical students participated in 16 case scenarios. Surveys revealed that this experience contributed educational value and reinforced the learning that happened in conventional lectures. In 2017, another online module was created to improve the detection of abnormal findings on chest radiographs using game-like elements as an additional support for learning⁵⁵. Sixty participants, which included medical students, trainees and specialists, attempted to solve 74 cases in 20 min. The authors concluded that a gamified online module can improve abnormality detection rates among users who have scant chest radiography experience. In 2020, another online module was developed for the detection of pneumothorax. It included 195 cases⁵⁶ and was completed by 126 medical students, radiology trainees and technicians. The game was called RapRad due to the rapid succession of cases and it incorporated different gamification elements such as avatars, points, progress bars and a leaderboard. It was concluded that this online approach can improve diagnostic confidence and reduce error rates in the detection of pneumothorax in a fun and entertaining way.

Virtual escape rooms

During the pandemic, the American College of Radiology designed an online escape room that can be found on its website⁵⁷. It has two possible levels of difficulty, one for first- and second-year medical students and the other for radiology trainees. It was designed to improve social skills and communication, improve awareness, increase levels of satisfaction and happiness, create unique memories, improve time management skills, and develop a team-oriented mindset along with problem-solving skills.

The SERAM League

The SERAM League is a project of the Spanish Society of Medical Radiology's (SERAM) Working Group of Trainees⁵⁸. It consists of a clinical case competition for teams of diagnostic imaging trainees and its aim is to boost their learning in different areas of radiology. The first edition of the competition took place between October 2021 and May 2022, with participation from 145 teams of radiology trainees. The first of two phases was held on a monthly basis on an online platform, with participants from two associations (Spanish and Inter-American). In the second phase, the three teams with the highest points competed in person at the SERAM conference in Malaga. Its gamification format encouraged participation through a points system with a visible leaderboard and prizes which were awarded to the top three finalists, the winning team and the best clinical case submitted.



Figure 4 Screenshots with gamification scenes in the Second Life® virtual world. Above: students competing in the League of Rays game, viewing three slides with teaching content (left) and team members reviewing an individual quiz together (right). Below: students attending a session of the game *Pasapalabra*® (left), one of the groups at the end of the ECOE-RX experience, after the final seminar.

Gamification in virtual worlds

A virtual world is a three-dimensional space reproduced on a computer screen, where users—through representations of themselves called avatars—can move, interact and communicate with others^{59,60}. A lot of interest has been generated in the use of virtual worlds for education, as they provide realistic ‘face-to-face’ communication between avatars⁶¹ and facilitate productive forms of collaborative learning^{62,63}. Virtual worlds provide interesting platforms for gamification, because the user’s immersion in the three-dimensional environment through their avatar is a kind of game in itself. Second Life® is considered to be the most popular virtual world among educators and it is the most widely used version in higher education. Many activities have been developed in Second Life® for the training of health professionals⁶⁴. Shown below are a number of radiology-based gamification experiences (Fig. 4).

Competitive multiplayer games for radiology education

The first radiology-based competitive multiplayer online game took place in Second Life® in 2015, with voluntary participation from 90 third-year medical students⁶⁵. League of Rays was set on a virtual island and it ran over the course of six weeks. Each weekly block covered anatomy and semiotics in either thoracic, abdominal, or musculoskeletal radiology. Participants were required to view the educational content during the first four days and take a 15-question quiz during the remaining three days. They were ranked according to the points they scored. In 2016 and 2017, 191 and 182

students respectively participated on a mandatory basis²⁴. The game was very well rated by the students and it proved to be a good support activity alongside their formal radiology training. However, in the mandatory experiences, the ratings were somewhat lower, probably due to the participation of a less motivated group of students. Later, the rules were modified so that students could compete in teams of four, thus encouraging collaborative learning⁶⁶. Three inter-university competitions were held between 2020 and 2022. The competitions received 652 student registrations, but the final number of competitors was 516 students (129 teams), originating from 21 Spanish universities. In each of the editions, the participants gave high ratings to the content, organisation and its usefulness for their training as doctors. Competitive radiology games designed for learning purposes and developed in 3D virtual worlds, such as League of Rays, have great teaching potential and it would be well worth exploring similar activities for diagnostic imaging trainees.

Social games in Second Life®

In 2021, due to the restrictions on hospital placements caused by the pandemic, various additional activities were proposed to students at the University of Malaga, including virtual classroom game sessions which took place in Second Life®. An adaptation of Trivial Pursuit® was developed for thoracic radiology, in which participants competed in teams, and an adaptation of the words/alphabet-based *Pasapalabra*® was developed with questions about the thorax, in order to support the learning of third-year medical students. Five two-hour sessions were held and 174 pupils

took part. The experience was rated very positively, with students appreciating the efforts invested, the fun nature of the games and the sense of having learned during the session. This experience demonstrated that typical classroom learning games can be reproduced in three-dimensional virtual environments which have the additional advantage of providing remote access, which was a useful solution for some of the issues formerly caused by COVID-19. However, 8% of the participants reported some technical problems⁶⁷.

Gamification with virtual OSCEs

Objective Structured Clinical Examinations (OSCE) are commonly used to assess the professional competence of medical students in their final year of studies^{68,69}. A typical OSCE test is composed of 10–20 individual stations, which includes at least one station which evaluates how the student handles the interpretation of complementary tests such as diagnostic imaging.

Over the last two academic years, a gamification experience has taken place at the University of Malaga, as a mandatory part of the sixth-year radiology rotation. It is called ECOE-RX and is based on virtual OSCE stations created in Second Life[®]. For this activity, seven successive groups of 24–28 students were subdivided into seven teams of 3–4 students, with each team named after a colour of the rainbow. Each team member was given a t-shirt in their team's colour for their avatar. The students had ten days to review seven OSCE stations that included virtual monitors with radiological images associated with a hypothetical emergency clinical case. On the ninth day, two cases were assigned to each team and a written response was requested. The students were also required to send screenshots from their computers with the highest possible quality and originality. A two-part Second Life[®] seminar was held on the tenth day. In the first part of the seminar, each team presented a case to their colleagues. In the second part, there was a short practical presentation on emergency radiology and several questions were asked at the end. Students showed great enthusiasm for the virtual presentation of OSCE cases, and they found this highly gamified activity interesting, captivating, fun, useful, and successful in the way it simulated reality and gave the sense of being there in person⁷⁰.

Conclusion

Gamification is an alternative approach that encourages motivation and engagement during learning, by incorporating game design principles into the educational environment. It can serve an important role as a complement to diagnostic imaging training, and it can be adapted to suit the level and learning objectives at both undergraduate and postgraduate levels. Gamification activities can take place in physical environments, such as classrooms, meeting rooms, seminars, or conferences, but there are also some interesting online formats that facilitate remote access and user management. These have gained relevance thanks to technological progress and the need to connect people during the COVID-19 pandemic.

The possibilities of using gamification in virtual worlds to support undergraduate radiology learning are very promising and it is also worth exploring its use with radiology trainees.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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