

Gamification in Radiology: A Systematic Review

Mohammad Kiani Feizabadi¹, Amir Mahdi Mafakherian², Ahmadrza Goudarzi³, Shadi Asadzandi^{4,5}, Mahshad Ahmadi¹,
Shoaleh Bigdeli^{6,7}

¹ Department of Medical Education, Tehran University of Medical Sciences, Tehran, Iran

² Department of Nano Chemistry, Tehran University of Science and Technology, Tehran, Iran

³ Department of Radiology Sciences, Isfahan University of Medical Sciences, Isfahan, Iran

⁴ Department of Medical Library and Information Sciences, School of Health Management and Information Sciences, Iran University of Medical Sciences, Tehran, Iran

⁵ Virtual School, Center for Excellence in ELearning in Medical Education, Tehran University of Medical Sciences, Tehran, Iran

⁶ Center for Educational Research in Medical Sciences (CERMS), Iran University of Medical Sciences, Tehran, Iran

⁷ Department of Medical Education, School of Medicine, Iran University of Medical Sciences, Tehran, Iran

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Abstract- Radiology gamification articles were examined to determine the purpose and effect of games on the target audience and to provide a basis for researchers who aim to develop a new gamification. The articles related to radiology gamification, games, and simulations were retrieved from databases, including ProQuest, Springer, Cochrane Library, Ovid, PubMed, Scopus, and Web of Science via electronic search. To assess the quality of the articles Prisma and CASP checklists were used. Finally, according to the inclusion criteria, the appropriate articles were selected. Among 6917 retrieved articles, only 13 articles were related to radiology gamification, two of which were related to the analysis of the effects of radiology gamification in different areas such as differential diagnosis, education, dental radiology, and the number of drugs taken for imaging. These studies show that radiology gamification is few, and there are different forms of gamification, including but not limited to board games, physical games, and video games. Furthermore, in designing an educational game, learner's characteristics, educational goals, and developing educational content are major steps.

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Introduction

During recent decades, education is reformed, and its new form and concept have emerged. In this regard, the traditional teacher-centered approach in which the teacher was conveyor of teaching materials within educational settings, and students were receivers and reservoirs of teaching materials has been changed. With magnificent changes in educational paradigms, today, there are various methods and instruments to facilitate teaching and learning, among which gamification is a newly emphasized one.

The term 'gamification,' first used by Nick Pelling in 2002 (1), is an umbrella for a broader concept of games. Generally, a game is a system in which players challenge abstract concepts (2); and, its environment has certain rules that are monitored by counting achievements of the

players. Moreover, gamification is the application of game elements in non-game contexts. (1,3-5) Gamification adds features of games such as target, rules, and regulations, entertainment, excitement, feedback, reward, and progress to the real commercial or educational environments (6).

The proper game design facilitates active learning (7), fulfills educational or commercial needs (8), creates an interactive educational environment (9), increases motivation, critical thinking and problem-solving skills (10), permits repetition and facilitates test-taking (11), and improves learners' skills (12). Since games have specific mechanics that result in excitement, encouragement, and punishment, they are appropriate tools for education, and their use are highly advised (13). Tracking brain functions by FMRI2 indicates that after playing games, the brain becomes more active, and its

Corresponding Author: Sh. Bigdeli

Center for Educational Research in Medical Sciences (CERMS), Iran University of Medical Sciences, Tehran, Iran
Tel: +98 21 88622601, Fax: +98 21 88622607, E-mail addresses: bigdeli.sh@iums.ac.ir; sbigdeli@alumni.sfu.ca

Gamification in radiology

prefrontal, and parietal lobes are more productive as the result of game reward (14). In addition, gamification has been used in many areas of medical sciences, and its effectiveness has also been studied widely (15-18).

Similar to nursing, dentistry, and medicine (19), radiology, as a medical discipline, has employed gamification for its purposes. Radiology is a new dynamic medical specialty that uses rays (e.g., X-ray) to diagnose and treat patients and abnormal conditions (20) by advanced imaging methods, and seeks effective educational aids for utmost learning (21,22). In this context, radiology management is crucial and addresses for its better understanding of radiology students and teachers and increases radiology workers efficiency. On the other hand, the realization of radiology history is attractive and informative for the field researchers.

Designing and developing radiology gamification requires an extensive literature review; therefore, this study is an attempt to review all radiology gamification systematically. In this study, all types of radiology gamification are examined to determine their purpose and features, their underpinning learning theories, and their impact on the target audience. Finally, the results of this study provide a clear view of history and clinical management in radiology gamification.

Materials and Methods

To retrieve articles related to radiology gamification and educational games, databases including ProQuest, Springer, Cochrane Library, Ovid, PubMed, Scopus, and Web of Science were searched electronically. The time limitation for searches was from the establishment of each database to 2017. In order to do advance searching, the following search strategy was used by applying Boolean operators, brackets, and truncation:

((("Radiology"[ti, ab] OR "CT"[ti, ab] OR "MRI"[ti, ab] OR "Sonography"[ti, ab] OR "Medical imaging"[ti, ab]) AND ("gamification"[ti, ab] OR "Game Based Learning"[ti, ab] OR "Digital game"[ti, ab] OR "Video game"[ti, ab] OR "Game(s)"[ti, ab] OR "Simulation"[ti, ab] OR "Gaming"[ti, ab] OR "Computer-assisted gaming"[ti, ab] OR "Serious Game(s)"[ti, ab] OR "Educational game(s)"[ti, ab] OR "Role-playing game(s)"[ti, ab] OR "Real-world game(s)"[ti, ab] OR "massively multi player online"[ti, ab] OR "role play simulation"[ti, ab] OR "story telling game"[ti, ab] OR "edutainment"[ti, ab])).

PICO is also considered; the population of this study was all people who associated with radiology gamification (doctor, radiologists, student, etc.).

Gamification tools are used as an intervention to compare this tool with other learning tools and finally study its effectiveness. The inclusion criteria included access to the full text of articles, English language, and articles classification under radiology gamification. The exclusion criteria included lack of access to the full text of articles and non-English articles. The retrieved articles are summarized in pre-designed forms, including name of author, title of article, time and location of publication, sample of research, design of article, purpose of study, type of game, and study results. To assess the quality of the articles, the Critical Appraisal Skills Program (CASP) checklists were used. Finally, according to the performed study and considering the inclusion and exclusion criteria, 13 articles compatible with the purposes of the study were extracted.

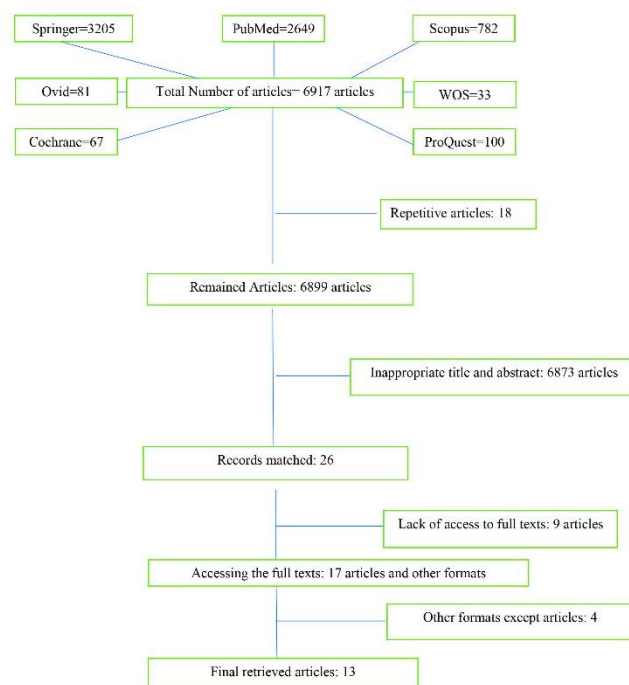


Figure 1. Flow Diagram for the selection of the Retrieved Articles

Results

The bibliographic features of articles are identified in table 1.

Table 1. Bibliographic information of articles

Row	Title of papers	Journal	Affiliation of authors	Publication year	Type of research	DOI
1.	Novel card games for learning radiographic image quality and urologic imaging in veterinary medicine	Journal of Veterinary Medical Education	Christopher P. Ober, DVM, Ph.D., Dipl. ACVR is Associate Professor of Medical Imaging, Department of Veterinary Clinical Sciences, University of Minnesota College of Veterinary Medicine	2017	Original research	10.3138/jvme.0715-108R
2.	Use of a novel board game in a clinical rotation for learning thoracic differential diagnoses in veterinary medical imaging	American College of Veterinary Radiology	Christopher P. Ober, DVM, Ph.D., Dipl. ACVR is Associate Professor of Medical Imaging, Department of Veterinary Clinical Sciences, University of Minnesota College of Veterinary Medicine	2016	Original research	10.1111/vru.12452
3.	Assessing the learning potential of an interactive digital game versus an interactive-style didactic lecture: the continued importance of didactic teaching in medical student education	Pediatric Radiology	Jesse Courtier, Department of Radiology and Biomedical Imaging, University of California, San Francisco UCSF Benioff Children's Hospital--- Emily M. Webb, Department of Radiology and Biomedical Imaging, University of California, San Francisco-- Andrew S. Phelps, Department of Radiology and Biomedical Imaging, University of California, San Francisco UCSF Benioff Children's Hospital--- David M. Naeger, Department of Radiology and Biomedical Imaging, University of California, San Francisco	2016	Original research	DOI 10.1007/s00247-016-3692-
4.	An interactive videogame designed to improve respiratory navigator efficiency in children undergoing cardiovascular magnetic resonance	Journal of Cardiovascular Magnetic Resonance	Sean M. Hamlet, Department of Electrical Engineering, University of Kentucky, Lexington, KY, USA, Department of Pediatrics, University of Kentucky, Lexington, KY, USA--- Christopher M. Haggerty, Department of Pediatrics, University of Kentucky, Lexington, KY, USA, Institute for Advanced Application, Geisinger Health System, Danville, PA, USA--- Jonathan D. Suever, Department of Pediatrics, University of Kentucky, Lexington, KY, USA, Institute for Advanced Application, Geisinger Health System, Danville, PA, USA--- Gregory J. Wehner, Department of Pediatrics, University of Kentucky, Lexington, KY, USA, Department of Biomedical Engineering, University of Kentucky, Lexington, KY, USA---	2016	Original research	DOI 10.1186/s12968-016-0272-
5.	App Review Series: Radiology Pocket Game	Journal of Digital Imaging	V. B. Surya Prasath, Computational Imaging and VisAnalysis (CIVA) Lab, Department of Computer Science, University of Missouri, Columbia, MO, 65211, USA	2016	Review	DOI 10.1007/s10278-016-9924-7

Table 1. (Cont.)

6.	From analog to apps – developing an app to prepare children for medical imaging procedures	Journal of Visual Communication in Medicine	Gigi Williams, The Royal Children's Hospital Melbourne--- Siobhan Greene, The Royal Children's Hospital, Melbourne, Australia	2015	Original research	DOI: 10.3109/17453054.2015.1108285
7.	CT brush and CancerZap!: two video games for computed tomography dose minimization	Theoretical Biology and Medical Modeling	Graham Alvare , BioInformation Technology Laboratory, Department of Plant Science, University of Manitoba, Current address: Faculty of Medicine, University of Manitoba, Box 107, Winnipeg, Canada --- Richard Gordon, Embryogenesis Center, Gulf Specimen Aquarium and Marine Laboratory, C.S. Mott Center for Human Growth and Development, Department of Obstetrics and Gynecology, Wayne State University, Stellarray, 9210 Cameron Road Suite #300, Austin Andrew S. Liteplo, M.D., RDMS, attending physician at Massachusetts General Hospital's Department of Emergency Medicine. Assistant Professor of Surgery at Harvard Medical School--- Nova Panebianco, MD, MPH ,Assistant Professor of Emergency Medicine at the Hospital of the University of Pennsylvania--- Teresa Liu, M.D., RDMS ,Associate Director, Ultrasound , Health Sciences Assistant Clinical Professor--- Alice Fiona Murray, MBChB Instructor, Pediatrics--- Geoffrey Hayden, MD Jefferson University Physician--- Resa E. Lewiss, MD, Director of Point-of-Care Ultrasound, Department of Emergency Medicine, Department of Radiology, University of Colorado School of Medicine	2015	Original research	DOI 10.1186/s12976-015-0003-4
8.	Sonogames An innovative approach to emergency medicine resident ultrasound education	American Institute of Ultrasound in Medicine	Teresa Liu, M.D., RDMS ,Associate Director, Ultrasound , Health Sciences Assistant Clinical Professor--- Alice Fiona Murray, MBChB Instructor, Pediatrics--- Geoffrey Hayden, MD Jefferson University Physician--- Resa E. Lewiss, MD, Director of Point-of-Care Ultrasound, Department of Emergency Medicine, Department of Radiology, University of Colorado School of Medicine	2014	Original research	10.7863/ultra.33.10.1843
9.	The potential for gaming techniques in radiology education and practice	American College of Radiology	Bruce Reiner, MD, Baltimore VA Medical Center, Diagnostic Imaging, Baltimore, Maryland 21201, USA--- Eliot Siegel, MD from the University of Maryland	2008	Review	DOI: 10.1016/j.jacr.2007.09.002
10.	Development of software for dental radiology education using VB.NET	International Congress Series	H. Tanimoto, Department of Hard Tissue Research, Graduate School of Oral Medicine Oral Science, Matsumoto Dental University, Japan--- Y. Arai, Department of Hard Tissue Research, Graduate School of Oral Medicine Oral Science, Matsumoto Dental University, Japan--- K. Gro'ndahl, Department of Oral and Maxillofacial Radiology, The Sahlgrenska Academy, University of Go'teborg, Sweden---H.-G. Gro'ndahl, Department of Oral and Maxillofacial Radiology, The Sahlgrenska Academy, University of Go'teborg, Sweden	2005	Original research	https://doi.org/10.1016/j.ics.2005.03.119
11.	The slice is right (an exercise in ct windowing)	Canadian Journal of Medical Radiation Technology	BruceWhalenRTR,Diagnostic Imaging Department, Janeway Child Health Centre/Children's Rehabilitation Centre, Health Care Corporation of St. John's, NL	2003	Original research	https://doi.org/10.1016/S0820-5930(09)60033-5

Table 1. (Cont.)

12.	Development and evaluation of an interactive web-based breast Imaging Game for Medical Students An interactive multimedia program for imaging the spleen: Concept, design, and development	Academic Radiology	Marilyn A. Roubidoux, MD, Department of Radiology, University of Michigan Health System, Ann Arbor--- Chris M. Chapman, BS--- Mary E. Piontek, MA, PhD	2002	Original research	PMID: 12385511
13.		Radiographics	Paul S. Calhoun, BFA Eliot K Fishman, MD	1994	Original research	DOI:10.1148/radiographics.14.6.7855349

Table 2. Game features of radiology gamification

Title	Type of Game	Purpose of Game	Method of Game Production	Features of Game
Novel card games for learning Radiographic image quality and urologic imaging in veterinary medicine	Card Game	Assessing the utility of card games for learning the fundamentals of radiographic image quality and differential list generation in a veterinary classroom	First, the data were collected, and cards were designed. Then, card game regulations were set	This card game was designed to transfer different concepts of veterinary imaging within classrooms. Cards focus on the quality of radiographic images or differential diagnosis.
Use of a novel board game in a clinical rotation for learning thoracic differential diagnoses In veterinary medical imaging	Board Game	Helping students to generate appropriate lists of differential diagnoses when faced with various radiographic findings	First, the data were collected, after that, the winning conditions, card, and game regulations were set, and cards were designed	The game designs involve a little chance, and the possibility of winning or losing is completely related to players' skills.
Sonogames an innovative approach to emergency medicine resident ultrasound education	Physical Game	Assessing all aspects of emergency medicine (the clinician performs an ultrasound examination at the bedside, interprets the images, and immediately implements this into clinical decision making)	The game data were collected; then, regulations and conditions of the game were designed.	The game is somewhat similar to simulators. It is done within three stages, each of which lasts four hours. The game is running as an event; different teams take part in this game and achieve scores.
Ct brush and cancerzap! two video games for computed tomography dose minimization	Video Game	Capturing and using human intuition for reducing CT dose	The data is collected, and the game is implemented on Java as a videogame	The game production and design are very simple. The player should shoot the X-ray photons to tumors and should avoid shooting to the normal tissues.
Development and evaluation of an interactive web-based breast imaging game for medical students	Online Game	To develop an interactive computer teaching tool for breast imaging targeted toward the general, 4th-year medical student and to make it available on the World Wide Web	The data is collected, and the game is designed as an online game.	The game is competitive and is completely designed with Visual Elements ¹
An interactive videogame designed to improve respiratory navigator efficiency in children undergoing cardiovascular magnetic resonance	Video Game	Navigator-controlled videogame helps to control breathing patterns and to improve navigator efficiency and maintain image quality	The game was produced by custom software called MATLAB	This game uses avatars as visual feedback and process the respiratory navigator image in real-time during CMR. The game encourages children to breathe so that the avatar is positioned within the navigator acceptance window throughout image acquisition
App review series: radiology pocket game	Video Game	Teaching the user's anatomy using radiological images	The data is collected, and each game is implemented as a videogame.	This game is based on asking question and answer process, and the educational aspect of the game is emphasized.

All these games were designed to improve a process or to teach a concept that is an exact match of the

Gamification in radiology

gamification goals. In all the above-mentioned studies to design the gamification, at the very beginning, data was collected to select the best platform and type of gamification in accordance with the teaching-learning

content. The research findings of the effects or end results of games, game audiences, and learning theories applied to develop games are shown in table 3.

Table 3. Features of radiology gamification

Row	Game name	Study participants	Bloom domain of educational objectives	Underpinning learning theory	Game result/Effectiveness
1	Card games	99 veterinary students	Application	Artifact recognition/ Cognitive processes	Card game has positive impact on students' classroom perception
2	Ain't Doin' Right: Thorax (ADR: Thorax)	100 fourth-year veterinary students	Comprehension	Not mentioned	Beneficial in improving student understanding of veterinary medical imaging with respect to developing differential lists for thoracic radiographic findings. Students' fewer tendencies in learning via digital Games compared to traditional speech.
3	Simple interactive digital Tic-tac-toe quiz module	50 students	Evaluation	Self-directed learning	
4	Bubble Gulp (navigator feedback videogame)	Fifty children with no significant past medical history	Application	Not mentioned	Using the designed game was successful, and researchers found that games can play effective roles in education, which leads to increasing interactions among individuals.
5	Radiology Pocket Game (RPG)	Not Mentioned	Application	Not mentioned	Not mentioned
6	Okee in Medical Imaging	children 4–8 years	Application	Not mentioned	Significantly reduce procedural anxiety and bolster the support patients and families receive from one of the the department's dedicated Play Therapists
7	CT Brush	Not mentioned	Application	Not mentioned	The effects of games on general education are noted, and this is known as one of the methods of teaching public.
8	SonoGames	Allopathic emergency medicine residencies	Knowledge	Cognitive	Not Mentioned
9	Gaming Techniques in Radiology	Not Mentioned	Knowledge	Not Mentioned	Games could be a new attractive method for all the staff in the medical imaging area. This approach also provides objective duplicable data that are sharply demanded by the regulators, refunding units, and those who hope to supply imaging services to the market.
10	VB.NET	Not mentioned	Application	Not mentioned	Students can learn how to position sets of radiographs in a logical order to facilitate their viewing and interpretation. Enables the production of versatile and platform-independent programs the Contents of which are easy to change for the teachers using them in their education.
11	The slice is right	Not mentioned	Application	Not mentioned	Not mentioned
12	Interactive Web-based breast imaging game	4th-year medical students	Evaluation	Problem-based learning (PBL)	It is both interactive and competitive, which may increase student motivation and interest
13	Interactive multimedia program	Not mentioned	Application	Not mentioned	Not mentioned

In some of the reviewed articles, the results of the research are not completely clarified. Among the reviewed articles, two of them were specifically focused on the effects of radiology games. The article entitled "Assessing the learning potential of an interactive digital game versus an interactive-style didactic lecture: the

continued importance of didactic teaching in medical student education" aimed to compare traditional education with gamified education. In this article, researchers found that education by applying lectures¹ and educational games could be very effective compared to traditional methods, and games can be used along with

other methods.

The article entitled "The Potential Gaming Techniques in Radiology Education and Practice" reviewed the effects and potentials of games. The researcher also found that video games are effective educational tools in teaching radiology. In addition, the game could be amusing and transfer educational content

in environments similar to the real world. Finally, it could increase individuals' clinical skills.

All the mentioned games applied Bloom's taxonomy of educational objectives; however, most of them lack explicit underpinning educational theories.

In table 4, the articles are reviewed from their relations to radiology areas via using gamifications.

Table 4. Radiology gamification and education of health professions

Row	Title	Active radiology areas	Subspecialty
1	Novel card games for learning radiographic image quality and urologic imaging in veterinary medicine	Quality of images and differential diagnosis of radiographic findings in veterinary medicine	Veterinary Medicine
2	Use of a novel board game in a clinical rotation for learning thoracic differential diagnoses in veterinary medical imaging	Thoracic differential diagnoses in the veterinary clinical setting	
3	Sonogames an innovative approach to emergency medicine resident ultrasound education	Education and assessment of ultrasound skills of emergency medical residents	Emergency Medicine
4	Assessing the learning potential of an interactive digital game versus an interactive-style didactic lecture: the continued importance of didactic teaching in medical student education	Pediatric radiology	Pediatrics
5	From analogue to apps – developing an app to prepare children for medical imaging procedures	Medical imaging procedures in children	
6	An interactive videogame designed to improve respiratory navigator efficiency in children undergoing cardiovascular magnetic resonance	Cardiovascular magnetic resonance	Cardiovascular
7	App review series: radiology pocket game	Radiological imaging in anatomy	Anatomy
8	Ct Brush And Cancerzap! two video games for computed tomography dose minimization	X-ray dose from computed tomography (CT) scanner	Medicine (computed tomography (CT))
9	The slice is right (an exercise in CT windowing)	CT windowing	
10	The potential for gaming techniques in radiology education and practice	Medical imaging	
11	Development and evaluation of an interactive web-based Breast imaging game for medical students	Breast imaging	Medicine (Imaging)
12	Development of software for dental radiology education using VB.NET	Dental radiology	Dentistry
13	An interactive multimedia program for imaging the spleen: concept, design, and development	Radiologic imaging from spleen	Gastrointestinal radiology

Discussion

Game production aims to increase cooperation and collaboration among individuals to perform an activity and to increase or develop certain traits in users (23). This new trend can lead to changing behavior or occurring certain activities among individuals, e.g., respecting nature, paying attention to personal health, and increasing the level of cooperation in an organization (24). Gamification could be used in diverse scientific fields and disciplines. For instance, in medicine, the game 'Pain Squad' can be easily used to detect the amount of pain in cancerous children. The game 'Speed Camera' will

provoke drivers to obey certain speed limits for security and protection purposes. In addition, in education, gamification tools have been used for teaching educational processes to learners. In fact, this instrument increases the motivation of learners to gain knowledge and encourages them to cooperate in educational activities (10,25,26).

In the present study, among 6917 extracted articles from different databases, only 13 articles related to educational radiology gamification were retrieved and, only two of them dealt specifically with analysis of the effects of gamification in this area. These studies focused on the positive impact of the games on students' learning

processes. In fact, other articles emphasized the positive impact of educational games on education (27-30). It is worth mentioning that in one of the articles (Table 1. Number 5) the applied game was not effective as an educational tool, and live interaction among learners, the realization of content and enjoyment from learning scored much higher than gamification. The authors considered the importance of gamification completely and mentioned that as a complementary educational tool, it could be used and suggested conducting future studies with a broader statistical population and other educational methods in comparison to gamification (31).

In teaching and learning environments, lack of cooperation, and lack of ability to create motivation among learners are usually observed. Therefore, educators should apply new educational techniques such as gamification to enhance teaching and learning processes. One of the probable methods is giving rewards to positive trials or activities that increases the level of motivation among learners. In fact, gamification by making use of game components enhances these processes (32). In several studies, it has been proved that using game mechanics could increase the ability of learners to learn new skills or gain knowledge (33). Also, in the 13 reviewed articles, in diverse areas of radiology such as differential diagnosis, education, and dental radiology, different games have been designed, and their effectiveness was approved. Moreover, there are similarities between games and education; for instance, they both have specified goals and try to create a pleasing environment to remove teaching and learning barriers. In addition, a certain skill or concept is taught via them, or they increase cooperation among the involved parties and convey the intended content. Either in education or educational games assessing individual players is crucially important to understand whether they have reached the intended goals or not (32). However, it is worth saying that games not only increase learners' behavior, commitment, and motivation but consequently improve their knowledge or skill acquisition (23). Game studies show that game production is not limited to a specific type (30), and different types of games (e.g., board game, physical game, video game, etc.) could be produced and applied in diverse educational settings. In designing an educational game, recognizing learner's character, educational goals, and developing educational content as well as activities for producing games are crucially important (23,32).

The key point for game producers, in designing an appropriate game, is to consider roles, tasks, and responsibilities that learners should undertake. Successful

gameplay results in achieving more scores, rewards, passing to the next step, winning the game, and finally achieving educational goals (31). Therefore, it was concluded that, although radiology is a new discipline, using gamification for conveying the contents is highly noted.

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