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# 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 randomised studies reporting the effectiveness of e-learning methods compared to "no intervention" or to any other educational methods and including 1,243 learners met the inclusion criteria. The meta-analytical results revealed that e-learning was significantly better than "no intervention" [d = 1.4, 95% confidence interval (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 healthcare are based on the best available, valid, and relevant evidence (1). Frenk et al. (2) stated that teaching EBP to healthcare professionals could be transformative, in terms of decision making, through a shift from memorising information to critical thinking.

The practice of evidence-based medicine, evidence-based healthcare or evidence-based dentistry comprises five steps, which include the ability to: (1) formulate appropriate questions; (2) retrieve information; (3) critically appraise evidence in order; (4) apply evidence to practice; and (5) 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 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 prioritised 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, comparative randomised trials were included.

## 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 randomisation such as quasi-randomised or randomised 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 January 2023. The search strategy screened for articles that: (1) reported results from comparative randomised studies; (2) used undergraduate, postgraduate medical, dental or allied health students or healthcare professionals; (3) reported at least one primary outcome; and (4) were published in peer-refereed journals. Search terms for OVID MEDLINE were first finalised 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").

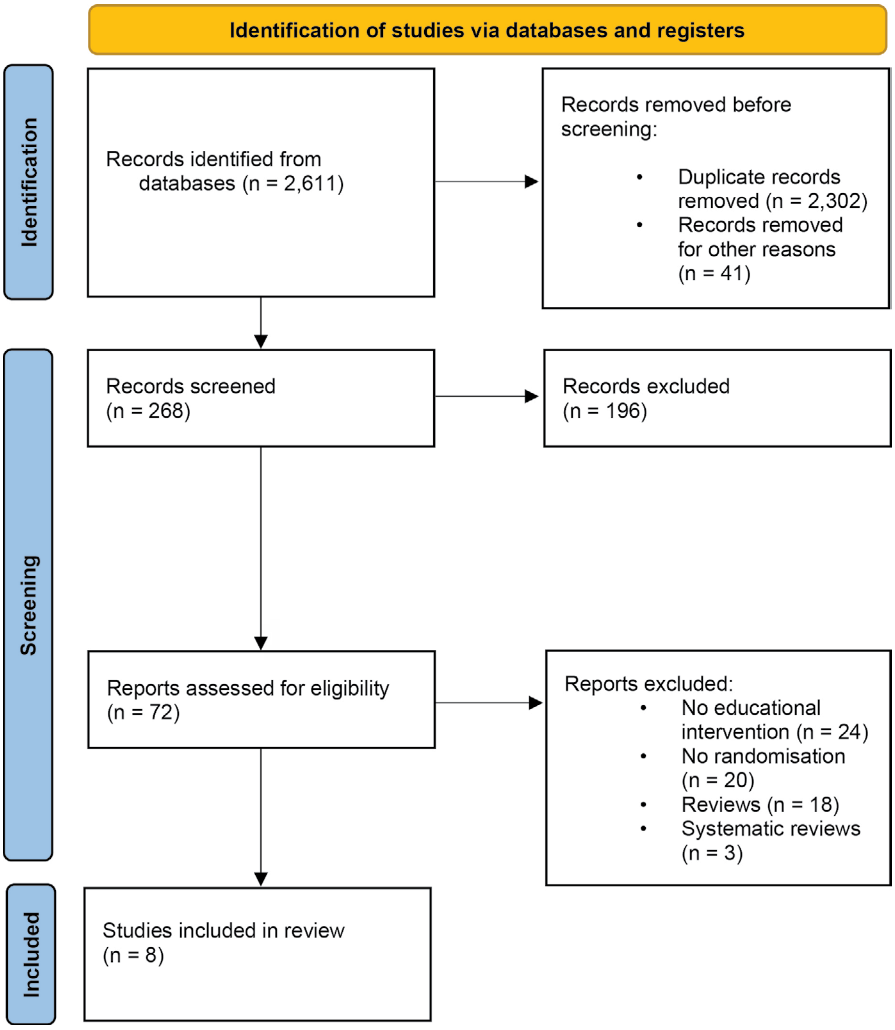



**Figure 1:** PRISMA flow diagram.

## 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 authors (KY and VZ) and disagreements were discussed until full consensus was attained. The best evidence medical education (BEME) collaboration sample coding sheet was used for data extraction (25).

### Data Collection Process and Data Outcomes

After agreement, data were 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: (1) adjusted scores; (2) long-term retention knowledge scores; and (3) 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 standardised 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), a weighted effect size using random effects model was employed when the number of studies were higher than five with an inconsistency test value ($I^2$) of more than 50%. In all other cases, the fixed effect model was used. 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).

### Risk of Bias Assessment

The risk of bias of the comparative studies was assessed using the Cochrane Collaboration's tool (26). The scoring system developed by Yammine and Violato (27) was used to score quality and strength, two out of the six QUESTS (quality, utility, extent, strength, target, setting) dimensions elaborated by Harden et al. (28).

## RESULTS

### Search Results

The initial electronic search yielded 2,611 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 randomisation (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 1,243 learners (Table 1). Figure 1 shows the PRISMA flow diagram. Appendix 1 summarises the individual data of each included study.

**Table 1:** Characteristics of the included RCT studies

| Studies | Setting | Participants | Initial sample size | Randomisation sequence generation | Randomisation concealment | Blinding | Intervention (duration) | Control (duration) |
|---|---|---|---|---|---|---|---|---|
| Bergold et al. (17) | Germany | First-year residents | 114 | By computer | Arbitrary telephone calls | Not mentioned | Online course (3 months) | No intervention |
| Bradley et al. (10) | Norway | Tenth semester medical students | 175 | Random numbered tables | Sealed opaque envelops | Blinded outcome assessment | Computer-assisted (5 half-days) | Workshops (5 half-days) |
| Davis et al. (19) | 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. (18) | UK | UG medical students | 229 | By computer | Coded envelops by a third party | Blinded outcome assessment | CD-ROM (40 min) | Lecture (40 min) |
| Hadley et al. (22) | UK | Junior residents (multiple specialties) | 160 | By computer | Not mentioned | Not mentioned | e-learning (6 weeks) | Lecture (3 hours) |
| Kulier et al. (23) | Europe | Junior obgyn residents | 61 | By computer (cluster randomisation stratified by country) | Not mentioned | Not mentioned | Clinically integrated e-learning (4–6 weeks) | Lecture (4–6 weeks) |
| Kulier et al. (21) | Low-middle-income countries | Reproductive health trainees | 166 | By computer (cluster randomisation stratified by country) | Mentioned with no details | Not mentioned | Clinically integrated e-learning (8 weeks) | Online slides (8 weeks) |
| Schilling et al. (20) | US | Third and fourth-year family medicine residents | 197 | Not mentioned | Not mentioned | Mentioned with no details | e-learning (5 weeks) | No intervention |

Note: UG = undergraduate.

## *Gain in knowledge (unadjusted scores)*

*Computer-based instructions vs. all other instructions*

Eight studies with nine arms (10, 17–23) having 1,243 participants yielded a weighted estimate of 1.8 [95% confidence interval (CI) = 0.845 to 2.761, $I^2$ = 98.2%, $p$ < 0.001; 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).

## *Subgroup analysis*

*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).

*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).

*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.

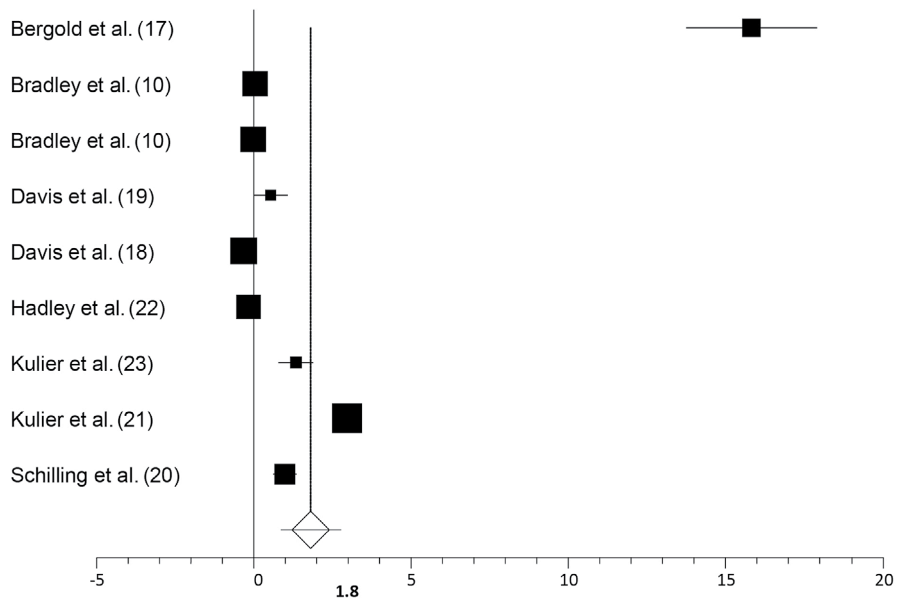
### *Gain in knowledge (adjusted to baseline scores)*

*Computer-based instructions vs. all other instructions*

Five studies (18, 19, 21–23) reported the score difference between baseline knowledge score and 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).

*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). Appendix 2 show the forest plots of the subgroup analyses.



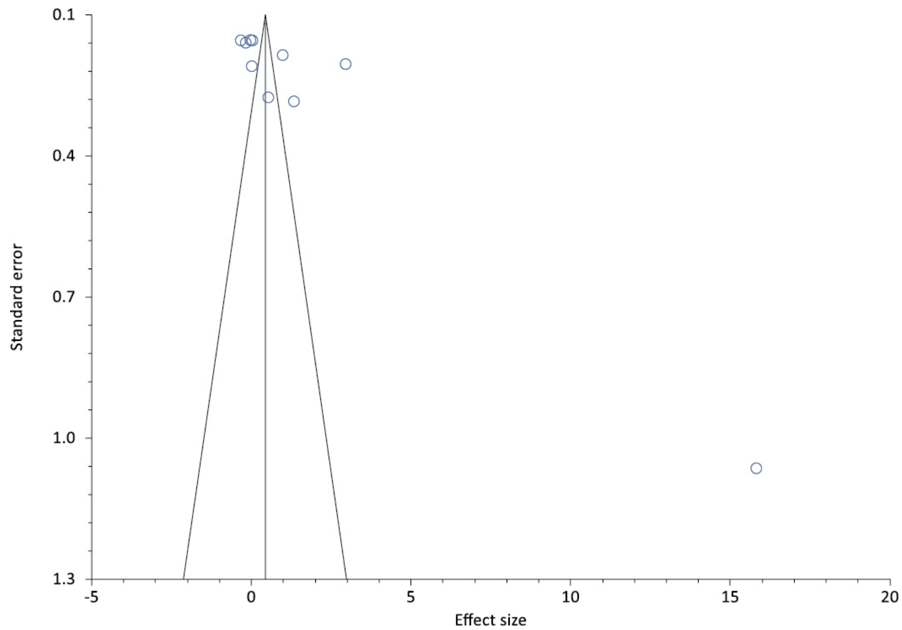



**Figure 2:** Effect size meta-analysis and funnel plots.

Note: UG = undergraduate.

### *Attitudinal gain*

Bradley et al. (10) reported a better improvement of learners' attitudes to EBP from baseline in favour of the e-learning group but the difference did not reach significance. Schilling et al. (20) reported a significant difference in seven out of eight attitude outcomes in favour of the e-learning group. Three studies (18, 19, 23) used the same attitude outcome measurement (on a 5-point Likert scale) with a total of 269 learners and 1,603 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 14.0% vs. 20.7% ($p < 0.001$) for e-learning and lecture groups, respectively.

### *Assessment of risk of bias*

*Randomisation process*

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

*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).

*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 analysed in the group they were randomised in (10, 21, 22).

### *Moderator variables*

*Baseline characteristics of participants*

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

*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.

*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. (18, 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 2.1/5.0; compared to the BEME rating scale, the 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 et al. (17) | + | + | – | ? | ? | + | + | ? |
| Bradley et al. (10) | + | + | – | – | + | + | + | ? |
| Davis et al. (19) | + | + | – | – | + | + | + | ? |
| Davis et al. (18) | + | + | – | – | + | + | + | ? |
| Hadley et al. (22) | + | ? | – | – | ? | + | + | ? |
| Kulier et al. (23) | + | ? | – | + | ? | – | + | ? |
| Kulier et al. (21) | + | + | – | ? | ? | + | + | ? |
| Schilling et al. (20) | + | ? | – | ? | + | + | + | ? |

**Figure 3:** The Cochrane Collaboration's tool for assessing risk of bias in randomised 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 analysed. 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). All these studies were included in the overall effect because this study 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 this study are particularly substantial to teaching EBP during the current COVID-19 pandemic. The changes introduced in medical education 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 1,243 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. This study 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 multiple choice questions (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 randomised studies is the highest the authors could expect (5/5), the strength score of 2.1 is found to be low and the 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). The findings would be highly relevant in the 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. These finding would reduce concerns over the effectiveness of EBP e-learning methods and would incite medical and health allied educators to favour 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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# APPENDICES

## Appendix 1: Individual Study Data

### *Unadjusted scores*

| Study | Sample (intervention) | Sample (control) | % correct answers (intervention) | SD | % correct answers (control) | SD |
|---|---|---|---|---|---|---|
| Bergold et al. (17) | 58 | 56 | 78.8 | 2.00 | 30.70 | 3.80 |
| Bradley et al. (10) | 83 | 85 | 70.0 | 15.20 | 69.40 | 20.50 |
| Bradley et al. (10) | 82 | 88 | 58.5 | 13.60 | 59.00 | 18.70 |
| Davis et al. (19) | 25 | 30 | 82.5 | 13.10 | 74.30 | 16.80 |
| Davis et al. (18) | 70 | 109 | 65.6 | 19.40 | 71.25 | 15.30 |
| Hadley et al. (22) | 88 | 73 | 71.0 | 19.70 | 74.20 | 15.80 |
| Kulier et al. (23) | 28 | 33 | 82.2 | 6.04 | 75.80 | 3.26 |
| Kulier et al. (21) | 123 | 81 | 69.5 | 3.38 | 61.45 | 1.10 |
| Schilling et al. (20) | 74 | 58 | 72.5 | 18.75 | 54.00 | 18.75 |

Note: SD = standard deviation.

### *Gain in knowledge (adjusted to baseline scores)*

| Study | Sample (intervention) | Sample (control) | Gain knowledge difference (intervention) | SD | Gain knowledge difference (control) | SD |
|---|---|---|---|---|---|---|
| Davis et al. (19) | 25 | 30 | 13.10 | 0.65 | 11.80 | 1.95 |
| Davis et al. (18) | 70 | 109 | 5.00 | 0.65 | 8.10 | 0.30 |
| Hadley et al. (22) | 88 | 72 | 10.73 | 1.27 | 9.20 | 5.53 |
| Kulier et al. (23) | 28 | 33 | 12.36 | 7.50 | 5.96 | 4.64 |
| Kulier et al. (21) | 123 | 81 | 9.00 | 0.85 | 0.70 | 0.07 |

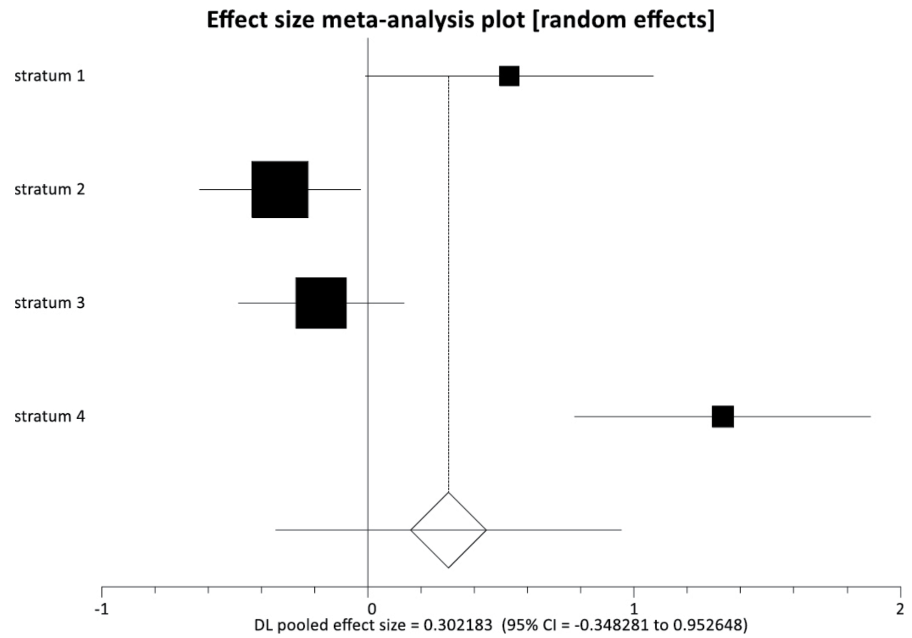
Note: SD = standard deviation.

### *Attitudinal gain*

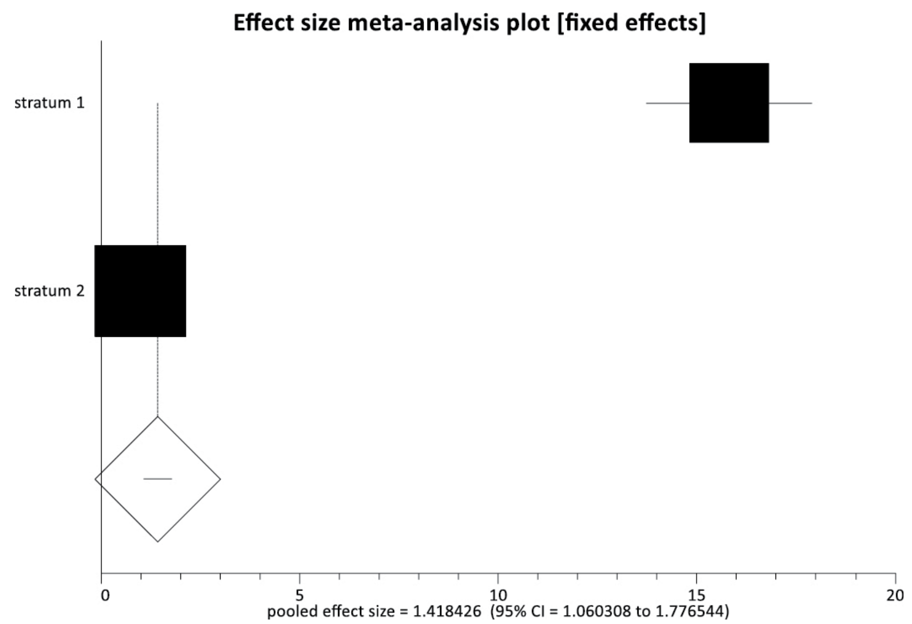
| Study | Sample computer-based | Sample lecture | Computer-based gain | Lecture gain | Computer-based no change | Lecture no change | Computer-based loss | Lecture loss |
|---|---|---|---|---|---|---|---|---|
| Davis et al. (19) | 115 | 140 | 30 | 36 | 90 | 107 | 13 | 14 |
| Davis et al. (18) | 420 | 648 | 152 | 189 | 211 | 325 | 57 | 134 |
| Kulier et al. (23) | 105 | 175 | 26 | 46 | 59 | 75 | 20 | 54 |

## Appendix 2: Forest Plots for Subgroup Analyses

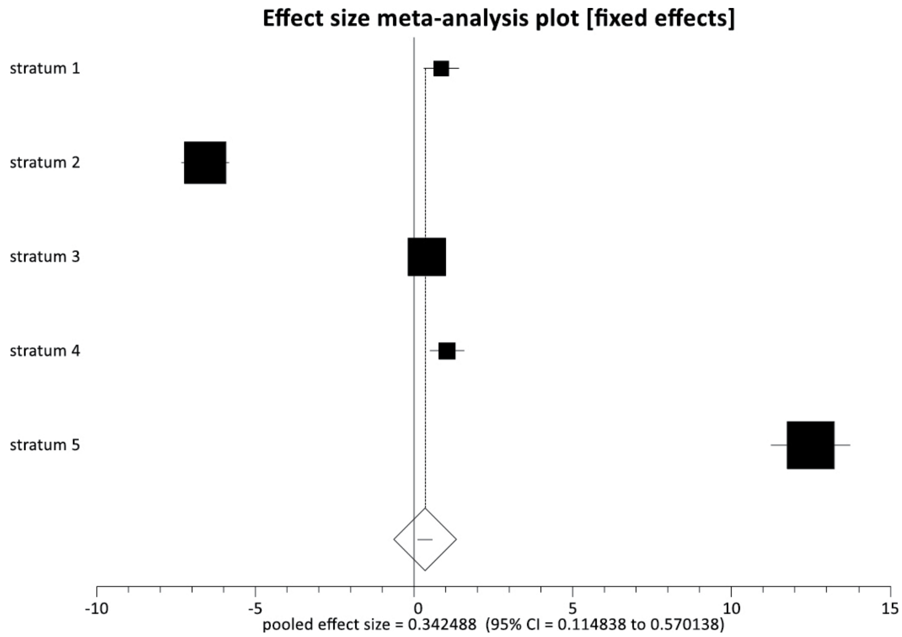
### *Computer-based instructions vs. lectures*




### *Computer-based instructions vs. no intervention*



***Computer-based instructions vs. all other instructions***




***Computer-based instructions vs. lectures***