Education in Medicine Journal

ORIGINAL ARTICLE

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Submitted Date: 29-05-2023

Accepted Date: 02-04-2024

Please cite this article as: Kaissar Yammine, Victor Zibara,2 Claudio Violato, Sola Aoun Bahous. A Meta-Analysis of E-learning Interventions in Teaching Evidence-Based Practice. Education in Medicine Journal. (early view).

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ORIGINAL ARTICLE

ARTICLE INFO

Submitted: 29-05-2023
Accepted: 02-04-2024

A Meta-Analysis of E-learning Interventions in Teaching Evidence-Based Practice for Health Science Students

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ABSTRACT

Evidence-based practice (EBP) is currently considered as the golden standard for patient care. Many universities offer EBP courses to their healthcare professions students. However, no quantitative evidence synthesis has been conducted to compare EBP e-learning instructional methods to traditional methods, to better inform health education policymakers. Eight randomized studies reporting the effectiveness of e-learning methods compared to "no intervention" or to any other educational methods and including 1243 learners met the inclusion criteria. The meta-analytical results revealed that e-learning was significantly better than "no intervention" ($d = 1.4$, 95% CI = 1.060 to 1.776, $I^2 = 99.5\%$, $p < 0.0001$) and as effective as other traditional methods such as lectures ($d = 0.30$, 95% CI = -0.348 to 0.952, $I^2 = 90.5\%$, $p = 0.3$). The same conclusions were found when using the adjusted exam scores in relation to confounding variables such as the baseline characteristics and prior EBP knowledge of participants. The present meta-analysis demonstrates that teaching EBP via e-learning is an effective instructional method in times when lecture hours and face-to-face didactics are reduced or not possible such as during this COVID-19 pandemic and the likely-to-happen future outbreaks.

Keywords: *medical education; evidence-based medicine; evidence-based practice; e-learning; COVID-19*

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INTRODUCTION

Evidence-Based Practice (EBP) requires that decisions about health care are based on the best available, valid and relevant evidence (1). Frenk et al. stated that teaching EBP to healthcare professionals could be transformative, in terms of decision making, through a shift from memorizing information to critical thinking (2).

The practice of evidence-based medicine, evidence-based health care or evidence-based dentistry comprises five steps, which include the ability a) to formulate appropriate questions, b) to retrieve information, c) to critically appraise evidence in order, d) to apply evidence to practice, and e) to evaluate subsequent changes and outcomes in practice (1,3). Teaching these steps using lectures and workshops has been the traditional method of EBP knowledge transfer (4). It has been demonstrated through a number of systematic reviews and with no surprise, that teaching EBP significantly increases EBP knowledge and skills (4-7). The use of short classroom-based courses has been proven to be effective in teaching EBP to medical students and residents when compared to "no intervention" or to the traditional medical learning curriculum (8-10).

Electronic methods for pedagogy are widely used in education; medical education is no exception. This came into focus in the medical education field with the outbreak of the novel coronavirus named SARS-CoV-2 and the Coronavirus Disease 2019 (COVID-19) pandemic. In reponse to the virus, and in attempts to reduce the risk of contracting and spreading the infection, almost all didactic, and many experiential curricula switched to online and virtual formats to avoid interruptions in education. Such a step was already initiated to some extent in several instutitions. Virtual learning using various platforms has become the new norm in several medical schools worldwide (11,12). This prioritized the importance and the need of videoconferencing, webinars, and new technologies in an effort to replicate, though virtually, in-person experience in the workplace for all trainees (13).

The efficacy of electronic methods, also called web-based learning, internet-based learning, online learning, distributed learning and computer-assisted instruction, has been widely reported (14-16). In the recent years, directed interventions have been compared to self-directed e-learning instructions to look for any significant differences between the two methods (10,17–23). A systematic quantitative synthesis of the evidence has not yet been conducted, however. The aim of the present meta-analysis was to evaluate the effectiveness of e-learning interventions when compared to all other methods of EBP instruction. To enhance the internal validity of the study, we included comparative randomized trials.

METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (24) was used as the guideline for the present systematic review.

Eligibility Criteria

Only studies that had a prospective comparative design with a sort of randomization such as quasi-randomized or randomized clinical trial (RCT) studies were included. Experimental, quasi-experimental, retrospective studies, expert reviews and case reports were excluded. The term e-learning includes computer-assisted learning, internet-based (or web-based) learning, and any other intervention using a pre-defined set of information which is read or downloaded on androids, IPhone, tablets or computers.

Information sources and search strategy

Using a combination of broad and specific terms, a comprehensive set of electronic databases was searched from inception to Jan 2023. The search strategy screened for articles that (1) reported results from comparative randomized studies, (2) used undergraduate, postgraduate medical, dental or allied health students or health care professionals, (3) reported at least one primary outcome, and (4) were published in peer-refereed journals. Search terms for OVID MEDLINE were first finalized and then adapted for the other databases (PubMed, ERIC, Scopus, EMBASE and Campbell Collaboration (Figure 1). Boolean operators were used for selected terms and subheadings: ("evidence-based medicine" OR "evidence-based practice" OR "evidence-based health" OR "evidence-based health care" OR "evidence-based dentistry" OR "evidence-based nursing" OR "critical appraisal" OR "searching skills" OR "decision analysis") AND (teaching OR learning OR course OR curriculum OR learner* OR student*) AND (internet OR web OR online OR computer-based OR e-learning OR self-directed OR electronic).

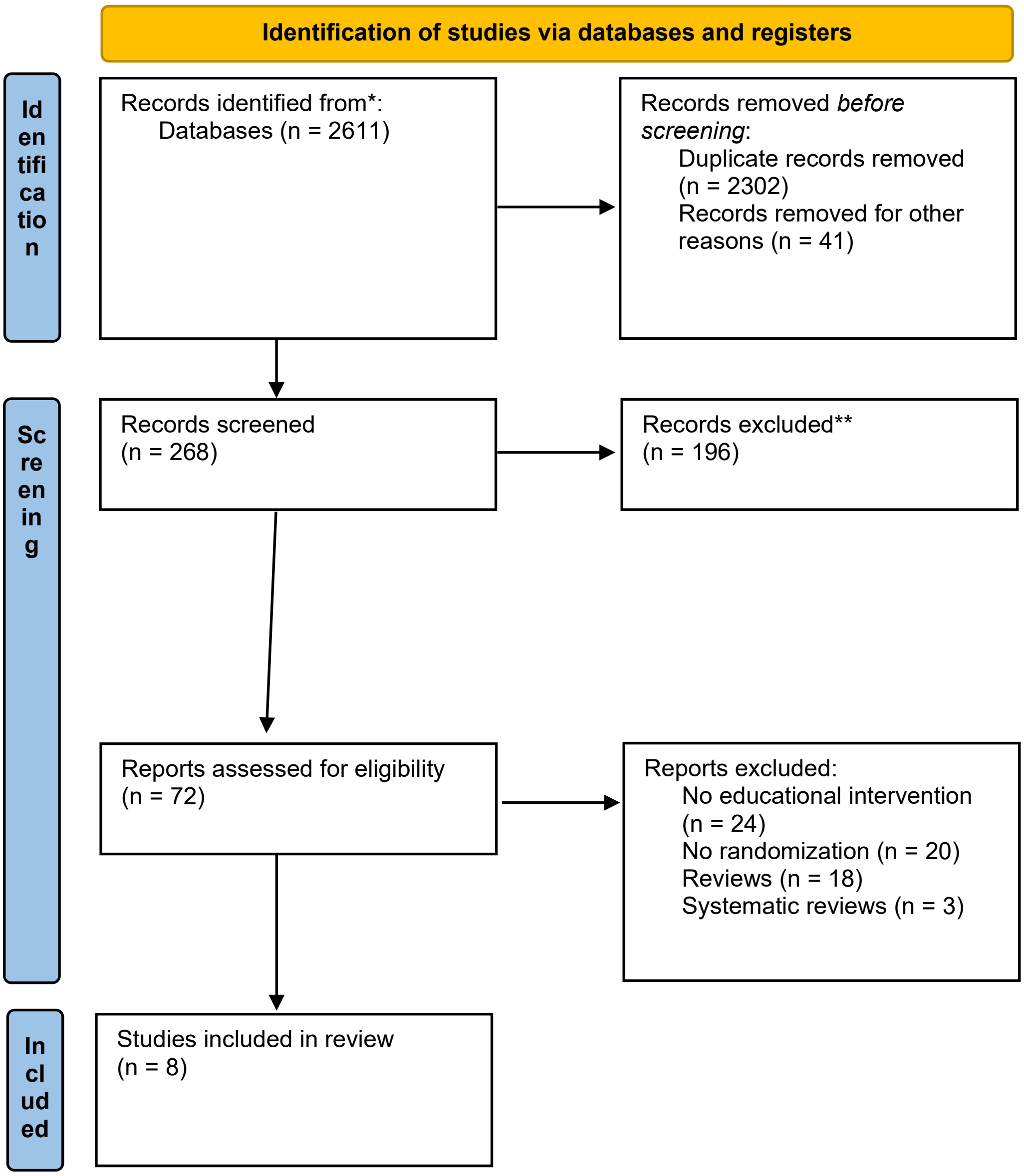

Figure 1. PRISMA flow diagram

Selection process

Title screening and abstract reviewing were applied first by each author independently, and then full-text manuscripts were obtained for potentially relevant papers. Five inclusion criteria based on a modification of Issenberg et al.'s (25) tool were then used to reduce the initial pool (Figure 1). Exclusion was performed by both authors and disagreements were discussed until full consensus was attained. The BEME- Best evidence Medical Education collaboration, sample coding sheet was used for data extraction (25).

Data collection process and data outcomes

After agreement, data was extracted and recorded using an Excel sheet. The primary outcome was set as the observed change of knowledge in terms of the raw unadjusted scores of EBP knowledge. Secondary outcomes were defined as a) adjusted scores, b) long-term retention knowledge scores, and c) the attitudinal scores of the learners. Comparisons between any form of computer-based learning instruction and any other educational technique were included.

Effect measures

The standardized mean difference (d) was used as the effect size. Dependent variables such as baseline characteristics of participants, prior EBP knowledge and the course content were identified for analysis.

Synthesis methods

As per Cochrane collaboration guidelines for effect size meta-analysis (26), we employed a weighted effect size using random effects model when the number of studies were higher than five with an I^2 test value of more than 50%. In all other cases, we used the fixed effect model. Forrest plots and I^2-tests for heterogeneity of effect sizes were performed for each analysis. The Begg-Mazumdar test was reported to assess publication bias. When possible, subgroup analysis were conducted either for a specific comparison of interventions or for those studies reporting long-term retention of knowledge gain. Statistical learning analyses were performed using StatsDirect, version 2.7.8 (StatsDirect Ltd., Cambridge, UK).

Study risk of bias assessment

The risk of bias of the comparative studies was assessed using the Cochrane Collaboration's tool (26) for assessing risk of bias.We used the scoring system developed by Yammine and Violato (27) to score Quality and Strength, two out of the six QUESTS dimensions elaborated by Harden et al. (28).

RESULTS

Search results

The initial electronic search yielded 2611 hits. Subsequent to title scanning, 268 abstracts were checked where 72 were found potentially relevant for full manuscript examination. Sixty-five studies were excluded; reasons for exclusion were as follows: no educational intervention (24), no randomization (20), reviews (18), and systematic reviews (3). Seven studies met the inclusion criteria.

Another study was included after reference checking. In total, 8 studies were included in the review with a total of 1243 learners (Table 1). Figure 1 shows the PRISMA flow diagram.

Supplement 1 summarizes the individual data of each included study.

Table 1. Characteristics of the included RCT studies.

Studies	Settings	Participants	Initial sample size	Randomization sequence generation	Randomization concealment	Blinding	Intervention (duration)	Control (duration)
Bergold et al., 2013	Germany	First-year residents	114	By computer	Arbitrary telephone calls	Not mentioned	Online course (3 months)	No intervention
Bradley et al 2005	Norway	10th semester med students	175	Random numbered tables	Sealed opaque envelops	Blinded outcome assessment	Computer-assisted (5 half-days)	Workshops (5 half-days)
Davis et al., 2007	UK	First-year residents	55	By computer	Coded envelops by a third party	Blinded outcome assessment	CD-ROM (40 min)	Lecture (40 min)
Davis et al., 2008	UK	UG[a] medical students	229	By computer	Coded envelops by a third party	Blinded outcome assessment	CD-ROM (40 min)	Lecture (40 min)
Hadley et al., 2010	UK	Junior residents (multiple specialties)	160	By computer	Not mentioned	Not mentioned	e-Learning (6 weeks)	Lecture (3 hours)
Kulier et al., 2009	Europe	Junior Ob-Gyn residents	61	By computer (cluster randomization stratified by country)	Not mentioned	Not mentioned	Clinically integrated e-Learning (4-6 weeks)	Lecture (4-6 weeks)
Kulier et al., 2012	Low-middle–income countries	Reproductive health trainees	166	By computer (cluster randomization stratified by	Mentioned with no details	Not mentioned	Clinically integrated e-Learning (8 weeks)	Online slides (8 weeks)

				country)				
Schilling et al., 2006	USA	3rd & 4th year family med residents	197	Not mentioned	Not mentioned	Mentioned with no details	e-Learning (5 weeks)	No intervention

[a] UG: undergraduate.

Gain in knowledge (unadjusted scores)

Computer based instructions vs. all other instructions

Eight studies with 9 arms (10,17–23) having 1243 participants yielded a weighted estimate of 1.8 (95% CI = 0.845 to 2.761, $I^2 = 98.2\%$, $p < 0.001$) [Figure 2], Begg-Mazumdar: Kendall's tau = 0.67, $p = 0.01$) [Figure 2]. Even though there was no comparison group in the Bergold et al. (17) and Schilling et al. (20) studies, they were included in the calculation of the overall effect since a weighted random effects model was employed (29).

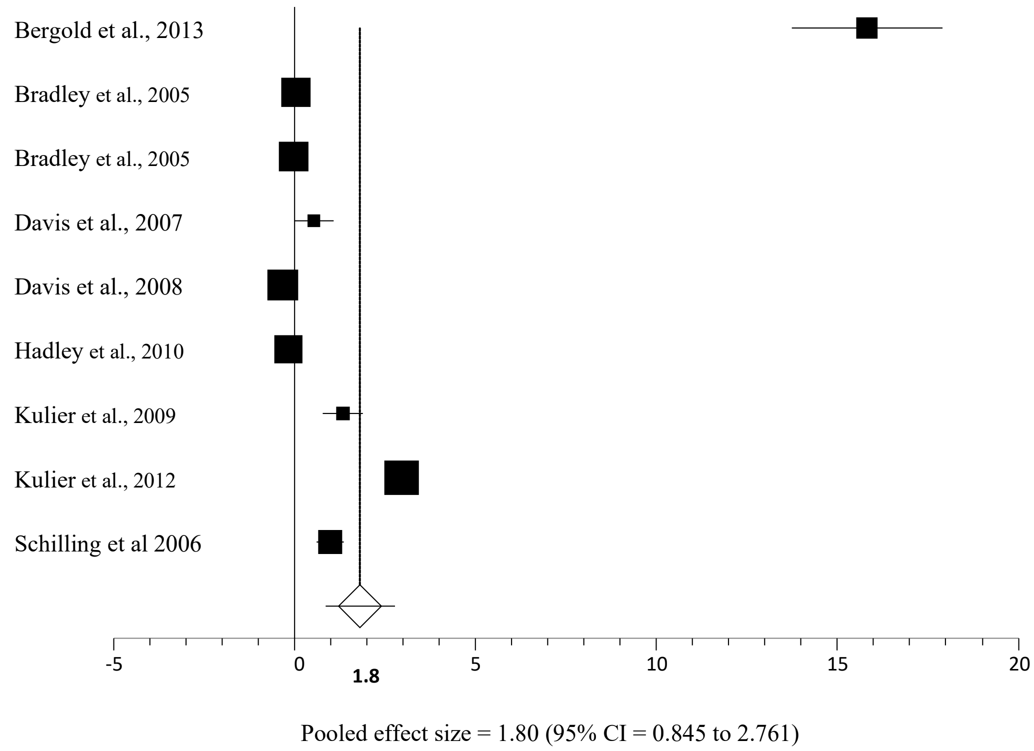

Figure 2: Effect size meta-analysis and funnel plot

Subgroup analysis

A) Computer based instructions vs. lectures

Four studies (18,19,22,23) having 455 participants yielded a weighted estimate of 0.30 (95% CI = -0.348 to 0.952, $I^2 = 90.5\%$, $p = 0.30$; Begg-Mazumdar: Kendall's tau = 1, $p = 0.08$).

B) Computer-based instructions vs. no intervention

Two studies (17,20) having a total of 311 participants yielded a weighted estimate of 1.4 (95% CI = 1.060 to 1.776, $I^2 = 99.5\%$, $p < 0.0001$)

C) Long-term knowledge retention

Only one study (17) reported the long-term gain of knowledge compared to the post-intervention score percentage of 79%; 73% and 76% at 6 and 12 months, respectively.

Gain in knowledge (adjusted to baseline scores)

A) Computer based instructions vs. all other instructions

Five studies (18,19,21–23) reported the score difference between baseline knowledge score and that after intervention/comparator with a total of 659 learners and a weighted estimate of 0.34 (95% CI = 0.114 to 0.570, I^2 =99.4%, $p < 0.005$; Begg-Mazumdar: Kendall's tau = 0.2, p = 0.8).

B) Computer based instructions vs. lectures

Four studies (18,19,21,23) with a total 455 participants yielded a weighted estimate of -0.07 (95% CI = -0.309 to 0.153, I^2 =99.1%, p = 0.5; Begg-Mazumdar: Kendall's tau = -0.67 P = 0.08).

Supplement 2 show the forest plots of the subgroup analyses.

Attitudinal gain

Bradley et al. (10) reported a better improvement of learners' attitudes to EBP from baseline in favor of the e-learning group but the difference didn't reach significance. Schilling et al. reported a significant difference in 7 out of 8 attitude outcomes in favor of the e-learning group (20). Three studies (18,19,23) used the same attitude outcome measurement (on a 5-points Likert scale) with a total of 269 learners and 1603 answers; a gain in attitude outcomes was reported by 32.5% vs. 28.2% (p = 0.06), no change by 56.5% vs. 52.8% (p = 0.3), and a loss by 14% vs. 20.7% ($p < 0.001$) for e-learning and lecture groups, respectively.

Assessment of Risk of Bias

A) Randomization process

Randomization was generated by computer programs in 6 studies (17–19,21–23) and by random number table in one study (10). Randomization process was not described in one study (20). Sealed envelopes were used for allocation in three studies (10,18,19) . Bergold et al. used telephone for allocation concealment with a blinded third party (17). Blinding of assessors was reported in 3 studies (10,18,19).

B) Sample size e-learning calculation

Two studies (10,21) conducted an *a priori* sample size calculation along with power analysis, and one study did a *post hoc* statistical power computation showing the ability of their sample size to detect the needed difference (22).

C) Intention-to-treat analysis/ Lost to follow-up

Four studies (10,21-23) reported the number of drop-outs; however, only three performed an intention to treat analysis where all participants were analyzed in the group they were randomized in (10,21,22).

Moderator Variables

A) Baseline characteristics of participants

Four studies (10,17–19) reported in details the baseline characteristics of their recruited participants with no to minimal statistical difference between the compared groups.

B) Prior EBP knowledge

All studies but that of Schilling et al. (20), reported the baseline status of EBP knowledge/skills of their participants. None of those studies found significant differences between intervention and control groups.

C) The course content

The content was different between the included studies in most cases; it was worthy to note that both studies of Davis et al. (17,19) used a similar course and so was the case for the two included studies of Kulier et al. (21,23).

Quality and Strength of the included studies

Since all included studies were RCTs, the overall Quality score is 5/5. On the other hand, the overall Strength of the results was only 2.1/5; compared to the BEME rating scale, our results are to be interpreted as trends or probable, at best. Figure 3 shows the risk of bias of each included study based on the Cochrane appraisal tool.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants (performance bias)	Blinding of intervention providers (detection bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (publication bias)	Other bias
Bergold 2013	+	+	-	?	?	+	+	?
Bradley 2005	+	+	-	-	+	+	+	?
Davis 2007	+	+	-	-	+	+	+	?
Davis 2008	+	+	-	-	+	+	+	?
Hadley 2010	+	?	-	-	?	+	+	?
Kulier 2009	+	?	-	+	?	-	+	?
Kulier 2012	+	+	-	?	?	+	+	?
Schilling 2006	+	?	-	?	+	+	+	?

Figure 3. The Cochrane Collaboration's tool for assessing risk of bias in randomized trials

DISCUSSION

Our findings showed that computer-based instructions are significantly better than “no intervention” and are equally effective as lectures in teaching EBP. The results showed that the findings are the same when adjusted scores are analyzed. While there was no statistically significant improvement in attitude outcomes using e-learning instructions, a loss of such positive outcome scores was significantly more prevalent among lecture groups. To our knowledge, it is the first time where the effectiveness of e-learning in teaching EBP is quantified via a meta-analysis.

Most of the studies (six) were based on effect sizes of e-learning compared to either lectures or other didactic models while two studies had no comparison group (17,20). We were able to include this in the overall effect because we employed a weighted random effects model which assumes that the studies were drawn from populations that differ from each other (e.g., no comparison group) in ways that could have an impact on the treatment effect (29).

The results of this meta-analysis are in line with those found by Cook et al. (15); internet-based learning among healthcare professionals yielded statistically significant effects for knowledge, skill, and behavior outcomes when compared to no educational interventions, while no significance was found when compared to non-internet-based interventions.

The findings of our study are particularly substantial to teaching EBP during the current COVID-19 pandemic. The changes introduced in medical medication during the pandemic, including synchronous and asynchronous remote learning, were reviewed by Gordon et al. (30). With the introduced changes predominantly described by positive terms such as “ overwhelmingly positive” and “highly satistifed”, the review demonstrates that remote learning contributed to an enhanced students’ flexibility, effectiveness, communication, engagement, and efficiency (30). This further strengthens the argument that e-learning will become an integral part of teaching EBP.

There are some limitations to this systematic review. Though the number of studies is relatively low, the pooled sample of 1243 participants could be fairly considered as large. Nonetheless, the pooled sample sizes for subgroup analyses are lower, but still much larger than any individual study. The course content is thought by the authors to be the most important variable in this review; the delivered EBP courses lacked homogeneity between most of the included studies. We employed a weighted effect size, random effects model to mitigate this limitation when applicable. However, the fixed effect model was used for all other subgroup comparisons since the number of included studies in the meta-analysis was equal or less than five. Such a limitation is common in most educational research; its impact on the quantitative results of the reviews is commonly not known. Another potential limitation was the possibility of publication bias. The bias indicator for the comparison between all e-learning techniques versus all other instruction methods showed the probability of missed publications. On the contrary, the bias indicators in all subgroup analyses showed no publication bias with mild to moderate heterogeneity.

An EBP course usually includes the teaching of search strategies applied to electronic databases; these search skills are best assessed through Objective Structured Practical Exams rather than theoretical learning knowledge tests, such as MCQs or focused questions. A combined score of both tests, as it was the case in some of the included studies, could have contributed variance into the outcome assessment and possibly affected the reported scores in individual studies. As in every meta-analysis, the quality and strength of its evidence depend on the quality and strength of its included studies. While the Quality score of the included randomized studies is the highest we could expect (5/5), the Strength score of 2.1 is found to be low and our results should be interpreted with caution; e-learning methods are probably as effective as lectures in teaching EBP.

The implication for practice is that e-learning could be used with the same effectiveness when lecture hours are limited in number or are not possible (31). Our findings would be highly relevant in our current time where the COVID-19 pandemic is spreading throughout the globe. The very high number of infected people with the recommended physical measures to mitigate spread impose amounting pressure on health educators and health school administartors to look for novel educational methods.

CONCLUSION

The results of this review are encouraging with data analysis supporting the effectiveness of e-learning in teaching EBP. We hope that these finding would reduce concerns over the effectiveness of EBP e-learning methods and would incite medical and health allied educators to favor such instructional methods during this pandemic and the likely-to-happen future outbreaks. Future research could be designed to investigate and develop assessment tools for EBP knowledge gain and in particular, EBP search skills.

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