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The effect of educational games on medical students' learning outcomes: A systematic review: BEME Guide No 14

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Abstract

Background: An educational game is 'an instructional method requiring the learner to participate in a competitive activity with preset rules.' A number of studies have suggested beneficial effects of educational games in medical education.

Aim: The objective of this study was to systematically review the effect of educational games on medical students' satisfaction, knowledge, skills, attitude, and behavior.

Methods: We used the best evidence medical education (BEME) collaboration methods for conducting systematic reviews. We included randomized controlled trials (RCT), controlled clinical trials, and interrupted time series. Study participants were medical students. Interventions of interest were educational games.

Results: The title and abstract screening of the 1019 unique citations identified 26 as potentially eligible for this article. The full text screening identified five eligible papers, all reporting RCTs with low-to-moderate methodological quality. Findings in three of the five RCTs suggested but did not confirm a positive effect of the games on medical students' knowledge.

Conclusion: 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 and this article will inform this research.

Introduction

A number of definitions for educational games exist. One definition describes an educational game as 'an instructional method requiring the learner to participate in a competitive activity with preset rules (Fitzgerald 1997).' Another describes it as a type of experiential learning where the learner 'engages in some activity, looks back at the activity critically, abstracts some useful insight from the analysis and puts the results to work (Pfeiffer & Jones 1980).' Most games differ from other educational strategies in their competitive nature and the use of prescribed settings constrained by rules and procedures (Allery 2004).

The 2006 Horizon Report described four categories of games: simulations, virtual environments, social and cooperative play, and alternative reality games. Simulations or role playing interventions are strategies to replicate real situations with guided experiences in a fully interactive way (e.g. endoscopy or cardiopulmonary resuscitation simulation). Virtual environments are web-based applications offering interaction in virtual environments that are visually rich and engaging (e.g. Second Life and World of Warcraft). Social and cooperative games are based on interaction with other players in a social setting and in a cooperative way (e.g. board games and games based on television game shows). Alternative reality games mix gameplay and real life and challenge players to discover and then solve a mystery.

Using games as an educational intervention may improve education outcomes. Indeed, Kolb describes learning as a process whereby knowledge is created by the transformation of experiences (Kolb 1984). This process has four phases: (1) concrete experience, (2) reflective observation, (3) abstract conceptualization, and (4) active experimentation. Games have the potential to facilitate and enhance this process by providing an active experience in which the learner conceptualizes knowledge and then actively experiment with the concept in the game (Thatcher 1990). Thus, educational games have the potential to promote the learning of facts as well as the learning of cognitive processes (Abt 1966; Greenblat & Duke 1981).

Schoolteachers have been creating and using educational games to teach different content areas to students of different grade levels (Ormiston 2001). Similarly, business and management education has a long history with educational gaming (Wolfe 1993). Nurses have used TV game shows formats to teach infection control (Akl et al. 2008b), board games to teach about the conceptual models of nursing (Cessario 1987),

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Practice points

Key messages for education practice:

- Medical educators might use educational games when other types of educational interventions are perceived or proven to have limited effectiveness.
- Medical educators should weigh the potential benefits of implementing an educational game against its costs, and the time and effort needed for its development (or adaptation) and for its implementation.
- In adopting or adapting a game, medical educators need to keep the likely mediators of any potential benefit of educational games in mind: ensuring an active learning experience, integrating fun and excitement in the learning process, and providing feedback.

Implications for future evaluations:

- Future evaluative studies should be designed as high-quality RCTs comparing the educational games to the best available alternative and assessing relevant educational and clinical outcomes.
- Investigators should conduct process evaluation studies to assess the delivery of the intervention and explore the mechanisms underlying its effects.
- Investigators should improve the reporting of studies evaluating educational games.

and card games to teach about the gastrointestinal system (French 1980).

A number of studies have suggested beneficial effects of using educational games in medical education. Ogershok and Cottrell (2004) implemented a board game format during a pediatric clerkship and noted positive feedback from medical students, pediatric residents, and faculty (Ogershok & Cottrell 2004). Boreham et al. (1989) found that an interactive computer game increased the percentage of medical students making optimal decisions in managing phenytoin doses (Boreham et al. 1989). Moy et al. (2000) reported positive evaluations from medical students of 'Who Wants to Be a Physician', an educational game used to teach pulmonary physiology (Moy et al. 2000).

The objective of this study was to review the effect of educational games on medical students' satisfaction, knowledge, skills, attitude and behavior.

Methods

Inclusion/exclusion criteria

Types of studies: we included randomized controlled trials (RCT), controlled clinical trials, and interrupted time series (as defined by the effective practice and organisation of care (EPOC) Cochrane group).

Types of participants: study participants were medical students. We excluded health professionals (e.g. residents and practicing physicians) and students of other health professions (e.g. nursing students).

Types of interventions: interventions of interest were educational games based on social and cooperative play such as board games (e.g. Trivial Pursuit®) and games based on television game shows (e.g. Jeopardy!®). Our article did not cover the other categories of educational games, i.e. simulations, virtual environments, or alternative reality games. Interventions in the control group could have been: (a) no intervention; (b) standard educational activity; (c) untargeted activity; and (d) another intervention.

Types of outcomes: outcomes of interest were medical students' satisfaction, knowledge, skills, attitude, and behavior.

Search strategy

In January 2007, we searched for related reviews in the Database of abstracts of reviews of effectiveness (DARE). We also searched for primary studies in the following electronic databases: EPOC Register and the database of studies awaiting assessment, Cochrane central register of controlled trials (CENTRAL), MEDLINE (1966 onwards), EMBASE (1980 onwards), PsycINFO (1967 onwards), CINAHL (1982 onwards), AMED (1985 onwards), ERIC (1966 onwards), and dissertation abstracts online (1980 onwards). The search strategies for the electronic databases combined the methodological component of the search strategy of EPOC with MeSH terms and free text terms relating to educational games. We used the appropriate controlled vocabulary for each database and used no language restrictions (Appendix).

In addition to the above electronic searches, we screened the reference list of included studies and relevant reviews, we contacted authors of relevant papers regarding any further published or unpublished work, and we searched ISI® Web of Science® for papers citing studies included in this article.

Selection methods and judgment of methodological quality

Two reviewers independently judged the potential eligibility of articles by screening their titles and abstracts. If at least one reviewer judged the article as potentially eligible, we retrieved its full text. Then, two reviewers independently judged the eligibility of the full text articles and resolved their disagreements by discussion or with the help of an arbitrator. We did not include abstracts for which we could not obtain full reports of study methods and results.

Two reviewers independently assessed the methodological quality of included studies. They resolved their disagreements by discussion or with the help of an arbitrator. The criteria were derived from EPOC quality criteria and were, for RCTs:

- Pre- and post-intervention assessment of the outcome (i.e. conducting a baseline assessment in addition to the post-intervention assessment);
- Using valid and reliable outcome measure (validity is the degree to which a measurement instrument accurately measures the outcome of interest; reliability is the consistency of the measurement);
- Protection against contamination (contamination occurs when subjects who are not supposed to receive an intervention receive it);
- Allocation concealment (process that keeps investigators and study participants unaware of upcoming assignments).

Data extraction

The data extraction was based on the EPOC checklist and was consistent with the best evidence medical education (BEME) checklist. We extracted information about the game: type (e.g. alternative reality game, social and cooperative play), whether rules were clearly described, material needed (e.g. audiovisual), educational content (subject, source of information, quality of information), context and location, duration, intensity, costs (both human resource and financial), challenges to implementation, and whether or not the authors stated clearly the learning objectives. We extracted similar information about the control intervention. Two reviewers independently extracted data and resolved disagreements by discussion or with the help of an arbitrator.

Data analysis

We calculated the agreement between the two reviewers for the assessment of eligibility using kappa (κ) statistic. We did not conduct a planned meta-analysis because studies reported different summary statistics and varied in terms of the type of intervention, type of control, outcome measures, and methodological quality (see below).

Results

Figure 1 shows the study flow. We identified 1156 citations, 137 of which duplicates. The title and abstract screening of the 1019 unique citations identified 26 as potentially eligible for this article. The full text screening of these citations identified five eligible papers, all reporting RCTs (Table 1). Agreement between reviewers for trial eligibility was high (kappa = 0.82). We excluded 13 papers reporting single arm studies because they did not meet the study design eligibility (Table 2). We excluded eight additional papers because they did not report any evaluation of the game being described (Table 3).

Overview of the studies included in the review

Table 1 reports the characteristics of included studies. Participants were dental students in one study (Udin & Kuster 1985) and medical students in the remaining ones. We decided to include the study with dental students because there is no prior knowledge suggesting the effect would be different than in the population of medical students. Studies were conducted in UK ($n = 2$), USA ($n = 2$), and Brazil ($n = 1$).

In terms of intervention, no two included studies assessed the same game. The types of games assessed by the five included studies were: TV show type of games ($n = 1$) (O'Leary et al. 2005), board games ($n = 2$) (Udin & Kuster 1985; Siqueira et al. 1992), interactive computer games ($n = 1$) (Boreham et al. 1989), and charade type of game ($n = 1$) (Selby et al. 2007). One study covered a basic science topic: biochemical pathways (Siqueira et al. 1992). Four studies covered clinical science topics: sensitization toward handicapped dental patient (Udin & Kuster 1985), drug-dose management (Boreham et al. 1989), ectopic pregnancy

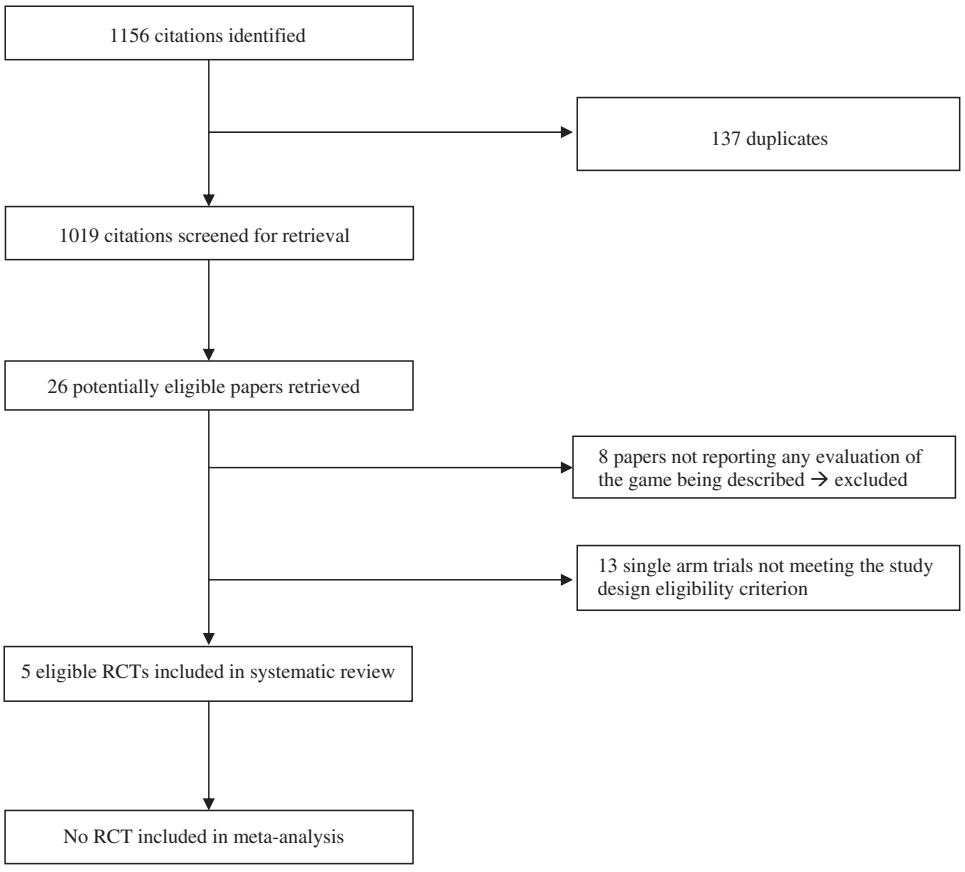

Figure 1. Study flow.

Table 1. Characteristics of randomized controlled trials included in the systematic review.

Study	Study design	Intervention	Participants	Outcomes	Methodological quality	Results
Udin and Kuster (1985)	Randomized controlled trial:	'Smile'	42 senior dental students learning to manage handicapped dental patients; (intervention: 10; control: 13; no intervention: 19)	Confidence in dealing with handicapped children: nine right–wrong questions	Pre & post outcome assessment	No differences between the three groups in terms of confidence or willingness to treat handicapped children
	Intervention: playing the game	Description: board game that involved chance (roll of dice) and created clinical situation with possible outcomes and their sequelae	Country: USA	Willingness to treat handicapped children: 8 five-point Likert scale	Validity and reliability of outcome measure not reported; based on a previously developed test	
	Control: standard small group lecture; content apparently different than intervention group (dental techniques for treating the handicapped)	Educational content: behavior management strategies and modifications of treatment			Protection against contamination: not clear	
	No intervention	Learning outcome: appropriate management of handicapped dental patient			Allocation concealment: not clear	
Boreham et al. (1989)	Randomized controlled trial:	'The Phenytoin Game'	32 final year medical students taking clinical pharmacology courses; (intervention: 17; control: 15)	Knowledge test: case base test asking for a decision on the phenytoin dose	Post-outcome assessment	Percentage of optimal decisions: 65% (intervention) versus 29% (control); $p < 0.001$
	Intervention: playing the game once	Description: interactive computer game with case histories of 10 patients with varying degrees of acuity of seizure disorder	Country: UK		Validity and reliability of outcome measure not reported	
	Control: no intervention	Educational content: management of phenytoin dose Learning outcome: appropriate dosage of phenytoin at each stage of case management			Protection against contamination: not clear Allocation concealment: not clear	
Siqueira et al. (1992)	Randomized controlled trial:	'Dynamic Metabolic Diagrams (DMD)'	89 freshmen medical students (intervention: 36; control: 53)	Knowledge: written examination (including calculations and open ended questions) 1 week later	Post outcome assessment (higher scores better than lower scores)	Scores were higher for the intervention group; data presented as percentages for six ranges of scores but no overall percentage reported; no statistical testing reported
	Intervention: educational material with dynamic metabolic diagrams (DMD) ($n = 36$)	Description: board game with cardboard showing boxes in compartments and tissues where reactions would occur and cards showing metabolites structures or name of enzymes and coenzymes.	Country: Brazil		Validity and reliability of outcome measure not reported	

(*continued*)

Table 1. Continued.

Study	Study design	Intervention	Participants	Outcomes	Methodological quality	Results
	Control: educational material without DMD ($n = 53$)	Educational content: metabolic pathways Learning outcome: to fill display the entire metabolic pathway			Protection against contamination: not clear Allocation concealment: not clear	
O'Leary et al. (2005)	Randomized controlled trial:	Description: Jeopardy!® style game, cards with increasing dollar values displayed for different categories	104 third year medical students; (intervention: 52; control: 52)	Knowledge test: 20-item multiple choice test	Pre & post knowledge test (higher scores better than lower scores)	Knowledge scores: pre = 12.52, post = 17.04(1.27) (intervention) versus pre = 11.33, post = 16.98(1.62) (control): scores improved from pre to post in each group; no statistical testing reported for difference in improvement between two groups
	• Intervention: playing the game	Educational content: epidemiology and differential diagnosis, risk factors, signs and symptoms, diagnosis, and treatment of ectopic pregnancy	Country: USA	Satisfaction with and evaluation of the game: 4 5-point Likert scale questions and 3 true-false questions	Content experts validated knowledge test; satisfaction survey taken from validated tests	Ratings of the game were overall better than ratings of the standard lecture
	• Control: standard lecture	Learning outcome: collect points based on degree of difficulty and complexity of questions			Protection against contamination: not clear	
	• Efforts made to keep content similar in two groups (same tutor, educational material)				Allocation concealment: not clear	
Selby et al. (2007)	Randomized controlled trial:	'Development charades'	100 fifth year medical students during their pediatric module; (intervention: 52; control: 48)	Knowledge test immediately after teaching session: 'best of five' multiple choice questionnaireObjective structured clinical examination (OSCE)	Post-knowledge test (higher scores better than lower scores)	Knowledge scores: 43.6 (95% CI 17–70) (intervention) versus 37.15 (95% CI 11–63) (control); $p < 0.01$
	Intervention: playing the game	Based on the game 'charades'; each card describes a milestone. A student plays the mother answers questions and another plays the child acts out activities. Remaining students gauge the age of the child	Country: UK		Validity and reliability of knowledge test not reported; OSCE is a standardized test	OSCE scores: 20.5 (95% CI 14–27) (intervention) versus 19.5 (95% CI 14–25) (control); difference not statistically significant
	Control: interactive lecture	Educational content: milestones and behavior for key developmental ages			Protection against contamination: not clear	
	Efforts made to keep content similar in two groups (same duration, tutor, educational material)	Learning outcome: developmental milestones			Allocation concealment: Yes	

Table 2. Characteristics of single arm studies excluded from the systematic review.

Study	Study design	Intervention	Participants	Outcomes	Methodological quality	Results
Fleiszer et al. (1997)	Single arm study	'Doughnut Rounds'	25 medical students on surgical intensive care unit rotation	Satisfaction with and evaluation of the game	Post-outcome assessment	Ratings of the game were overall positive
	Intervention: playing the game once	TV game show format	Country: Canada		Validity and reliability of outcome measures not reported	
		Educational content: critical care in surgery				
Colombo et al. (1998)	Single arm study	'Cellular & Humoral Immunology Game'	93 fourth semester medical students taking medical immunology course	Satisfaction with and evaluation of the game	Post-outcome assessment	Ratings of the game were overall positive
	Intervention: playing the game once	Card game	Country: Brazil		Validity and reliability of outcome measure not reported	
		Educational content: immunology				
Fukuchi et al. (2000)	Single arm study	'Oncology Game'	16 third year medical students	Knowledge test	Pre- and post-knowledge test (higher scores better than lower scores)	Knowledge scores: pre = 4.86(0.42) versus post = 5.63(0.26) $p = 0.26$ (round 1; all 16 students); pre = 10.75(0.62) versus post = 11.5(0.85) $p < 0.001$ (round 2; eight students who passed round 1);
	Intervention: elimination tournament playing the game	Interactive, computer-assisted board game; case based	Country: USA	Self reported improvement in knowledge	Validity and reliability of outcome measures not reported	Self reported improvement in understanding and knowledge
		Educational content: Cancer treatment				
Moy et al. (2000)	Single arm study	'Who Wants to Be a Physician?'	109 first year medical students	Satisfaction with and evaluation of the game	Post-outcome assessment	Ratings of the game were overall positive
	Intervention: playing the game once	TV game show format	Country: USA		Validity and reliability of outcome measures not reported	
		Educational content: pulmonary physiology				
Howard et al. (2002)	Single arm study	'Survivor'	179 first year medical students	Satisfaction with and evaluation of the game	Post-outcome assessment	Ratings of the game were overall positive
	Intervention: playing the game once	TV game show format	Country: USA	Comparison of the game to a previously used game 'Who Wants to Be a Physician?' (Moy et al. 2000)	Validity and reliability of outcome measures not reported	Scores were significantly higher than those for 'Who Wants to Be Physician?' (Moy et al. 2000)
		Topic: pulmonary physiology				
Mann et al. (2002)	Single arm study	'The breast game'	33 medical students	Knowledge test	Pre & post knowledge test (higher scores better than lower scores)	Knowledge scores: pre = 6.43(0.30) versus post = 7.14(0.30) $p = 0.006$
	Intervention: playing the game once	Computerized board game; case based	Country: USA	Satisfaction with and evaluation of the game	Validity and reliability of outcome measures not reported	Ratings of the game were overall positive
		Educational content: management of breast nodule				
Roubidoux et al. (2002)	Single arm study	'Breast Cancer Detective' Link	42 medical students taking radiology elective	Satisfaction with and evaluation of the game	Post-outcome assessment	Ratings of the game were overall positive
	Intervention: playing the game once	Interactive web-based game; case based Content related to breast cancer	Country: USA		Validity and reliability of outcome measure not reported	

(*continued*)

Table 2. Continued.

Study	Study design	Intervention	Participants	Outcomes	Methodological quality	Results
Steinman et al. (2002)	Single arm study	Host defense trading card game	Eight first year medical students (in addition to 8th & 10th graders)	Knowledge test	Pre- and post-knowledge test	pre = 80% versus post = 88% average percentage correct answers $p = 0.049$
	Intervention: playing the game once	Card game Educational content: principles of host disease interactions	Country: USA	Satisfaction with and evaluation of the game	Validity and reliability of outcome measures not reported	There was no improvement in answers to 'control questions' Ratings of the game were overall positive
Eckert et al. (2004)	Single arm study	'T-lymphocyte and B-lymphocyte tolerance game'	120 second year medical students attending immunology course	Knowledge test	Pre- and post-knowledge test (higher scores better than lower scores)	Knowledge scores: pre = 7.6 versus post = 9.5 $p < 0.0001$ (previous reading assignment); pre = 6.1 versus post = 8.3 $p < 0.0001$ (no previous reading assignment)
	Intervention: playing the game once	Card game Educational content: immunology	Country: Brazil	Satisfaction with and evaluation of the game	Validity and reliability of outcome measures not reported	Ratings of the game were overall positive
Ogershok et al. (2004)	Single arm study	'Pediatric Board Game'	37 third year medical students and residents	Satisfaction with and evaluation of the game	Post-outcome assessment	Ratings of the game were overall positive
	Intervention: playing the game once	Board game Educational content: core pediatric knowledge	Country: USA		Validity and reliability of outcome measures not reported	
Da Rosa et al. (2006)	Single arm study	'Hepatitis Game'	140 undergraduate medical students	Knowledge test	Pre and post knowledge test (higher scores better than lower scores)	Knowledge scores: pre = 7.52(2.1) versus post = 8.87(1.08) $p < 0.0001$ (previous reading assignment); pre = 5.84(1.9) versus post = 8.58(1.09) $p < 0.0001$ (no previous reading assignment)
	Intervention: playing the game once	Card game; case based Educational content: viral hepatitis	Students were classified based on whether they had a previous reading assignment Country: Brazil	Satisfaction with and evaluation of the game	Validity and reliability of outcome measures not reported	Ratings of the game were overall positive
Girardi et al. (2006)	Single arm study	'T- and B-Cell Ontogeny Game'	72 fourth semester medical students taking immunology course	Knowledge in immune system ontogeny	Pre- and post-outcome assessment (higher scores better than lower scores)	Knowledge scores: pre = 8.0(0.9) versus post = 9.0(0.8) $p < 0.001$ (with previous reading); pre = 4.8(1.1) versus post = 8.3(0.8) $p < 0.001$ (without previous reading)
	Intervention: four sessions of the game with a 7-day interval between	Board game	Country: Brazil	Satisfaction with and evaluation of the game	Validity and reliability of outcome measures not reported	Ratings of the game were overall positive
Hudson et al. (2006)	Single arm study	'Who Wants to Be a Millionaire'	107 first year medical students	Satisfaction with and evaluation of the game	Post-outcome assessment	Ratings of the game were overall positive
	Intervention: playing the game once	TV game show format; case based Educational content: physiology of growth and puberty	Country: UK		Validity and reliability of outcome measures not reported	

Table 3. Characteristics of studies excluded because no evaluation was reported.

Game, citation	Target, educational content	Type, description of the game
'The diagnosis game' (Schneiderman & Muller 1972)	Target: medical students Educational content: simulated medical diagnostic problems	Computer-based game Students individually solve a clinical problem. The computer provides clinical data when queried by the student. An instructor leads a small group discussion after all students are done.
'Coverage©' (MacLeod & Smith 1984)	Target: medical students on a 6-week clerkship in community health Educational content: health care financing	Board game A player moves around the board using dices and lands on spaces that may be purchased or require the player to draw a card representing a health event and the associated costs.
'Important pursuit' (Robertson & Tannahill 1986)	Target: medical students Educational content: health education	Board game A circular game board divided into 16 sectors has an arrow in the middle which, when spun, will stop on a health education question in one of the sections
'To Tell The Truth (TTTT)' (Hafferty 1990)	Target: medical students Educational content: physician identity and stereotypes	TV show format (To Tell The Truth) Four contestants—one physician and three imposters—are interviewed by the class to determine the real physician.
'The Lactation Game' (Elder & Gregory 1996)	Target: medical students and obstetrics/gynecology residents Educational content: breast feeding	Board game Learners answer questions regarding breast physiology and community lactation resources
'Diversophy'® (Salimbene 1998)	Target: health-care workers and medical students Educational content: cultural competency	Board game Players collect dividends by caring for diverse patient scenarios successfully
'Context is key' (Ballon & Silver 2004)	Target: multiple health disciplines Educational content: psychiatric diagnoses	Card-sorting game 1 of 5 psychiatric diagnoses is suggested by the context of symptom clusters
'Trivial Pursuit of Physiology' (Zakaryan et al. 2005)	Target: 1st year medical students Educational content: cardiovascular physiology	TV game show format Class review session lead by the instructor who clicks the game wheel and other control buttons from the front of the class. Points are awarded for answering questions correctly. A buzzer is used.

(O'Leary et al. 2005), and child development (Selby et al. 2007). Two games were case based (Udin & Kuster 1985; Boreham et al. 1989).

The types of outcomes assessed included satisfaction ($n = 1$) (O'Leary et al. 2005), knowledge ($n = 4$) (Boreham et al. 1989; Siqueira et al. 1992; O'Leary et al. 2005; Selby et al. 2007), skills ($n = 1$) (Selby et al. 2007), and attitude ($n = 1$) (Udin & Kuster 1985). None of the studies assessed behavior.

Methodological quality of studies

Of the five RCTs, four had an active control group (Udin & Kuster 1985; Siqueira et al. 1992; O'Leary et al. 2005; Selby et al. 2007), with two reporting efforts to keep content similar to the one in the intervention group (O'Leary et al. 2005; Selby et al. 2007). Only two studies used pre- and post-intervention assessment of at least one of their outcomes (Udin & Kuster 1985; O'Leary et al. 2005). Two studies employed validated or structured outcome measures: O'Leary et al. used a knowledge test validated by content experts (O'Leary et al. 2005) while Selby et al. used an objective structured clinical examination (Selby et al. 2007). None of the studies reported efforts to protect against contamination. One study reported concealing allocation (Selby et al. 2007).

Narrative comment on review results

The findings of the five RCTs were as follows:

- A board game to sensitize dental students toward handicapped patients was not statistically different from a standard lecture or no intervention in the effect on attitudes (Udin & Kuster 1985). The RCT met one of the four methodological quality criteria.
- A Jeopardy!®-style game about ectopic pregnancy was not statistically different from a standard lecture in the effect on knowledge (O'Leary et al. 2005). The RCT met two of the four methodological quality criteria.
- A charades game for teaching child development was statistically superior to an interactive lecture in the effect on knowledge but not in the effect on objective structured clinical examination assessment (Selby et al. 2007). The RCT met two of the four methodological quality criteria.
- An interactive computer game to improve knowledge related to managing phenytoin dose resulted in a statistically higher percentage of students making optimal decisions when compared with no intervention (Boreham et al. 1989). The RCT met none of the four methodological quality criteria.
- A board game appeared to improve knowledge related to metabolic pathways when supplementing, compared with not supplementing, standard educational material; however, no statistical testing was reported (Siqueira et al. 1992). The RCT met none of the four methodological quality criteria.

Meta-analysis results

The only outcome reported by at least two studies was knowledge. The available data could not be pooled for that outcome as each study reported a different summary statistic: percentages (Boreham et al. 1989), percentages for six

ranges of scores but no overall percentage, (Siqueira et al. 1992) pre- and post-intervention scores (O'Leary et al. 2005), and post-intervention scores (Selby et al. 2007). Moreover, these studies varied in terms of the type of intervention, type of control, outcome measures, and methodological quality.

Discussion

The systematic review identified five studies evaluating different types of educational games for medical students and covering both basic and clinical science topics. These five studies had a low-to-moderate methodological quality. Findings in three of the five RCTs suggested a positive effect of the games on medical students' knowledge.

Three out of five educational games evaluated (i.e. a charades game for teaching child development, an interactive computer game to improve knowledge related to managing phenytoin dose, and a board game to improve knowledge related to metabolic pathways) suggest a beneficial effect. However, it is unlikely that this would translate into a general recommendation of the use of educational games.

This systematic review's major strength is the use of BEME rigorous systematic review methodology including: (1) a specific research question with pre-specified outcomes of interest; (2) a comprehensive search strategy; and (3) duplicate and independent screening, methodological quality assessment, and data extraction. We are unaware of other work that systematically reviewed the evidence about the use of educational games in medical students.

The limitations of this systematic review are related to the limitations of the included studies. First, we have identified a limited number of studies that met all eligibility criteria. Second, we were not able to conduct a planned meta-analysis because studies reported different summary statistics and varied in terms of the type of intervention, type of control, outcome measures, and methodological quality. The conclusions are thus based on data from individual studies. Third, we limited the scope of the systematic review to social and cooperative games. Thus, our conclusions do not apply to other types of interventions sometimes labelled as games, such as role playing and simulations.

Inferences from this article are limited by the methodological quality of included studies. The five included RCTs suffer from a number of methodological shortcomings that could have biased the results. An additional limitation is related to the comparison of the educational game interventions either to no intervention or to an intervention that is not the 'best comparator' (e.g. comparing a game to a didactic lecture instead of an interactive lecture).

Most of the published literature on educational games for medical students that we identified reports either no evaluation ($n=8$ papers) or a single arm study evaluation ($n=13$ papers). All but one of 13 single arm studies reported participants' ratings of the game which were all positive. Five of the 13 single arm studies assessed outcomes pre- and post-intervention with five showing positive results (Mann et al. 2002; Steinman & Blastos 2002; Eckert et al. 2004; Da Rosa et al. 2006; Girardi et al. 2006). However, any inferences that we draw would be very weak given the weakness of the study design, especially that none of these studies reported on the validity or reliability of their outcome measures.

A Cochrane systematic review reviewing the effects of educational games in health professionals identified only one eligible RCT of fair methodological quality. The game was based on the television game show 'Family Feud' and focused on infection control. The authors concluded that the findings neither confirm nor refute the utility of games as a teaching strategy for health professionals and called for additional high-quality research (Akl et al. 2008b).

Another Cochrane systematic review compared educational games to standard teaching approaches in mental health professionals and identified one eligible RCT of limited methodological quality (Bhoopathi et al. 2007). The game was based on 'Trivial Pursuit™' and the content was psychiatry related. The authors concluded that the limited evidence suggests educational games could help mental health students improve their knowledge.

Conclusions

Implications for practice

Due to the limited number of studies, their low-to-moderate methodological quality, and the inconsistent results, the evidence is unlikely to support a general recommendation for the use of educational games in medical schools. However, given their potential effectiveness, medical educators might use them when other types of educational interventions (e.g. didactic lectures) are perceived or proven to have limited effectiveness. This should ideally happen in the context of research to provide additional data.

When making the decision of substituting an educational game for another educational intervention, medical educators should weigh the potential benefits of the game against its costs, and the time and effort needed for its development (or adaptation) and for its implementation (Begg 2008). Also, medical educators have to be very careful in adapting a particular game to their specific setting and specific content and continuously assess whether the game is helping them meet their teaching goals (Akl et al. 2008a).

In adopting or adapting a game, medical educators need to keep the likely mediators of any potential benefit of educational games in mind. The first of these factors is the active learning experience through which educational games stimulate higher thinking such as analysis, synthesis, and evaluation, (Akl et al. 2008b). Another factor is the integration of fun and excitement in the learning process as they can reduce stress and anxiety (Allery 2004; Ballon & Silver 2004) and subsequently increase retention (Begg 2008). An additional factor that applies to educational strategies in general is providing feedback.

Implications for future evaluations

More and better-designed studies to assess the effectiveness of educational games are needed. Such studies should ideally be designed as RCTs adhering to high methodological standards such as allocation concealment and protection

from contamination (Akl et al. 2007). They should assess relevant educational and clinical outcomes (e.g. behavioral change) using pre- and post-intervention outcome assessment and validated outcome measures. In parallel to conducting an RCT, authors should consider conducting process evaluation studies (e.g. using qualitative designs) to explore the delivery of the intervention (how it was implemented and to what extent it was implemented as intended) and the mechanisms underlying its effects (e.g. increased motivation, reduce stress and anxiety). Qualitative studies would be additionally useful in exploring the impact of games on the interactions and the relationships between teachers and learners and among learners. Given the relatively challenging research methodology for educational interventions, it would be of great benefit that research teams including educators, games designers, and trial methodologists conduct such research projects.

It is important that future studies compare an educational game intervention to the best available alternative (e.g. interactive lecture as opposed to a didactic lecture). The game developers need to make sure that, besides the delivery method (i.e. use of game), the control intervention is similar in all aspects to the educational game intervention. This includes the educational content, the duration of the intervention, the person delivering the intervention, etc.

There is also a need to better report studies assessing the effectiveness of educational games. This includes a detailed description of the game (e.g. educational content, rules of the game, technological tools required), the intervention (e.g. length of each game session, frequency of administration, associated activities), the trial characteristics (e.g. whether allocation was concealed) and the analytical approach. Better reporting would enable better judgment about both the internal and external validity of the study results. It would also help with replication of the intervention.

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Appendix: Search strategies of electronic databases

MEDLINE

(1) Video games/
(2) 'Play and Playthings'/
(3) Games, experimental/
(4) (game? or gaming).tw.
(5) structured experience?.tw.
(6) or/1–5
(7) exp *education,continuing/
(8) exp Education, Professional/
(9) professional development.tw.
(10) exp Learning/
(11) ((medical or clinical or professional or clinician) adj (train$ or learn$)).tw.
(12) (behavio?r$ adj2 intervention?).tw.
(13) or/7–12
(14) exp Students, Health Occupations/
(15) exp Health Personnel/
(16) (provider? or practitioner? or doctor? or gp? or physician? or nurs$).tw.
(17) ((health or healthcare or health care or medical) adj (student? or staff or worker? or professional? or personnel)).tw.
(18) or/14–17
(19) 6 and 13 and 18

EMBASE

(1) exp Recreation/
(2) Play/
(3) Game/
(4) (game? or gaming).tw.
(5) structured experience?.tw.
(6) or/1–5
(7) exp Medical Education/
(8) exp Paramedical Education/
(9) Continuing Education
(10) professional development.tw.
(11) exp Learning/
(12) ((medical or clinical or professional or clinician) adj (train$ or learn$)).tw.
(13) (behavio?r$ adj2 intervention?).tw.
(14) or/7–13
(15) exp Health Personnel/
(16) (provider? or practitioner? or doctor? or gp? or physician? or nurs$).tw.
(17) ((health or healthcare or health care or medical) adj (student? or staff or worker? or professional? or personnel)).tw.
(18) or/15–17
(19) 6 and 14 and 18

CINAHL

(1) Video Games/
(2) 'Play and Playthings'/
(3) Games/
(4) (game? or gaming).tw.
(5) structured experience?.tw.
(6) or/1–5
(7) exp Education, Health Sciences/
(8) professional development.tw.
(9) exp Learning/
(10) exp Teaching Methods/
(11) ((medical or clinical or professional or clinician or practitioner or nurs$) adj (train$ or learn$)).tw.
(12) (behavio?r$ adj2 intervention?).tw.
(13) or/7–12

(14) exp Health Personnel/
(15) (provider? or practitioner? or doctor? or gp? or physician? or nurs$).tw.
(16) ((health or healthcare or health care or medical) adj (student? or staff or worker? or professional? or personnel)).tw.
(17) or/14–16
(18) 6 and 13 and 17

PsycINFO

(1) exp Games/
(2) Game Theory/
(3) (game? or gaming).tw.
(4) structured experience?.tw.
(5) or/1–4
(6) exp Medical Education/
(7) exp Continuing Education/
(8) Professional Development/
(9) exp Learning/
(10) ((medical or clinical or professional or clinician) adj (train$ or learn$)).tw.
(11) (behavio?r$ adj2 intervention?).tw.
(12) or/6–11
(13) exp Health Personnel/
(14) (provider? or practitioner? or doctor? or gp? or physician? or nurs$).tw.
(15) ((health or healthcare or health care or medical) adj (student? or staff or worker? or professional? or personnel)).tw.
(16) or/13–15
(17) 5 and 12 and 16

AMED

(1) 'Play and playthings'/
(2) video game?.tw.
(3) (game? or gaming).tw.
(4) structured experience?.tw.
(5) or/1–4
(6) exp Education Professional/
(7) professional development.tw.
(8) exp Learning/
(9) ((medical or clinical or professional or clinician) adj (train$ or learn$)).tw.
(10) (behavio?r$ adj2 intervention?).tw.
(11) or/6–10
(12) exp Health Personnel/
(13) (provider? or practitioner? or doctor? or gp? or physician? or nurs$).tw.
(14) ((health or healthcare or health care or medical) adj (student? or staff or worker? or professional? or personnel)).tw.
(15) or/12–14
(16) 5 and 11 and 15

ERIC (EBSCOhost)

(S1) SU play
(S2) SU video games
(S3) SU games
(S4) TI (game* or gaming)
(S5) TI (structured experience*)
(S6) S1 or S2 or S3 or S4 or S5
(S7) SU medical education
(S8) SU continuing education
(S9) SU professional development
(S10) SU learning
(S11) SU medical schools
(S12) TI (medical N1 train* or medical N1 learn* or clinical N1 train* or clinical N1 learn* or professional N1 train* or professional N1 learn* or clinician N1 train* or clinician N1 learn*)
(S13) TI (behaviour* N2 intervention or behavior* N2 intervention)
(S14) S7 or S8 or S9 or S10 or S11 or S12 or S13
(S15) SU health personnel
(S16) SU nurses
(S17) SU physicians
(S18) SU medical students
(S19) TI (provider* or practitioner* or doctor or doctors or gp* or physician* or nurse*)
(S20) TI (health N1 student or health N1 staff or health N1 worker* or health N1 professional* or health N1 personnel or healthcare N1 student or healthcare N1 staff or healthcare N1 worker* or healthcare N1 professional* or healthcare N1 personnel or health care N1 student or health care N1 staff or health care N1 worker* or health care N1 professional* or health care N1 personnel or medical N1 student or medical N1 staff or medical N1 worker* or medical N1 professional* or medical N1 personnel)
(S21) S15 or S16 or S17 or S18 or S19 or S20
(S22) S6 and S14 and S21

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(game* or gaming or video game*) OR IF(play*) OR TITLE(structured experience*) AND (medical educat* or medical school*) OR (continuing education) OR (professional development) OR IF (learn*) OR IF (teaching) OR TITLE((medical or clinical or professional or clinician) w/1 (train* or learn*)) OR TITLE((behavior* or behaviour*) w/2 intervention*) AND (provider* or practitioner* or doctor* or gp* or physician* or nurs*) OR IF (health personnel) OR IF(medical student*) OR TITLE((health or healthcare or health care or medical) w/1 (student* or staff worker* or professional* or personnel)).