Gamification and Multimedia for Medical Education: A Landscape Review

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Background: Medical education is rapidly evolving. Students enter medical school with a high level of technological literacy and an expectation for instructional variety in the curriculum. In response, many medical schools now incorporate technology-enhanced active learning and multimedia education applications. Education games, medical mobile applications, and virtual patient simulations are together termed *gamified training platforms*.

Objective: To review available literature for the benefits of using gamified training platforms for medical education (both preclinical and clinical) and training. Also, to identify platforms suitable for these purposes with links to multimedia content.

Methods: Peer-reviewed literature, commercially published media, and grey literature were searched to compile an archive of recently published scientific evaluations of gamified training platforms for medical education. Specific educational games, mobile applications, and virtual simulations useful for preclinical and clinical training were identified and categorized. Available evidence was summarized as it related to potential educational advantages of the identified platforms for medical education.

Results: Overall, improved learning outcomes have been demonstrated with virtual patient simulations. Games have the potential to promote learning, increase engagement, allow for real-word application, and enhance collaboration. They can also provide opportunities for risk-free clinical decision making, distance training, learning analytics, and swift feedback. A total of 5 electronic games and 4 mobile applications were identified for preclinical training, and 5 electronic games, 10 mobile applications, and 12 virtual patient simulation tools were identified for clinical training. Nine additional gamified, virtual environment training tools not commercially available were also identified.

Conclusion: Many published studies suggest possible benefits from using gamified media in medical curriculum. This is a rapidly growing field. More research is required to rigorously evaluate the specific educational benefits of these interventions. This archive of hyperlinked tools can be used as a resource for all levels of medical trainees, providers, and educators.

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Gamification is "the process of game-thinking and game mechanics to engage users and solve problems."[1(p.xiv)] Advances in education of preclinical sciences, distance education, gamification, and classroom technologies have contributed to increased emphasis on multiple learning media in higher education.[2-4] As a result, over the past 15 years, there have been developments in technology-enhanced active learning and multimedia applications for medical education. Organizations such as the American Association of Colleges of Osteopathic Medicine and the Association of American Medical Colleges support the scholarly exchange of ideas regarding gamification for health care training.[5,6]

To meet the needs of the Internet generation,[4,5] both preclinical and clinical medical training need to evolve beyond traditional approaches to infuse new tools and media into curriculum.[7,8] According to the Horizon report,[3] the current generation of students must have various skill sets to be successful. These skills include digital literacy, complex thinking, and creativity. Other education experts[9] recommend learner-centered approaches including adaptive, differentiated environments tailored to individual student needs. Medical students enter their programs with previous experience with video games and Web 2.0 technologies such as mobile applications (often called *apps*), podcasting, instant messaging, blogs, wikis, media sharing, and social networking.[7,8] Educational games, mobile applications, and electronic simulations may be useful for this generation of medical students.[8,10]

The current review is a descriptive study of current gaming resources available for use in medical education. First, we discuss the potential educational advantages of gamified learning strategies and tools. Second, we present current, established, or published electronic medical education games, mobile applications, and virtual patient simulations (together termed *gamified training platforms*) suitable for general preclinical and clinical medical education. By exploring the current landscape of resources, including those designed specifically for osteopathic medical training, we hope to identify a body of gamified learning resources useful as a foundation for an expanding, sharable resource archive of new media.

Methods

We searched the available literature for scientific evaluations, reviews, and rigorous validation studies of gamified training platforms for medical education. Platforms were defined as follows:

- *Electronic games* are "instructional method[s] requiring the learner to participate in a competitive activity with preset rules"[11(p16)] presented in electronic formats.
- *Medical mobile applications* are medical software applications used on handheld devices such as personal digital assistants, cell phones, or tablet devices. Mobile applications are increasingly used by clinicians as part of medical practice.[12] We included those applications particularly useful during training exercises.
- *Virtual patient simulations* are interactive computer simulations of real-life clinical scenarios for medical training, education, or assessment.[13] These learning exercises provide "situated learning,"[14] a process whereby trainees gain orientation to a professional culture by participating in activities of the practice through a limited, mentored apprenticeship, gradually assuming responsibility over time.

To identify education advantages of gamified training platforms, we used a landscape review methodology used by education innovators to describe the large picture and current products available.[15] The present study drew upon a range of publicly available literature, including independent research, published systematic re-

views, textbooks on education game instruction, and Internet resources. PsychInfo, Ovid, and Medline searches were conducted using the key words *serious games* or *gamification* with *medical education* or *medical students* for articles published between 2005 and 2015. In addition, we reviewed grey literature such as game database websites, webzine articles, executive reports, video resources, and material presented at health care game conferences. Internet Google searches using the terms *virtual patient simulation*, *medical education simulation*, *medical education games*, *healthcare education games*, *mobile apps for medical education*, and *healthcare apps* were conducted to identify additional gamified training platforms. Articles and other materials were included in this landscape review if they presented valid methods and offered evidence toward the potential benefits of games for medical education.

Available evidence was summarized as it relates to potential educational advantages of gamified training tools for medical education. Potential educational advantages were identified as the ability to identify learning outcomes through increased engagement and enhanced collaboration. Additional potential educational advantages included real-world application, clinical decision making, distance training, learning analytics, and swift feedback. Symbols were chosen to represent each potential educational advantage (*Table 1*).

To identify gamified training platforms currently available for medical training, we used literature review, Internet searches, and conference proceedings. We identified the most likely use for each gamified training tool and categorized them as best suited for preclinical or clinical training. Further, we categorized each platform as an electronic game, mobile application, or a virtual patient simulation. We used discussion and group consensus for the final categorizations.

Games that were not electronic or that were specific to 1 medical specialty were excluded. We focused on games that were identified as useful for preclinical or general clinical training. Although mobile reference materials are plentiful and are often used in medical education and patient care, bedside care, and point-of-care, mobile applications and programs without gamified elements were excluded. We reviewed each resource and identified any available evidence related to potential educational advantages. We independently reviewed each training resource and identified which potential educational advantage could apply. When there was literature to support or document the educational advantages for specific tools, the literature was cited. Additionally, we identified links to multimedia content so readers may sample gamified learning exercise formats.

Using the review techniques described, pilot studies or innovations were also identified. These sources were journal articles that described the development of new media for health care training, but the software or hardware platforms were not commercially available. These types of articles were included to provide a thorough landscape review and a glimpse into possibilities for the future.

Results

The field of gamification for medical education is innovative and dynamic. Publication and rigorous validation studies are not yet available for many gamified training platforms.[16] In the following sections, we identify potential educational advantages and published literature to support these advantages, as well as detail major published gamified training resources for medical education. Platforms are categorized and described briefly, and hyperlinks are provided in electronic versions of this article when available.

Potential Education Advantages of Gamified Training Platforms

Games, mobile applications, and virtual patient simulations can be used in medical curricula to promote learning,[11,17-19] engagement,[20,21] collaboration,[22-24] real-world application,[25] clinical decision making,[18] distance training,[8] learning analytics,[16] and swift feedback.[6]

Learning Outcomes

Rigorous research regarding the effectiveness of games, simulations, and mobile applications for health care learning is still in its infancy. Akl et al[11] state, "The available evidence to date neither confirm nor refute the utility of educational games as an effective teaching strategy for medical students. There is a need for additional and better-designed studies to assess the effectiveness of these games." Several systematic reviews of educational research on games and simulations for health care have been completed in recent years.[11,16,26-29] These reports indicate that few rigorous, controlled trials have been conducted, and the results for substantial learning effects are mixed.

Table 1.
Icon Legend for Potential Educational Advantages of Gamified Training Platforms in Medical Education

Advantage	Icon
Increased engagement	
Enhanced collaboration	
Real-world application	
Clinical decision making	
Distance training	
Learning analytics	
Swift feedback	

A 2010 systematic review[11] reporting effects of educational games on medical student learning outcomes found "potential" for learning outcome improvement but called for more studies with rigorous methods to better inform this research. They reviewed 1019 abstracts and found 26 unique citations on educational games. Of these citations, 5 reported randomized controlled trials with "low-to-moderate methodological quality." Three of 5 educational games evaluated (charades game for teaching child development, interactive computer game to manage phenytoin dose, board game to improve knowledge of metabolic pathways) suggested a beneficial effect on learning outcomes. Given the potential of games for learning, the researchers recommended games when other methods are perceived to have limited effectiveness. They emphasized that games should align to learning goals, activate higher thinking, and provide feedback to learners. A Cochrane review[26] conducted in 2013 reported that there was insufficient evidence to confirm or refute the value of educational games in terms of learning benefit.

Research related to mobile health applications for medical education is limited. However, research related to virtual patient simulations and learning outcomes is promising. In a 2009 review[29] of virtual patient simulation literature, Cook and Triola identified 8 studies, which all found significant learning gains. All of these studies evaluated 1 intervention with virtual patient simulation and did not use comparison groups. The authors[29] also identified 4 studies comparing virtual patient simulations to other education interventions, and all showed favorable but not statistically significant results. In their review of computer games in mental health care, Gamberini et al[22] reported the success of virtual reality for clinical training in mental health care settings.

A number of challenges have been associated with completing randomized controlled trials and other methodologically rigorous studies designed to assess learning gains. Challenges include using valid knowledge measures before and after gamified training platform use, testing learner performance with standardized outcome measures that match the learning content of the intervention, protection against contamination to ensure control groups do not sample the intervention, and allocation concealment (ensuring students do not preview upcoming assignments).[11] Challenges also exist with obtaining large enough sample sizes,[23] survey fatigue,[30] and the time it takes to conduct pilot studies and subsequently refine criterion variables.[31]

Increased Engagement

Studies on games and virtual patient simulations for medical education measure domains of engagement, such as learner satisfaction, flow (fun, enjoyment, and concentration),[32] and variety. Games and gamification elements introduce fun and excitement in stressful environments.[11,20] Well-designed games are cognitively challenging, but not overwhelmingly so. They keep students engaged and facilitate progression through difficult tasks.[33,34] Games support the need for adult learners to inventory and master short-term and long-term aims by breaking activities into a series of networked activities[33] that are varied and interesting. These tasks engage learners in different aspects of serious play, such as strategizing, collaborating, decision making, competing, evidence gathering, reviewing feedback, and reflecting.

Cognitive engagement makes sense from a neurologic perspective. As noted by Chatfield,[33] games activate pleasure centers in the brain. Research suggests video game play results in increased dopamine levels.[35] Cognitive scientists conclude that games should be fast[32] and should include an element of unpredictability. An absence of predictability activates distributed attention, leading to errors that indicate that adjustments in students' behaviors are needed.[35]

Enhanced Collaboration

Games and simulations offer opportunities to practice working as part of a team.[23] These skills are necessary for health care delivery in the future.[36] Education experts assert students scaffold more knowledge through discussions and activities with instructors and other classmates.[37] Games for social and cooperative play are based on interaction with other players in a social setting, requiring teamwork or competition.[11] Examples of games and simulations supporting cooperative teamwork are Bravo (C-3 Softworks), TurningPoint (Turning Technologies, LLC), and DecisionSim (Kynectiv, Inc).

The process of game play has the potential to connect people to learning communities.[25,38] For example, video game players often join collaborative communities, blog about experiences, and analyze statistics associated with game play. Thus, including opportunities for game participants to reflect and strategize through debriefings aligns with health care education using case-based instruction, a method that uses patient cases to simulate critical thinking and decision making in the classroom.[39]

Real-World Application

Games and virtual patient simulations may be designed to allow students to solve real-world problems.[40-43] Contextualizing patient case practice allows students to safely apply medical theory to a specific instance, sometimes mediated by a mentor.[14,37] For example, video games set in virtual worlds present realistic challenges,[43-45] which align with the notion of "authentic learning" that is deemed useful for practicing real-life decision making.[4] This approach is intended to enhance the realism and relevance of a lesson.

Clinical Decision Making

Medical students require ample deliberate practice in clinical reasoning.[46] Learning exercises that engender intrinsic motivation and make deliberate practice engaging are valuable. Games offer platforms for deliberate practice and provide multiple opportunities for demonstrating competence and receiving feedback. Clinical reasoning, information retrieval, and diagnostic acumen are skills practiced in games and virtual simulations for medical education.[47] Video game play also allows for deliberate, risk-free practice of reasoning and technical skills while enhancing spatial and temporal visual systems.[32,35] For these reasons and others, games are being developed to augment skill training related to surgical training.[16]

Distance Training

Modern health care curricula incorporate blended learning, field-based experiences, and distance learning.[2,48] In these

environments, electronic games, mobile applications, virtual patient simulations, and other technology-enhanced learning tools are useful for tracking competency-based learning and supporting a variety of interactive experiences. Furthermore, a key advantage of gamified training platforms in distance training is that some, such as Turning Technologies, LLC, can integrate with a learning management system.

Learning Analytics

While students benefit from deliberate practice in risk-free environments, educators benefit from the analytics (scoring systems, statistical reports) offered by many electronic games and virtual patient simulation platforms. For example, decision-based games may be designed to automatically track every decision a student makes[47] and allow educators to focus on the review of observed deficits after instruction. Instructors can review end-of-game reports to evaluate key learning takeaways and provide feedback to individuals or groups.[49]

Swift Feedback

Games leverage the motivational power of reward schedules, instant feedback, dashboards, and meters to guide a learner along a self-training pathway.[33,47,50,51] Mobile case-based games such as Prognosis: Your Diagnosis (Medical Joyworks) and virtual patient simulations such as DecisionSim (Kynectiv, Inc)[52] offer opportunities to review concepts, retry, and finally attain a better score. For example, when a student selects the wrong answer or makes a clinical error, he or she is stimulated to seek more medical information.

Patient statistics, medical knowledge, preceptor advice, and mini-tutorials may be packaged attractively inside games and virtual patient simulations. For example, virtual patient cases may be outfitted with meters, electronic health record information, tutorials, patient vital signs, feedback, and instructions.[52] Game experts assert that games stimulate students to read more than they would normally read.[38] For example, during a health care game or simulation, the player must refer to instruction panels and information links to make decisions and succeed in treating a patient. Medical educators can use these learning affordances and menus to store copious learning content or enrichment links.

Major Published Gamified Training Platforms

Gamified training platforms can be used in the classroom or individually by students, residents, interns, fellows, and practicing providers of all levels. Platforms we identified through this review are described and characterized as appropriate for preclinical or clinical training. Electronic versions of the tables contain hyperlinks to commercially available resources when available.

Preclinical Training

Gamified training platforms that we identified for preclinical training included 5 electronic games (some with audience response systems[20] and some accessed online) and 4 mobile applications. *Table 2* lists these resources by platform type and summarizes descriptions and advantages of each platform.

Clinical Training

For clinical training, we identified 5 electronic games, 10 mobile applications, and 12 virtual patient simulation tools. *Table 3* summarizes these resources for clinical training by platform.

Pilot Studies

Many games and simulations are not yet commercially available but have been developed by medical education faculty. Results from the development or implementation of these tools are described in journal articles and may be of interest to faculty or others designing interventions. *Table 4* details gamified training platform pilot studies published from 2008 to 2015 that may be useful for training medical students. Nine platforms were identified.

Table 2.
Gamified Training Platforms for Preclinical Training

Title	Publisher	Description	Advantage[a]	Access
Electronic Games				
3D Anatomy	Cyber-Anatomy, Inc	Virtual dissection tool		$5/mo online
Bravo	C3 Softworks	Customizable game templates for any topic[20]		Purchase download
Fold It	Center for Game Science	Online puzzles about protein folding		Free download
TurningPoint	Turning Technologies, LLC	Game-based assessment delivery and data collection for learning environments		Purchase download
Quizlet	Quizlet, LLC	Tools for studying: flashcards, quizzes, games; able to create your own		Free on iTunes Free on Android Free website access
Mobile Applications				
Doctor's Dilemma	American College of Physicians	Quizzes reviewing medical knowledge topics		Free on iTunes
DO OMT	American College of Osteopathic Family Physicians	Videos demonstrating OMT		$9.99 on iTunes
Neuroanatomy: Draw It to Know It	Draw It to Know It, LLC	Visual tutorials, drawing, labeling for neuroanatomy		iTunes in-App purchases Workbook for purchase Purchase online access
Socrative	MasteryConnect	Classroom resource to distribute quizzes and play games on smartphones, tables, laptops		Free on iTunes Free on Android Free website access

[a] Icon key for educational advantages is available in *Table 1*.

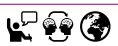
Abbreviation: OMT, osteopathic manipulative treatment.

Discussion

Multimedia tools are plentiful; however, well-designed research evaluating the benefits of games for medical education is lacking. Although it is challenging and important to measure learning effects from these tools, many domains represent other potential benefits. Games and multimedia products have the potential to improve learner engagement, teamwork, and problem solving for real-world issues. The long-term benefits of deliberate practice of specific skills are difficult to measure. There are often confounding variables and challenges with conducting rigorous research given the complexities of medical education and its crowded curricula.

New tools and strategies for clinical reasoning inspire medical educators to consider new media suitable for training students in modern health care settings.[57] As additional educational technology tools are integrated into kindergarten through grade 12 and undergraduate instruction, each generation of medical students will enter with a higher degree of digital literacy than the

Table 3.
Gamified Training Tools for Clinical Education

Title	Publisher	Description	Advantage[a]	Access
Electronic Games				
Dapper	Unity Point Methodist and Bradley University	Web-based games to improve outcomes for patients with type 2 diabetes[54]		Free website access
ElderQuest	Brainstorm Rising, LLC	Video game about pharmacotherapy for geriatric patients		Free website access
Image Challenge	Massachusetts Medical Society	Collection of images to help identify health conditions		Free website access
Second Life	Linden Lab	Residents access a virtual world to browse podcasted talks and events on diseases and illnesses		Free website access
Septris	Stanford University	Web-based game with case scenarios of best practice guidelines for sepsis[47,53]		Free website access
Mobile Applications				
3M Littmann Sound Builder	3M Company	Audio clips and sound-building capabilities to practice auscultation skills		Informational website Free on iTunes
12-Lead ECG Challenge	Limmer Creative, LLC	12-Lead ECG interpretation for cardiac pathologies		Informational website $5.99 on iTunes
CathSource	ECGsource, LLC	Photos and videos demonstrating various cardiac anomalies[54]		Informational website $2.99 on iTunes
Clinical Sense	Medical Joyworks	Role-playing game for physicians presenting difficult clinical scenarios to solve		Free website access Free on iTunes Free on Android
drawMD	Visible Health, Inc	Tool to improve communication with patients by drawing medical sketches		Informational website Free on iTunes
Essential Anatomy 5	3D4Medical	3D Anatomy visualization tool		Informational website $24.99 on iTunes
Heart Pro III	3D4Medical	3D heart images allow users to cut, zoom, rotate, screenshot, and make notes		Informational website $14.99 on iTunes
Prognosis: Your Diagnosis	Medical Joyworks	Simulated clinical cases to test diagnostic ability		Free website access Free on iTunes Free on Android
Radiology 2.0: One night in the ED	Daniel Cornfeld	Series of cases to simulate CT scans; includes extensive discussion after each case		Informational website Free on iTunes
Upper Respiratory Virtual Lab	Georgia Regents University	3D simulator of upper respiratory tract[53]		Free on iTunes

(continued)

Table 3 (continued).
Gamified Training Tools for Clinical Education

Title	Publisher	Description	Advantage[a]	Access
Virtual Patient Simulations				
3DiTeams	Duke University Medical Center	Emergency department team training with virtual simulation controlled by an instructor[16,55]		Purchase download
At-Risk in Primary Care	Kognito	CME- and CNE-approved online virtual patient simulations in various clinical scenarios		Publisher website
CliniSpace	Innovations in Leaning, Inc	3D, immersive, virtual simulation team training in acute, critical care, and daily medicine[16]		Purchase download
DecisionSim	Kynectiv, Inc	Faculty create virtual patient scenarios and use them to evaluate participants at all levels[17]		Purchase download
CLIPP	MedU	Online patient cases for education using a medical home model		Free website access
HumanSim	Virtual Heroes	Medical schools may commission immersive 3D interactive virtual scenarios for health care training		Publisher website Informational video
i-Human	i-Human Patients, Inc	Online interactive, competency-based virtual patient encounters		Purchase download
MedU	MedU	Interactive virtual patient cases		Free website access
Open Labyrinth	GitHub	No-cost authoring software useful for designing interactive virtual patient scenarios		Free download
QuantiaMD	Quantia	Online community to interact with experts, ask questions, solve test cases		Free website access
SimCoach	University of Southern California	Interact with virtual human agents to help military families break down barriers to care		Publisher website
VPSim	University of Pittsburgh	Clinical encounter simulation and virtual patient interaction		Publisher website

[a] Icon key for educational advantages is available in *Table 1*.

Abbreviations: CME, continuing medical education; CNE, continuing nursing education; CT, computed tomography; ECG, echocardiogram; OMT, osteopathic manipulative treatment; 3D, 3-dimensional.

previous generation.[7] In the future, more emphasis will be on creative production of collaborative, multimedia projects.[7] Therefore, it makes sense to consider involving students in the selection and design of tools to stimulate their interest in solving complex health care problems. At some medical schools, students are encouraged to design new technology-enhanced learning tools.[62] Medical educators may be able to leverage greater student involve-

Table 4.
Gamified, Virtual Environment Training Tools With Published Pilot Reports

Title	Publisher	Description	Advantage[a]	Access
Burn Center	360Ed (now Junyo, Inc)	Virtual simulation of triage and resuscitations for burn patients[16,56]		Informational video
Casebook	NA	Virtual patient simulations iPad app useful for constructing cases based on EMR[57]		NA
The Virtual First Responder	University of Michigan Medical School	Immersive, virtual experience in triage training[58]		Informational website
CliniSpace	Innovation in Learning, Inc	Immersive web-based 3D environment[59]		Publisher website
EMedOffice	NA	A collaborative serious game for teaching medical students to run a medical office[60]		NA
Heart Murmur Sim	Second Life	Educational virtual world for cardiac auscultation training[45]		Informational video
Nuclear Event Triage Challenge	NA	Virtual training for triage in nuclear events[63]		NA
Pulse	Breakaway, Ltd	Virtual learning space for training clinical skills in responding to catastrophic situations[16]		Informational website
TheraSim	TheraSim, Inc	Virtual simulations for topics such as pharmacology[61]		Publisher website

[a] Icon key for educational advantages is available in *Table 1*.

Abbreviation: EMR, electronic medical record; NA, not available; OMT, osteopathic manipulative treatment; 3D, 3-dimensional.

ment through new educational media, including electronic games, mobile applications, and virtual patient simulations.[8] Incorporating these media into the curricula may inspire educators to increase their own digital literacy and allow them to more effectively facilitate rich, interactive educational experiences. Technology-enhanced training experiences will better equip the rising generation of physicians with the technological fluency required for modern clinical practice.

One limitation of the present review is that several domains of technology-enhanced learning media were not reviewed. These media, which include classroom multimedia tools, learning management systems, smart devices and bio-monitoring gear, online learning tools, social media, medical communications technology, mobile tools for medical students, role-play games, and memory games, were outside the scope of our review.

Additional game tools and resources are posted on websites such as Games and Simulation for Healthcare (http://healthcaregames.wisc.edu/index.php) and the National Health Institute's archive Medline Plus: Games (https://www.nlm.nih.gov/medlineplus/games.html). Virtual patient simulations designed specifically for training health care professionals in various specialties have been reviewed by Ricciardi and De Paolis.[63]

Conclusion

There are many potential educational advantages of games for medical training. Although rigorous studies confirming learning gains are limited, the field of research is growing. The literature provides evidence of positive learning outcomes from virtual simulations. Further, games, mobile applications, and virtual patient simulations have all been shown to promote engagement and to offer opportunities for deliberate practice in clinical reasoning. The portfolio of available resources is continuously expanding. The archive of hyperlinked tools provided in this review can serve as a resource for medical educators and students. We hope this article will inspire experimentation, stimulate discussions on cross-platform integration, and lay the groundwork for designing an extensive resource website or database useful to health care practitioners of all levels—students, residents, fellows, and practicing providers.

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Author Contributions

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