TITLE:

Effectiveness of Teaching Evidence-Based Medicine to Undergraduate Medical Students: A BEME Systematic Review

RUNNING HEAD:

Teaching EBM to Medical Students

AUTHORS:

Seyed-Foad Ahmadi, MD, MPH [1]; Hamid R Baradaran, MD, PhD [2]; Emad Ahmadi, MD [3].

[1] I. Postdoctoral Fellow (previously) at Center for Educational Research in Medical Sciences, Iran University of Medical Sciences, Tehran, Iran; II. Postdoctoral Fellow at Department of Medicine, University of California Irvine, Irvine, CA, USA.

[2] Associate Professor of Clinical Epidemiology/ Deputy of Research at Center for Educational Research in Medical Sciences, Iran University of Medical Sciences, Tehran, Iran.

[3] I. Postdoctoral Fellow (previously) at Digestive Diseases Research Institute, Tehran University of Medical Sciences, Tehran, Iran; II. Postdoctoral Fellow at Department of Radiology, Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA.

CORRESPONDENCE:

Hamid R Baradaran

Associate Professor of Clinical Epidemiology/ Deputy of Research

Center for Educational Research in Medical Sciences

Iran University of Medical Sciences

Zip Code: 14496-14535

Tehran, Iran.

Tel: +98-21-86702216

Fax: +98-21-86702237

Email: baradaran.hr@iums.ac.ir

DECLARATION OF INTEREST:

The authors have no competing interest to declare.

ABSTRACT

Background: Despite the widespread teaching of evidence-based medicine (EBM) to medical students, the relevant literature has not been synthesized appropriately as to its value and effectiveness.

Aim: To systematically review the literature regarding [1]the impact of teaching EBM to medical students on their EBM knowledge, attitudes, skills, and behaviors.

Methods: MEDLINE, SCOPUS, Web of science, ERIC, CINAHL, and Current Controlled Trials up to May 2011 were searched; backward and forward reference checking of included and relevant studies was also carried out. Two investigators independently extracted data and assessed the quality of the studies.

Results: 10,111 potential studies were initially found, of which 27 were included in the review: Six studies examined the effect of clinically integrated methods, of which five had a low quality and the other one used no validated assessment tool. Twelve studies evaluated the effects of seminars, workshops and short courses, of which eleven had a low quality and the other one lacked a validated assessment tool. Six studies examined e-learning, of which five having a high or acceptable quality reported e-learning to be as effective as traditional teaching in improving knowledge, attitudes and skills. One robust study found problem-based learning less effective compared to usual teaching. Two studies with high or moderate quality linked multicomponent interventions to improved knowledge and attitudes. No included study assessed the long-term effects of the teaching of EBM.

Conclusions: Our findings indicated that some EBM teaching strategies have the potential to improve knowledge, attitudes and skills in undergraduate medical students, but the evidenced

base does not demonstrate superiority of one method. There is no evidence[l2] demonstrating transfer to clinical practice.

Keywords: Teaching, Evidence-Based Medicine, Undergraduate Medical Education, Outcome Measure, Systematic Review.

INTRODUCTION

Evidence-based medicine (EBM) is "the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients" (Sackett et al., 1996). The practice of EBM usually requires the following five steps: 1) Translating the uncertainties into answerable questions (asking); 2) Searching for and retrieving evidence to answer the questions (acquiring); 3) Critically appraising the evidence for validity and clinical importance (appraising); 4) Applying the appraised evidence to inform the clinical decisions (applying); and 5) Evaluating the performance in the pervious four steps (assessing) (Dawes et al., 2005).

The Teaching of EBM has become increasingly popular in both undergraduate and postgraduate medical education programs worldwide (Crilly et al., 2009). EBM is now a component of the foundation years training program in the UK, (Colleges., 2007) the focus of graduate assessment in the USA (Stewart, 2001) and a requirement of practicing physicians in Canada (Frank et al., 2005). However, there is limited robust-evidenced research that has examined the teaching methods of EBM (Hatala and Guyatt, 2002).

EBM experts have systematically reviewed the literature regarding teaching EBM to postgraduates (Coomarasamy and Khan, 2004, Flores-Mateo and Argimon, 2007) and allied health professionals (Dizon et al., 2012), teaching critical appraisal (Parkes et al., 2001, Taylor et al., 2000b, Norman and Shannon, 1998), assessing the effectiveness of journal clubs (Harris et al., 2011, Ebbert et al., 2001), evaluation methods of EBM education (Shaneyfelt et al., 2006, Walczak et al., 2010), and barriers to EBM application by residents (van Dijk et al., 2010). However, the most effective methods for teaching EBM to undergraduate medical students have remained unclear.

Hence, the aim of this systematic review was to evaluate the effect of various EBM teaching strategies on medical students' knowledge, attitudes, skills, and behaviors. In addition, the teaching of EBM is reported to be improved by breaking it into the steps of asking, acquiring (or accessing), appraising, applying, plus an evaluating (or assessing) step (Del Mar et al., 2004). Therefore, we also examined whether the educational interventions could improve the above EBM steps.

METHODS

Criteria for inclusion of studies:

We included the comparative studies i.e. randomized controlled trials, non-randomized controlled trials, and self-controlled trials that: A) had recruited undergraduate medical students (defined as medical school students who have not yet enrolled in the residency programs), B) had carried out at least one educational intervention (defined as coordinated educational activity, of any medium, duration or format) to teach EBM, and C) had objectively assessed the impact of the intervention(s) on students' knowledge, attitudes, skills, or behaviors using tests, questionnaires, clinical performance, etc. Self-reported perceived knowledge, skills or behaviors were not eligible since they are loosely connected to their objective measurements (Caspi et al., 2006, Khan et al., 2001).

Identification and selection of studies:

We searched the following databases up to May 2011: MEDLINE, SCOPUS, ISI Web of Science, Educational Resource Information Center (ERIC), and Cumulative Index to Nursing and Allied Health Literature (CINAHL) using the following search strategy:

((evidence-based medic) OR (evidence based medic*) OR (evidence-based practic*) OR (evidence based practic*) OR (critic* AND apprais*) OR (pre-filter*) OR (prefilter*) OR (pre-digest*) OR (predigest*))* ***AND*** *(educat* OR teach* OR cours* OR workshop* OR learn* OR instruct* OR curriculum* OR (journal* AND club*) OR (case discuss*))* ***AND*** *(student* OR intern OR interns OR internship* OR (clinical clerk*) OR undergraduat*).*

We also searched the Current Controlled Trials for relevant unpublished studies. For this purpose, we tailored the above search strategy accordingly. Furthermore, we performed a backward and forward reference checking by: A) screening the references of our included studies

and relevant systematic reviews, and B) screening the studies that have cited any of our included studies as their references (citation checking). We performed the latter using Science Citation Index and SCOPUS.

The retrieved studies were imported into EndNote X3 software and the duplicated studies were removed. The remaining studies were subsequently screened for inclusion based upon their titles and abstracts initially, and their full-text finally. One of the two investigators (SFA, EA) decided upon including each study (this step was not performed in duplicate).

Data abstraction and risk of bias assessment:

Two investigators (SFA and EA) independently summarized the study characteristics, key results, and quality indicators using an electronic data abstraction form in Microsoft Excel Software. Disagreements between the two investigators were resolved by third reviewer negotiation. For studies with unclear or inadequate results, we sent an electronic data abstraction form to the corresponding author and requested further details.

For quality assessment, two sets of criteria were used: A) a set of criteria developed by the Cochrane Effective Practice and Organisation of Care (EPOC) group (Parkes et al., 2001) and "using validated assessment tools" criterion (the investigators used this set to code the overall risk of bias as high, moderate, or low); and B) a modified version of another criteria developed by Reed *et al.* to appraise the reports of medical education interventions (Reed et al., 2005). These criteria are available in *Table 2*.

Synthesis of results:

We synthesized the results qualitatively by tabulating the characteristics of the included studies (*Table 1*) and whether they fulfill the quality criteria (*Table 2*). We also classified the studies

based on their interventions, and discussed the effects of the interventions on the knowledge, attitudes, skills, and behaviors of asking, acquiring, appraising, and applying.

Inter-rater agreement was quantified using Kappa scores. To calculate the Kappa scores for our data abstraction, we compared the codes that the two investigators assigned to the study designs, intervention categories, and assessment types of the included studies (*Table 1*). To calculate the Kappa scores for our quality assessments, we compared the assigned codes to the quality criteria (*Table 2*).

We attempted to meta-analyze the results of the studies with similar outcome assessments and with minimal diversity in their study designs, participants, and interventions. However, we found few studies with the above characteristics and therefore felt meta-analysis to be an inappropriate statistical endeavor in this context.

RESULTS

Description of included studies:

We retrieved 10,111 records in total, of which 27 were included in this study (*Table 1*). Included studies with non-randomized designs and high risks of bias were predominant: The number of self-controlled trials, parallel non-randomized controlled trials, and randomized controlled trials was 11, 6, and 10, respectively (*Table 1*). In addition, the number of studies with a high, moderate, and low risk of bias was 17, 5, and 5, respectively (*Table 2*). No included study evaluated the long-term effects of the intervention(s), and only 16 studies reported their results in adequate detail (*Table 2*). Kappa values were 0.87, 0.69,and 0.72 for the inter-rater agreement in data abstraction and in the two parts of the quality assessment, respectively.

Effects of clinically integrated methods:

The teaching of EBM is believed to be more effective if it is integrated into clinical practice (Coomarasamy and Khan, 2004). We identified seven studies evaluating such clinically integrated methods (West et al., 2011, Lai and Nalliah, 2010, Aronoff et al., 2010, Lai and Teng, 2009, Krueger, 2006, Alper and Vinson, 2005, Dorsch et al., 2004), while the remaining twenty studies evaluated standalone methods in no clinical practice context. Dorsch *et al.* reported the earliest clinically integrated teaching of EBM to the students, in which they observed slightly improved asking skills, acquiring attitudes and skills, and appraising skills (Dorsch et al., 2004). Another study also observed no effect of a clinically integrated method on acquiring attitudes (Lai and Nalliah, 2010). However, they reported no *a priori* sample size calculation; thus, they might lack sufficient power to detect a possibly existent educational effect.

The other five studies of clinically integrated methods reported improved acquiring skills (Alper and Vinson, 2005), appraising knowledge and skills (Krueger, 2006), and EBM knowledge

(West et al., 2011) and skills (Lai and Teng, 2009, Aronoff et al., 2010, West et al., 2011). However, four of them had a high risk of bias (*Table 2*), and the only exception – with a moderate risk of bias – lacked a validated assessment tool (Krueger, 2006). In addition, in one of these five "positive" studies, participants who were educated earlier received lower post-test scores, which indicates that the educational effect might be short-term (Lai and Teng, 2009).

Effects of short instructions:

Eleven studies examined the effect of seminars, workshops and short courses (Sastre et al., 2011, Taheri et al., 2008, Weberschock et al., 2005, Gruppen et al., 2005, Sanchez-Mendiola, 2004, Fritsche et al., 2002, Rosenberg et al., 1998, Landry et al., 1994, Frasca et al., 1992, Bennett et al., 1987, Radack and Valanis, 1986), from which two studies reported no effect on acquiring behavior or appraising skills (Radack and Valanis, 1986, Landry et al., 1994), and another study reported no effect on EBM knowledge but improved attitudes towards the use of scientific evidence (Sanchez-Mendiola, 2004). The other eight studies found positive effects. However, ten of these eleven studies had a high risk of bias, and the only exception with an acceptable quality (Rosenberg et al., 1998) lacked a validated assessment tool (*Table 2*).

Notably, in the study by Weberschock *et al.* medical students successfully delivered the compulsory EBM course to their peers, which yielded improved knowledge and skills of EBM (Weberschock et al., 2005).

Effects of e-learning:

Six studies investigated the effects of the online or computer-assisted courses and instructions (Bradley et al., 2005, Bolboaca and Jantschi, 2006b, Schilling et al., 2006, Davis et al., 2007, Davis et al., 2008, Hadley et al., 2010), from which three studies with a low risk of bias reported computer-assisted sessions to be as effective as usual teaching sessions in teaching acquiring

knowledge, appraising knowledge and skills, and EBM knowledge and attitudes, generally (Bradley et al., 2005, Davis et al., 2007, Davis et al., 2008). Similarly, another study with a moderate risk of bias found online modules similarly effective as usual teaching in training asking, acquiring, and appraising knowledge (Hadley et al., 2010).

The other two studies compared e-learning with no intervention: one study linked an online module to improved skills of acquiring and calculation of number needed to treat (Schilling et al., 2006), while the other study correlated a CD-ROM e-course to improved EBM knowledge (Bolboaca and Jantschi, 2006b). However, the former used no validated assessment tool – despite its acceptable quality – and the latter had a high risk of bias (*Table 2*).

Effects of problem-based learning:

Johnston *et al.* compared a stand-alone problem-based learning intervention with usual teaching in a high-quality study (*Table 2*) and found "usual" teaching more favorable in improving EBM knowledge and attitudes (Johnston et al., 2009).

In another study from McMaster University (the pioneer of problem-based learning), educators used problem-based material but no real problem-based learning strategy to teach EBM (Bennett et al., 1987); therefore, their results were not elaborated here.

Effects of other multi-component interventions:

Lee and colleagues compared a multi-component intervention – consisting of short courses plus self-reading and practice – with no intervention in a randomized controlled trial (RCT) and observed an improved knowledge of decision analysis but no improved knowledge of cost-effectiveness or sensitivity analyses (Lee et al., 2007). The authors presented their intervention as a clinically integrated teaching method; however, we categorized their teaching as stand-alone since their teaching was not carried out in a clinical context. This study also used no validated

assessment tool (*Table 2*). Furthermore, their intention-to-treat analysis is questionable since participants consented to enter the study after being randomly allocated, and those who did not consent were not included in analyses.

In a cross-over RCT, Leung *et al.* compared the effects of adding the following interventions to a workshop: A) Providing guides and "InfoRetriever" on personal digital assistants (PDAs); B) Providing educational pocket cards of the same guides; and C) No intervention (Leung et al., 2003). They observed improved perceptions regarding the use of EBM and the integration of EBM in clinical teaching in both active arms although the PDA arm yielded a larger effect. Notably, despite the researchers' potential control over participants' assignment and study design, the participants were rotated through the three study arms in a disorganized manner, and neither the total number of experiments per arm nor the crossing-over order was balanced. However, the study had a low risk of bias (*Table 2*).

DISCUSSION

The findings of this systematic review showed that teaching EBM has the potential to improve knowledge, attitudes and skills in undergraduate medical students. However, there is still insufficient evidence to support the statement that EBM teaching either improves students' behaviors or yields a long-term mastery of EBM. In addition, we found no study assessing patient outcomes or health delivery processes, possibly because undergraduate students would be rarely the final decision makers regarding patient management. Studies of the clinically integrated methods and short instructions were weak and inconsistent. In contrast, a number of robust studies supported the use of e-learning strategies. A single strong study found problem-based learning less effective than usual teaching. Finally, few studies linked other multicomponent interventions to improved knowledge and attitudes.

Our study as well as other systematic reviews has found the studies of EBM teaching generally weak (Harris et al., 2011, Flores-Mateo and Argimon, 2007, Ebbert et al., 2001, Parkes et al., 2001, Taylor et al., 2000b). However, the lack of high-quality evidence is not merely confined to the teaching of EBM, but it is a universal dilemma for the teaching of various sciences .(Hatala and Guyatt, 2002). Therefore, we should not under-value the teaching of EBM to undergraduate medical students due to the lack of insufficient robust evidence. Instead, we should focus on providing robust evidence by the conduct of the future studies in higher qualities with a focus on the skills and behaviors as well as the long-term educational effects. Only two of our included studies measured behaviors following the educational interventions (Sastre et al., 2011, Landry et al., 1994).

Although we did not aim to appraise the validity of the assessment tools of our included studies, another review (Shaneyfelt et al., 2006) found that only seven of our included studies have high-

quality assessment tools (West et al., 2011, Aronoff et al., 2010, Lai and Teng, 2009, Bradley et al., 2005, Weberschock et al., 2005, Fritsche et al., 2002, Bennett et al., 1987). When we attempted to pool the results of the included studies, we ended up with no more than five studies (West et al., 2011, Lai and Teng, 2009, Aronoff et al., 2010, Fritsche et al., 2002, Weberschock et al., 2005) since the other included studies had used miscellaneous tools rather than established validated tools such as Fresno Test or Berlin Questionnaire. Using similar assessment tools would enable the researchers to quantitatively pool the results together in meta-analyses, which yields larger statistical powers and improved generalizability. Selection of the assessment tools should be based on not only their quality, but also their purpose. As an example, although the Berlin Questionnaire and the Fresno Test are both established assessment tools, the former is designed to test applied knowledge through its multiple-choice format, thus it should be avoided in evaluating the skills of asking or acquiring. On the other hand, the latter is suitable to test the knowledge and skills across the four steps of EBM (West et al., 2011).

Our systematic review also calls for more robust studies of the clinically integrated methods. Notably, our included studies examined no ideal "on foot" EBM teaching as described elsewhere (Richardson, 2005). In addition, our included studies of the clinically integrated methods were inconsistent and of low quality.

A systematic review (Coomarasamy and Khan, 2004) has found that in postgraduate medical professionals, clinically integrated methods would improve their EBM knowledge, attitudes, skills, and behaviors, while standalone methods would improve only knowledge and possibly skills. In contrast, our results have indicated that for undergraduate students, standalone methods are able to improve not only the EBM knowledge but also the attitudes and skills. This may be because students are hypothetically driven by external factors such as the curriculum and the

assessments. Such factors are possibly addressed by either stand-alone or clinically integrated methods. In contrast, postgraduates are usually driven by self-motivation and relevance to clinical practice, which are properly addressed by clinically integrated methods only (Coomarasamy and Khan, 2004). This argument is supported by another systematic review in which standalone instructions in critical appraisal improved the knowledge of undergraduate students, but such instructions yielded limited knowledge gain in residents (Norman and Shannon, 1998).

A robust systematic review by Hartling *et al.* drew no net conclusion about the effectiveness of problem-based learning for undergraduate medical education because of the inconsistencies in the included studies (Hartling et al., 2010). Another systematic review linked problem-based learning in medical school to post-graduation improvements, but mainly in social and cognitive competencies rather than in clinical knowledge and skills (Koh et al., 2008). Our single identified study of teaching EBM by problem-based learning methods found it less favorable than usual teaching (Johnston et al., 2009). However, this study was in Hong Kong where didactic teaching is culturally dominant and the successful delivery of interactive approaches is challenging (Khan and Coomarasamy, 2006). In addition, this study was brief while effective problem-based learning methods usually need substantial student-educator interactions (Koh et al., 2008). Researchers inferred that students may need to initially learn the basics and subsequently receive problem-based learning in order to successfully grasp the skills to apply their knowledge (Khan and Coomarasamy, 2006). Considering the above argument, we were unable to draw net conclusions regarding the true effects of problem-based learning.

A systematic review by Cook *et al.* found the internet-based learning strategies as effective as traditional teaching methods (Cook et al., 2008). Their findings are in line with the findings of

our included studies, particularly the three high-quality studies of computer assisted sessions. Since e-learning can provide a wide spectrum of teaching strategies, it may make learning more exciting, effective, and likely to be retained (Greenhalgh, 2001). However, our included studies of e-learning assessed no behavior, and only one study assessed skills (of acquiring and applying) (Schilling et al., 2006). This is possibly because higher order impacts (such as improved behaviors) result from interactive rather than deductive interventions (Greenhalgh, 2001) while none of our included studies of e-learning adopted an ideally interactive e-learning strategy. In addition, the best EBM teaching models occur at the bedside (Richardson, 2005), which e-learning cannot easily recreate it. Therefore, e-learning should be considered as a complement for – rather than a substitute of – clinically integrated bedside models to teach EBM. Straus *et al.* have previously distinguished the "using mode" from the "doing mode" of practicing EBM (Straus et al., 2010). In the "using mode", physicians search within pre-appraised sources, thus they bypass the time-consuming appraising step. Although the previous studies of the EBM education are majorly focused on the "doing mode" and particularly "critical appraisal" (Hatala and Guyatt, 2002), we found three studies emphasizing the "using mode" and the "searching within pre-appraised sources" (Sastre et al., 2011, Schilling et al., 2006, Fritsche et al., 2002). Moreover, another included study showed the positive effects of accessing "InfoRetriever" through PDAs (Leung et al., 2003). Since the use of such sources is linked to better clinical decision making (Alper et al., 2005), we would call for more robust studies of teaching the using mode and the skills to use pre-appraised sources.

One included study reported a successful EBM teaching by medical students (Weberschock et al., 2005). Trained students have been also reported to be as good as faculty educators in teaching clinical principles and skills (Haist et al., 1998, Tolsgaard et al., 2007, Graziano, 2011).

These observations can inspire a model for EBM education, particularly for institutions with limited faculty educators. However, the current evidence supporting such a model is still insufficient.

Our systematic review had a number of limitations: We had no access to EMBASE while conducting this review, thus we could not search it. In addition, despite using comprehensive search strategies, we used no abbreviated term such as EBM or EBP in our search queries. Moreover, to identify the unpublished studies, we only searched the Current Controlled Trials that includes few educational studies. Furthermore, only one investigator decided upon including each study due to the limited time and resources of the team. Thus, we cannot exclude potential biases in the identification of the including studies. Finally, we were rather strict in including only comparative studies and in appraising our included studies based on meticulous quality criteria.

CONCLUSIONS

Implications for practice:

Teaching EBM has the potential to improve knowledge, attitudes and skills in undergraduate medical students. However, there is still insufficient evidence to support the statement that EBM teaching either improves students' behaviors or yields a long-term mastery of EBM. Evidence[I3] supporting the use of clinically integrated methods (i.e. educational activities integrated into clinical practice) and stand-alone short instructions (i.e. brief educational activities conducted in no real clinical practice context) are currently insufficient. However, high quality evidence has supported that computer-assisted instructions are as effective as traditional educational strategies in improving EBM knowledge and attitudes. Nevertheless, their effects on the students' skills and behaviors are unclear. We have also drawn no net conclusion about the effectiveness of problem-based learning of EBM since only one high-quality study examined it. Finally, the effects of other multicomponent interventions were heterogeneous and inconclusive.

Implications for research:

We suggest future studies of teaching EBM to medical students to focus on: A) Reporting the participants, interventions, outcomes, and results in sufficient details in order to allow replication; B) Examining the effects of EBM teaching on long-term skills and behaviors using robust assessment tools; C) Evaluating appropriate "on foot", real world clinically integrated methods, problem-based learning, interactive e-learning strategies, and short courses and instructions; D) Comparing the teaching of the using and the doing modes of practicing EBM; and E) Studying the student educator model to test whether trained students are able to teach EBM effectively.[I4]

PRACTICE POINTS

- Although several systematic reviews have explored various aspects of evidence-based medicine (EBM), no prior study has attempted to systematically review the effectiveness of teaching EBM to undergraduate medical students.
- We systematically reviewed the studies of clinically integrated methods of teaching EBM, short courses and instructions, e-learning, problem-based learning, and other multicomponent interventions. However, we drew no net conclusion since the included studies were either weak, few, or inconsistent.
- In general, teaching EBM has the potential to improve knowledge, attitudes and skills in undergraduate medical students. However, evidence supporting the effect of EBM teaching on students' behaviors is currently insufficient.
- We suggest future studies to focus on assessing long-term higher-order mastery of EBM and use robust methods and high-quality assessment tools.

NOTES ON CONTRIBUTORS

SFA was a Postdoctoral Fellow at Center for Educational Research in Medical Sciences, Iran University of Medical Sciences, at the time of this study; he is currently a postdoctoral fellow at Department of Medicine, University of California Irvine.

HRB is an Associate Professor of Clinical Epidemiology and the Deputy of Research at Center for Educational Research in Medical Sciences, Iran University of Medical Sciences.

EA was a Postdoctoral Fellow at Digestive Diseases Research Institute, Tehran University of Medical Sciences, at the time of this study; he is currently a Postdoctoral Fellow at Department of Radiology, Massachusetts General Hospital, Harvard Medical School.

ACKNOWLEDGMENTS

We would like to thank Prof. Hammick for all her thoughtful assistance in writing this systematic review.

REFERENCES

ALPER, B. S. & VINSON, D. C. 2005. Experiential curriculum improves medical students' ability to answer clinical questions using the internet. *Fam Med,* 37**,** 565-9.

ALPER, B. S., WHITE, D. S. & GE, B. 2005. Physicians answer more clinical questions and change clinical decisions more often with synthesized evidence: a randomized trial in primary care. *Ann Fam Med,* 3**,** 507-13.

ARONOFF, S. C., EVANS, B., FLEECE, D., LYONS, P., KAPLAN, L. & ROJAS, R. 2010. Integrating evidence based medicine into undergraduate medical education: combining online instruction with clinical clerkships. *Teach Learn Med,* 22**,** 219-23.

BENNETT, K. J., SACKETT, D. L., HAYNES, R. B., NEUFELD, V. R., TUGWELL, P. & ROBERTS, R. 1987. A controlled trial of teaching critical appraisal of the clinical literature to medical students. *JAMA,* 257**,** 2451-4.

BOLBOACA, S. D. & JANTSCHI, L. 2006a. *Assessment of a computer based curriculum in evidence-based medicine*.

BOLBOACA, S. D. & JANTSCHI, L. Assessment of a computer based curriculum in evidence-based medicine. *In:* CALLAOS, N., LESSO, W., TREMANTE, A., BARALT, J. & REBIELAK, J., eds. Wmsci 2006: 10th World Multi-Conference on Systemics, Cybernetics and Informatics, Vol Vii, Proceedings, 2006b. 405-409.

BRADLEY, P., OTERHOLT, C., HERRIN, J., NORDHEIM, L. & BJORNDAL, A. 2005. Comparison of directed and self-directed learning in evidence-based medicine: a randomised controlled trial. *Med Educ,* 39**,** 1027-35.

CASPI, O., MCKNIGHT, P., KRUSE, L., CUNNINGHAM, V., FIGUEREDO, A. J. & SECHREST, L. 2006. Evidence-based medicine: discrepancy between perceived competence and actual performance among graduating medical students. *Medical Teacher,* 28**,** 318-325.

COLLEGES., F. P. C. O. T. A. O. M. R. 2007. *Curriculum for the foundation years in postgraduate education and training.* [Online]. UK: Departments of Health. Available: http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4107594 2011].

COOK, D. A., LEVINSON, A. J., GARSIDE, S., DUPRAS, D. M., ERWIN, P. J. & MONTORI, V. M. 2008. Internet-based learning in the health professions: a meta-analysis. *JAMA,* 300**,** 1181-96.

COOMARASAMY, A. & KHAN, K. S. 2004. What is the evidence that postgraduate teaching in evidence based medicine changes anything? A systematic review. *BMJ,* 329**,** 1017.

CRILLY, M., GLASZIOU, P., HENEGHAN, C., MEATS, E. & BURLS, A. 2009. Does the current version of 'Tomorrow's Doctors' adequately support the role of evidence-based medicine in the undergraduate curriculum? *Medical Teacher,* 31**,** 938-944.

DAVIS, J., CHRYSSAFIDOU, E., ZAMORA, J., DAVIES, D., KHAN, K. & COOMARASAMY, A. 2007. Computer-based teaching is as good as face to face lecture-based teaching of evidence based medicine: a randomised controlled trial. *BMC Med Educ,* 7**,** 23.

DAVIS, J., CRABB, S., ROGERS, E., ZAMORA, J. & KHAN, K. 2008. Computer-based teaching is as good as face to face lecture-based teaching of evidence based medicine: a randomized controlled trial. *Med Teach,* 30**,** 302-7.

DAWES, M., SUMMERSKILL, W., GLASZIOU, P., CARTABELLOTTA, A., MARTIN, J., HOPAYIAN, K., PORZSOLT, F., BURLS, A., OSBORNE, J., SECOND INTERNATIONAL CONFERENCE OF EVIDENCE-BASED HEALTH CARE, T. & DEVELOPERS 2005. Sicily statement on evidence-based practice. *BMC Med Educ,* 5**,** 1.

DEL MAR, C., GLASZIOU, P. & MAYER, D. 2004. Teaching evidence based medicine. *BMJ,* 329**,** 989-90.

DIZON, J. M. R., GRIMMER-SOMERS, K. A. & KUMAR, S. 2012. Current evidence on evidence-based practice training in allied health: a systematic review of the literature. *Int J Evid Based Healthc,* 10**,** 347-60.

DORSCH, J. L., AIYER, M. K. & MEYER, L. E. 2004. Impact of an evidence-based medicine curriculum on medical students' attitudes and skills. *J Med Libr Assoc,* 92**,** 397-406.

EBBERT, J. O., MONTORI, V. M. & SCHULTZ, H. J. 2001. The journal club in postgraduate medical education: a systematic review. *Medical Teacher,* 23**,** 455-461.

FLORES-MATEO, G. & ARGIMON, J. M. 2007. Evidence based practice in postgraduate healthcare education: a systematic review. *BMC Health Serv Res,* 7**,** 119.

FRANK, J. R., JABBOUR, M. & AL., E. 2005. *The CanMEDS 2005 Physician Competency Framework: Better standards, better physicians, better care.* [Online]. Royal College of Physicians and Surgeons of Canada. Available: http://rcpsc.medical.org/canmeds/CanMEDS2005/index.php 2011].

FRASCA, M. A., DORSCH, J. L., ALDAG, J. C. & CHRISTIANSEN, R. G. 1992. A multidisciplinary approach to information management and critical appraisal instruction: a controlled study. *Bull Med Libr Assoc,* 80**,** 23-8.

FRITSCHE, L., GREENHALGH, T., FALCK-YTTER, Y., NEUMAYER, H. H. & KUNZ, R. 2002. Do short courses in evidence based medicine improve knowledge and skills? Validation of Berlin questionnaire and before and after study of courses in evidence based medicine. *BMJ,* 325**,** 1338-41.

GRAZIANO, S. C. 2011. Randomized surgical training for medical students: resident versus peer-led teaching. *Am J Obstet Gynecol,* 204**,** 542 e1-4.

GREENHALGH, T. 2001. Computer assisted learning in undergraduate medical education. *BMJ,* 322**,** 40-44.

GRUPPEN, L. D., RANA, G. K. & ARNDT, T. S. 2005. A controlled comparison study of the efficacy of training medical students in evidence-based medicine literature searching skills. *Acad Med,* 80**,** 940-4.

HADLEY, J., KULIER, R., ZAMORA, J., COPPUS, S. F., WEINBRENNER, S., MEYERROSE, B., DECSI, T., HORVATH, A. R., NAGY, E., EMPARANZA, J. I., ARVANITIS, T. N., BURLS, A., CABELLO, J. B., KACZOR, M., ZANREI, G., PIERER, K., KUNZ, R., WILKIE, V., WALL, D., MOL, B. W. & KHAN, K. S. 2010. Effectiveness of an e-learning course in evidence-based medicine for foundation (internship) training. *J R Soc Med,* 103**,** 288-94.

HAIST, S. A., WILSON, J. F., BRIGHAM, N. L., FOSSON, S. E. & BLUE, A. V. 1998. Comparing fourth-year medical students with faculty in the teaching of physical examination skills to first-year students. *Acad Med,* 73**,** 198-200.

HARRIS, J., KEARLEY, K., HENEGHAN, C., MEATS, E., ROBERTS, N., PERERA, R. & KEARLEY-SHIERS, K. 2011. Are journal clubs effective in supporting evidence-based decision making? A systematic review. BEME Guide No. 16. *Medical Teacher,* 33**,** 9-23.

HARTLING, L., SPOONER, C., TJOSVOLD, L. & OSWALD, A. 2010. Problem-based learning in pre-clinical medical education: 22 years of outcome research. *Med Teach,* 32**,** 28-35.

HATALA, R. & GUYATT, G. 2002. Evaluating the teaching of evidence-based medicine. *JAMA,* 288**,** 1110-2.

JOHNSTON, J. M., SCHOOLING, C. M. & LEUNG, G. M. 2009. A randomised-controlled trial of two educational modes for undergraduate evidence-based medicine learning in Asia. *BMC Med Educ,* 9**,** 63.

KHAN, K. S., AWONUGA, A. O., DWARAKANATH, L. S. & TAYLOR, R. 2001. Assessments in evidence-based medicine workshops: loose connection between perception of knowledge and its objective assessment. *Med Teach,* 23**,** 92-94.

KHAN, K. S. & COOMARASAMY, A. 2006. A hierarchy of effective teaching and learning to acquire competence in evidenced-based medicine. *BMC Med Educ,* 6**,** 59.

KOH, G. C., KHOO, H. E., WONG, M. L. & KOH, D. 2008. The effects of problem-based learning during medical school on physician competency: a systematic review. *CMAJ,* 178**,** 34-41.

KRUEGER, P. M. 2006. Teaching critical appraisal: a pilot randomized controlled outcomes trial in undergraduate osteopathic medical education. *J Am Osteopath Assoc,* 106**,** 658-62.

LAI, N. M. & NALLIAH, S. 2010. Information-seeking practices of senior medical students: the impact of an evidence-based medicine training programme. *Educ Health (Abingdon),* 23**,** 151.

LAI, N. M. & TENG, C. L. 2009. Competence in evidence-based medicine of senior medical students following a clinically integrated training programme. *Hong Kong Med J,* 15**,** 332-8.

LANDRY, F. J., PANGARO, L., KROENKE, K., LUCEY, C. & HERBERS, J. 1994. A controlled trial of a seminar to improve medical student attitudes toward, knowledge about, and use of the medical literature. *J Gen Intern Med,* 9**,** 436-9.

LEE, A., JOYNT, G. M., HO, A. M. H., GIN, T. & HAZLETT, C. B. 2007. Effect of an integrated teaching intervention on clinical decision analysis: a randomized, controlled study of undergraduate medical students. *Medical Teacher,* 29**,** 231-236.

LEUNG, G. M., JOHNSTON, J. M., TIN, K. Y., WONG, I. O., HO, L. M., LAM, W. W. & LAM, T. H. 2003. Randomised controlled trial of clinical decision support tools to improve learning of evidence based medicine in medical students. *BMJ,* 327**,** 1090.

NORMAN, G. R. & SHANNON, S. I. 1998. Effectiveness of instruction in critical appraisal (evidence-based medicine) skills: a critical appraisal. *Cmaj,* 158**,** 177-81.

PARKES, J., HYDE, C., DEEKS, J. & MILNE, R. 2001. Teaching critical appraisal skills in health care settings. *Cochrane Database Syst Rev***,** CD001270.

RADACK, K. L. & VALANIS, B. 1986. Teaching critical appraisal and application of medical literature to clinical problem-solving. *J Med Educ,* 61**,** 329-31.

REED, D., PRICE, E. G., WINDISH, D. M., WRIGHT, S. M., GOZU, A., HSU, E. B., BEACH, M. C., KERN, D. & BASS, E. B. 2005. Challenges in systematic reviews of educational intervention studies. *Ann Intern Med,* 142**,** 1080-9.

RICHARDSON, W. S. 2005. Teaching evidence-based practice on foot. *Evidence Based Medicine,* 10**,** 98-101.

ROSENBERG, W. M., DEEKS, J., LUSHER, A., SNOWBALL, R., DOOLEY, G. & SACKETT, D. 1998. Improving searching skills and evidence retrieval. *J R Coll Physicians Lond,* 32**,** 557-63.

SACKETT, D. L., ROSENBERG, W. M., GRAY, J. A., HAYNES, R. B. & RICHARDSON, W. S. 1996. Evidence based medicine: what it is and what it isn't. *Bmj,* 312**,** 71-2.

SANCHEZ-MENDIOLA, M. 2004. Evidence-based medicine teaching in the Mexican Army Medical School. *Med Teach,* 26**,** 661-3.

SASTRE, E. A., DENNY, J. C., MCCOY, J. A., MCCOY, A. B. & SPICKARD, A. 2011. Teaching evidence-based medicine: Impact on students' literature use and inpatient clinical documentation. *Med Teach,* 33**,** e306-12.

SCHILLING, K., WIECHA, J., POLINENI, D. & KHALIL, S. 2006. An interactive web-based curriculum on evidence-based medicine: design and effectiveness. *Fam Med,* 38**,** 126-32.

SHANEYFELT, T., BAUM, K. D., BELL, D., FELDSTEIN, D., HOUSTON, T. K., KAATZ, S., WHELAN, C. & GREEN, M. 2006. Instruments for evaluating education in evidence-based practice: a systematic review. *JAMA,* 296**,** 1116-27.

STEWART, M. G. 2001. *ACGME Core Competencies.* [Online]. Accreditation Council for Graduate Medical Education. Available: http://www.acgme.org/acwebsite/RRC_280/280_corecomp.asp 2011].

STRAUS, S. E., RICHARDSON, W. S., GLASZIOU, P. & HAYNES, R. B. 2010. *Evidence-based Medicine: How to Practice and Teach EBM,* Edinburgh, Churchill Livingstone.

TAHERI, H., MIRMOHAMADSADEGHI, M., ADIBI, I., ASHORION, V., SADEGHIZADE, A. & ADIBI, P. 2008. Evidence-based medicine (EBM) for undergraduate medical students. *Ann Acad Med Singapore,* 37**,** 764-8.

TAYLOR, R., REEVES, B., EWINGS, P., BINNS, S., KEAST, J. & MEARS, R. 2000a. A systematic review of the effectiveness of critical appraisal skills training for clinicians. *Med Educ,* 34**,** 120-5.

TAYLOR, R., REEVES, B., EWINGS, P., BINNS, S., KEAST, J. & MEARS, R. 2000b. A systematic review of the effectiveness of critical appraisal skills training for clinicians. *Medical Education,* 34**,** 120-125.

TOLSGAARD, M. G., GUSTAFSSON, A., RASMUSSEN, M. B., HOIBY, P., MULLER, C. G. & RINGSTED, C. 2007. Student teachers can be as good as associate professors in teaching clinical skills. *Med Teach,* 29**,** 553-7.

VAN DIJK, N., HOOFT, L. & WIERINGA-DE WAARD, M. 2010. What are the barriers to residents' practicing evidence-based medicine? A systematic review. *Acad Med,* 85**,** 1163-70.

WALCZAK, J., KALETA, A., GABRYS, E., KLOC, K., THANGARATINAM, S., BARNFIELD, G., WEINBRENNER, S., MEYERROSE, B., ARVANITIS, T. N., HORVATH, A. R., ZANREI, G., KUNZ, R., SUTER, K., BURNAND, B., ARDITI, C., RENGERINK, K. O., HARRY, G., MOL, B. W. J. & KHAN, K. S. 2010. How are "teaching the teachers" courses in evidence based medicine evaluated? A systematic review. *Bmc Medical Education,* 10.

WEBERSCHOCK, T. B., GINN, T. C., REINHOLD, J., STRAMETZ, R., KRUG, D., BERGOLD, M. & SCHULZE, J. 2005. Change in knowledge and skills of Year 3 undergraduates in evidence-based medicine seminars. *Med Educ,* 39**,** 665-71.

WEST, C. P., JAEGER, T. M. & MCDONALD, F. S. 2011. Extended evaluation of a longitudinal medical school evidence-based medicine curriculum. *J Gen Intern Med,* 26**,** 611-5.

TABLES

Table 1: Characteristics of included studies.

Study ID	Design, setting and participants	Interventions (Teaching methods)	Outcomes (Assessment)	Key Results
(West et al., 2011)	**SCT**[1] in Mayo Medical School, USA (2006-2008) on 99 2nd-year medical students	**Integrated Method**: I. 20 to 22-hour lectures plus small-group discussions in EBM principles and appraisal of various study types in 2nd year, II. Electronic feedback on developing CATs[2] from real patients in 6-7 rotations of 3rd year.	**Validated**: Survey with Berlin Questionnaire and/or Fresno Test prior to and after short course, and upon completion of 3rd year.	**Knowledge and skills of EBM:** improved
(Sastre et al., 2011)	**SCT** in Vanderbilt Medical School, USA (2007-2008) on 100 3rd-year medical students	**Short instruction**: 3-hour workshop in asking, acquiring, and pros and cons of pre-appraised sources.	**Partly validated**[3]: Pre- and post-workshop analysis of computer log data of searches, expert scoring of EBM content in clerkship notes, and survey to	**Behaviors of acquiring and applying** and **Attitudes toward EBM and acquiring**: improved

			assess attitudes towards EBM and acquiring.	
(Lai and Nalliah, 2010)	**SCT** in International Medical University of Malaysia (2005-2006) on 65 Final-year medical students	**Integrated Method**: I. 2 sessions in EBM principles, acquiring, and appraising, II. Electronic exploratory notes, III. 6 x 2-hour small-group bedside sessions to exercise asking, IV. Self-searching, V. Presenting CATs in journal clubs, VI. EBM reports in portfolios.	**Validated**: Pre- and post-course questionnaire to assess preferred information sources.	**Attitudes toward acquiring**: unchanged
(Hadley et al., 2010)	**Cluster RCT[4]** in seven teaching hospitals in UK West Midlands (2007) on 237 Interns (Foundation year 2 doctors)	**e-learning**: **Intervention A**: 3-hour session with modules in asking, acquiring, and appraising; **Intervention B**: 6-week web access to e-learning modules in the same topics.	**Validated**: Module-specific multiple-choice questions to assess knowledge before and after each module.	**Knowledge of asking, acquiring and appraising:** comparable
(Aronoff et	**SCT** in Temple	**Integrated Method**: I. 18-week	**Validated**: Pre- and post-course	**Skills of EBM**:

al., 2010)	University, USA (2005) on 153 3rd-year medical students	access to 6 online modules, plus supervised assignments in asking, acquiring, appraising various study types, and applying, II. Completion of 4 CATs from real patients.	Fresno Test.	improved
(Lai and Teng, 2009)	**SCT** in International Medical University of Malaysia (2006) on 72 Final-year medical students	**Integrated Method**: I. 2 sessions in EBM resources and appraising plus electronic exploratory notes, II. 6 x 2-hour small-group bedside sessions to exercise asking, III. Self-searching, IV. Presenting CATs in journal clubs, V. Developing EBM reports in portfolios.	**Validated**: Pre- and post-course Modified Fresno Test.	**Skills of EBM**: improved
(Johnston et al., 2009)	**Cross-over RCT** in University of Hong Kong (2007) on 129 2nd-year	**Problem-based learning**: **Intervention A**: 4 x 4-hour usual teaching sessions to practice asking,	**Validated**: Before, post-phase 1, and post-phase 2 KAB Questionnaire to assess EBM	**Knowledge of and attitudes toward EBM**: favor usual teaching.

	medical students	acquiring, appraising, and applying; **Intervention B**: 4 x 4-hour problem-based learning sessions to practice the same steps.	knowledge, personal application and current and future use of EBM, and attitudes towards EBM.	
(Taheri et al., 2008)	**SCT** in Isfahan University of Medical Sciences, Iran (2005) on 24 5th- and 6th-year medical students	**Short instruction**: 4-day workshop (each day: 2-hour lecture + 1-hour small-group session) in asking, acquiring, appraising, and applying.	**Validated**: Pre- and post-workshop questionnaire to assess knowledge of asking, plus expert evaluation of acquiring.	**Knowledge of asking** and **Skills of acquiring**: improved
(Davis et al., 2008)	**RCT** in University of Birmingham, UK (2006) on 229 1st-year medical students	**e-learning**: **Intervention A**: 40-minute computer based session to teach asking, acquiring, appraising, and applying; **Intervention B:** 40-minute lecture based session to teach the same topics.	**Validated**: Pre- and post-session questionnaire to measure EBM knowledge and attitudes.	**Knowledge of EBM**: comparable; **Attitudes toward EBM**: *mostly* comparable

(Lee et al., 2007)	**RCT** in Chinese University of Hong Kong (2005) on 155 5th-year medical students	**Multicomponent**: **Intervention**: teaching about performing and appraising decision, sensitivity, and cost-effectiveness analyses through: I. reading a handbook, II. 3 x 40-minute lectures, III. 1-hour small-group session, IV. home-appraising, V. 1-hour workshop on using software. **Control**: none.	**Non-validated**: Pre- and post-course questionnaire to assess knowledge of decision analysis, sensitivity analysis graphs, and cost-effectiveness ratios.	**Knowledge of apply subsets**: *partly* improved
(Davis et al., 2007)	**RCT** in five teaching hospitals in UK West Midlands (2005) on 55 Interns (Foundation year 1 doctors)	**e-learning**: **Intervention**: 40-minute computer based session in asking, acquiring, appraising and applying; **Control**: 40-minute lecture based session in the same topics.	**Validated**: Pre- and post-session questionnaire to measure EBM knowledge and attitudes.	**Knowledge of and attitudes toward EBM**: comparable
(Schilling et al., 2006)	**RCT** in Boston University, USA, on 238	**e-learning**: **Intervention**: 4-week web access to four online modules in	**Partly validated**: Post-course expert evaluation of captured	**Skills of acquiring** and a **minor skill of**

	3rd-year medical students	MEDLINE, pre-appraised sources, Study designs, and NNT calculation; **Control**: none.	OVID MEDLINE searches, retrieval of high-quality evidence, correct calculation of NNT, and number of MEDLINE searches.	**applying**: improved
(Krueger, 2006)	**RCT** in University of Medicine and Dentistry of New Jersey, USA (1998-1999) on 77 3rd-year students of osteopathic medicine	**Integrated Method**: **Intervention**: I. Lecture in EBM, II. 2 small-group discussions in appraising, III. Reading materials in applying, IV. Journal club, V. Instruction in Cochrane Library, IV. EBM assignment; **Control**: Lectures in other topics.	**Non-validated**: Post-course multiple-choice question Critical Appraisal Examination to assess appraising knowledge/ skills.	**Knowledge/ skills of appraising**: improved
(Bolboaca and Jantschi, 2006a)	**SCT** in IuliuHatieganu University of Medicine and Pharmacy, Romania	**e-learning**: 3-month access to a CD-ROM e-course consisting of: I. 14 tutorials in EBM steps and appraising	**Non-validated**: Pre- and post-e-course Test of EBM knowledge.	**Knowledge of EBM**: improved

	(2005) on 40 4th- to 6th-year medical students	various study types plus self-evaluation tests, II. Supplementary material including glossary, Romanian guidelines, and relevant papers and software.		
(Weberschock et al., 2005)	**SCT** in Johann Wolfgang Goethe University, Germany (2003-2004) on 132 3rd-year medical students	**Short instruction**: 4 x 3-hour EBM lectures and small-group discussions in EBM principles and asking, acquiring through MEDLINE, and applying therapy and diagnosis studies.	**Validated**: Pre- and post-course Question papers (2 sets) to assess application of principles, and Berlin questionnaire.	**Knowledge and skills of EBM:** improved
(Gruppen et al., 2005)	**NCT[5]** in University of Michigan, USA (2001-2003) on 92 4th-year medical students	**Short instruction**: **Intervention**: 2-hour additional session in using Ovid MEDLINE, consisting of a brief lecture and guided hand-on practice during an EBM course; **Control**:	**Non-validated**: Pre-session and 1-month post-session expert scoring of the quality of a particular search using a pre-developed scoring sheet.	**Skills of acquiring**: improved

		EBM course alone.		
(Bradley et al., 2005)	**RCT** in University of Oslo, Norway (2002-2003) on 175 10th-semester medical students	**e-learning**: **Intervention A**: Workshop (directed learning) of 5 x 3-hour sessions in asking, acquiring, appraising and applying; **Intervention B**: Computer-assisted modules (self-directed learning) in the same topics.	**Validated**: 18 weeks post intervention questionnaire to assess acquiring and appraising knowledge, expert scoring of participant-developed CATs to assess appraising skills, and 1 to 17 weeks post intervention questionnaire to assess attitudes toward EBM.	**Knowledge of acquiring**, **Knowledge and skills of appraising** and **Attitudes toward EBM**: comparable
(Alper and Vinson, 2005)	**SCT** in University of Missouri-Columbia, USA, on 90 3rd-year medical students	**Integrated Method**: I. 90-minute computer lab session in acquiring, II. Access to free internet portal, III. Handout of practical points for acquiring and applying, IV. 2 acquiring assignments from real	**Non-validated**: Pre- and post-intervention student recorded time-to-answer and number of searched sites to answer 3 clinical questions, and expert evaluation of the quality of	**Skills of acquiring**: improved

		patients, V. Follow-up 90-minute computer lab session.	answers.	
(Sanchez-Mendiola, 2004)	**NCT** in Mexican Army Medical School (2001-2002) on 131 5th- and 6th-year medical students	**Short instruction**: **Intervention**: 14 x 2-hour sessions in EBM;**Control**: none.	**Validated**: Post-course questionnaire to assess attitudes towards acquiring and self-reported preferred information sources, plus knowledge of EBM.	**Attitudes toward acquiring:** Improved; **Knowledge of EBM**: unchanged
(Dorsch et al., 2004)	**SCT** in University of Illinois, USA (2000-2001) on 36 3rd-year medical students	**Integrated Method**: I. 8 x 1-hour weekly seminars plus pre-session reading materials in EBM principles and asking, acquiring, and appraising diagnosis, therapy, and meta-analysis studies; II. Developing and presenting CATs from real patients in 3 sessions.	**Non-validated**: Pre- and post-seminar self-reported frequently used information sources, and expert scoring of written test of EBM steps.	**Attitudes toward acquiring** and **Skills of asking and acquiring**: *minimally* changed; **Skills of appraising:***partly* changed

(Leung et al., 2003)	**Cross-over RCT** in University of Hong Kong (2001) on 169 4th-year medical students	**Multicomponent**: **Intervention "P" (Pocket Card)**: 2 x 2-hour sessions in EBM principles, asking, acquiring, and applying; using pocket card of EBM guides; and supervised practicing of EBM steps; **Intervention "I" (InfoRetriever)**: similar to "P", but PDA with InfoRetriever and digital pocket card was also provided; **Control (C)**: none.	**Validated**: Baseline and post-phase 1 to 3 questionnaires to assess personal applicationas well as current and future use of EBM.	**Attitudes toward EBM**: improved by Pocket Card, *further* improved by InfoRetriever.
(Fritsche et al., 2002)	**SCT** in various short EBM courses in Germany (1999-2001) on 203 3rd-year medical students	**Short instruction**: 3-day course in EBM principles and in asking, appraising, and applying plus using pre-appraised evidence and estimating risk, benefit, and harm.	**Validated**: 0 to 4 weeks pre- and post-workshop Berlin Questionnaire.	**Knowledge and skills of EBM**: improved

(Rosenberg et al., 1998)	**RCT** in Oxford University, UK, on 108 1st-year clinical students	**Short instruction**: **Intervention**: 3-hour small-group session in asking and acquiring through WinSpirs MEDLINE; **Control**: none.	**Non-validated**: Pre- (in intervention group) and post-session expert scoring of search strategies and number and quality of retrieved citations.	**Skills of acquiring**: improved
(Landry et al., 1994)	**NCT** in 4 army universities in DC (Intervention), and Maryland, Ohio, and Texas (Control), on 146 3rd-year clinical clerks	**Short instruction**: **Intervention**: 2 x 90-min seminars in types of medical literature and study design, and in appraising diagnostic test and therapy articles; **Control**: none.	**Non-validated**: 1-week pre-seminars and 5-weeks post-seminars expert scoring of literature use in patient write-ups.	**Behavior of acquiring**: unchanged
(Frasca et al., 1992)	**NCT** in 2 campuses of University of Illinois, USA, on 92 3rd-year clinical clerks	**Short instruction**: **Intervention**: I. 10 x 1.5-hour sessions in acquiring and appraising diagnostic test, prognosis, etiology or causation, and therapy effectiveness studies, II.	**Non-validated**: Post-course questionnaire to assess acquiring skills and appraising knowledge.	**Skills of acquiring** and **Knowledge of appraising**: improved

		Supervised development of a CAT; **Control**: none.		
(Bennett et al., 1987)	**NCT** in McMaster University, Canada, on 92 Final-year clinical clerks	**Short instruction**: **Intervention**: 8 x 2-hour small-group sessions to teach appraising diagnostic test and therapy effectiveness studies;**Control**: none.	**Non-validated**: Pre- and post-sessions expert scoring of appraising a diagnostic test and 2 therapy effectiveness studies.	**Skills of appraising**: improved
(Radack and Valanis, 1986)	**NCT** in University of Cincinnati, USA (1984-1985) on 34 4th-year clinical clerks	**Short instruction**: **Intervention**: 5 x 50-min small-group sessions in appraising clinical measurement, diagnostic testing, and therapeutic efficacy;**Control**: none.	**Non-validated**: Pre- and post-sessions unidentified test of appraising diagnosis and therapy.	**Skills of appraising**: unchanged

[1] SCT: Self-controlled trial; [2] CAT: Critically appraised topic;[3] Partly validated: Asubset (and not all) of outcomes were assessed using validated assessment tools[4] RCT: Randomized controlled trial; [5] NCT: Non-randomized controlled trial.

Table 2: Risk of bias assessment and ancillary quality criteria.

	Appraisal checklist for risk of bias assessment											**Ancillary quality criteria**							
Study ID	Generation of randomization sequence	Allocation concealment	Similar baseline outcome measurements	Similar baseline characteristics	Addressing incomplete outcome data	Blinding of the outcome assessors	Protection against contamination	No selective outcome reporting	No other risks of bias	Validated assessment tools	***Overall risk of bias***	Description of learner characteristics	Description of teaching objectives and content	Description of teaching methods	Description of assessment methods	Assessment of long-term effects	Power analysis for sample size calculation	Appropriate statistical tests	Reporting results in adequate details[1]
(West et al., 2011)	N[2]	N	N	N	Y[3]	U[4]	N	Y	Y	Y	**High**	Y	Y	Y	Y	N	N	Y	Y
(Sastre et al., 2011)	N	N	N	N	Y	Y	N	Y	Y	Y	**High**	Y	Y	Y	Y	N	N	Y	Y
(Lai and Nalliah, 2010)	N	N	N	N	Y	Y	N	Y	Y	Y	**High**	Y	Y	Y	Y	N	N	Y	Y
(Hadley et al., 2010)	U	U	Y	N	N	Y	Y	Y	Y	Y	**Moderate**	Y	Y	Y	Y	N	Y	Y	Y
(Aronoff et al., 2010)	N	N	N	N	Y	U	N	Y	Y	Y	**High**	Y	N	Y	Y	N	N	Y	Y

(Lai and Teng, 2009)	N	N	N	N	N	U	N	Y	Y	Y	**High**	Y	Y	Y	Y	N	Y	Y	Y
(Johnston et al., 2009)	U	Y	Y	Y	Y	Y	N	Y	Y	Y	**Low**	Y	Y	Y	Y	N	N	Y	Y
(Taheri et al., 2008)	N	N	N	N	Y	Y	N	Y	Y	Y	**High**	Y	Y	Y	Y	N	N	Y	Y
(Davis et al., 2008)	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	**Low**	Y	N	Y	Y	N	Y	Y	Y
(Lee et al., 2007)	Y	Y	Y	U	Y	Y	U	Y	Y	N	**Moderate**	Y	Y	Y	Y	N	N	Y	N
(Davis et al., 2007)	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	**Low**	Y	Y	Y	Y	N	Y	Y	Y
(Schilling et al., 2006)	Y	U	U	U	Y	Y	Y	Y	Y	N	**Moderate**	Y	Y	Y	Y	N	N	Y	Y
(Krueger, 2006)	U	U	U	Y	Y	Y	U	Y	Y	N	**Moderate**	Y	Y	Y	N	N	N	Y	N
(Bolboaca and Jantschi, 2006a)	N	N	N	N	Y	U	N	Y	Y	N	**High**	Y	Y	Y	Y	N	N	Y	N
(Weberschock	N	N	N	N	Y	Y	N	Y	Y	Y	**High**	Y	Y	Y	Y	N	Y	Y	N

et al., 2005)																			
(Gruppen et al., 2005)	N	N	Y	U	N	U	N	Y	Y	N	**High**	Y	Y	Y	Y	N	N	Y	Y
(Bradley et al., 2005)	Y	Y	U	N	Y	Y	U	Y	Y	Y	**Low**	Y	N	Y	Y	N	Y	Y	Y
(Alper and Vinson, 2005)	N	N	N	N	Y	Y	N	Y	Y	N	**High**	Y	Y	Y	Y	N	N	Y	N
(Sanchez-Mendiola, 2004)	N	N	U	U	U	Y	U	Y	Y	Y	**High**	Y	N	N	Y	N	N	Y	N
(Dorsch et al., 2004)	N	N	N	N	U	N	N	Y	Y	N	**High**	Y	Y	Y	Y	N	N	Y	Y
(Leung et al., 2003)	Y	Y	Y	Y	Y	Y	U	Y	Y	Y	**Low**	Y	Y	Y	Y	N	Y	Y	Y
(Fritsche et al., 2002)	N	N	N	N	N	N	N	Y	Y	Y	**High**	Y	Y	Y	Y	N	N	Y	N
(Rosenberg et al., 1998)	Y	U	U	U	Y	Y	Y	Y	Y	N	**Moderate**	Y	Y	Y	Y	N	N	Y	Y
(Landry et al., 1994)	N	N	U	N	Y	N	Y	Y	Y	N	**High**	Y	Y	Y	Y	N	Y	U	N

(Frasca et al., 1992)	N	N	Y	N	U	U	Y	Y	Y	N	**High**	Y	Y	Y	Y	N	N	Y	N
(Bennett et al., 1987)	N	N	N	U	Y	Y	Y	Y	Y	N	**High**	Y	Y	Y	Y	N	N	Y	Y
(Radack and Valanis, 1986)	N	N	U	U	N	U	Y	Y	Y	N	**High**	Y	Y	Y	N	N	N	U	N

[1] Reporting results in adequate details: Reporting numerical results for educational significance/effect size and measures of dispersion/confidence intervals/*P* values; [2] N: No; [3] Y: Yes; [4] U: Unclear.

FIGURES

Figure 1: Flow diagram of study selection.