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Effective In-Service Training Techniques, Frequency, Setting and Media:

Evidence from an Integrative Review of the Literature

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Acronyms

ACCP	American College of Chest Physicians
AHRQ	Agency for Healthcare Research and Quality
ANOVA	Analysis of variance
BEME	Best Evidence in Medical Education
CINAHL	Cumulative Index to Nursing and Allied Health Literature
CME	Continuing medical education
CPE	Continuing professional education
CPR	Cardiopulmonary resuscitation
JHU EPC	Johns Hopkins University Evidence-Based Practice Center
MeSH	Medical subject heading
NREMT	National Registry of Emergency Medical Technicians
PBL	Problem-based learning
RCT	Randomized controlled trial

Executive Summary

For nearly 40 years Jhpiego has supported countries to establish national training systems. Decreasing global resources, a pervasive critical shortage of skilled health workers and growing disease burden have pushed national ministries and professional bodies to pursue shorter, less expensive in-service training or continuing professional education (CPE) interventions.[1] The terms in-service training and continuing professional education are used as the same concept in this report. Jhpiego has undertaken a review of the evidence to determine how to increase the effectiveness, efficiency and sustainability of in-service training or continuing professional educational interventions.

This review of the literature analyzes and discusses the evidence regarding the influence educational techniques, frequency, setting and media used for delivery have on learning outcomes. The 69 articles selected for analysis consisted of systematic reviews, randomized controlled trials (RCTs) and program evaluations in peer-reviewed journals. There is a lack of quality constructed trials, especially in low- and middle-income countries and a need for researchers to use the same terminology and construct more rigorous evaluations in order to produce high-quality evidence.

Educational techniques are the most critical factor in learning outcomes. The evidence supports the use of multiple techniques that allow for interaction, and for learners to process and apply information. The use of case-based learning (such as case studies, or case-based questions), clinical simulations, and practice and feedback have been found to be more effective for knowledge and skill acquisition than didactic techniques. Didactic methods that involve passive learning, such as reading or lecture, have been found to be of little or no impact. There is sufficient evidence supporting the use of live (face-to-face) training activities that combine the use of interactive techniques, simulation, practice and feedback, and role play. Whether the instruction was delivered live, via computer, or in teams was not as important as the techniques selected.

Repetitive interventions, rather than single interventions, are superior for learning outcomes. This is supported by several RCTs and systematic reviews of the literature. “Low-dose, high-frequency” interventions resulted in better retention of learning in several studies.

Setting should be selected to ensure that it is similar to the practice setting and reduces absenteeism and increases training efficiency. Setting was not found to impact knowledge acquisition in several small studies, but did impact skill acquisition and performance. Several small RCTs found no difference in skill performance between those trained in a simulation center and those trained in the

[1] Throughout this report, we refer to “continuing professional education” as the same concept as “in-service training.”

workplace. The educational literature reinforces the concept that learning should occur in an environment as similar to the practice setting as possible.

Media used for delivery of instruction should be selected based on how it will support educational techniques and efficiency. Computer-based learning can be equally effective as or more effective than live instruction and more cost efficient, but case-based techniques, opportunities for practice and interaction with the educator should be prioritized. Reminders sent via text messages in Kenya increased compliance with national treatment protocols.

This integrative review[2] of the literature provides a synthesis of the effect that educational techniques, frequency, setting and media used for delivery have on learning outcomes and subsequent practice behaviors. There is a severe lack of quality data in low-income countries on this topic. A future educational research agenda includes well-constructed quality RCTs or systematic reviews of the effects of technique, frequency, setting and media used for delivery both individually and in various combinations in low-resource settings. This review provides evidence to guide best practices for the design and delivery of continuing education programs.

[2] An integrative review expands the variety of research designs within a review's inclusion criteria and allows for incorporation of qualitative and quantitative information.

I. Introduction and Background

1.1. Background

Jhpiego has been a recognized leader in health worker education and training for nearly 40 years. With a focus on competency and strategies aimed at development of knowledge and skills needed for optimal job performance, Jhpiego's training approach has become widely respected by governments, donors and other international stakeholders. Its comprehensive system for developing high-quality trainers, attention to well-managed training and applicability to a wide range of cadres has led to widespread acceptance throughout the developing world.

The need to maximize the effectiveness and efficiency of training has never been greater. Decreasing global resources, a pervasive critical shortage of skilled health workers and growing disease burden are all factors driving requests for shorter, less expensive and more effective training/continuing professional education (CPE). While the need is unprecedented, so are the opportunities. Growing access to mobile and electronic technologies is only beginning to be creatively applied to promote transfer of learning.

This integrative review of the literature provides an in-depth analysis of the effect that educational techniques, frequency, setting and mode of delivery have on learning outcomes and subsequent practice behaviors. Key evidence-based recommendations intended to maximize training effectiveness and efficiency of CPE/training are included. Where evidence is insufficient, areas for future educational research are suggested.

1.2. Purpose and Objectives

This integrative review of the education and training literature presents evidence to support the design and delivery of training. Focus is placed on evidence-based best practices that promote transfer of learning and positive change in practice behaviors. The discussion considers the evidence and provides recommendations for low-resource settings in order to: (a) maximize the use of scarce training resources; (b) minimize absenteeism caused by traditional training; (c) maximize learner involvement in achieving educational objectives; and (d) appropriately leverage emerging technologies.

1.3. Review Questions

In the area of CPE:

- Do particular educational techniques make a difference in learning outcomes?
- Does the frequency of instruction make a difference?

    - Single events
    - Repetitive
- Does the setting make a difference in learning outcomes?
- Does the type of media used to deliver the curriculum make a difference in promoting learning outcomes?
- What evidence exists of outcomes derived from CPE, using any mixture of technique, media or frequency?

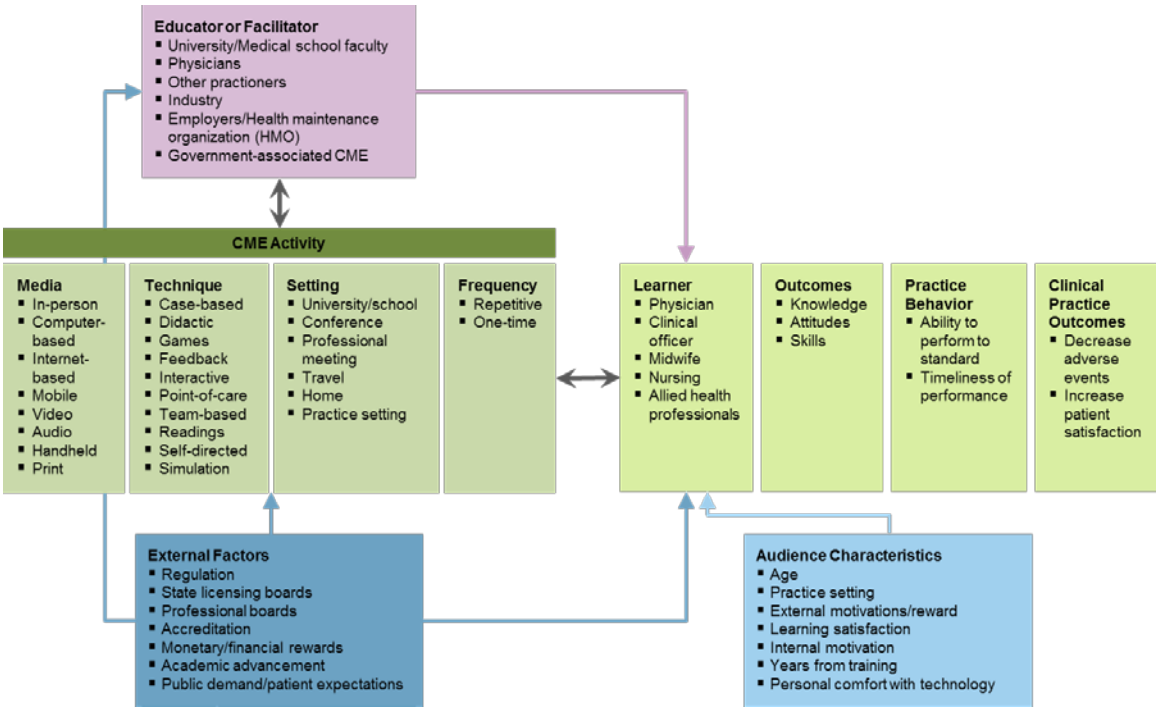
Relevant articles were looked at independently, and the interplay between techniques, frequency, setting and media were all considered and discussed.

II. Methods

2.1. Conceptual Model

A conceptual model for this review of CPE was adapted from the model developed by the Evidence-Based Practice Center at Johns Hopkins University for a systematic review of continuing medical education (CME) [1], and is outlined in Figure 1.

Figure 1. Conceptual Model for Continued Professional Education



Adapted with permission from:
Marinopoulos SS, Baumann MH, American College of Chest Physicians Health and Science Policy Committee: Methods and definition of terms: effectiveness of continuing medical education: American College of Chest Physicians Evidence-Based Educational Guidelines. Chest 2009, 135 (3 Suppl):17S–28S.

2.2. Literature Review

A sequential review process was used to extract data. After an initial search, a second, more experienced reviewer assessed the data to minimize the potential for errors. A research coordinator searched the electronic, peer-reviewed literature from multiple databases including PubMed, the Cochrane Library and the Cumulative Index to Nursing and Allied Health Literature (CINAHL) between May and June of 2011. The searches were restricted to "human studies" published in the English language between 2000 and 2011. Medical subject headings (MeSHs) and key search terms that focused on both the media and the delivery with which the educational

program was delivered are presented in List 1. Articles selected for analysis consisted of systematic reviews, randomized controlled trials (RCTs) and program evaluations in peer-reviewed journals. Articles excluded from analysis were observational studies, qualitative studies, editorial commentary, letters and book chapters. Articles that did not present an abstract were also excluded from the review. The bibliography of this report includes additional literature resources that informed our discussion but were not included in the analysis.

List 1. MeSH and Key Search Terms

Group-based education
Facility-based education
On-the-job education
Group-based training
Facility-based training
On-the-job training
Point-of-care training
Mobile technologies
Asynchronous distance learning
Synchronous distance learning
Online learning
Distance learning
Continuing medical education
Continuing nursing education
Nursing education
Medical education
Teaching methods
Health care professionals
Education methods
Continuing education methods
Nursing education methods
Medical education methods

2.3. Review of Abstracts/Methodological Grading

An initial review of the titles and abstracts produced 244 results, which were downloaded into RefWorks, an online data management tool. The senior consultant, an experienced researcher, suggested initial selection criteria, which were vetted by a panel of experts. Articles were prioritized into two tiers for quality control. Table 1 presents the criteria used to grade the quality of a study. Articles were then categorized into two tiers as displayed in Table 1.

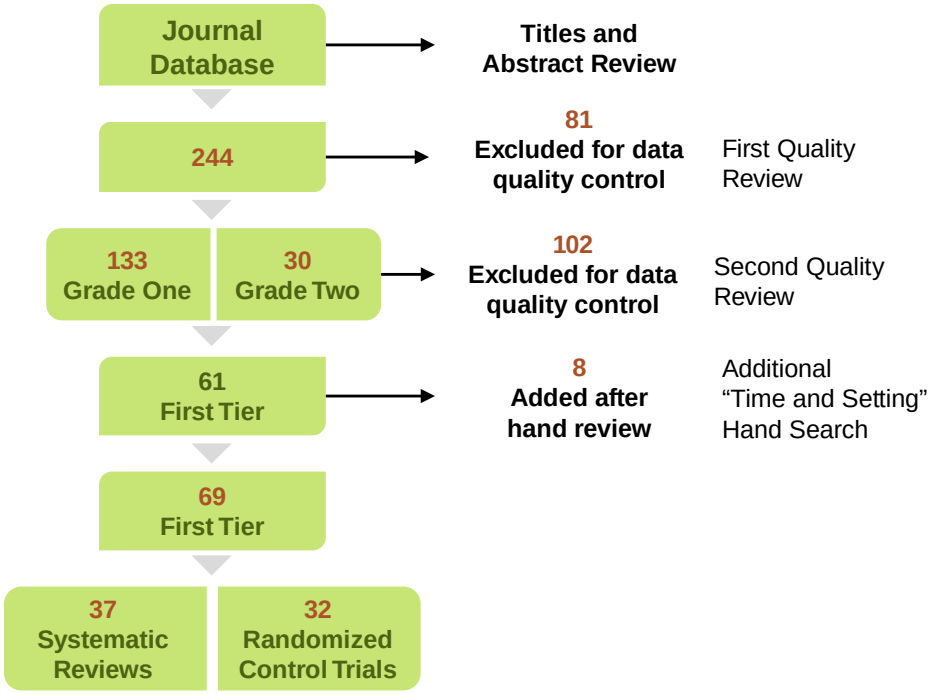
Table 1: Grading Criteria

Design	N/Type of Groups	Literature Grade	Tier
Meta-analysis or systematic review		**1**	**1**
Experimental	Between subjects (experimental and control)	**2**	
	Within subjects (crossover)	**2**	
Quasi-experimental	Non-equivalent control group	**3**	**2**
	Repeated measures	**3**	

Design	N/Type of Groups	Literature Grade	Tier
Pre-experimental	Comparison group	**4**	
	Pre-test/post-test	**4**	
	Post-test only	**5**	

After prioritization of the articles, 133 Grade One and 30 Grade Two articles were reviewed by a senior public health professional. After the second review, 61 Grade One studies were selected to be included in the analysis. An additional hand search for articles was conducted that focused on the frequency and setting of education activities. Key search terms included group-based training AND nursing education, group-based training AND medical education, on-the-job training AND medical education, and on-the-job training AND nursing education. This resulted in including an additional eight articles for a total of 69 studies, including 37 systematic reviews and 32 RCTs. As the effect sizes for the articles were not uniformly reported across studies, a quantitative meta-analysis of the results was not performed. See Figure 2 for a summary of the process used to identify the articles for analysis.

Figure 2. Inclusion Process



2.4. Data Extraction and Coding Sheet Developed

A spreadsheet for selecting how to extract and organize the data was created based on the Best Evidence in Medical Education (BEME) group [2] coding sheet. All articles were categorized based on the terminology presented by the Johns Hopkins

University Evidence-Based Practice Center (JHU EPC) group in its systematic review conducted for the Education Committee and the Health and Science Policy Committee of the American College of Chest Physicians (ACCP) in collaboration with the Agency for Healthcare Research and Quality (AHRQ) [3]. Articles were placed into the summary tables in this report based on the CPE component that most closely reflected the goals of the study or systematic review, although many addressed more than one aspect, for example, both media and technique. In addition, the use of terminology was highly inconsistent (e.g., some of the articles reported on computer-based instruction as a technique, when it was actually discussing the computer as the media used for delivery of instruction). Each article was reviewed and categorized in the table using the JHU EPC [1] terms for reporting. The terminology definitions are included in List 2.

List 2. Definitions of Techniques/Educational Methods

Academic detailing: Detailing provided by an institution or hospital

Audience response systems: Addresses knowledge objectives. Used in combination with live lectures or discussion groups, these are computerized feedback tools that allow the teacher/instructor to pose a question to a large group and receive immediate feedback from each learner, which is collated and presented on a screen. Instructor may choose to alter content based on audience response

Case-based learning: Addresses higher order knowledge and skill objectives. Actual or authored clinical cases are created to highlight learning objectives; clinical material is presented and followed with questions usually determined by the instructor

Clinical experiences: Addresses skill, knowledge and attitudinal objectives. Generally refers to a preceptorship or observership with an expert, as in attending a specialty clinic or operating room

Demonstration: Addresses skill and/or knowledge (knows how) objectives; can be presented live, or with video or audio. Teacher determines amount and pace of content

Discussion group: Addresses knowledge, especially application or higher order knowledge, or affective objectives; usually requires preparation with readings, or another experience, such as viewing a videotape or a role play. Can be facilitated by instructor, but group often determines content

Feedback: The provision of information about an individual's performance to learners

Lecture: Presentation of knowledge content; live, video, audio or slide presentation available online. Teacher/instructor determines amount and pace of content

Mentor/Preceptor: Addresses higher order cognitive, skill and affective objectives. Learner is paired with a mentor who may observe, review documentation of performance, advise, coach and facilitate learning

Point of care: Addresses knowledge and higher order cognitive objectives (decision-making). Information which is provided at the time of clinical need, integrated into chart or electronic medical record

Problem-based learning or team-based learning: Addresses higher order knowledge objectives, metacognition and some skill (group work) objectives. A clinical scenario is presented to a team, who identify the learning objectives, assign information-seeking tasks, and return to share information and answer questions about the case. Can be facilitated or non-facilitated

Programmed learning: Addresses knowledge objectives. Content is delivered in sequential steps, which are tested with the learner, before moving to the next, usually more complicated, step. Pace is determined by the learner, but objectives are set by the program (teacher). Can be delivered in text or online

Readings: Presentation of knowledge content or background for attitudinal objectives. Requires learner to complete; can be done at learner's pace. Teacher/instructor directed or self-directed (e.g., journals, newsletters, searching online)

Role play: Addresses skill, knowledge and affective objectives. Learners assume role of patients and/or clinicians in practicing focused encounters around training problems, usually when standardized patients are unavailable. Encounter may be recorded and reviewed or followed with a discussion group. Rarely used as sole method of education

Simulation (other than standardized patient or role play): Addresses knowledge and skill objectives; ability to simulate potentially addresses higher order integrative objectives, such as responding to an emerging clinical situation, understanding the unfolding of a protein structure, working in teams. Technology can be used for simulation training of procedures, as in endoscopy virtual reality trainers or anesthesia simulators. Includes also models, such as joint injection and suture. Requires active participation of learner; can use multiple learners in some scenarios

Standardized patient: Addresses skill and some knowledge and affective objectives. Usually used for communication skills training and assessment, the standardized patient or simulated patient is trained in a specific patient scenario and presentation of a clinical problem. Encounter may be audio or videotaped and timed. Review offers opportunity for reflection and "replay" of the scenario

Writing/Authoring: Addresses knowledge and affective objectives. Can include authoring test items and participation in test development. Journaling is used frequently for affective objectives, and may be followed with discussion groups or review with a mentor

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Marinopoulos SS, Baumann MH, American College of Chest Physicians Health and Science Policy Committee: Methods and definition of terms: effectiveness of continuing medical education: American College of Chest Physicians Evidence-Based Educational Guidelines. Chest 2009, 135 (3 Suppl):17S–28S, United States.

Figure 3: Illustration of How Terminology Was Used to Categorize Articles

Figure 3a illustrates an educational intervention delivered via computer media that used didactic techniques with little interaction (e.g., PowerPoint with audio).

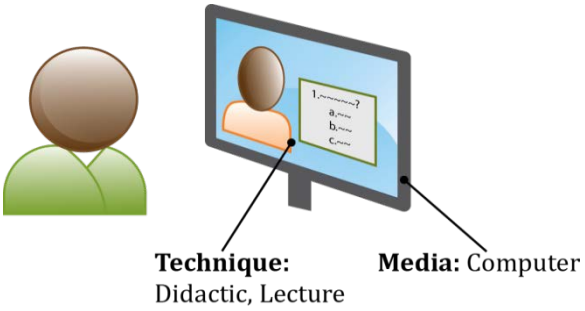


Figure 3b illustrates using computer as the media for delivery, but case-based and interactive techniques used for the instruction.

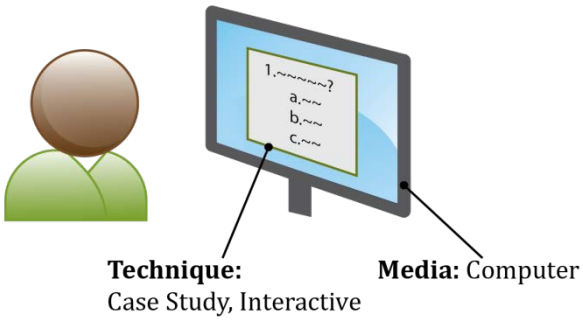
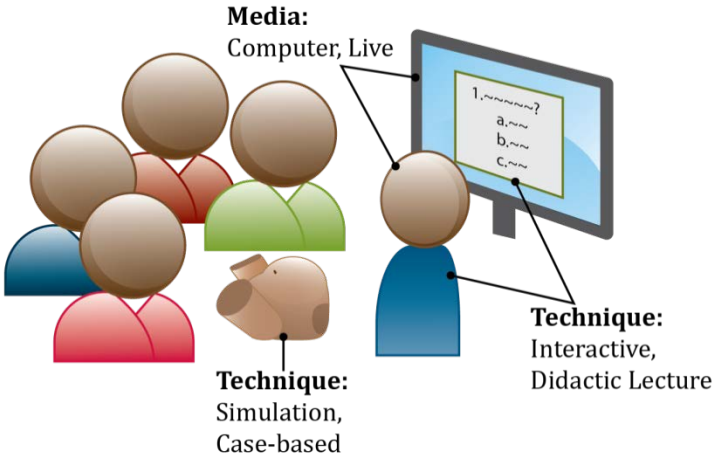


Figure 3c illustrates instruction provided live, in a group, using a combination of techniques including didactic (lecture and reading), plus interactive techniques, including case-based or simulations. Articles were organized in the table that most closely matched the focus of the article, although there was often overlap.



III. Results

3.1. Characteristics of Included Studies

The following analysis incorporates Tier 1 and Tier 2 articles only. Reflection on information obtained from lower tier articles or other literature is included where necessary to address an area of interest in the discussion.

3.2. Techniques

The articles or studies that specifically addressed educational techniques are summarized in Table 2. Technique refers to the educational methods used in the instruction. The techniques discussed in this literature review follow below; notably, not all techniques were relevant or sufficiently described to include in this technical report but do merit further explanation. In addition to the techniques listed, this review also reports on interactive techniques, defined as those requiring interaction and participation from the learner.

Case-Based Learning

Though case-based learning was not specifically compared to other techniques in the literature reviewed, it was often mentioned in the articles that discussed interactive techniques as one of the methods utilized. Case-based learning was also noted as a technique used for computer-delivered CPE courses. Triola et al. (2006) compared types of media utilized for case-based learning and found similar outcomes with cases of live standardized patient and computer-based virtual patient [4] (Table 5).

Didactic Instruction/Lecture

Didactic instruction (often referred to in the literature as traditional instruction, lecture-based or didactic teaching) was not found to be an effective educational technique compared to other methods. Five studies specifically compared didactic instruction to other methods [5], [6], [7], [8], [9]. Two studies [9], [8] found no statistical difference in learning outcomes and the other three [5], [6], [7] found didactic to be less effective than other techniques. Reynolds had a small sample size (N=50), but found that the simulation group had a significantly higher mean post-test score (6.38 vs. 5.16, $p<0.01$) as well as significantly greater inter-test score progression ($p<0.0001$). Overall learner satisfaction was also higher in this group ($p<0.01$).

In addition to the individual studies, systemic reviews identified didactic instruction as a less effective educational technique [10], [11], [12], [13], [14], [15], [3].

Games

One rigorous systematic review found limited studies and low-to-moderate methodological quality with inconsistent results. The review did indicate that three out of five RCTs suggested that educational games can have a positive effect on increasing medical student knowledge. A key recommendation is that educators should ensure that games include an active learning experience, are fun and feedback is provided [16].

Feedback

Herbert et al. [17] compared individualized feedback in the form of a graphic prescribing portrait (report on personal history of drug prescribing practices) to small group discussion of the same material and found that both the feedback and the interactive, live session were somewhat effective at changing prescribing behaviors in physicians. Significantly improved adherence to clinical guidelines was seen when monthly feedback and chart audit sessions followed a CME intervention, but the intervention as described was closer to supportive supervision, not feedback, as defined in List 2 [18]. A Cochrane review of the evidence to support CME suggested the importance of feedback and instructor interaction in improving learning outcomes [19], (Table 6).

While less discussed than other techniques, feedback shows promise for improving learning outcomes.

Interactive

Five articles specifically compared interactive CPE to other methodologies [13], [14], [5], [17], [18]. Interactive techniques (techniques that include interaction between participants and the facilitator) [10] were found by DeLorenzo and Abbot to be moderately better than didactic lecture. Scores in the interactive group were higher for the internal course grade and the National Registry of Emergency Medical Technicians (NREMT) exam written score, but not significant ($p > 0.05$) for the NREMT written pass rates, though the trend was higher for the interactive [5]. Simulations were found to be more effective than interactive instruction for knowledge acquisition in one study [13] and equally effective in another [14]. However, Daniels found that the simulation group had significantly ($p<0.01$) improved performance on clinical drills (Daniels et al. 2010, 40–45). Two other studies found interactive techniques were more effective when feedback from chart audits was added to the intervention [17], [18].

Interactive techniques were found to be more effective than didactic, but in several studies, less effective than simulation.

Three systematic reviews and one meta-analysis specifically noted the importance of learner interactivity or engagement in learning in achieving positive learning outcomes [20], [21], [22], [23].

Point-of-Care

Two articles specifically addressed point-of-care as a technique. One systematic review found three articles that addressed point-of-care as a technique and noted that while the findings were weak, they did indicate that point-of-care led to improved knowledge and confidence [24]. In an examination of media, Leung (see

Table 5) determined that handheld computers were more effective than print-based, point-of-care support [25], although outcome measures were all self-reported behaviors. Though not specific to point-of-care, You et al. [26] found improved performance on a procedure among surgery residents who received point-of-care mentoring via a video using a mobile device compared to those who received only didactic instruction (overall success $p<0.01$, time to success, $p<0.001$) .

Problem-Based Learning

Four articles specifically compared problem-based learning to other methods. One study identified problem-based learning as slightly better [6], and two studies indicated it to be relatively equal to didactic instruction [8], [9]. Lin found a statistically significant difference between the ethical discrimination scores of the two groups ($p<0.05$), with the experimental group (problem-based, peer learning) on average scoring higher than the control group (didactic) [6].

Problem-based learning was found to be less effective than simulation for acquisition of critical assessment and management skills by fourth-year medical students in one small study (N=21). Both the simulation and problem-based learning groups had similar mean initial assessment scores (problem-based learning 0.44, simulation 0.47, $p=0.64$). The simulation group performed better than the problem-based group on the final assessment (0.72 and 0.53, $p<0.0001$). When change in score was compared, simulation groups performed better (mean improvement 25 percentage points vs. 8 percentage points, $p<0.04$) [27]. A systematic review of 10 studies on problem-based learning found inconclusive evidence to support it, although several studies reported increased critical thinking skills and confidence in making decisions [28]. In a systematic review that examined evidence-based clinical teaching, Werb and Matear identified that problem-based learning led to higher scores on national dentistry boards vs. those in a traditional curriculum [29].

Team-Based Learning

Note that the articles reporting on team-based training focused on training individuals together in their work teams, rather than using a collaborative, team approach to solve problems as the "team-based" technique defined in List 2. Articles that looked at training teams in teamwork skills were excluded. These findings focus on the technique of providing training to teams of co-workers.

One systematic review specifically looked at team-based training and reviewed eight articles [30] two of which [31], [32] are also included and discussed in the Settings section. This systematic review found that there is limited and inconclusive evidence to support team-based training. Two of the articles reporting on the same CPE study did not identify any improvements in performance or knowledge acquisition with the addition of using a team-based approach [31], [32]. A rigorous meta-analysis of 31 studies suggests focusing training on groups of physicians from a single discipline, rather than team-based training across cadres [21].

Readings

Only one small trial (N=53) specifically compared reading to self-directed distance learning modules that included case studies and questions. No significant difference was found between the two groups [33].

A systematic review [34] and one cluster RCT [35] looking at media found that distribution of guidelines or provision of print media for reading to be an ineffective technique. In addition, systematic reviews reinforced that provision of print media for reading is not a preferred technique [36], [37], [3], [38], [10] (Table 6).

Print media was found to be less effective and not preferred compared to other techniques across multiple sources.

Reminders

One cluster RCT conducted in Kenya found that using mobile devices for repetitive reminders resulted in significant improvement in health care providers' case management of pediatric malaria and these gains were retained over a six-month period [39]. Intention-to-treat analysis showed that correct management improved by 23.7% (95% CI 7.6–40.0, $p<0.01$) immediately after intervention and by 24.5% (8.1–41.0, $p<0.01$) six months later compared to the control group [39]. Reminders were also noted as an effective strategy by two of the systematic reviews [12], [10] (Table 6).

Self-Directed

This term was difficult to extract for analysis due to widely varying terminology. Some authors called it "distance learning," and some articles used it to define media, rather than technique. For example, the learning may be self-directed and also use an interactive, case-based, problem-based or didactic technique for instruction. This analysis specifically discusses articles that were consistent with the description for self-directed learning presented in List 2, even if the authors used a different terminology.

Two articles focused on self-directed learning as a technique. A recent systematic review identified that moderate quality of evidence suggests a slight increase in knowledge domain compared with traditional teaching, but notes that this may be due to the increased exposure of a blended learning intervention [40]. One RCT found modest improvements in knowledge using a self-directed approach, but noted it was less effective at impacting attitudes or readiness to change [33].

Multiple studies that focused on delivery media also noted that self-directed instruction was equally effective as or more effective than instructor-led didactic or interactive instruction and potentially more efficient [41], [42], [43], [44], [45], [46], [47], [48] (Table 5).

Simulation

Simulation was noted across the systematic reviews as an effective technique for learning outcomes, particularly for the development of psychomotor skills. The systematic reviews all highlighted inconclusive and weak methodology in the studies reviewed, but noted that simulation is useful for psychomotor and communication skill development [49], [50], [51] and to facilitate learning [52]. The Lamb systematic review suggests that patient simulators, whether computer or anatomic models, are one of the more effective techniques for simulations.

The four RCTs all found simulation to be better than the techniques to which they were compared, including interactive [13], [14] didactic [7], and problem-based approaches [27]. The Daniels study is of particular interest. This investigation found that although knowledge outcomes were similar between the interactive and the simulation group, the simulation team performance in a labor and delivery clinical drill was significantly higher for both shoulder dystocia (11.75 vs. 6.88, $p<0.01$) and eclampsia (13.25 vs. 11.38, $p=0.032$) at one month, post intervention [14]. Bruppacher et al. found that simulation training was better than interactive group seminars for teaching about weaning patients from anesthesia. The simulation group scored significantly higher on knowledge and skill post-tests ($p<0.05$) [13].

The value of simulation was also noted in other articles analyzed. The Crofts and Ellis studies (previously discussed) found simulation to be effective at increasing knowledge, independent of setting or team-based training, and to be more effective than interactive methods for skill performance in a clinical drill [31], [32]. Simulation was also found to be useful for identifying additional learning gaps, such as how to mix magnesium sulfate for administration drill [31]. A systematic review focused on resuscitation training identified simulation as an effective technique, regardless of media or setting used to deliver it [53]. The JHU EPC systematic review recommendations support simulation as effective for psychomotor and procedural skills [3]. The Nestel systematic review notes that there is sufficient evidence to support simulation for addressing knowledge and psychomotor skills [15].

Table 2: Summary of Articles Focused on Techniques

LEGEND: C=Control, CME=Continuing medical education, I=Intervention, NR=Not reported, PBL=Problem-based learning, POC=Point-of-Care, RCT=Randomized Controlled Trial, SDL=Self-directed learning, SR=Systematic Review

Citation	Study Design	Participants	Intervention	Key Findings
Akl, E. et al. 2010	Systematic Review (SR): 5 articles reviewed to determine the effectiveness of educational gaming on learning	Mostly medical students	Technique: Educational Games Media: Multiple Frequency: Not reported (NR)	Findings in 3 of the 5 randomized controlled trials (RCTs) suggested but did not confirm a positive effect of the games on medical students' knowledge.
Blaya, J. et al. 2010	SR: 45 were included for review, included qualitative and quantitative data—only 3 of those related to point-of-care (POC) support	Nurses in developing countries	Technique: Didactic vs. Point-of-Care Media: Computer-based vs. Live Frequency: NR	POC findings: studies were weak, but indicate knowledge improved and increased report in trusting personal judgment.
Bruppacher, H. et al. 2010	Prospective, Single-Blinded RCT to determine if simulation or interactive techniques are better for teaching weaning a patient from anesthesia	Anesthesiology trainees, postgrad year 4 I=10 C=10 Country: China	Technique: Simulation vs. Interactive Media: Live Frequency: Single Intervention group received simulation-based training, control an interactive seminar.	The simulation group scored significantly higher than the seminar group at both post-test and retention test. Clinical decision-making/psychomotor skills can be acquired via simulation.
Daniels, K. et al 2010	Prospective RCT to determine if simulation is more effective than didactic in obstetric emergency management	Residents and labor and delivery nurses I=16 C=16	Technique: Simulation vs. Interactive Media: Live Frequency: Single Intervention group received simulation-based training; control an interactive seminar.	Performance testing performed as a labor and delivery drill showed statistically significant higher scores for the simulation-trained group. In an academic training program, didactic and simulation-trained groups showed equal results on written test scores. Simulation-trained teams had superior performance scores when tested in a labor and delivery drill.
De Lorenzo, R. and Abbott, C. 2004	RCT to determine if the adult-learning model improves student learning in terms of cognitive performance and perception of proficiency in military medic training	Army medic students 150 I=81 C=69 Country: United States	Technique: Interactive vs. Didactic Media: Live Frequency: Single Intervention group: emphasized the principles of adult learning, including small-group interactive approach, self-directed study, multimedia didactics, and intensive integrated practice of psychomotor skills. Control: traditional, lecture-based course	An adult-learning model offers only a modest improvement in cognitive evaluation scores over traditional teaching. Additionally, students in the traditional teaching model assess themselves as proficient more frequently than instructors, whereas instructor and student perception of proficiency more closely matched in the adult-learning model.

Citation	Study Design	Participants	Intervention	Key Findings
Harder, B.N. 2010	SR: 23 articles reviewed to evaluate the use of clinical simulation in health care education	Health professionals	Technique: Simulation Media: Multiple Frequency: Single	Inconclusive evidence about the use of simulation due to a low number of studies. However, the use of simulation, as opposed to other education and training methods (motor skills laboratory sessions with task trainers, computer-based programs and lecture classes), increased the students' clinic skills in the majority of the studies.
Herbert, C. et al. 2004	RCT to assess the impact of individualized feedback and interactive, live group education upon prescriptive practices	Physicians I1=48 audit and feedback only I2=47 interactive module only I3=49 interactive plus audit and feedback C=56, nothing 4,394 charts reviewed Country: Canada	Technique: Audit and Feedback vs. Interactive plus Audit and Feedback vs. Interactive Session Only vs. Nothing Media: Live Frequency: Single Intervention groups received either an educational module, chart audits and feedback, an educational module plus chart audits and feedback, or nothing.	Increase in prescribing preference for correct drug class in module and portrait group. Evidence-based educational interventions combining personalized prescribing feedback with interactive group discussion can lead to modest but meaningful changes in physician prescribing.
Issenberg, S. et al. 2005	SR: 109 studies reviewed to determine the use of high-fidelity medical simulations that lead to most effective learning	Health professionals	Technique: Simulation Media: Multiple Frequency: Both single and multiple	The weight of the best available evidence suggests that high-fidelity medical simulations facilitate learning under the right conditions. These conditions include providing feedback, repetitive practice, curriculum integration, range of difficulty, multiple learning strategies, capture clinical variation, controlled environment, individualized learning, defined outcomes, simulator validity.

Citation	Study Design	Participants	Intervention	Key Findings
Lamb, D. 2007	Literature Review: 9 articles reviewed to determine effectiveness of experiential (focused on simulations) learning	Health professionals	Technique: Simulation Media: Multiple Frequency: Both single and multiple	None of studies showed conclusively that simulated learning improves patient outcome; however, evidence suggests human patient simulators to be advantageous over other modalities. They have proven to be at least as effective as traditional teaching by didactic methods. Both human patient simulators (models) and computer-simulations may be effective.
Laprise, R. et al. 2009	Cluster-Randomized Trial of 122 general practitioners to determine if chart audits and feedback reminders after a continuing medical education (CME) event would lead to better adherence to clinical guidelines	General practitioners 122 I=61 C-61 Chart audit of 2,344 consenting patient charts Country: Canada	Technique: Audit and Feedback plus Interactive vs. Interactive Only Media: Live Frequency: Single vs. Multiple Intervention group and control group received the same CME intervention, a 2-hour interactive, live workshop. The intervention group also received a total of 6 monthly follow-up visits from a nurse that included chart screening, audits and feedback, and a print-based checklist distribution and a print summary of expert recommendations.	This study demonstrated significantly improved adherence in the intervention group using chart audits vs. CME alone. The magnitude of the difference observed between the 2 groups in absolute pre-post intervention change is consistent with previous studies on the effectiveness of chart prompting in preventive care.
Lin, C. et al. 2010	RCT to determine if peer-tutored, problem-based learning (PBL) is preferable to didactic-based instruction for teaching nursing ethics	Nursing students I=72 C=70 Country: Taiwan	Technique: Problem-Based vs. Didactic Media: Live Frequency: Single Intervention group received problem-based learning technique and control didactic-based instruction.	Peer-tutored, problem-based learning was shown to be more effective than lecture-type conventional teaching. Peer-tutored, problem-based learning has the potential to enhance the efficacy of teaching nursing ethics in situations in which there are personnel and resource constraints.
McGaghie, W. et al. 2009 (JHU EPC SR)	SR: 9 of the JHU EPC SR articles reviewed to determine the effectiveness of simulation methods in medical education outside of CME	Health professionals	Technique: Simulation Media: Multiple Frequency: Both single and multiple	Due to a low number of studies, evidence on simulation methods is inconclusive; however, the direction of evidence points to the effectiveness of simulation training, especially for psychomotor skills and communication skills. Data analysis revealed a highly significant "dose-response" relationship among practice and achievement, with more practice producing higher outcome gains.

Citation	Study Design	Participants	Intervention	Key Findings
Merien, A. et al. 2010	SR: 8 articles reviewed to determine the effectiveness of team-based training for obstetric care	Health professionals	Technique: Team-Based Media: Live Frequency: NR	Due to a low number of studies, evidence on teamwork training in simulation is inconclusive. However, introduction of multidisciplinary teamwork training with integrated, acute obstetric training interventions in a simulation setting is potentially effective in the prevention of errors, thus improving patient safety in acute obstetric emergencies.
Murad, M.H. et al. 2010	SR: 59 articles (enrolled 8,011 learners) reviewed to determine effectiveness of self-directed learning (SDL)	Health professionals	Technique: Self-Directed Media: Multiple Frequency: NR	Moderate-quality evidence suggests that SDL in health professions education is associated with moderate improvement in the knowledge domain compared with traditional teaching methods, and may be as effective in the skills and attitudes domains.
Perry, M. et al. 2011	SR: 6 articles representing 5 studies were reviewed to determine effect of educational interventions in primary dementia care	Health professionals	Technique: Multiple Media: Multiple Frequency: Both single and multiple	Interactive workshops and decision support systems led to increased detection rates. Evidence shows moderate improvements in knowledge, and techniques that required learner active participation tended to improve detection rates.
Reynolds, A. et al. 2010	RCT to compare students' knowledge using either simulation or didactic lecture	Midwifery students I=26 C=24 Country: Portugal	Technique: Simulation vs. Didactic Media: Live Frequency: Single Intervention group received simulation-based training, control a didactic lecture with print visuals.	A significantly higher short-term reinforcement of knowledge and greater learner satisfaction were obtained using simulation sessions compared to image-based lectures. The simulation group showed both significantly higher mean test scores and higher overall learner satisfaction compared to the didactic lecture group. A significantly higher short-term reinforcement of knowledge and greater learner satisfaction were obtained using simulation sessions compared to image-based lectures when teaching routine management of normal delivery and resolution of shoulder dystocia to midwives in training.
Smits, P. et al, 2003	RCT to compare effectiveness of problem-based learning (PBL) vs. didactic for management of mental health problems	Post-graduate medical training I=59 C=59 Country: Netherlands	Technique: Problem-Based vs. Didactic Media: Live Frequency: Single Intervention group received PBL technique and control didactic-based instruction.	The study found that both PBL and didactic-based instruction are effective, but no statistical difference. The problem-based program appeared to be more effective than the lecture-based program in improving performance, but received less favorable evaluations.

Citation	Study Design	Participants	Intervention	Key Findings
Steadman, R. et al. 2006	RCT to determine if simulation is better than problem-based for teaching assessment and management skills	Fourth-year medical students I=15 C=16	Technique: Simulation vs. Problem-Based Media: Live Frequency: Single Intervention group received simulation-based training, control PBL.	Simulation-based learning was superior to PBL for the acquisition of critical assessment and management skills.
Sturm, L. et al. 2008	SR: 11 articles reviewed to determine if skills acquired by simulation-based training transfer to the operative setting	Surgeons	Technique: Simulation Media: Multiple Frequency: Both single and multiple	Due to limited quality and methodology and a lack of relevant studies, a weak conclusion can be made supporting the transfer of skills developed in simulation to the operative setting. Evidence from 1 study showed better performance for participants who received simulation-based training before undergoing patient-based assessment than their counterparts who did not receive previous simulation training.
Werb, S. and Matear, D. 2004	SR: 3 systematic reviews and 9 original research articles reviewed to examine evidence-based clinical teaching and faculty continuing education	Allied health professionals	Technique: Problem-Based Media: Multiple Frequency: Both single and multiple	PBL and evidence-based health care interventions were effective in increasing student knowledge of medical topics and their ability to search, evaluate and appraise medical literature. Dental students in a PBL curriculum, emphasizing evidence-based practices, scored higher on the National Dentistry Boards, Part I, than students in traditional curricula.
White, M. et al. 2004	RCT to investigate effectiveness of PBL vs. didactic for asthma management	Physicians I=23 C=29 Country: Canada	Technique: Problem-Based vs. Didactic Media: Live Frequency: Single Intervention group received PBL technique and control didactic-based instruction.	There was no significant difference in knowledge gained or satisfaction with the facilitator between the PBL group and lecture-based group. The PBL group rated the educational value higher than the didactic group.
Young, J. and Ward, J. 2002	Randomized Trial to determine effect of self-directed (distance) learning on knowledge, attitudes, and practices related to smoking cessation	Family physicians I=26 C=27 Country: Australia	Technique: Self-directed vs. Reading Media: Print Frequency: Single Intervention group received a self-directed learning module, control group received guidelines only.	Modest changes from baseline to post-test for both the distance learning group and self-directed group suggest a lack of significant evidence to support a distance or self-directed approach to address changes in practice.

Citation	Study Design	Participants	Intervention	Key Findings
Yuan, H. et al. 2008	SR: 10 studies were reviewed to determine the evidence to support PBL	Nursing students	Technique: Problem-Based Media: Multiple Frequency: Both single and multiple	Inconclusive evidence to support PBL. While several studies showed increased reported self-confidence in ability to make decisions, and several showed increased skills in critical thinking questions from the PBL group, overall findings were inconclusive due to a lack of quality studies.
Zurovac, D. et al. 2011	Cluster RCT at 107 rural health facilities to determine if text-message reminders would improve provider adherence to national malaria treatment guidelines	Health professionals 119 health workers Case-management practices were assessed for 2,269 children who needed treatment, divided by: I=1,157 C=1,112 Country: Kenya	Technique: Reminders Media: Mobile phone Frequency: Repetitive Intervention group received repetitive text messages over a 6-month period, control group received nothing.	The use of mobile technology showed significant improvements in case management practices for pediatric malaria cases among physicians with repetitive text-message reminders compared to control group.

3.3. Frequency

Frequency refers to the exposure to instruction over time. This review included consideration of single versus repetitive exposure. The findings regarding frequency are summarized in Table 3.

- **Single** indicates an educational intervention that is provided once for a specific audience, and not repeated for that audience.
- **Repetitive** indicates that an educational intervention has been offered, and offered again at a subsequent time or times for the same audience.

Sufficient evidence exists to support repetitive interventions over single interventions.

Repetitive is preferable to single frequency for training interventions. The three articles that focused on frequency all support the use of repetitive interventions [54–56]. These well-constructed RCTs evaluated repetition using the Spaced Education platform (now called Qstream), an Internet-based media system that uses repeated questions and targeted feedback. The evidence from these three articles demonstrated that repetitive, time-spaced education exposures resulted in better knowledge outcomes, better retention and better clinical decisions. The RCT that compared a single educational intervention or bolus education to repetitive, spaced education found that residents in the spaced education cohort demonstrated significantly greater online test scores than those in the bolus cohort (analysis of variance [ANOVA] $p<0.001$). One-way ANOVA with trend analysis revealed that online test scores for the spaced education cohort remained stable with no significant differences with time, while test scores in the bolus cohort demonstrated a significant linear decrease ($p<0.01$) [56]. The findings were reinforced in a subsequent trial in 2009, with comparison of one exposure versus three exposures. This study found a mean increase in scores from 44.9% in cycle 1 to 75.7% in cycle 3, a 57% relative increase compared with controls ($p<0.001$; Cohen effect size, 2.2). Similarly, cohort B scores increased from 45.2% in cycle 1 to 69.5% in cycle 3, a 56% relative increase compared with controls ($p<0.001$; effect size, 2.2) [55]. The same authors found a positive effect on diagnostic skills with the use of spaced education [54]. Residents' performance over time and preference of online learning formats (bolus vs. spaced) were also evaluated. This RCT found spaced education and web-based training (bolus) generated mean long-term score increases of 15.2% (SD 15.3%) and 3.4% (SD 16.3%), respectively ($p<0.01$). Spaced education increased long-term learning efficiency 4-fold [54]. This study looked at exam results at weeks 18 and 45 of the intervention, demonstrating the value of spaced, repetitive interventions. Distributed spacing of content through online, spaced education substantially improves histopathology diagnostic skills compared with bolus web-based modules that delivered the same content.

The use of multiple exposures was also highlighted in other systematic reviews of the literature [11], [37], [3], [53] (Table 6), as well as the RCT that used repeated reminders and demonstrated an improvement in the intention to treat [39] (Table 2).

Table 3: Summary of Articles Focused on Frequency

LEGEND: C=Cohort, CPGs=Clinical practice guidelines, HP=Hematuria and priapism, IC=Intervention cohort, ISE=Interactive Spaced Education, RCT=Randomized Controlled Trial, SIA=Staghorn calculi, infertility, and antibiotic use, WBT=web-based teaching

Citation	Study Design	Participants	Intervention	Key Findings
Kerfoot, B.P. et al. 2007	Randomized Controlled Trial (RCT) to determine if spacing principles can improve acquisition and retention of medical knowledge	5 Cohorts with 76–80 people in each cohort urology residents 537 participants: 400 (74%) completed the online staggered tests and 515 (96%) completed the In-Service Examination Cohort 1 (C1)=bolus, single intervention Cohort 2 (C2)=multiple, spaced intervention	Frequency: Multiple vs. Single Technique: Self-directed Media: Internet-based C1 received bolus education—96 study questions (June 2005), C2 daily emails over 27 weeks (June–December 2005), each with 1–2 questions in spaced pattern. In November, all completed the urology exam. Participants randomized to 5 cohorts and completed a 32-item online test at staggered time points (1–14 weeks) after completion of SpacedEd.	Conclusive evidence to support repetitive, spaced education in online learning because residents in the spaced education cohort demonstrated significantly greater online test scores than those in the bolus cohort. The scores for the spaced cohort remained stable with no significant differences over time, while test scores in the bolus cohort demonstrated a significant linear decrease.
Kerfoot, B.P. et al. 2009	RCT to determine if SpacedEd is an effective form of continuing medical education	Urologists and urology residents Cohort A=80 urologists, 160 residents, completed by 196 Cohort B=80 urologists, 160 residents, completed by 182 Completed by 71% of urologists and by 83% of residents Country: USA (March–July 2007)	Frequency: Multiple vs. Single Technique: Self-Directed Media: Internet-based One-hundred-sixty urologists and 320 urology residents were randomized to 1 of 2 cohorts. Participants were stratified by training level (urologist in practice vs. resident) and urology training year (residents only) and were block randomized (block size=8) to 1 of 2 cohorts. Participants in cohort A received the 3-cycle Interactive Spaced Education (ISE) course on the hematuria and priapism (HP) clinical practice guidelines (CPGs), with 24 control items on the staghorn calculi, infertility, and antibiotic use (SIA) CPGs in cycle 3. Participants in cohort B received the 3-cycle ISE course on SIA CPGs, with 24 control items on HP CPGs in cycle 3. The trial was structured in this manner to allow the topic-specific learning gains from the ISE courses to be identified in cycle 3.	Conclusive evidence to support the use of interactive spaced education programs. Knowledge scores of ISE intervention were statistically significantly higher than those of the control bolus method.

Citation	Study Design	Participants	Intervention	Key Findings
			Since the 24 items were presented simultaneously to both cohorts in cycle 3, the learning gains of physicians who had completed 2 cycles of the ISE program could be directly compared with those of physicians who were presented with the material for the first time (controls).	
Kerfoot , B.P. et al. 2010	RCT to determine if SpacedEd can address knowledge transfer and the ability to make diagnostic decisions Transfer and retention of diagnostic skills between SpacedEd vs. bolus, web-based teaching (WBT)	Urology residents, (June 2007–June 2008) Cohort 1=164 Cohort 2=194 completed Country: USA	Frequency: Multiple vs. Single Technique: Self-directed Media: Internet-based All residents were sent both spaced education and WBT, but the set of topics delivered by each method varied by intervention cohort (IC). Residents in IC-1 received 3 cycles of spaced education on prostate-testis (weeks 1 to 4, 5 to 8, and 13 to 16) and 3 WBT modules on bladder-kidney (weeks 14 to 16). Residents in IC-2 received 3 cycles of spaced education on bladder-kidney (weeks 1 to 4, 5 to 8, and 13 to 16) and 3 WBT modules on prostate-testis (weeks 14 to 16). The spaced education items were delivered each weekday through emails containing 1 question/answer, and the spaced education material was distributed in 3 cycles or repetitions to take advantage of the spacing effect. The WBT used the identical content and delivery system, with the questions aggregated into three 20-question modules delivered through separate emails in week 14. The trial was specifically structured to ensure that, within a given set of topics (bladder-kidney or prostate-testis), the only difference between intervention cohorts was the spacing of content.	Conclusive evidence to support spaced, web-based education as compared to web-based teaching. Spaced education demonstrated a statistically significant increase in knowledge and long-term retention of knowledge compared with bolus web-based modules that delivered the same content of histopathology diagnostic skills.

3.4. Setting

Setting is the physical location within which the instruction occurs. Facility- or practice-based versus workshop or external location is of particular interest in this review.

We identified three articles that looked specifically at setting for training. Two of them [31, 32] stemmed from the same intervention. Crofts et al. specifically addressed the impact of setting and technique (team-based training) on knowledge, and found no significant difference in the post-score (two-way analysis of variance p=0.785). Similarly, the inclusion of team-based training did not increase knowledge score (p=0.965) [31]. The same RCT also looked at skills performance in simulation and demonstrated that all the cohorts were able to perform more efficiently after the intervention [32]. A systematic review of eight articles evaluating the effectiveness of team-based training for obstetric care did not find significant differences in learning outcomes between a simulation center or a clinical setting [30] (Table 2).

However, the Coomarasamy and Khan systematic review of stand-alone versus clinically integrated teaching for evidence-based medicine suggests that clinically integrated teaching is more effective when teaching clinical decision-making and attitudes [57]. This was supported by the Hamilton systematic review of CPE, which suggests that teaching in a clinical setting or simulation setting is more effective [53] (See Table 6, as well as the Raza et al. systematic review of 23 studies to evaluate stand-alone versus clinically integrated teaching.) This review suggested that clinically integrated teaching improved skills, attitudes and behavior, not just knowledge [19].

Table 4: Summary of Articles Focused on Setting

LEGEND: I=Intervention, MCQ=Multiple-Choice Questionnaire, RCT=Randomized Controlled Trial, SR=Systematic Review

Citation	Study Design	Participants	Intervention	Key Findings
Coomarasamy, A. and Khan, K. 2004 (link to Raza work as a follow-up)	Systematic Review (SR): 23 articles reviewed to determine the effects of stand-alone compared to clinically integrated teaching in evidence-based medicine	Post-graduate physicians, allied health professionals	Technique: Multiple, Focus on Case-Based Media: Live Frequency: Both single and multiple	Sufficient evidence to support the use of clinically integrated teaching over stand-alone education. While stand-alone teaching improved knowledge, there were no improvements in skills, attitudes or behaviors, whereas clinically integrated teaching showed improvements in knowledge, skills, attitudes and behavior.
Crofts, J. et al. 2007	Prospective Randomized Controlled Trial (RCT) to explore if knowledge acquisition is influenced by the training setting or a teamwork training approach Total 140, interdisciplinary teams of 4/6 in 4 blocks	Senior doctors, junior and senior midwives Intervention 1 [I1]=1-day interactive at hospital (no team-based training) I2=1-day interactive at simulation center (no team-based training) I3=2-day team training at hospital I4=2-day interactive in simulation center Country: UK	Technique: Team-Based vs. Interactive Media: Live Frequency: Single (1) 1-day course at local hospital, (2) 1-day course at simulation center, (3) 2-day course with teamwork training at local hospital, and (4) 2-day course with teamwork training at simulation center. Main outcome measure: 185 Multiple Choice Questionnaire (MCQ) 3 weeks pre and 3 weeks post.	Statistical evidence to support the use of live, multi-professional, obstetric emergency training to increase midwives' and doctors' knowledge of obstetric emergency management. However, neither the location of training either in a simulation center or in local hospitals, nor the inclusion of teamwork training, made any significant difference in the acquisition of knowledge in obstetric emergencies.
Ellis, D. et al. 2008 (same intervention as Crofts study from 2007)	Same as previous	Same as previous	Same as previous	Statistical evidence to support the use of live, eclampsia training to increase providers' performance rate for completion of basic tasks. Neither the location (simulation center or in local hospitals), nor the inclusion of teamwork training made any significant difference in the performance results for basic task completion.

3.5. Media

Media refers to the means used to deliver the curriculum. The articles or studies that specifically addressed educational techniques are summarized in List 3.

List 3: Method Definition

Any CME activity that is**:**

Live: Conducted in person

Computer-based, offline: Conducted on the computer, but is not conveyed through the Internet (e.g., CD-ROM)

Internet, real time (e.g., streaming): Conducted in real time via the Internet

Internet, not real time: Conducted via the Internet, but is not conducted in real time

Video: Uses video to convey its message

Audio: Uses an audiotape to convey its message

Handheld: Handheld materials (e.g., laminated card)

Print: Conducted via educational printed materials or readings

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The majority of RCTs compared self-paced or individual instruction delivered via computer versus live, group-based instruction [42], [41], [43], [44], [45], [46]. One RCT [47] and two systematic reviews specifically targeted computer-based instruction [58], [48], and one systematic review addressed live instruction [59]. One RCT compared video, didactic instruction to interactive computer-based instruction [60]. Two articles looked at print as a media, one systematic review [34] and one RCT [35] compared print to live instruction. Three studies evaluated the use of mobile devices for delivery of feedback [26], providing video-mentoring [61] and compared mobile to print instruction [25]. Triola and Turner compared the use of a live standardized patient to use of a computer-based, virtual patient for educational simulations [4], [62].

Live vs. Computer-Based

Live instruction was found to be somewhat effective in improving knowledge [42], [41], [43], [44], [45], [46], but less so in changing clinical practice behaviors [59]. When comparing live to computer-based instruction, a frequent finding was that computer-based instruction led to knowledge performance on post-tests that was either equal to or slightly better than live instruction [42], [41], [43], [44], [45], [46]. One of the few to identify a difference in outcomes, Harrington and Walker found the computer-based group outperformed the instructor-led group on the knowledge post-test ($F(1)=4.596$, $p<0.05$). Differences between groups for post-test to follow-up gain scores were significant for the knowledge subtest ($F(1)=5.606$, $p<0.05$), and participants in the computer-based group, on average, spent less time completing the training than participants in the instructor-led group [45]. One RCT that compared interactive, computer-based instruction to a video of a lecture,

found an improvement in post-test scores after adjusting for the length of experience in neurological nursing for the computer-based group ($F=4.81$, $p<0.05$). There was a positive correlation between assessment correctness on the second post-test and length of experience in neurological nursing ($r=0.35$, $p<0.05$) [60].

Systematic reviews indicate that the evidence supports the use of computer-delivered instruction for knowledge and attitudes, but insufficient evidence exists to support its use to change practice behaviors [58], [48]. The Raza Cochrane systematic review identified 16 randomized trials that evaluated the effectiveness of Internet-based education among practicing health care professionals. Six studies showed a positive change in participants' knowledge and three showed a change in practice in comparison to traditional formats [19]. Several other articles noted the importance of interactivity to achieving an impact on clinical practice behaviors [38], [10] (Table 6), and [58] (Table 5).

A significant number of articles reinforced the use of computers to deliver instruction, several citing possibilities to increase efficiency and reduce costs.

Two RCTs indicated that the use of a computer-based virtual patient was equally effective as a live, standardized patient, and both reported the potential for cost efficiencies [4], [62].

Mobile

One article assessed the use of animations against audio instructions in cardiopulmonary resuscitation (CPR) using a mobile phone, and found the group that had audiovisual animations performed better than the group that received live instruction over the phone in performing CPR [61]. It is notable that neither group was able to perform the psychomotor skill measures correctly, possibly due to the lack of simulation training [61]. One prospective randomized study found the group that used mobile phones to video identifying the correct landmark for needle thoracocentesis and received simultaneous feedback performed better (success, $p<0.05$, time to success, $p<0.05$) than the control group. Both had received a live lecture and demonstration before performing the procedure [26]. Leung found that providing point-of-care decision support via a mobile device resulted in slightly better self-reporting on outcome measures compared to print-based job aids, but that both the print and mobile groups showed improvements in use of evidence-based decision-making [25].

Print

The Farmer systematic review of print-based materials did not find sufficient evidence to support the use of print media to change clinical practice behaviors [34]. Comparing the use of print-based guidelines to a live interactive workshop found that those who completed live instruction were slightly better able to identify patients at high risk of an asthma attack ($p=0.05$), but neither intervention resulted in changed practice behaviors related to treatment plans [35]. A separate analysis of pediatric and adolescent patients cared for by the same providers found that adolescents reported improved quality of life, but that overall the intervention did not result in improved asthma control or quality of life [63]. Multiple systematic

reviews caution against the use of print media [38], [10], [36] (Table 6), concluding that live instruction is preferable to print only [3], [23] (Table 6). Another consistent theme was support for the use of multiple media in CPE interventions [37], [64], [3], [21], [65], [36], [11], [19].

Table 5: Summary of Articles Focused on Media Used to Deliver Instruction

LEGEND: C=Control, CME=Continuing medical education, CPR=Cardiopulmonary resuscitation, EBM=Evidence-based medicine, GP=General practitioner, I=Intervention, NR=Not reported, PDA=Personal digital assistant, RCT=Randomized Controlled Trial, SR=Systematic Review

Citation	Study Design	Participants	Intervention	Key Findings
Augestad, K. and Lindsetmo, R. 2009	Systematic Review (SR): 51 articles reviewed to determine usefulness of videoconferencing as a clinical and educational tool	Surgeons, Norway and developed countries	Media: Video Technique: Multiple Frequency: Not reported (NR)	Review discussed primarily observational data on the use of videoconferencing for provision of lecture, mentoring and point-of-care support for emergencies or trauma settings. Methodology of studies is weak, but shows promise for providing point of care and mentoring to rural settings from specialists in other geographic areas.
Bloomfield, J. et al. 2010	Randomized Controlled Trial (RCT) to test if the theory and skill of handwashing can be taught more effectively when taught using computer-assisted learning compared with conventional face-to-face	Nursing students 245 recruited, 231 randomized I=118 C=113 Country: UK	Media: Computer-Based vs. Live Techniques: Multiple Frequency: Single Intervention group received theory via computer-based module and control via instructor-led. The objectives and content were the same; both included practice opportunities.	The computer-assisted learning module was an effective strategy for teaching both theory and practice of handwashing to nursing students and was found to be at least as effective as conventional, face-to-face teaching methods. However, this finding must be interpreted with caution in light of sample size and attrition rates.
Bradley, P. et al. 2005	Prospective RCT and Qualitative Evaluation to compare self-directed, computer-based learning to traditional, live interactive education techniques	Medical students I=85 C=90	Media: Computer-Based vs. Live Technique: Self-Directed vs. Interactive Frequency: Single Intervention group received self-directed, computer-based modules on evidence-based medicine; control group received live, interactive sessions.	There were no differences in outcomes for the computer-based group compared to the live interactive group in knowledge acquisition, critical appraisal skills or attitudes toward evidence-based medicine (EBM). This trial and its accompanying qualitative evaluation suggest that self-directed, computer-assisted learning may be an alternative format for teaching EBM.

Citation	Study Design	Participants	Intervention	Key Findings
Choa, et al. 2008	Single blind, Cluster Randomized Trial to determine—in a person who does not know cardiopulmonary resuscitation (CPR)—whether audiovisual animated instruction will be more effective than audio, dispatcher-assisted instruction: both via mobile phones	Allied health professionals, hospital employees I=44 C=41 Country: Korea	Media: Mobile: Audiovisual Animation vs. Audio Instructions from Live Dispatcher Technique: Point of Care Frequency: Single Intervention group used mobile phone application with audiovisual animation instructions for CPR; control group received audio guidance from a live dispatcher	Audiovisual animated CPR instruction through cellular phone resulted in better scores in checklist assessment and time interval compliance in participants without CPR skill compared to those who received CPR instructions from a dispatcher. However, the accuracy of important psychomotor skill measures was unsatisfactory in both groups.
Chui, S. et al. 2009	Experimental Research Design with 2 groups, 1 pre-test and 2 post-tests to determine the effectiveness of computer-based interactive instruction vs. video didactic instruction	Nurses I=44 C=40 Country: Taiwan	Media: Computer-Based vs. Video Technique: Self-directed: Interactive vs. Didactic Frequency: Single Intervention group received computer-based, interactive educational module; control group watched a video of a lecture	Interactive, computer-assisted instruction increased student assessment correctness as compared to video didactic instruction for in-service neurological nursing education after statistical adjustments for length of experience.
Curran, V. and Fleet, L. 2005	SR: evaluate the nature and characteristics of the web-based continuing medical education (CME), based on Kirkpatrick levels of evaluation; 86 studies were identified, majority were descriptive	Physicians	Media: Internet Technique: Multiple Frequency: Both single and multiple	Inconclusive evidence to identify the most effective characteristics of web-based CME program due to a lack of studies focusing on performance change. Findings suggest web-based is effective in enhancing knowledge and attitudes. Several studies suggest interactive CME that requires participant activity and the chance to practice skills can effect changes in practice behaviors.
Farmer, A. et al. 2008	SR: 23 studies reviewed to determine the usefulness of print-based materials in practice behaviors or clinical practice outcomes	Health care professionals	Media: Print Technique: Didactic Frequency: Single	Insufficient information to support the effectiveness of print-based education material compared to other interventions. Print materials may have a beneficial effect on process outcomes compared to no intervention, but not on clinical practice outcomes.

Citation	Study Design	Participants	Intervention	Key Findings
Fordis, M. et al. 2005	RCT to see if Internet-based CME can produce changes comparable to those produced via live, small-group, interactive CME with respect to physician knowledge and behaviors that have an impact on patient care	Physicians 97 I=44 randomly assigned Internet-based over 2 weeks C=49 single (live, interactive session) and C=18 from same sites received nothing Country: United States	Media: Internet-Based vs. Live, Interactive Technique: Self-directed vs. Interactive Frequency: Single Intervention: intervention group received Internet-based modules over 2 weeks; control group received a live, interactive session and other control received nothing	Internet-based CME can produce objectively measured changes in behavior as well as sustained gains in knowledge that are comparable or superior to those realized from an effective, live group-based activity. The Internet-based intervention was associated with a significant increase in the percentage of high-risk patients treated with pharmacotherapeutics according to guidelines as compared to the live group-based control group.
Hadley, J. et al. 2010	Cluster RCT to evaluate the educational effectiveness of a clinically integrated e-learning course for teaching basic EBM among postgraduate medical trainees compared to a traditional lecture-based course of equivalent content	Post-graduate medical trainees, interns 7 clusters of 237, completed by: I=88 C=72 Country: UK	Media: Internet vs. Live Techniques: Multiple Frequency: Single Intervention group received clinical, integrated e-learning course on evidence-based medicine, vs. the control group, which received live, didactic-based course	An e-learning course in EBM was as effective in improving knowledge as a standard lecture-based course. There was no statistically significant difference in knowledge of participants in the e-learning course compared to the lecture-based course. The benefits of an e-learning approach include standardization of teaching materials, and it is a potential cost-effective alternative to standard, lecture-based teaching.
Harrington, S. and Walker, B. 2004	RCT to determine effectiveness of computer-based training compared with the traditional, instructor-led format	1,294 nurses I: 670 C: 624 Country: United States	Media: Computer-Based vs. Live Technique: Didactic vs. Self-directed Frequency: Single Intervention group provided with self-directed, computer-based instruction. Control group with instructor-led, live instruction. Same objectives and content.	The computer-based group significantly outperformed the instructor-led group on the knowledge subtest at post-test (gain of 28% vs. 26%). Participants reported satisfaction with computer-based learning and researchers noted potential for efficiencies and cost reduction.
Horiuchi, S. et al. 2009	RCT to compare web-based to live instruction	Nurses or midwives 93 C=45, web-based I=48, live Country: Japan	Media: Internet vs. Live Techniques: Multiple Frequency: Single Intervention group received web-based instruction, control group, didactic live instruction.	No significant differences in knowledge were observed between the web-based and face-to-face group. However, the web-based program was rated as more flexible and affordable and had a lower drop-out rate than the face-to-face program.

Citation	Study Design	Participants	Intervention	Key Findings
Kemper, K. et al. 2006	National Randomized 2 x 2 Factorial Trial: a) delivering four (4) modules weekly over ten (10) weeks by email (drip-push); b) modules accessible on website with 4 reminders weekly for 10 weeks (drip-pull); c) 40 modules delivered within 4 days by email (bolus-push); and d) 40 modules available on the Internet with 1 email informing participants of availability (bolus-pull)	Health professionals 1,267, completion rate 62%, Group a: 318 Group b: 318 Group c: 318 Group d: 313 Country: United States	Media: Internet – 4 different delivery modes Technique: Self-directed Frequency: Single	There were statistically significant improvements in knowledge, confidence and communication scores after the course for each of the Internet–based delivery methods, with no significant differences in any of the 3 outcomes by delivery strategy. Outcomes were better for those who paid for continuing education credit.
Leung, G. et al. 2003	RCT to compare the effectiveness of mobile, point-of-care support vs. print-based job aids	Fourth-year medical students 169 fourth year medical students (1 lost to follow-up: I=54 C/Pocket Card=59 C/Nothing=55 Country: China	Media: Mobile vs. Print Technique: Point of care Frequency: Single Intervention group given personal digital assistant (PDA) devices with clinical decision support tools compared with a control group given a pocket card containing guidelines and a control group with no intervention.	Both the inforetriever and pocket-card groups showed improvements in scores for personal application and current use of EBM. The inforetriever group showed slightly higher scores in all 5 outcomes, whereas those for the pocket-card group were not appreciably different from the previous rotation.
Liaw, S. et al. 2008	Cluster Randomized Trial to determine the effectiveness of locally adapted practice guidelines and education about pediatric asthma management, delivered to general practitioners (GPs) in small group interactive workshops	GPs from 29 practices randomly assigned I=18 live, interactive plus guidelines C/guidelines only=18 C/nothing=15 Country: Australia	Media: Live vs. Print Only Technique: Interactive vs. Reading Frequency: Single Intervention group received interactive, live session plus guidelines; control groups received guidelines only and no intervention.	Using interactive small group workshops to disseminate locally adapted guidelines was associated with improvement in general practitioners' knowledge and confidence to manage asthma compared to receiving guidelines alone in the control arm, but did not change their self-reported provision of written action plans.
Rabol, L. et al. 2010	SR: 18 studies reviewed to determine outcomes of live, classroom-based multiprofessional team training	Health professionals	Media: Live Technique: Multiple Frequency: Single	Although most studies had weak design methods, findings from the 18 studies conclude that team-based training led to positive participant evaluation, knowledge gain and behavior change. However, the impact on clinical outcomes is limited.
Sulaiman, N. et al. 2010 (links also to Liaw 2008 article)	Same as previous, but used surveys to determine any impact on patient outcomes	411 patient surveys at baseline, 341 at follow-up Country: Australia	See Liaw, S.	The interactive small group workshops failed to translate into increased ownership of written action plans, improved control of asthma, or improved quality of life compared to receiving guidelines alone or control intervention.

Citation	Study Design	Participants	Intervention	Key Findings
Triola, M. et al. 2006	RCT to compare effectiveness of virtual patients to live, standardized patients for improving clinical skills and knowledge	Health professionals I=23 C=32 Country: USA	Media: Virtual Patient vs. Live Patient Technique: Case-based Frequency: Single Intervention group received 2 live, standardized patient cases, and 2 virtual patient cases. Control group received 4 standardized patient cases.	Improvements in diagnostic abilities were equivalent in groups who experienced cases either live or virtually. There was no subjective difference perceived by learners. Using virtual cases has the potential for cost efficiencies.
Turner, M. et al. 2006	Randomized Controlled Cross-Over Trial to compare efficacy, student preference and cost of web-based, virtual patient vs. live, standardized patient	Second-year medical students I=25 C=24 Country: USA	Media: Virtual Patient vs. Live Patient Technique: Case-based Frequency: Single Intervention group received web-based instruction for one topic, then standardized patient for another topic. This was reversed for the second cohort, or control group, standardized patient first followed by web-based instruction.	There was no statistical difference in learning outcomes between the web-based and standard patient; however, students preferred the standard patient format. Start-up costs were comparable, but the ongoing costs of the web-based format were less expensive, suggesting that web-based teaching may be a viable strategy.
Wutoh, R. et al. 2004	SR: 16 articles reviewed to determine the effect of Internet-based CME interventions on physician performance and health care outcomes	Physicians	Media: Internet Technique: Multiple Frequency: Both single and multiple	Results demonstrate that Internet-based CME programs are just as effective in imparting knowledge as traditional formats of CME. However, there is a lack of quality studies to conclude significant positive changes in practice behavior and additional studies are needed.
You, J. et al. 2009	Prospective Randomized Study to investigate usefulness of using video via mobile device as an instruction tool	Medical students I=24 C=25	Media: Mobile Videoconferencing/Feedback Technique: Interactive, live with and without mobile point-of-care feedback using video. Frequency: Single Intervention: Both groups had didactic session; intervention groups performed a thoracocentesis on a manikin while using video on a mobile phone and receiving feedback from a live instructor. Control group did not receive any video-aided guidance.	The overall success rate for performing needle thoracocentesis was significantly higher in the mobile video telephony intervention compared to the control group without aided instruction. Participants also rated the mobile telephony intervention with significantly higher scores for instrument difficulty and procedure satisfaction.

3.6. Outcomes

Outcomes are consequences that occur as a result of an intervention. This literature review focuses on changes in cognitive knowledge or attitudes and changes in psychomotor, clinical decision-making or communication skills, as well as effects on practice behaviors and clinical outcomes. All of the articles that focused on outcomes were systematic reviews of the literature. These systematic reviews conclude the following regarding specific outcomes.

Despite reportedly weak evidence, CPE can effectively address **knowledge** outcomes [12], [37], [3], [21], [36], [66], [15], [19], [67]. Computer-based instruction is found to be equally effective as or more effective than live instruction for addressing knowledge [42], [41], [43], [44], [45], [46], and multiple, repetitive exposure leads to better knowledge gains than a single exposure [55], [56]. Games can contribute to knowledge if designed as active learning experiences that stimulate higher thinking through analysis, synthesis or evaluation [16].

No studies or systematic reviews looked only at **attitudes**, but CPE that includes clinical integration, simulations and feedback may help address attitudes [12]. The JHU EPC group systematic review evaluation of the short- and long-term effects of CPE on physician attitudes reviewed 26 studies, and despite the heterogeneity of the studies, identified trends supporting the use of multimedia and multiple exposures for addressing attitudes [3].

Several systematic reviews looked specifically at **skills**, concluding that there is weak but sufficient evidence to suggest that **psychomotor** skills can be addressed with CPE interventions that include simulations, practice with feedback and/or clinical integration [38], [53], [3], [50], [52], [49], [15]. The Sturm systematic review to determine if simulation was appropriate for operating room skill performance summarized that "it seems that simulation-based training does result in skills transfer to the operative setting. Simulation-based training therefore provides a safe, effective, and ethical way for trainees to acquire surgical skills before entering the operating room [51]." In addition, several RCTs found improved skill performance through the use of simulation [13], [14], [31], [32], [49]. "Dose-response," or providing sufficient practice and feedback was identified as important for skill-related outcomes [50], [36], [66]. Other RCTs suggest clinically integrated education [57] (Table 4) and the use of video-delivered mentoring and feedback during a procedure [26], (Table 5) for supporting skill development. Of note, the Choa intervention found that neither the audio mentoring via mobile or animated graphics via mobile resulted in the desired psychomotor skills, reinforcing the need for practice and feedback for psychomotor skill development identified in other articles [61] (Table 5).

Two systematic reviews focused on **communication skills** and found that techniques that include behavior modeling, practice and feedback, and longer duration or more practice opportunities were more effective than others [68].

Evidence suggests communication skill development requires interactive techniques, which include practice-oriented strategies and feedback, and limit lecture and print-based materials to supportive strategies only [38].

Critical thinking skills were not the only focus of any of the articles, but findings suggest that simulation, problem-based learning, multiple exposures, and clinically integrated CPE can improve critical thinking skills [54], [57], [14], [19]. The Issenberg systematic review of simulation did suggest simulation as an effective technique for the development of critical thinking skills [52]. Mobile-based point-of-care support was found to be more useful in development of critical thinking than print-based job aids [25].

Several systematic reviews specifically looked at CPE and **practice behaviors, and the behaviors of the provider,** and found despite reportedly weak evidence, interactive techniques that involved feedback, interaction with the educator, longer durations, multiple exposures, multiple media, multiple techniques and reminders may influence practice behaviors [12], [10], [64], [23], [69].

Clinical practice outcomes [21], A targeted review of 37 articles from the JHU EPC review drew no firm conclusions, but multiple exposures, multiple media and multiple techniques were recommended to improve potential outcomes [65], also supported by additional articles [3], [21], [36] and [10]. Interaction and feedback were found to be more useful than print or educational meetings (systematic review of nine articles) [23], and print-based, unsolicited materials were not found to be effective [34]. The Forsetlund systematic review of educational meetings suggests that CPE via interactive (not didactic) meetings can have a small impact on clinical practice behaviors and practice outcomes, but not on changing complex behaviors [20]. The Rabol systematic review of live, classroom-based, multi-professional training found "the impact on clinical outcomes is limited [59]."

Several RCTs looked specifically at provider practice behaviors and/or clinical practice outcomes. One trial found no impact from live, interactive or didactic sessions, and print-based materials [63]. There was inconclusive evidence to support paper-based, self-directed learning [33], while one study found an increase in correct treatment according to guidelines in a small intervention group that received computer-based instruction compared to the group that received live instruction [43]. One study in Kenya found a significant improvement in adherence to treatment protocols when repetitive text reminders were delivered via mobile device [39]. Two studies suggest that the use of follow-up chart audits and feedback result in significantly improved adherence to protocols [18], [17].

Table 6: Summary of Articles Focused on Outcomes—Knowledge, Attitudes, Types of Skills, Practice Behavior, Clinical Practice Outcomes

LEGEND: CME=Continuing medical education, JHU EPC= Johns Hopkins University Evidence-Based Practice Center, SR=Systematic Review

Citation	Study Design	Participants	Intervention	Key Findings
Alvarez, M. and Agra, Y. 2006	Systematic Review (SR): 18 articles reviewed to determine educational interventions in palliative care and their impact on practice behaviors	Physicians and other allied health professionals	Practice Behaviors Technique: Multiple Media: Live Frequency: Both single and multiple	Due to a lack of quality studies, there are insufficient data to draw strong conclusions about the impact of palliative care interventions on primary care physician practice performance. Although improvements in knowledge, some attitudes and provider satisfaction were demonstrated, there were no significant effects reported on practice behaviors. Didactic education alone was found to be ineffective. Interventions involving multiple techniques, reminders and feedback were found to be more effective at changing behaviors.
Berkhof, M. et al. 2010	SR: 12 systematic reviews reviewed to determine effective educational techniques to teach communication to physicians	Physicians	Communication Skills Technique: Multiple Media: Multiple Frequency: Both single and multiple	Sufficient evidence from 12 systematic reviews to recommend training programs last at least 1 day, are learner-centered, and focus on practicing skills. The best training strategies within the programs included role play, feedback and small group discussions. Training programs should include active, practice-oriented strategies. Oral presentations on communication skills, modeling and written information should only be used as supportive strategies.
Bloom, B. 2005	SR: 26 articles (all systemic reviews or meta-analyses) reviewed to examine effectiveness of current continuing medical education (CME) tools and techniques in changing physician clinical practices and improving patient health outcomes	Physicians	Practice Behaviors and Clinical Practice Outcomes Technique: Multiple Media: Multiple Frequency: Both single and multiple	Sufficient evidence to conclude that interactive techniques (audit/feedback, academic detailing/outreach, reminders) are the most effective CME methods at impacting practice outcomes and behaviors while clinical guidelines and opinion leaders are less effective. Didactic presentations and distributing printed information has little to no effect on physician practice.
Bordage, G. et al. 2009 Johns Hopkins University Evidence-Based Practice Center (JHU EPC) SR	SR: 28 articles reviewed to determine if CME leads to an increase in physician knowledge	Physicians and health professionals	Knowledge Technique: Multiple Media: Multiple Frequency: Both single and multiple	Despite low quality of evidence presented in the literature, there is sufficient evidence to confirm an increase in physician knowledge with the use of multimedia, multiple instructional techniques and multiple exposures in CME.

Citation	Study Design	Participants	Intervention	Key Findings
Davis, D. and Galbraith, R. 2009 (JHU EPC SR)	SR: 105 studies reviewed to determine impact of CME on practice behaviors	Health professionals	Practice Behaviors Technique: Multiple Media: Live Frequency: Both single and multiple	Sufficient evidence to support the use of single live or multiple media and multiple educational techniques as effective CME methods in changing physician performance. Recommend multiple exposures over single exposures.
Forsetlund, L. et al. 2009	SR: 81 articles were reviewed to determine the effects of educational meetings on practice behaviors and clinical practice outcomes	More than 11,000 health professionals	Practice Behaviors and Clinical Practice Outcomes Technique: Multiple Media: Live Frequency: Single	Sufficient evidence to conclude that educational meetings alone or combined with other interventions can have a small improvement on professional practice and health care outcomes, but no effect on changing complex behaviors. Previous reviews found that interactive workshops resulted in moderate improvements, whereas didactic sessions did not.
Gysels, M. et al. 2005	SR: 16 articles were reviewed to evaluate effective educational techniques for teaching communication skills	Health professionals	Communication Skills Technique: Multiple Media: Multiple Frequency: Both single and multiple	Sufficient evidence to recommend communication training programs that are learner-centered, carried out over a long period of time, and combine didactic theoretical components with practical rehearsal and constructive feedback.
Hamilton, R. 2005	SR: 24 articles were reviewed to determine how to enhance retention of knowledge and skills during and after resuscitation training	Health professionals	Knowledge, Skills Technique: Multiple Media: Multiple Frequency: Both single and multiple	Sufficient evidence to recommend in-hospital simulation to teach resuscitation training for nurses in clinical areas in addition to remedial training and the availability of resuscitation equipment for self-study. Video self-instruction has been shown to improve competence in resuscitation.
Marinopoulos, S. et al. 2007 (JHU EPC SR)	SR: from 68,000 citations, 136 studies and 9 systematic reviews were identified and reviewed	Health professionals and allied health professionals	Knowledge, Skills, Practice Behaviors and Clinical Practice Outcomes Technique: Multiple Media: Live Frequency: Both single and multiple	Firm conclusions are not possible due to the overall low quality of the literature. Despite this, the literature overall supported the concept that CME was effective in the acquisition and retention of knowledge, attitudes, skills, behaviors and clinical outcomes. Common themes included that live media was more effective than print, multimedia was more effective than single media interventions, multiple exposures were more effective than a single exposure, and that simulation methods are effective in the dissemination of psychomotor and procedural skills.
Mansouri, M. and Lockyer, J. 2007	Meta-Analysis: 31 studies were reviewed to determine the impact of CME on knowledge, skills and clinical practice outcomes	Mostly physicians	Knowledge, Skills, Practice Behaviors and Clinical Practice Outcomes Technique: Multiple Media: Live Frequency: Both single and multiple	Sufficient information to conclude that the impact of CME on physician performance and patient outcome is small but has a medium effect on knowledge and a larger effect when the interventions are interactive, use multiple methods and are designed for a small group of physicians from a single discipline.

Citation	Study Design	Participants	Intervention	Key Findings
Mazmanian, P. et al. 2009 (JHU EPC SR)	SR: 37 articles reviewed to look at impact of CME on clinical practice outcomes	Physicians, nurse-practitioners, nurses, allied health professionals	Clinical Practice Outcomes Technique: Multiple Media: Multiple Frequency: Both single and multiple	Due to low quality of evidence, there is no firm conclusion on the impact of CME on clinical practice outcomes; however, multiple media, multiple techniques of instruction and multiple exposures to content are suggested to meet instructional objectives intended to improve clinical outcomes.
Moores, L. et al. 2009 (JHU EPC SR)	SR: 136 articles and 9 systematic reviews were reviewed to evaluate what makes CME effective	Health professionals	General Technique: Multiple Media: Multiple Frequency: Both single and multiple	Significant evidence to support the use of CME interventions that use multimedia in instruction, multiple instruction techniques, and frequency of exposure to have a positive effect on knowledge, psychomotor skills, practice performance and clinical outcomes. The use of print media alone is not recommended.
Nestel D., et al. 2011	SR: 81 articles retrieved to summarize the best evidence related to use of simulation for learning	Health professionals	Psychomotor Skills Technique: Multiple Media: Multiple Frequency: Both single and multiple	Sufficient evidence is available to conclude that use of simulation leads to improved knowledge and skill. Studies with low-quality evidence suggest a transfer of skills to the clinical setting. Instructional design and educational theory, contextualization, transferability, accessibility and scalability must all be considered in simulation-based education programs.
O'Neil, K. et al. 2009 (JHU EPC SR)	SR: From the 136 studies identified in the systematic review, 15 articles, 12 addressing physician application of knowledge and 3 addressing psychomotor skills, were identified and reviewed	Health professionals and allied health professionals	Knowledge, Psychomotor Skills Technique: Multiple Media: Multiple Frequency: Both single and multiple	Sufficient evidence to support CME as effective in improving physician application of knowledge. Multiple exposures and longer durations of CME are recommended to optimize educational outcomes. Quality of evidence does not speak to psychomotor skill development.
Rampatige, R. et al. 2009	SR: 476 articles selected for inclusion; Section A relates to continuing professional education in general (Section B is not relevant); 9 studies were reviewed to determine effect of CME on practice behaviors and clinical practice outcomes	Health professionals	Practice Behaviors and Clinical Practice Outcomes Technique: Multiple Media: Multiple Frequency: Both single and multiple	Interactive and practice enabling strategies are more useful than print-based and educational meetings. Multiple education efforts combined with good feedback/interaction between educators and learners are most effective. Opinion leaders and outreach visits shown to be effective.
Raza, A. et al. 2009 (follow-up to earlier Coomarasamy/Khan 2004 study)	SR: Cochrane review of 32 studies reviewed to determine evidence to support effective CME	Health professionals	General Technique: Multiple Media: Multiple Frequency: Both single and multiple	Evidence from 23 studies support interactive and clinically integrated learning sessions, and interactive classroom teaching as second choice for effective form of CME. Review demonstrated that interactive workshops improved knowledge and practice behaviors.

Citation	Study Design	Participants	Intervention	Key Findings
Satterlee, W. et al. 2008	SR: 9 articles reviewed to determine impact of CME on clinical practice outcomes		Clinical Practice Outcomes Technique: Multiple Media: Multiple Frequency: Both single and multiple	Combined didactic presentations and interactive workshops and combined didactic presentations were more effective than traditional didactic presentations alone. The use of multiple interventions over an extended period increase effectiveness. Targeted education should focus on changing a behavior that is simple, because effect size is inversely proportional to the complexity of the behavior.
Thomson O'Brien, M.A. et al. 2001	SR: 32 articles were reviewed to determine the effects of educational meetings on practice behaviors and clinical practice outcomes	Health professionals (total N=2,995)	Practice Behaviors and Clinical Practice Outcomes Technique: Multiple Media: Live Frequency: Single	Moderate data quality suggests interactive workshops can result in moderately large changes in professional practice. Didactic sessions alone are unlikely to change professional practice.
Williams, J. et al. 2008	SR: 9 studies were reviewed to evaluate if disaster training improves knowledge and skills	Health professionals and allied health professionals	Knowledge, Skills Technique: Multiple Media: Multiple Frequency: Both single and multiple	Insufficient data quality exists to report on the impact of disaster response training interventions on knowledge and skills. Data suggest that both computer-based and live instruction may increase knowledge.

IV. Discussion

4.1. Limitations of this Study

The following limitations apply to the methodology that we selected for this study, and have an impact on the interpretations that can be drawn from our analysis. We selected an integrative review of the literature, rather than a systematic review or meta-analysis, because the information presented in a majority of the reports did not include all of the information (such as power and effect size) required for more rigorous analytical approaches. While articles were graded and only tier 1 articles included in the analysis, this review did not attempt to reanalyze or combine primary data, nor did it make determinations regarding the quality of original studies. We adopted a structured grading method for inclusion or exclusion of articles, and involved several reviewers in this process.

We faced an additional limitation in that many articles included in the review were not fully transparent, nor consistent with terminology definitions used in other reports. For example, some articles report on computer-based learning as a technique, rather than as a media channel for delivery of instruction. Therefore, for the purpose of this review, articles were reviewed and categorized according to the terminology established by the JHU-EPC for its review of CPE strategies. This approach promoted comparability between these reviews. In addition, certain topics were underdeveloped in the literature, and very few articles of sufficient rigor were conducted in low- and middle-income countries. This limits the interpretation that can be drawn on these topics in those settings. In addition, the overwhelming majority of studies focused on health professionals in developed or middle-income countries, which limits what we can say regarding the application of these findings among health workers of a lower educational level and in lower-resourced communities.

"Didactic techniques and providing printed materials alone clustered in the range of no-to-low effects, whereas all interactive programs exhibited mostly moderate-to-high beneficial effects. The most commonly used techniques, thus, generally were found to have the least benefit." (Bloom 2005, 380–385)

4.2. Techniques Discussion

The importance of interactive techniques that require learner engagement and interactivity in learning and the ineffectiveness of didactic techniques were reinforced in the systematic reviews. The effectiveness of using educational techniques that require active learner mental processing is reinforced in educational psychology literature [70]. There is sufficient high-quality evidence to reinforce the use of simulation as a preferred educational technique, notably for psychomotor, communication or critical thinking skills. Compared with traditional interactive seminars, simulation-based training led to improved performance in patient care in two RCTs. Lecture has been found to be ineffective compared to other educational techniques. Reading, another passive technique, was also found to be less effective than other methods. "The most effective education tools were interactive programs among practitioners and educators." [10]

Self-directed learning was also found to be an effective strategy, but requires the use of interactive techniques that engage the learner. For example, didactic-style, self-directed learning did not generate sufficient evidence to support it. On the other hand, self-directed learning, using either a case-based or simulation technique, was associated with specific positive learning outcomes in all three Kerfoot RCTs included in this review [54–56]. Limited evidence was found to support team-based learning or the provision of training in work teams, and some evidence was found to support problem-based learning as a means of developing critical thinking skills.

Self-directed learning is only as good as the techniques used within it.

Frequency Discussion

The evidence suggests that low-dose, high-frequency exposures are effective frequency for CPE interventions. This approach is supported in the educational psychology literature recommendations regarding cognitive overload [71], which also promote limiting information to essentials and not overloading the learner, as well as supporting repetition [72]. Another important consideration is that the techniques used in the SpacedEd RCTs [54–56] were effective ones; typically case-based, requiring direct application of knowledge rather than recall. Given the evidence against didactic methods, using effective educational techniques remains the critical point to consider when designing CPE interventions.

Setting Discussion

Setting should be selected for its ability to contribute to effective educational techniques (e.g., case-based, interactive, application), be similar to the work environment, and allow for clinical practice when required. While three articles did not find a significant difference in setting for CPE, five suggested clinically integrated teaching. These articles did not clearly demonstrate whether the value was in the setting or in the technique; the technique (e.g., including more case-based studies and using an effective teaching methodology) may have been more influential than the setting. A randomized trial of education of site-based (referred to as "educational outreach") compared to no intervention in South Africa found that re-treatment patients in clinics that received site-based training had higher cure or completion rates (OR 1.78, 95% CI 1.13–2.76) [73]. Despite the lack of strong evidence from this literature review, conclusions from literature in educational psychology [74], [75], [76] reinforce the importance of "situating" learning to make the experience as similar to the workplace as possible. Techniques used in learning are more important than the setting within which learning occurs; for example, a facility-based CPE intervention delivered using didactic instruction may be less effective than a computer-based, self-directed CPE intervention using case-based, interactive techniques.

Clinical integration may be an effective method for better addressing clinical practice behaviors, attitudes and critical thinking and communication skills.

Media Discussion

The techniques used within computer-based instruction may be ineffective and represent a passive knowledge push, or may be a more effective, interactive, case-based approach that requires the learner to conduct mental processing and engage in learning for better outcomes.

Certain common themes emerged in the many articles that commented on the role of media in CPE effectiveness. Multiple systematic reviews suggest the use of multiple media in CPE. Many studies about media did not focus on the educational technique used or the role of technique in CPE effectiveness. Computer-based instruction has been studied extensively; most assessments are focused on the comparative advantage of this mode of instruction to other instructional media and/or to the outcomes of learning.

The findings from multiple studies suggest that for knowledge transfer, computer-based instruction can be as effective as and more efficient than live instruction. However, it is important to note that several of the RCTs that found similar knowledge outcomes between computer-based and live instruction stated that both media utilized interactive methodologies [45], [60]. It is possible that the effectiveness was due to the interactivity of the technique, rather than the medium through which it was delivered. Two different RCTs identified that the use of a computer-based virtual patient was as effective as a live, standardized patient, and both reported the potential for cost efficiencies [4], [62], supporting the argument that technique, not mode of delivery is what matters most.

This view is supported by other bodies of research that argue that the technology used to deliver instruction does not influence the learning outcomes, rather the techniques used to produce desired learning outcomes are what matters [77]. A large meta-analysis found no significant difference between classroom or live instruction and computer-delivered instruction [78]. This was further supported by the more recent United States Department of Education meta-analysis of online learning studies that found that, on average, online learning resulted in modest improvements over live instruction, and that blended learning (combining computer with live instruction) resulted in somewhat better outcomes. Their analysis proposes that the blended learning approach typically includes activities not provided in live instruction, and that students spend additional time with the materials in blended learning [79] "This finding suggests that the positive effects associated with blended learning should not be attributed to the media, per se." The focus when designing CPE interventions should be on identifying techniques that will engage the learner in mental processing and provide appropriate and relevant learning practices to promote learning [80].

Outcomes Discussion

CPE can positively impact learning outcomes if effective techniques are used. The majority of the articles cited in this review reinforce the use of multiple media, multiple instructional techniques, multiple exposure and interactivity and feedback for effective CPE interventions. Gysels' systematic review addressing communication noted the importance of CPE being "learner-centered," and focused on the practical

and relevant work or real-life issues (2005). This critical and often overlooked aspect is well recognized in learning and instructional design theory (i.e., learning interventions must be tailored to previously identified learner gaps) [81].

V. Conclusion

In-service training has been and will remain a significant investment for continuing professional education, essential for maintaining competencies required for optimal public health. While the quality of evidence available is currently limited, we believe that there is sufficient evidence to continue to pursue the following strategies using well-planned combinations of training techniques, frequency, settings and media to deliver instruction.

Limit educational techniques that use a passive transfer of information, such as lecture and reading, in favor of techniques that require the learner to engage in mental processing (e.g., case studies, simulation and other interactive strategies). Regardless of media, frequency and setting, use of techniques that do not fully engage the learner in mental processing are unlikely to change practice behaviors. For example, a creative computer-based program including interactive exercises will be more effective than one that relies solely on narrated presentations.

Select media for delivery of instruction based on its ability to deliver a desired technique, to the intended location at the most appropriate moment. Take great care not to allow the desire to use a new medium to determine your educational technique.

Limited evidence, supported by educational psychology literature, supports selecting a setting that places learners in a situation very similar to their work environment. Select settings for CPE that will maximize the use of educational techniques that require active learner engagement, and allow for sufficient, realistic practice opportunities similar to the workplace. On-the-job training has the added benefit of helping identify barriers to implementing new practices, improving worker productivity and increasing cost-effectiveness.

Replace single event training with shorter, more frequent training opportunities that reinforce important messages, provide opportunities to practice important skills and foster interaction. The use of highly available mobile technologies in the developing world can support delivery of these types of evidence-based training techniques.

There is sufficient evidence to support the use of traditional, competency-based training activities that combine the use of interactive techniques, simulation, practice and feedback, and role play.

Impacting clinical practice behavior is difficult and there is a lack of quality research to provide evidence to support CPE interventions that are scalable in low-resource settings. CPE interventions that allow for effective, interactive, practice-based techniques that maximize feedback and practice opportunities should be prioritized.

Given current gaps in high-quality evidence from low- and middle-income countries, the future educational research agenda must include well-constructed

evaluations of effective, cost-effective and culturally appropriate combinations of technique, setting, frequency and media, developed for and tested among all levels of health workers in low- and middle-income countries.

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