Interactive Spaced Education to Assess and Improve Knowledge of Clinical Practice Guidelines

A Randomized Controlled Trial

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Objective: To determine whether Interactive Spaced Education (ISE) is an effective and acceptable form of graduate and continuing medical education (GME/CME), using clinical practice guideline (CPG) education as an experimental system.

Summary Background Data: ISE is a novel form of online education, which combines the pedagogical merits of the spacing and testing effects. Its efficacy for GME and CME is not known.

Methods: One-hundred sixty urologists and 320 urology residents were randomized to 1 of 2 cohorts. We developed and validated 48 ISE items (questions and answers) on 5 urology CPGs (hematuria and priapism [HP]; staghorn calculi, infertility, and antibiotic use [SIA]). Physicians were sent 3 emails a week, each containing 2 questions. Content was repeated 3 times over 20 weeks. Cohort A physicians received the 3-cycle ISE course on HP, with 24 control items on SIA in cycle 3. Cohort B physicians received the 3-cycle ISE course on SIA, with 24 control items on HP in cycle 3.

Results: The ISE program was completed by 71% urologists and 83% residents. Cohort A scores on HP increased from mean 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 on SIA 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). Eighty-four percent of all participants requested to enroll in further ISE programs.

Conclusions: ISE is an effective and well-accepted form of GME and CME and is a promising new methodology to improve CPG knowledge.

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Ethical Approval to Perform the Study: The study protocol received institutional review board approval.

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Spaced education is a novel form of online education that has been shown in randomized controlled trials to improve knowledge acquisition,[1,2] boost knowledge retention,[1,3,4] improve learners' abilities to self-assess their performance,[3] and improve feedback behaviors.[5] In addition, it is extremely well-accepted by learners.[1,2,6] The spaced education methodology is based on the "spacing effect," the psychologic finding that educational encounters are spaced and repeated over time (spaced distribution) result in more efficient learning and improved retention, compared with massed distribution at a single time-point.[7,8] This effect has a distinct neurophysiologic basis. A recent study demonstrated that spaced learning by rats improves neuronal longevity in the hippocampus and that the strength of the rats' memories correlates with the number of new cells in this region of their brains.[9]

We currently deliver spaced education via periodic emails that contain clinical case scenarios and multiple-choice questions. Our newly-implemented system of "interactive spaced education" (ISE) allows learners to submit answers to the questions online and to immediately receive a web-page with the correct answer and learning points germane to the question. By testing the learner on the material, ISE takes advantage of the "testing effect," the psychologic finding that testing of learned material does not serve merely to evaluate a learner's performance. Rather, testing actually alters the learning process itself to significantly improve knowledge retention.[10,11]

Although ISE has been shown to be an effective and well-accepted form of online education for medical students,[2,6] it is not known whether ISE is similarly effective for graduate medical education (GME) or continuing medical education (CME). Using clinical practice guideline (CPG) education as an experimental system, we investigated whether ISE could significantly improve the CPG knowledge of urology residents and practicing urologists.

METHODS

Study Participants

All practicing, attending urologists and urology residents in the United States were eligible to participate in the trial. Recruitment was conducted via emails sent to all urologist and urology resident members (9102 and 1105 physicians, respectively) of the American Urological Association (AUA). There were no exclusion criteria for enrollment. Participation in the trial was limited to 160 urologists and 320 urology residents (80 from each year of urology training) who were randomly selected from those who requested participation. Institutional review board approval was obtained for the protocol.

ISE Online Delivery System

Each spaced education item consists of an evaluative component (a multiple choice question based on a clinical scenario) and an educational component (the correct answer, the take home message, explanation of incorrect answers, etc; **see Appendix, Supplemental Digital Content 1,** *http://links.lww.com/A890*). The spaced educa-

tion items were delivered to physicians via a new ISE delivery system developed in collaboration with the programmers at the Harvard Medical School Center for Educational Technology. Physicians receive ISE emails at designated time intervals, which contain 1 or more questions (**see Appendix, Supplemental Digital Content 1,** *http://links.lww.com/A890*). Upon clicking a hyperlink in the email, a web-page opens, which allows the physician to submit an answer to the question. After downloading this answer to a central server, physicians are then immediately presented the educational component. The submitted answers of physicians are recorded using the MyCourses web-based education platform. In the ISE program, evaluation and education are inextricably linked due to the question-answer format of the material. In effect, every ISE item acts as an individual test question, which in aggregate can be used to reliably assess baseline knowledge and knowledge gains.

Development of the Spaced Education Items

We constructed 77 questions on 5 CPGs published by the AUA in 2001 to 2005 and grouped them into 2 categories: hematuria and priapism (H-P) and staghorn calculi, infertility, and antibiotic prophylaxis (S-I-A).[12,13] The items were independently content-validated by 2 clinical urologists (M.L.R. and M.C.K.) and pilot tested by 32 urology chief residents (urology year 4). Psychometric analysis of the questions was performed using the Integrity test analysis software (Edmonton, Canada). On the basis of item difficulty, point-biserial correlation and Kuder-Richardson 20 score, 48 questions were selected for inclusion in the ISE course: 12 questions on hematuria, 12 on priapism, 6 on staghorn calculi, 12 on infertility, and 6 on antibiotic prophylaxis. The educational components of these 48 items were then constructed by 1 clinical urologist and independently content-validated by 2 others. When available, hyperlinks directly to the guideline documents were provided at the end of each educational component.

Structure of the ISE Intervention

During the study, participants were sent 3 emails a week (Monday, Wednesday, and Friday), each of which contained 2 spaced education items. To take advantage of the educational merits of the spacing effect, the ISE material was distributed in 3 cycles or repetitions (Fig. 1). This expanding pattern of spacing intervals has been demonstrated to improve retention of learning compared with fixed intervals,[14] although recent data have challenged these findings.[15,16] Cycles 1 and 2 were each 4-weeks long and consisted of 24 ISE items. The identical educational material presented in cycle 1 was repeated in the same order in the subsequent 2 cycles. For example, the first spaced education item in cycle 1 was presented in week 1, then presented for a second time in week 5 (as a 4-week cycled-review), and then presented for a third time in week 13 (as a 12-week cycled-review). From our prior experience, the repetition is not considered burdensome, but rather is seen by participants as a valuable means to test and reinforce their prior learning. Cycle 3 was 8-weeks long and consisted of 24 control items (with CPG content from the other cohort) in addition to the 24 items presented in cycled-review (48 items total). The time intervals between ISE cycles were established based on psychology research findings to optimize long-term retention of learning.[17]

Study Design and Organization

This randomized controlled trial was conducted over a 20-week period from March 2007 to July 2007. 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 one of 2 cohorts. Participants in cohort A received the 3-cycle ISE course on the HP CPGs, with 24 control items on the SIA CPGs in cycle 3 (Fig. 1). 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. Since the 24-items are 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 physicians who were presented with the material for the first time (controls).

Over the duration of the trial, each physician was sent 48 unique ISE items. Half were initially presented in cycle 1, and the other half were presented as the control items in cycle 3. By aggregating the scores on these items upon initial presentation, the baseline CPG knowledge levels of participating physicians was assessed.

At the end of the course, physicians were sent a short online survey (www.surveymonkey.com; Portland, OR), which asked them to indicate whether they would want to participate in future ISE programs (yes/no), how often they used the hyperlinks in the ISE items, and what would be the optimal number of cycles and questions per email. Upon completion of this survey and submission of answers to more than 80% of ISE items, urology residents received a $30 gift certificate to an online bookstore, while urologists received continuing education credit and a $60 gift certificate.

Outcome Measures

The primary outcome measure was the difference in topic-specific CPG knowledge between cohorts in cycle 3 among those physicians who completed the ISE course (per-protocol analysis). This compared the learning gains of physicians who completed 2

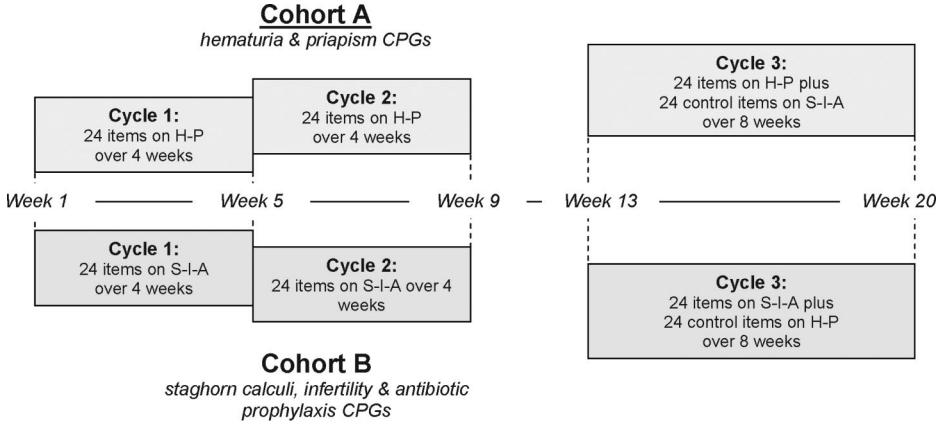

FIGURE 1. Structure of the randomized controlled trial. Timeline is not to scale.

TABLE 1. Characteristics of 480 Participants Randomized to Intervention Cohorts

	Cohort A		Cohort B	
	Urologist	Urology Resident	Urologist	Urology Resident
Participants randomized	80	160	80	160
Gender				
Male	76 (95%)	127 (79%)	74 (93%)	125 (78%)
Female	4 (5%)	33 (21%)	6 (8%)	35 (22%)
Age, in mean years (SD)	46.8 (9.8)	30.9 (2.9)	47.2 (10.5)	31.1 (3.1)
Degree				
MD	77 (96%)	152 (95%)	79 (99%)	146 (91%)
MD/other (PhD, MPH, etc.)	3 (4%)	6 (4%)	1 (1%)	12 (8%)
DO	0 (0%)	2 (1%)	0 (0%)	2 (1%)
Clinical setting				
Academic	17 (21%)	—	16 (20%)	—
Private practice	63 (79%)	—	64 (80%)	—
Clinical practice structure				
Group practice	63 (79%)	—	66 (83%)	—
Solo practice	16 (20%)	—	14 (18%)	—
No response	1 (1%)	—	0 (0%)	—
Years since residency, in mean (SD)	14.6 (10.4)	—	15.1 (10.5)	—
Certified by American Board of Urology (ABU)	Yes 64 (80%), No 15 (19%), No response 1 (1%)	—	Yes 66 (83%), No 14 (18%), No response 0 (0%)	—
Year of Urology training				
1	—	40 (25%)	—	40 (25%)
2	—	40 (25%)	—	40 (25%)
3	—	40 (25%)	—	40 (25%)
4	—	40 (25%)	—	40 (25%)

Percentages may not add to 100% due to rounding.

cycles of the ISE course to the knowledge of those physicians who were presented with the material for the first time (controls). Secondary outcome measures were (1) an intention-to-treat analysis of the difference in topic-specific CPG knowledge between cohorts in cycle 3 (2) the baseline CPG knowledge levels of physicians on all ISE items at initial presentation, and (3) the acceptability of ISE to physicians as a method of online education.

Statistical Analysis

Scores for each ISE cycle were calculated as the number of items answered correctly normalized to a percentage scale. In cycle 3, scores on control items and cycled-review items were calculated separately. Unanswered items were marked incorrect. To calculate baseline CPG knowledge, physicians' scores on cycle 1 were combined with their scores on the control items in cycle 3 and normalized to a percentage scale. During cycle 1, an error in one infertility question was identified; this question was corrected for subsequent cycles, and data for that question were excluded from all analyses. Reliability of the ISE cycles and the baseline CPG knowledge assessment was estimated with Cronbach α.[18] Cronbach α is the most widely used of all estimates of reliability,[19] and it assesses the systematic variance of a measure administered to a sample.[18] The range of α is theoretically a low of 0 to a high of 1 with higher values indicating higher levels of reliability. An α of 0.7 is generally considered to be adequate for group-level comparisons, whereas for high-stakes tests of individuals, an α of 0.9 or higher is desired.[20]

Both per-protocol and intention-to-treat analyses of the ISE score data were performed. The per-protocol analysis included those participants who completed the program (defined as submitting answers to ≥80% of the spaced education items in the entire program). The intention-to treat analysis included all 480 participants, whether or not they completed the program. Intervention effect sizes for learning were measured by means of Cohen d.[21] Cohen d expresses the difference between the means in terms of standard deviation units, with 0.2 generally considered as a small effect, 0.5 as a moderate effect, and 0.8 as a large effect.[22] Statistical calculations were performed with SPSS for Windows 15.0 (Chicago, IL).

RESULTS

In March 2007, 700 US urologists and 470 urology residents requested to participate in the trial. One-hundred sixty urologists and 320 urology residents were randomly selected to participate. The baseline demographic characteristics of the participants were similar between randomized cohorts (Table 1).

Seventy-one percent of urologists (114 of 160) and 83% of urology residents (264 of 320) completed the program. One-hundred ninety-six participants in cohort A (82%) and 182 participants in cohort B (76%) completed ≥80% of all the ISE items and were included in the per-protocol analysis (Fig. 2). Attrition was similar between cohorts ($P = 0.07$, χ^2). Average Cronbach alpha reliability was 0.71 and 0.73 for the HP and SIA cycles, respectively; α for all ISE items at initial presentation was 0.71.

Baseline CPG Knowledge

In the per-protocol analysis, baseline CPG knowledge was significantly higher among urologists than urology residents: urologists' mean scores on all ISE items at initial presentation was 49.3% (SD, 10.6) compared with 44.2% (SD, 9.9) for urology residents ($P < 0.001$). Among urology residents, baseline CPG

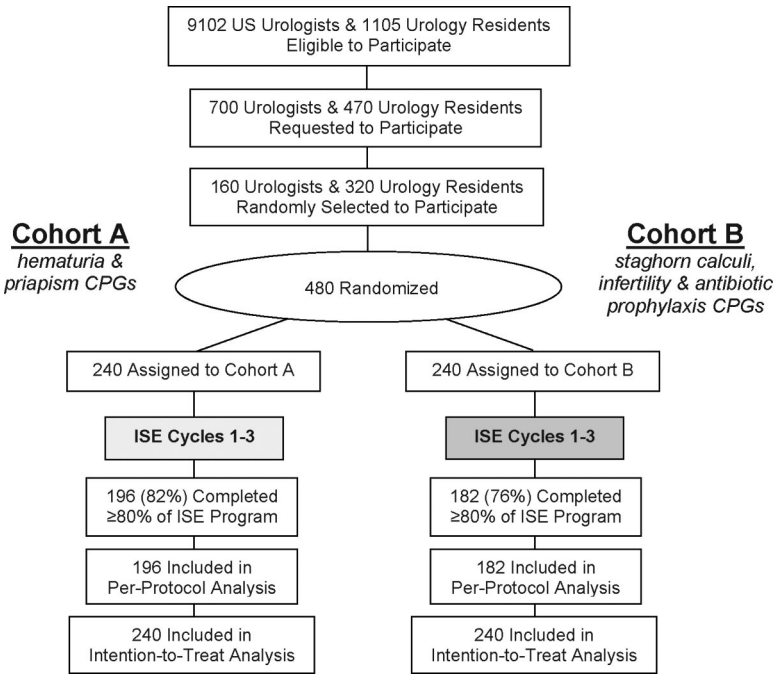

FIGURE 2. CONSORT flow chart of randomized controlled trial. All 480 participants were included in the intention-to treat analysis. The per-protocol analysis included those participants who submitted answers to ≥80% of all spaced education items in the program.

knowledge was significantly correlated to their year of urology training (Pearson r = 0.23, $P < 0.001$). Among urologists, there was no significant correlation between baseline scores and the number of years since residency training. In addition, there were no significant differences in baseline scores between urologists based on their clinical setting (academic vs. private practice), clinical practice structure (solo vs. group practice), or American Board of Urology certification status.

CPG Knowledge Improvement

During the ISE course, cohort A scores (on hematuria and priapism CPGs) increased from a mean 44.9% (SD, 14.9) in cycle 1 to 74.0% (SD, 15.0) in cycle 2 and 75.7% (SD, 13.7) in cycle 3 (Fig. 3). Compared with cycle 3 control scores (48.2%, SD: 12.6), the ISE course on HP generated a 27.5% absolute score increase and a 57% relative score increase ($P < 0.001$), corresponding to a Cohen effect size of 2.2. Similarly, cohort B scores (on staghorn calculi, infertility, and antibiotic prophylaxis CPGs) increased from a mean 45.2% (SD, 12.9) in cycle 1 to 65.5% (SD, 14.6) in cycle 2 and to 69.5% (SD, 11.4) in cycle 3 (Fig. 3). Compared with cycle 3 control scores (44.6%, SD: 11.5), the ISE course on S-I-A generated a 24.9% absolute score increase and 56% relative score increase ($P < 0.001$), corresponding to a Cohen effect size of 2.2. Urologists and urology residents within each cohort had similar knowledge gains (cycle 3 score − cycle 1 score) from the ISE course. Final CPG knowledge levels among residents (as measured by cycle 3 scores) varied by level of urology training, but not in a consistent pattern. Attending urologists in both cohorts demonstrated significantly higher final CPG knowledge levels than residents ($P = 0.035$ and 0.003 for cohorts A and B, respectively). Significant gains in knowledge were also demonstrated in the intention-to-treat analysis, with Cohen effect sizes of 1.54 and 0.75 for cohorts A and B, respectively (both $P < 0.001$).

ISE Acceptability and Utilization

The end-of-program survey was completed by 86% of participants (412 of 480). Respondents reported spending a median 3 minutes (IQR: 2–5) to complete each ISE email (2 items per email). Participants reported that the optimal number of ISE emails each week would be 3 (median, IQR: 2–4) and the optimal number of questions in each ISE email would be 2.5 (median, IQR: 2.0–3.0). When asked whether they would like to participate in future programs using ISE methodology, 84% of all 480 participants (87% urology residents and 78% urologists) answered "Yes." During the entire ISE course of 48 ISE emails (2 items per email), participants reported using the reference hyperlinks at the bottom of the educational components only a median 2 times (IQR: 0–8) to view the actual AUA CPG documents. There was no significant correlation between hyperlink utilization and CPG knowledge gains.

DISCUSSION

In this randomized controlled trial, ISE was demonstrated to be an effective online methodology for delivering graduate and continuing medical education. Although the educational intervention consisted of only 3 emails each week, ISE generated substantial gains in CPG knowledge among both urology residents and attending urologists. In addition, the ISE intervention was well-accepted by physicians, with 84% of all 480 participants requesting to participate in future ISE programs.

Spaced education compares favorably to other forms of education, both online and offline. For shorter-term learning (as in a 12-week clinical clerkship for medical students), spaced education seems to be equivalent to web-based teaching modules in short-term learning gains and in acceptability by learners.[6] For longer-term learning, ISE seems to be significantly more effective. In a randomized trial of 537 physicians comparing self-study to static (noninteractive) spaced education over a period of 40 weeks, the physicians who received spaced education demonstrated greater overall learning and improved retention compared with those in the self-study cohort.[1] Long-term follow-up of the physicians in this study found that the learning benefits from spaced education could be detected 2 years later.[23] In contrast to "binge-and-purge" bolus training, the gradual but long-term learning generated by ISE seems to be particularly well-suited for CPG dissemination. Work is currently underway to determine whether ISE is an effective means

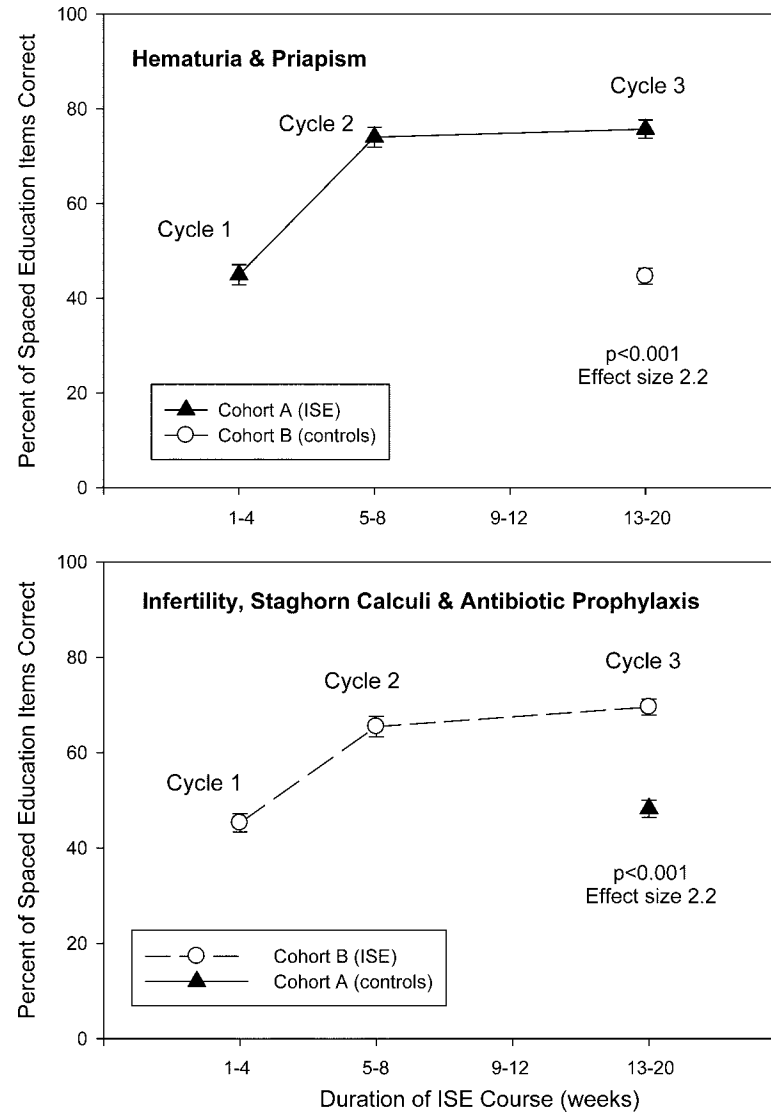

FIGURE 3. Knowledge gains from ISE course. Plots include those participants who submitted answers to ≥80% of the spaced education items (per protocol analysis). Bars represent 2× standard error. Timeline is not to scale.

to bring practitioners' clinical behaviors into alignment with CPG standards.

This study raises 2 important but unanswered questions. First, it is not clear why baseline CPG knowledge on core urology topics is so low among urologists: in the per-protocol analysis, their mean score on all ISE items at initial presentation was less than 50%. This finding cannot be explained by the novelty of the guidelines since they were published 2 to 6 years before our trial. It does indicate, though, that the AUA and other CPG-producing organizations need to increase their efforts to disseminate CPGs to their constituencies and need to harness more effective methods to do so. Merely providing clinicians with easy-to-use hyperlinks directly to CPG documents does not appear to be an effective method of guidelines dissemination. In our study, the hyperlinks to CPG documents in the ISE items were rarely used, and utilization of the hyperlinks did not generate detectable improvements in CPG knowledge. Second, it is not clear why learning appears to become saturated after 2 ISE cycles, with only limited score improvements in cycle 3 (Fig. 3). This suggests that some of the CPG content may be in direct conflict with clinical practice or may be difficult to remember over 8+ weeks.

There are several limitations to our study including that the content focused only on urology and participants were restricted to urology specialists. Further work is needed to demonstrate the generalizability of ISE's efficacy to other content domains and to other groups of learners. In addition, the control scores in our study do not reflect learning generated from a contrasting (non-ISE) educational methodology, but rather reflect the current "standard of urologic care" among urologists and urology residents. Further randomized trials comparing ISE directly to traditional and other internet-based instructional methods are currently being conducted. Strengths of the study include its randomized-controlled design, the large number of participants, and its focus on long-term learning outcomes.

In summary, ISE is a novel form of online education founded on core principles of learning that can effectively deliver both GME and CME. The ISE methodology is content-neutral so it can be readily implemented across educational domains and across provider types. By linking evaluation with education in a question-answer format, ISE is able to document the mastery of educational content by clinicians. Over time, the small amounts of learning

generated by each ISE email aggregate into substantial improvements in knowledge. Given its demonstrated efficacy and acceptability, ISE is a promising new methodology for online education.

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