Title

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

Review citation

Akl EA, Pretorius RW, Erdley WS, Sackett K, Bhoopathi PS, Alfarah Z, Schünemann HJ Educational games for medical students. BEME systematic review

Key words

Medical education, medical students, educational games

Synopsis

Using educational games has the potential to improve medical education outcomes. We reviewed the effect of educational games on medical students' satisfaction, knowledge, skills, attitude and behavior. We included 5 studies of low to moderate quality that evaluated different games. Findings suggested but did not confirm a positive effect of games on knowledge.

Key messages

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

Dates

Review commenced: March 2006

Literature search: January 2007

Review completed: August 2008

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Contributions of reviewers

EAA: conception and design, screening, data abstraction, data interpretation, manuscript drafting. RWP, KS, WSE: screening, data abstraction. PSB: screening, ZA: data abstraction. HJS: conception and design, screening, data interpretation. All authors critically reviewed the content of the report and approved its final version

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study design; in the collection, analysis, and interpretation of data; in the writing of the manuscript; and in the decision to submit the manuscript for publication.

Potential conflicts of interest

Three of the authors (EAA, PSB and HJS) are developing educational games. Otherwise, the authors report no academic, institutional, political, personal, financial or other conflicts of interest.

Abbreviations and Glossary

CCT: controlled clinical trials

CENTRAL: Cochrane Central Register of Controlled Trials

DARE: Database of Abstracts of Reviews of Effectiveness

EPOC: Cochrane Effective Practice and Organisation of Care Group

ITS: interrupted time-series

RCT: randomized controlled trial

Non-scientific executive summary

An educational game is “an instructional method requiring the learner to participate in a competitive activity with preset rules.” Using games to instruct medical students has the potential to improve their learning and clinical performance. Our question was: what is the impact of educational games on the satisfaction of medical students with their learning, on the knowledge, skills and attitudes they acquire from using these games, and on their clinical behavior?

To answer this question we conducted a systematic review of the medical literature. This type of review consists of conducting an extensive and laborious search of the literature, contacting authors of studies, and using standardized and rigorous methods to select relevant studies and abstract needed data. We selected only appropriately designed studies that tested educational games in instructing medical students.

We evaluated 1019 publications from which we identified five studies that could answer our question. The 5 studies evaluated 5 different educational games. The scientific quality of these studies was low to moderate, meaning that our confidence in their results is limited and likely to be influenced by additional research. Three of the five studies suggested but did not confirm a positive effect of the games on medical students’ knowledge. No study evaluated the impact of games on students’ satisfaction, skills, attitudes or clinical behavior.

The answers we obtained to our question do not confirm nor refute the utility of educational games as an effective teaching strategy for medical students. In order to clearly answer the question, there is a need for more and better-designed studies.

Abstract

Title

The effect of educational games on medical students' learning outcomes: a systematic review

Educational games for medical students

Authors

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Review completed: August 2008

Background and review context

Using games as an educational intervention may improve educational outcomes. For example, studies have suggested beneficial effects of educational games in medical education.

Objectives of the review

We reviewed the effect of educational games on medical students' satisfaction, knowledge, skills, attitude and behavior.

Review questions

What are the effects of educational games on the satisfaction, knowledge, skills, attitude and behavior of medical students?

Search strategy

We searched the following electronic databases from the date of their inception up to January 2007: DARE, Effective Practice and Organisation of Care (EPOC) Cochrane group Register, CENTRAL, MEDLINE, EMBASE, PsycINFO, CINAHL, AMED, ERIC, and Dissertation Abstracts Online. In addition, we screened the list of reference of included studies and contacted authors.

Topic definition and inclusion/exclusion criteria

An educational game is "an instructional method requiring the learner to participate in a competitive activity with preset rules." We included randomized controlled trials (RCT), controlled clinical trials, and interrupted time-series (as defined by EPOC). Study participants were medical students. Interventions of interest were educational games. Outcomes of interest were medical students' satisfaction, knowledge, skills, attitude and behavior.

Data collection, analysis and synthesis

We developed a data extraction form as a modified version of the BEME data checklist. Two reviewers independently extracted data from each study and resolved disagreements by discussion or consulting a third reviewer. 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, outcomes measures and methodological quality.

Headline results

The title and abstract screening of the 1019 unique citations identified 26 as potentially eligible for this review. The full text screening identified 5 eligible papers, all reporting RCTs with low to moderate methodological quality. Findings in 3 of the 5 RCTs suggested but did not confirm a positive effect of the games on medical students' knowledge.

Conclusions

The available evidence to date does not 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 review will inform this research.

Keywords

Medical education, medical students, educational games

Review citation

Akl EA, Pretorius RW, Sackett K, Erdley S, Bhoopathi PS, Alfarah Z, Schünemann HJ. Educational games for medical students. BEME systematic review

Introduction

A number of definitions for educational games exist. One definition describes an educational 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 and 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 (2006). 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). Educational games thus have the potential to promote the learning of facts as well as the learning of cognitive processes (Abt 1966; Greenblat and others 1981).

School teachers 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 and others 2008b), board games to teach about the conceptual models of nursing (Cessario 1987), 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 et al implemented a board game format during a pediatric clerkship and noted positive feedback from medical students, pediatric residents and faculty (Ogershok and Cottrell 2004). Boreham et al found that an interactive computer game increased the percentage of medical students making optimal decisions in managing phenytoin doses (Boreham and others 1989). Moy et al reported positive evaluations from medical students of "Who Wants to Be a Physician", an educational game used to teach pulmonary physiology (Moy and others 2000).

Objectives

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

Review questions

What are the effects of educational games on the satisfaction, knowledge, skills, attitude and behavior of medical students?

Review Methodology

Inclusion/exclusion criteria for studies, participants, interventions and outcomes

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 review 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; 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 1).

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 the review.

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 management techniques

Data extraction

The data extraction was based on the EPOC checklist and was consistent with the 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, outcomes measures and methodological quality (see below).

Findings

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 review. The full text screening of these citations identified 5 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 8 additional papers because they did not report any evaluation of the game being described (Table 3).

Overview of the studies included in the review

Tables 1 reports the characteristics of included studies. Participants were dental students in one study (Udin and 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 the 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 5 included studies were: TV show type of games (n=1) (O'Leary and others 2005), board games (n=2) (Siqueira and others 1992; Udin and Kuster 1985), interactive computer games (n=1) (Boreham and others 1989), and charade type of game (n=1) (Selby and others 2007). One study covered a basic sciences topic: biochemical pathways (Siqueira and others 1992). Four studies covered clinical sciences topics: sensitization towards handicapped dental patient (Udin and Kuster 1985), drug dose management (Boreham and others 1989), ectopic pregnancy (O'Leary and others 2005), and child development (Selby and others 2007). Two games were case based (Boreham and others 1989; Udin and Kuster 1985).

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

Methodological quality of studies

Of the 5 RCTs, 4 had an active control group (O'Leary and others 2005; Selby and others 2007; Siqueira and others 1992; Udin and Kuster 1985), with 2 reporting efforts to keep content similar to the one in the intervention group (O'Leary and others 2005; Selby and others 2007). Only 2 studies used pre and post intervention assessment of at least one of their outcomes (O'Leary and

others 2005; Udin and Kuster 1985). Two studies employed validated or structured outcome measures: O'Leary et al used a knowledge test validated by content experts (O'Leary and others 2005) while Selby et al used an objective structured clinical examination (Selby and others 2007). None of the studies reported efforts to protect against contamination. One study reported concealing allocation (Selby and others 2007).

Narrative comment on review results

The findings of the 5 RCTs were as follows:

- A board game to sensitize dental students towards handicapped patients was not statistically different from a standard lecture or no intervention in the effect on attitudes (Udin and Kuster 1985). The RCT met 1 of the 4 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 and others 2005). The RCT met 2 of the 4 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 and others 2007). The RCT met 2 of the 4 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 and others 1989). The RCT met none of the 4 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 and others 1992). The RCT met none of the 4 methodological quality criteria.

Meta-analysis results

The only outcome reported by at least 2 studies was knowledge. The available data could not be pooled for that outcome as each study reported a different summary statistic: percentages (Boreham and others 1989), percentages for 6 ranges of scores but no overall percentage ,(Siqueira and others 1992) pre and post intervention scores (O'Leary and others 2005), and post intervention scores (Selby and others 2007). Moreover, these studies varied in terms of the type of intervention, type of control, outcomes measure and methodological quality.

Summary of results

The systematic review identified 5 studies evaluating different types of educational games for medical students and covering both basic and clinical sciences topics. These 5 studies had a low to moderate methodological quality. Findings in 3 of the 5 RCTs suggested a positive effect of the games on medical students' knowledge.

Discussion

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.

Inferences from this review are limited by the methodological quality of included studies. The 5 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 (Da Rosa and others 2006; Eckert and others 2004; Girardi and others 2006; Mann and others 2002; Steinman and Blastos 2002). 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 do not confirm nor refute the utility of games as a teaching strategy for health professionals and called for additional high-quality research (Akl and others 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 and others 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 and others 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 [5]. Another factor is the integration of fun and excitement in the learning process as they can reduce stress and anxiety [6, 7] and subsequently increase retention [8]. 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 and others 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 amongst 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.

Strengths and limitations of the review

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, outcomes 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. Our conclusions do not thus apply to other types of interventions sometimes labeled as games, such as role playing and simulations.

This systematic review 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.

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BEME disclaimer

BEME review results are, necessarily, interpreted in light of individual perspectives and circumstances. The conclusions presented in this review are the opinions of review authors. Their work has been supported by BEME but their views are not necessarily shared by all BEME members.

The aim of BEME is to make the results of research into the effectiveness of educational interventions available to those who want to make more informed decisions. This information is an essential contribution to the process of deciding whether to adopt a particular educational intervention or not. Information and the assessment of needs, resources and values; as well as judgments about the quality and applicability of evidence are equally important. It is unwise to only rely on evidence about the impact of a particular educational intervention. Understanding learning process for the students in your context, knowledge of past success and failures and how educational interventions work are all vital. BEME does not accept responsibility for the results of decisions made on the basis of a BEME Review.

Tables

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

Study	Study design	Intervention	Participants	Outcomes	Methodological quality	Results
Udin 1985 (Udin and Kuster 1985)	Randomized controlled trial: · Intervention: playing the game · Control: standard small group lecture; content apparently different than intervention group (dental techniques for treating the handicapped) · No intervention	"Smile" · Description: board game that involved chance (roll of dice) and created clinical situation with possible outcomes and their sequelae · Educational content: behavior management strategies and modifications of treatment · Learning outcome: appropriate management of handicapped dental patient	· 42 senior dental students learning to manage handicapped dental patients; (intervention: 10; control: 13; no intervention: 19) · Country: USA	· Confidence in dealing with handicapped children: 9 right-wrong questions · Willingness to treat handicapped children: 8 5-point Likert scale	· Pre & post outcome assessment · Validity and reliability of outcome measure not reported; based on a previously developed test · Protection against contamination: not clear · Allocation concealment: not clear	· No differences between the 3 groups in terms of confidence or willingness to treat handicapped children
Boreham 1989 (Boreham and others 1989)	Randomized controlled trial: · Intervention: playing the game once · Control: no intervention	"The Phenytoin Game" · Description: interactive computer game with case histories of 10 patients with varying degrees of acuity of seizure	· 32 final year medical students taking clinical pharmacology courses; (intervention: 17; control: 15) · Country: UK	· Knowledge test: case base test asking for a decision on the phenytoin dose	· Post outcome assessment · Validity and reliability of outcome measure not reported · Protection against	· Percentage of optimal decisions: 65% (intervention) vs. 29% (control); $p<0.001$

		disorder · Educational content: management of phenytoin dose · Learning outcome: appropriate dosage of phenytoin at each stage of case management			contamination: not clear · Allocation concealment: not clear	
Siqueira 1992 (Siqueira and others 1992)	Randomized controlled trial: · Intervention: educational material with Dynamic Metabolic Diagrams (DMD) (n=36) Control: educational material without DMD (n=53)	"Dynamic Metabolic Diagrams (DMD)" · 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. · Educational content: metabolic pathways · Learning outcome: to fill display the entire metabolic pathway	· 89 freshmen medical students (intervention: 36; control: 53) · Country: Brazil	· Knowledge: written examination (including calculations and open ended questions) 1 week later	· Post outcome assessment (higher scores better than lower scores) · Validity and reliability of outcome measure not reported · Protection against contamination: not clear · Allocation concealment: not clear	· Scores were higher for the intervention group; data presented as percentages for 6 ranges of scores but no overall percentage reported; no statistical testing reported
O'Leary 2005 (O'Leary and others 2005)	· Randomized controlled trial: · Intervention: playing the game · Control: standard lecture	· Description: Jeopardy style game, cards with increasing dollar values displayed for different categories · Educational content:	· 104 third year medical students; (intervention: 52; control: 52) · Country: USA	· Knowledge test: 20-item multiple choice test · Satisfaction with and evaluation of the game: 4 5-point	· Pre & post knowledge test (higher scores better than lower scores) · Content experts	· knowledge scores: pre=12.52, post=17.04(1.27) (intervention) vs. pre=11.33, post=16.98(1.62)

	· Efforts made to keep content similar in 2 groups (same tutor, educational material)	epidemiology and differential diagnosis, risk factors, signs and symptoms, diagnosis, and treatment of ectopic pregnancy · Learning outcome: collect points based on degree of difficulty and complexity of questions		Likert scale questions and 3 true-false questions	validated knowledge test; satisfaction survey taken from validated tests · Protection against contamination: not clear · Allocation concealment: not clear	(control): scores improved from pre to post in each group; no statistical testing reported for difference in improvement between 2 groups · Ratings of the game were overall better than ratings of the standard lecture
Selby 2007 (Selby and others 2007)	Randomized controlled trial: · Intervention: playing the game · Control: interactive lecture; efforts made to keep content similar in 2 groups (same duration, tutor, educational material)	"Development charades" · 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 · Educational content: milestones and behavior for key developmental ages · Learning outcome: developmental milestones	· 100 fifth year medical students during their pediatric module; (intervention: 52; control: 48) · Country: UK	· Knowledge test immediately after teaching session: "best of five" multiple choice questionnaire · Objective Structured Clinical Examination (OSCE)	· Post knowledge test (higher scores better than lower scores) · Validity and reliability of knowledge test not reported; OSCE is a standardized test · Protection against contamination: not clear · Allocation concealment: Yes	· knowledge scores: 43.6 (95%CI 17-70) (intervention) vs. 37.15 (95%CI 11-63) (control); p<0.01 · OSCE scores: 20.5 (95%CI 14-27) (intervention) vs. 19.5 (95%CI 14-25) (control); difference not statistically significant

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

Study	Study design	Intervention	Participants	Outcomes	Methodological quality	Results
Fleiszer 1997 (Fleiszer and others 1997)	Single arm study · Intervention: playing the game once	"Doughnut Rounds" · TV game show format · Educational content: critical care in surgery	· 25 medical students on surgical intensive care unit rotation · Country: Canada	· Satisfaction with and evaluation of the game	· Post outcome assessment · Validity and reliability of outcome measure not reported	· Ratings of the game were overall positive
Colombo 1998 (Colombo and others 1998)	Single arm study · Intervention: playing the game once	"Cellular & Humoral Immunology Game" · Card game · Educational content: immunology	· 93 fourth semester medical students taking Medical Immunology course · Country: Brazil	· Satisfaction with and evaluation of the game	· Post outcome assessment · Validity and reliability of outcome measure not reported	· Ratings of the game were overall positive
Fukuchi 2000 (Fukuchi and others 2000)	Single arm study · Intervention: elimination tournament playing the game	"Oncology Game" · Interactive, computer-assisted board game; case based · Educational content: Cancer treatment	· 16 third year medical students · Country: USA	· Knowledge test · Self reported improvement in knowledge	· Pre & post knowledge test (higher scores better than lower scores) · Validity and reliability of outcome measures not reported	· knowledge scores: pre=4.86(0.42) vs. post=5.63(0.26) p=0.26 (round 1; all 16 students); pre=10.75(0.62) vs. post=11.5(0.85) p<0.001 (round 2; 8 students who passed round 1); · Self reported improvement in understanding and knowledge

Moy 2000 (Moy and others 2000)	Single arm study · Intervention: playing the game once	· "Who Wants to Be a Physician?" · TV game show format · Educational content: pulmonary physiology	· 109 first year medical students · Country: USA	· Satisfaction with and evaluation of the game	· Post outcome assessment · Validity and reliability of outcome measure not reported	· Ratings of the game were overall positive
Howard 2002 (Howard and others 2002)	Single arm study · Intervention: playing the game once	"Survivor" · TV game show format · Topic: pulmonary physiology	· 179 first year medical students · Country: USA	· Satisfaction with and evaluation of the game · Comparison of the game to a previously used game "Who Wants to Be a Physician?" (Moy and others 2000)	· Post outcome assessment · Validity and reliability of outcome measure not reported	· Ratings of the game were overall positive · Scores were significantly higher than those for "Who Wants to Be Physician?" (Moy and others 2000)
Mann 2002 (Mann and others 2002)	Single arm study · Intervention: playing the game once	"The breast game" · Computerized board game; case based · Educational content: management of breast nodule	33 medical students · Country: USA	· Knowledge test · Satisfaction with and evaluation of the game	Pre & post knowledge test (higher scores better than lower scores) · Validity and reliability of outcome measures not reported	· knowledge scores: pre=6.43(0.30) vs. post=7.14(0.30) p=0.006 · Ratings of the game were overall positive
Roubidoux 2002 (Roubidoux and others 2002)	Single arm study · Intervention: playing the game once	"Breast Cancer Detective" Link · Interactive web-based game; case based · Content related to breast cancer	· 42 medical students taking radiology elective · Country: USA	· Satisfaction with and evaluation of the game	· Post outcome assessment · Validity and reliability of outcome measure not reported	· Ratings of the game were overall positive

Steinman 2002 (Steinman and Blastos 2002)	Single arm study · Intervention: playing the game once	Host defense trading card game · Card game · Educational content: principles of host disease interactions	· 8 first year medical students (in addition to 8th & 10th graders) · Country: USA	· Knowledge test · Satisfaction with and evaluation of the game	· Pre & post knowledge test · Validity and reliability of outcome measures not reported	· pre=80% vs. post=88% average percentage correct answers p=0.049 · There was no improvement in answers to "control questions" · Ratings of the game were overall positive
Eckert 2004 (Eckert and others 2004)	Single arm study · Intervention: playing the game once	"T-lymphocyte and B-lymphocyte tolerance game" · Card game · Educational content: immunology	· 120 second year medical students attending immunology course · Country: Brazil	· Knowledge test · Satisfaction with and evaluation of the game	· Pre & post knowledge test (higher scores better than lower scores) · Validity and reliability of outcome measures not reported	· knowledge scores: pre=7.6 vs. post=9.5 p<0.0001 (previous reading assignment); pre=6.1 vs. post=8.3 p<0.0001 (no previous reading assignment) · Ratings of the game were overall positive
Ogershok 2004 (Ogershok and Cottrell 2004)	Single arm study · Intervention: playing the game once	"Pediatric Board Game" · Board game · Educational content: core pediatric knowledge	· 37 third year medical students and residents · Country: USA	· Satisfaction with and evaluation of the game	· Post outcome assessment · Validity and reliability of outcome measure not reported	· Ratings of the game were overall positive
Da Rosa 2006 (Da Rosa and others 2006)	Single arm study · Intervention: playing the game once	"Hepatitis Game" · Card game; case based · Educational content: viral hepatitis	· 140 undergraduate medical students · Students were classified based on whether they	· Knowledge test · Satisfaction with and evaluation of the game	· Pre & post knowledge test (higher scores better than lower scores) · Validity and	· knowledge scores: pre=7.52(2.1) vs. post=8.87(1.08) p<0.0001 (previous reading assignment); pre=5.84(1.9) vs.

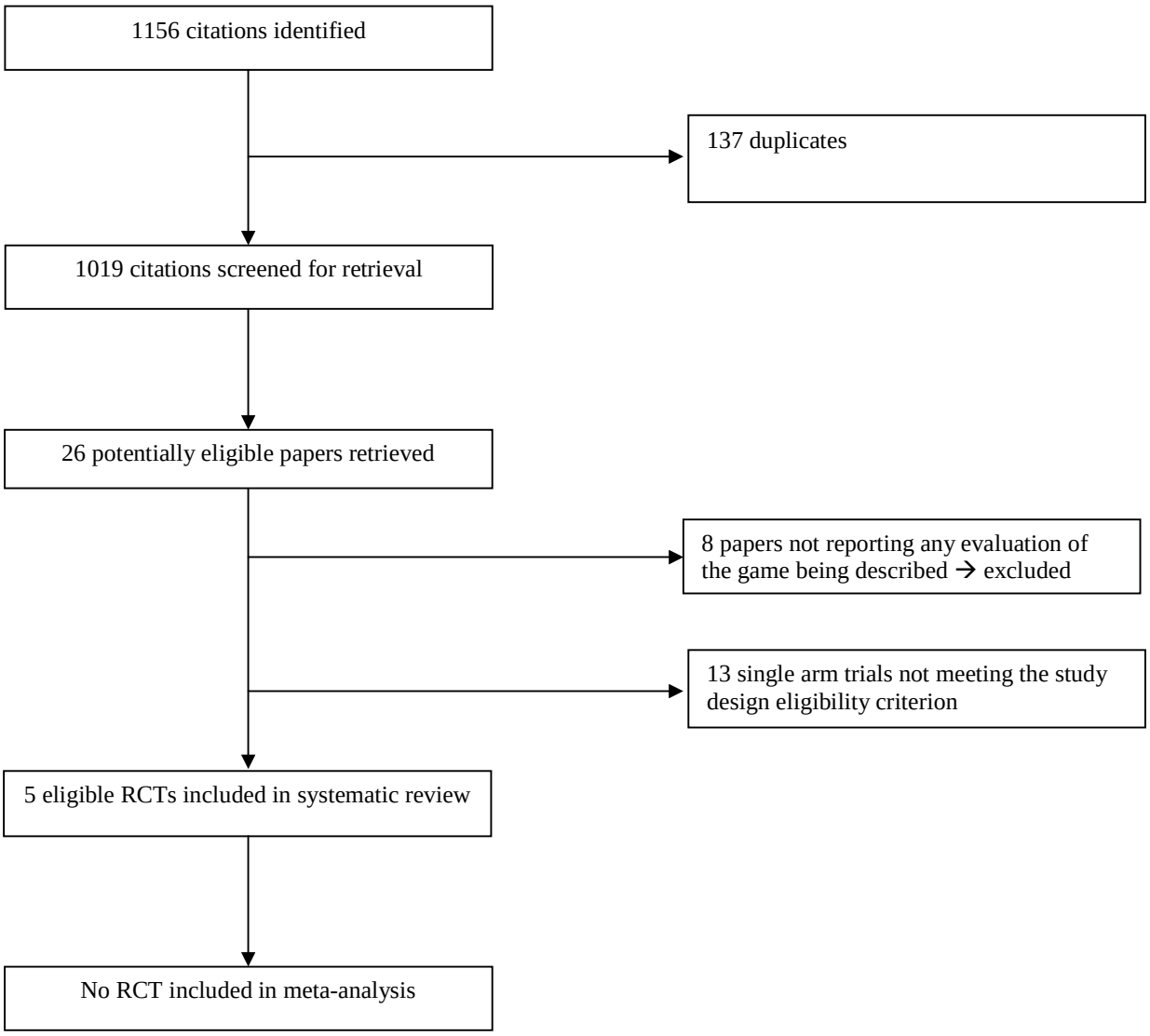
			had a previous reading assignment · Country: Brazil		reliability of outcome measures not reported	post=8.58(1.09) p<0.0001 (no previous reading assignment) · Ratings of the game were overall positive
Girardi 2006 (Girardi and others 2006)	Single arm study · Intervention: 4 sessions of the game with a 7-day interval between ·	"T- and B-Cell Ontogeny Game" · Board game. · Content related to T/B-cell ontogeny and medical immunology	· 72 fourth semester medical students taking immunology course · Country: Brazil	· Knowledge in immune system ontogeny · Satisfaction with and evaluation of the game	· Pre & post outcome assessment (higher scores better than lower scores) · Validity and reliability of outcome measure not reported	· Knowledge scores: pre=8.0(0.9) vs. post=9.0(0.8) p<0.001 (with previous reading); pre=4.8(1.1) vs. post=8.3(0.8) p<0.001 (without previous reading) · Ratings of the game were overall positive
Hudson 2006 (Hudson and Bristow 2006)	Single arm study · Intervention: playing the game once	"Who Wants to Be a Millionaire" · TV game show format; case based · Educational content: physiology of growth and puberty	· 107 first year medical students · Country: UK	· Satisfaction with and evaluation of the game	· Post outcome assessment · Validity and reliability of outcome measure not reported	· Ratings of the game were overall positive

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 1972 (Schneiderman and 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 1984 (MacLeod and 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 1986 (Robertson and 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 (Hafferty 1990)	· Target: medical students · Educational content: physician identity and stereotypes	· TV show format (To Tell The Truth) · Four contestants—one physician and 3 imposters—are interviewed by the class to determine the real physician.
"The Lactation Game" Elder 1996 (Elder and Gregory 1996)	· Target: medical students and obstetrics/gynecology residents · Educational content: breastfeeding	· Board game · Learners answer questions regarding breast physiology and community lactation resources
"Diversophy"® Salimbene 1998 (Salimbene 1998)	· Target: healthcare workers and medical students · Educational content: cultural competency	· Board game · Players collect dividends by caring for diverse patient scenarios successfully
"Context is key" Ballon 2004 (Ballon and Silver 2004)	· Target: Multiple health disciplines · Educational content: psychiatric diagnoses	· Card-sorting game · One of five psychiatric diagnoses is suggested by the context of symptom clusters
"Trivial Pursuit of Physiology" Zakaryan 2005 (Zakaryan and others 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.

Figures

Figure 1: Study flow



Appendices

Appendix 1: 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

ProQuest Dissertations & Theses: Full Text

(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))

Appendix 2: Quality criteria for the different study designs

For randomized controlled trials (RCT) and controlled clinical trials (CCT):

1. Concealment of allocation
2. Follow-up of professionals
3. Follow-up of patients or episodes of care
4. Blinded assessment of primary outcome(s)
5. Baseline measurement
6. Reliable primary outcome measure(s)
7. Protection against contamination

For interrupted time series analyses (ITS):

Protection against secular changes

1. Data were analyzed appropriately
2. Reason for the number of points pre and post intervention given
3. Shape of the intervention effect was specified

Protection against detection bias

4. Intervention unlikely to affect data collection
5. Blinded assessment of primary outcome(s)
6. Completeness of data set

Appendix 3: Data extraction form

Study ID:	First Author:	Year:

1. Language: 1. English 2. Other: _____

2. Country: 1. USA 2. Other: _____

3. Funding: 1. Governmental: 2. Private for profit:
3. Private not for profit: 4. Not funded
5. Not reported

4. IRB approval: 1. Done 2. Not Clear

5. Type of trial: 1. RCT 2. CCT
3. ITS

The intervention

6. Name of the Game: _____

7. Type of the game under investigation:
1. Board game 2. Based on a TV game show
3. Other (please describe):_____

8. Investigators adapted an already existing game (vs. developed it for the study):
1. Yes:_____ 2. No 3. Not clear

9. The game rules were clearly described:
1. Yes 2. No

10. The game has an element of fun
1. Yes 2. No 3. Not clear

11. The game has an element of competition:
1. Yes 2. No 3. Not clear

12. The player competes with:
1. Other players 2. Game/Computer/Self

13. Material needed to run the game (technological or other):
1. Described: _____
2. Not described

14. Participants play as:

1. Individuals 2. Groups; # players/group: _____
3. Not clear

15. Frequency and duration of exposure: _____

16. Location and context: _____

17. Rewards given

1. Course credit/grade 2. Monetary prize
3. Non-monetary prize:_____ 4. None
5. Not Clear

18. Educational process

1. Content transfer 2. Experiential learning
3. Other (please describe):_____

19. The Content relates to (area, topic): _____
Source of information: _____ Not reported

20. The Content is:

1. Fact based 2. Problem based (case based)
3. Not clear

21. Specific learning objectives were clearly stated

1. Yes 2. No 3. Not clear

22. Challenges to implementation

1. Yes:_____
2. None reported

23. Intervention in the control group:

1. No intervention
2. Standard teaching (please describe):_____
3. Another game (please describe): _____
4. Not applicable (no control group)
5. Other (please describe):_____

The health professional

24. Profession: ☐ Medicine ☐ Nursing ☐ Other: _____

25. Level: ☐ In practice ☐ In training ☐ Student

26. Age: ☐ Mean/SD:___/___ ☐ Median:____

27. Time since graduation: ☐ Mean/SD:___/___ ☐ Median:____

The patients

28. Patients involved in the study: 1. Yes 2. No (go to question 33)

29. Clinical problem: 1. _____ 2. Not Clear

30. Patients' age ☐ Mean/SD:___/___ ☐ Median:____

31. Patients' gender: ____% female

32. Patients' ethnicity: ____% African American ____%Caucasian
____%Hispanic ____% Other

33. Other characteristic (specify):

34. Number of patients included in the study:
1. Episodes of care:___ 2. Patients:___
3. Providers:___ 4. Practices:___
5. Hospitals:___ 6. Communities or regions:___

35. Please check for:

	Unit of allocation	Unit of Analysis
1. Patient	___	___
2. Provider	___	___
3. Practice	___	___
4. Institution	___	___
5. Community	___	___
6. Firm	___	___
7. Clinic day	___	___
8. Other (specify)	___	___
9. NOT CLEAR	___	___

36. Power calculation:
1. Done 2. Not done 3. Not clear

Outcome

37. Outcome (Circle all that apply):
1. Knowledge 2. Skills 3. Attitude

4. Behavior 5. Satisfaction 6. Patient outcome
7. Other:_____

38. Primary outcome:

Methodological quality

39. Follow-up of professionals: 1. Reported: _____% 2. Not reported

40. Follow-up of patients: 1. Reported: _____% 2. Not reported
3. Not applicable

Methodological criteria for RCT and CCT:

41. Blinded assessment of primary outcome
1. Done 2. Not done 3. Not clear

42. Baseline measurement
1. Done 2. Not done 3. Not clear

43. Reliable primary outcome measure
1. Done 2. Not done 3. Not clear

44. Protection against contamination
1. Done 2. Not done 3. Not clear

45. Allocation Concealment:
1. Done 2. Not Clear
3. Not Done 4. Not used (D)

Additional methodological criteria:

46. The study health care providers are representative
1. Yes 2. No (explain):_____

47. The study patients are representative
1. Yes 2. No (explain):_____

48. Potential for bias and confounding (based on quality criteria 39-46)
1. Yes 2. No (explain):_____

49. Description of intervention was clear enough to allow replication:
1. Yes 2. No (explain):_____

50. Outcomes assessment used a standardized measurement tool
1. Yes 2. No (explain):_____

51. Analytic approach clearly described an appropriate.
1. Yes 2. No (explain):_____

Results

52. Number of participants in group 1: _____

53. Number of participants in group 2: _____

54. Outcome: _____

55. Result:

56. Outcome: _____

57. Result: