An Exploratory Study of Live and Web-Based Education on Bioterrorism for Healthcare Professionals: Knowledge Acquisition and Retention

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INTRODUCTION
Healthcare professionals, including emergency medical technicians, nurses, and physicians, will be among the first responders after a bioterrorism attack and represent a first line of defense to initiate control measures [1-3]; however, the ability of many clinicians to recognize, diagnose, and manage diseases caused by a bioterrorism attack is limited [1].

Effective educational activities on bioterrorism are urgently needed to provide healthcare professionals with essential information on prevention and recognition of bioterrorism attacks, ongoing surveillance for potential outbreaks, infection-control strategies, and post-event quarantine combined with targeted response strategies. These activities must help prepare healthcare personnel for such attacks to make the best use of limited healthcare resources [3].

Background: To determine the value of specific educational designs for improving healthcare professionals’ knowledge of bioterrorism, we conducted an exploratory study to compare the effectiveness of live and Web-based learning modules and specified levels of interaction with regard to the acquisition and retention of knowledge of bioterrorism agents by healthcare professionals. The primary goal was to identify the most relevant continuing medical education approach.

Methods: This large educational intervention study included 4 different experimental groups in a 2 × 2 design (2 levels of delivery mode and 2 levels of instructor–participant interaction). Civilian and military healthcare professionals (eg, physicians, nurses and nurse practitioners, pharmacists, public health officials) were recruited. The 2 educational-delivery modes used were “live” instruction and Web-based instruction (asynchronous/archived). Study participants were randomly assigned to 1 of the 2 levels of interactivity (interactive versus didactic), which were used to teach content about the recognition, diagnosis, and management of patient exposure to avian influenza, smallpox, toxins, and anthrax. The relative efficacy of the 2 delivery modes and interactivity was evaluated by participants completing a precourse test, a postcourse test immediately after participation in the course, and follow-up tests at 3 months and 6 months after course completion. Statistical significance was set at an α level of .01.

Results: A total of 472 healthcare professionals registered for courses. Despite the large drop-off in participation for the 3-month and 6-month follow-up tests (61% and 74%, respectively), the vast majority of learners completed the precourse test (98%) and the postcourse test (97%). The precourse and postcourse test scores indicated that participants achieved a higher level of knowledge regarding bioterrorism agents in all activities. Although there was a statistically significant decrease in knowledge after the activity, as evidenced by the decrease between the postcourse and 3-month follow-up test scores for all topics (P < .01), there was no significant further erosion in knowledge, as measured by the change between the 3-month and 6-month scores (P > .01, all topics). Additionally, the 6-month scores remained higher than the precourse test scores for all topics—evidence of some long-term retention of knowledge. There was no difference in learning between the participants in the live and Web activities for 2 of 3 topics (avian influenza and smallpox), but there was a significant difference in the activities related to the toxins topic. Participants in the live activities showed a 30% increase in mean postcourse test scores, compared with an 11% increase for those participating in the Web activities (P < .001). The anthrax course was presented in live mode only, so comparisons between delivery modes were not possible for this topic.

Conclusions: This exploratory study showed that educational interventions regarding bioterrorism led to learning by healthcare professionals, regardless of the educational-delivery mode (live or Web-based instruction) or level of instructor–participant interaction. Although participants in the study did tend to lose some of their newfound knowledge in the 3 months after completing the courses, further erosion of knowledge between the 3- and 6-month follow-up tests appeared to be limited. Generally, Web-based activities were as effective as live activities, with a few exceptions favoring the live format. Further study is needed to confirm these findings.

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The US Centers for Disease Control and Prevention, local health departments, and medical institutions have developed various educational resources to educate physicians about bioterrorism [4]. Two of the most common approaches used to educate physicians and other healthcare personnel are traditional live activities and Web-based/online activities [5,6]. Although participants in a live classroom course are able to engage and personally interact with instructors and may prefer to attend an “off site” course (ie, away from potential distractions at the office), online continuing medical education (CME) courses may offer greater flexibility in training schedules, decreased travel time and expenses, and greater adaptability to individual learning styles [5].

With the growing risk of a bioterrorism attack, increasing the knowledge of healthcare workers in this area of public health is critical. Likewise, comparing the value of live and online activities is needed to make evidence-based decisions [5] about bioterrorism education on a national level. Bioterrorism is a unique CME topic because learned knowledge cannot be applied immediately to clinical practice, yet healthcare professionals need to be prepared for a potential attack. In the event of a bioterrorism attack, rapid dissemination of information by the government and local health authorities to local healthcare professionals is a key to survival [3].

It is important to determine the value of specific educational designs for improving the acquisition and retention of knowledge on bioterrorism. Our research evaluates the accuracy of the premise that live activities provide the best assimilation and retention of knowledge. Using a live activity as a “gold standard,” we conducted a large-scale exploratory study to evaluate and compare the effectiveness of live and Web-based (asynchronous/archived) learning modules on bioterrorism with the goal of improving the acquisition and retention of knowledge. We assessed knowledge acquisition and retention to identify the most relevant approach.

**METHODS**

**Study Design and Participants**

The educational-intervention study included 4 different experimental groups in a 2 × 2 design (2 levels of delivery mode and 2 levels of instructor-participant interaction). The specific healthcare professions targeted for participation included physicians, nurses and nurse practitioners, pharmacists, public health officials, physician assistants, certified laboratory scientists, respiratory therapists, and psychologists.

Recruitment for the study started in August 2006, and the study ended in August 2008. Recruitment methods included printed brochures, online banner advertising, e-mail “blasts,” phone calls, and fax blasts. The 2 educational-delivery modes used in the study were live instruction and Web instruction. Study participants were randomly assigned to 1 of the 2 levels of interactivity (interactive versus didactic), which were used to teach content about bioterrorism (in particular, avian influenza, smallpox, toxins, and anthrax). The education materials included information regarding the recognition, diagnosis, and management of symptoms and diseases caused by the bioterrorism agents.

The relative efficacies of the 2 delivery modes and teaching styles (interactive versus didactic) were tested by asking course participants to complete a precourse test before taking the course, a postcourse test immediately following the course, and follow-up tests at 3 months and 6 months after course completion. The follow-up tests were sent via e-mail, fax, and regular mail; some were even solicited in person. Follow-up phone calls were also made to individuals who had not responded to encourage them to complete the follow-up test. Civilian and military healthcare professionals were offered $50 for their completion of each of the 3-month and 6-month follow-up tests. Tests for each activity included 7 questions (multiple choice and true/false), and participants were asked to answer the same 7 questions (which were kept in the same order) for each testing period. Subject primers were available to participants prior to the follow-up tests.

Two live activities on all 4 of the bioterrorism topics were held. One was a didactic presentation in September 2006, and the other was an interactive discussion in January 2007. The live courses were held in Houston, Texas, and were promoted through save-the-date cards, printed brochures, and e-mail blasts. Six archived Web activities on 3 of the 4 bioterrorism topics (avian influenza, smallpox, and toxins; anthrax was not included in the Web activities because of the complexity of the course material and a limited budget) were available in April 2007. One was an online didactic module, and one was an online interactive module for each of the 3 topics. Web courses were promoted through printed brochures that included the Web link to the Web program and through Web advertising with a direct hyperlink to the program. Participants had to register prior to accessing the Web courses.

**Descriptions of Delivery Modes and Levels of Instructor–Participant Interaction**

**Live Didactic.** The live didactic format was modeled after a classroom presentation. Participants paid a registration fee of $195 and attended formal sessions taught by an instructor(s). The 4 bioterrorism topics were each 1-hour sessions split over a larger 1.5-day conference period. Educational materials included slides and handouts (in a syllabus) and reference lists. In this format, the participants were free to ask the instructor(s) questions at the end of each session. Thus, there was an opportunity for...
participants to make the sessions interactive. We had 4 instructors available for avian influenza, 2 for anthrax, 1 for toxins, and 1 for smallpox in the live didactic courses, and the instructors were trained on how to lead and focus the discussion and how to answer questions.

**Live Interactive.** As in the live didactic format, participants paid a registration fee of $195, attended formal 1-hour class sessions split over a larger 1.5-day conference period, and used similar educational materials. In this format, there was a greater opportunity for interaction between the instructor(s) and participants. For instance, the instructor addressed questions posed by participants or had the participants engage in discussion on whether a particular answer to a technical question was correct. The interactive mode also included clinical cases, panel discussions with the audience, audience-response technology, and audience-directed questions and discussion [7-10]. In the live interactive courses, we had 3 instructors available for avian influenza, 1 for anthrax, 1 for toxins, and 1 for smallpox, and the instructors were trained on how to lead and focus the discussion and how to answer questions. Correct answers were discussed with the learners in the session, and notation was made as to why they were correct.

**Web Didactic.** There was no registration fee for activities taken in the Web didactic format, which involved a prepared (archived) presentation watched by participants at their convenience. The presentation included instructor commentary (ie, video [with audio] of the instructor presenting educational materials) and slides. Participants had no input into the presentation and were asked to complete precourse, postcourse, and follow-up tests online. There was also no feedback for the learners in the Web didactic format.

**Web Interactive.** There was no registration fee for the Web interactive format. The Web interactive format was similar to the Web didactic format, but participants were asked to respond to questions during the presentation. This model also included links for participants to pursue further information on a variety of topics outside of the activity, as well as to access a discussion Web site after the activity. Participants were also asked to complete precourse, postcourse, and follow-up tests online. Except for the postcourse test, participants received feedback during the tests that noted if a participant’s answer was correct, what the correct answer was if it was incorrect, and why it was incorrect. There was no feedback for the postcourse test.

**Data Analysis**

All of the data in this study are descriptive, and analyses were conducted with various statistical approaches contained in the SPSS software package (version 16.0 for Windows; SPSS, Chicago, IL, USA). The study sample was defined by the total number of participants who registered and agreed to complete the precourse and postcourse tests. Given the voluntary nature of CME activities, a portion of the participants chose not to participate in the study by opting out of the pre- and postcourse test segments of the activity. Changes in knowledge level over time were evaluated by analyzing and comparing participants’ total pre- and postcourse test scores, postcourse and 3-month test scores, and 3-month and 6-month test scores; the summary outputs were expressed as aggregate mean scores (±SD). In all of the analyses, test scores for the 4 topics were kept separate because the tests for these topics were different (and participants did not appear to have the same level of initial knowledge across all topics).

We compared the participants’ mean scores over time, but the paired-difference analysis excluded participants who did not take both of the tests under comparison. Differences based on delivery mode or level of interaction were evaluated by independent-sample Student t tests, which were used to compare the change in knowledge from the precourse test to the postcourse test and the retention of knowledge from the postcourse test to the 3-month test and from the 3-month follow-up to the 6-month follow-up. Because of the large number of hypothesis tests conducted, we used a more stringent α level of .01 instead of the standard α level of .05 for determining the statistical significance of t test results. All P values were 2-sided.

**RESULTS**

**Participants**

The healthcare professionals who participated in these courses were a demographically and occupationally diverse group (Table). The mean ages of the participants in the live and Web courses were similar, but the majority of the participants in the Web courses were female.

The randomization for interactive versus didactic courses worked relatively well (particularly with the Web courses), and the demographic and occupational profiles of the participants in each type of activity were similar. Of the 472 healthcare professionals who registered and agreed to complete the pre- and postcourse tests for ≥1 of the courses, 26% completed the 6-month follow-up test. Despite the large drop-off in participation for the 3-month (61%) and 6-month (74%) follow-up tests, the vast majority of participants completed the precourse (98%) and postcourse (97%) tests.

**Overall Comparisons of Test Scores**

According to the pre- and postcourse test scores, learning was apparent for all topics regarding bioterrorism agents. Aggregate means for the postcourse test scores were clearly higher than for the precourse test (Figure 1). Notably, scores for avian influenza activities increased significantly from 58% in the precourse test to 72% in the postcourse test (Figure 1A). Scores for smallpox activities

Overall Comparisons of Test Scores
<table>
<thead>
<tr>
<th>Description of Participants*</th>
<th>Didactic†</th>
<th>Interactive†</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Live participants</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male sex, n (%)</td>
<td>34 (43)</td>
<td>44 (59)</td>
</tr>
<tr>
<td>Mean age (range), y</td>
<td>43 (25-69)</td>
<td>49 (24-79)</td>
</tr>
<tr>
<td>&lt;30 y, n (%)</td>
<td>15 (21)</td>
<td>4 (6)</td>
</tr>
<tr>
<td>30-49 y, n (%)</td>
<td>33 (45)</td>
<td>30 (48)</td>
</tr>
<tr>
<td>≥50 y, n (%)</td>
<td>25 (34)</td>
<td>29 (46)</td>
</tr>
<tr>
<td>Type of professional, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physician</td>
<td>22 (27)</td>
<td>26 (34)</td>
</tr>
<tr>
<td>Other‡</td>
<td>56 (69)</td>
<td>45 (58)</td>
</tr>
<tr>
<td>Declined to identify</td>
<td>3 (4)</td>
<td>6 (8)</td>
</tr>
<tr>
<td>Civilian or military service, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Civilian</td>
<td>45 (56)</td>
<td>49 (64)</td>
</tr>
<tr>
<td>Military</td>
<td>18 (22)</td>
<td>14 (18)</td>
</tr>
<tr>
<td>Declined to identify</td>
<td>18 (22)</td>
<td>14 (18)</td>
</tr>
<tr>
<td>Location of professional, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>74 (91)</td>
<td>71 (92)</td>
</tr>
<tr>
<td>Rural</td>
<td>6 (7)</td>
<td>4 (5)</td>
</tr>
<tr>
<td>Super-rural§</td>
<td>1 (1)</td>
<td>2 (3)</td>
</tr>
<tr>
<td><strong>Web participants</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male sex, n (%)</td>
<td>37 (23)</td>
<td>41 (28)</td>
</tr>
<tr>
<td>Mean age (range), y</td>
<td>50 (24-85)</td>
<td>49 (24-73)</td>
</tr>
<tr>
<td>&lt;30, n (%)</td>
<td>8 (5)</td>
<td>3 (2)</td>
</tr>
<tr>
<td>30-49, n (%)</td>
<td>60 (39)</td>
<td>70 (47)</td>
</tr>
<tr>
<td>≥50, n (%)</td>
<td>85 (56)</td>
<td>75 (51)</td>
</tr>
<tr>
<td>Type of professional, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physician</td>
<td>36 (22)</td>
<td>33 (22)</td>
</tr>
<tr>
<td>Other‡</td>
<td>127 (78)</td>
<td>118 (78)</td>
</tr>
<tr>
<td>Civilian or military service, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Civilian</td>
<td>155 (95)</td>
<td>144 (95)</td>
</tr>
<tr>
<td>Military</td>
<td>6 (4)</td>
<td>7 (5)</td>
</tr>
<tr>
<td>Declined to identify</td>
<td>2 (1)</td>
<td>—</td>
</tr>
<tr>
<td>Location of professional, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>106 (65)</td>
<td>109 (72)</td>
</tr>
<tr>
<td>Rural</td>
<td>35 (22)</td>
<td>24 (16)</td>
</tr>
<tr>
<td>Super-rural§</td>
<td>22 (13)</td>
<td>16 (11)</td>
</tr>
<tr>
<td>Declined to identify</td>
<td>—</td>
<td>2 (1)</td>
</tr>
</tbody>
</table>

*Participant data may be missing for some baseline factors.
†Unless otherwise noted.
‡Other: nurses and nurse practitioners, pharmacists, public health officials, physician assistants, certified laboratory scientists, respiratory therapists, and psychologists.
§Super-rural: the lowest 25th percentile of all rural populations arranged in order of magnitude by population density.
significantly increased from 49% to 78% (Figure 1B), scores for toxin activities increased significantly from 39% to 63% (Figure 1C), and scores for anthrax activities increased significantly from 50% to 76.5% (Figure 1D).

There was a statistically significant decrease in knowledge over time, as evidenced by the drop in scores from the postcourse test to the 3-month follow-up for all topics (Figure 1; all $P < .01$); however, there was no significant further erosion in knowledge as measured by the change between the 3-month and 6-month scores (Figure 1; all $P > .01$). In addition, the 6-month scores remained higher than the precourse test scores for all topics, indicating evidence of some long-term retention of knowledge.

Figure 1. Retention of knowledge of bioterrorism agents: overall test score averages. Pre Test indicates precourse test; Post Test, postcourse test; 3 Months, 3-month follow-up test; 6 Months, 6-month follow-up test.

Test Score Comparisons for Topics by Delivery Mode (Live versus Web)

Initially, participants were most knowledgeable about avian influenza, followed by anthrax and smallpox. Although participants in the course on toxins had the least initial knowledge, they showed the highest increase from the precourse test scores to the 6-month scores. In comparing longer-term knowledge retentions between the live and Web delivery modes, we observed statistically significant increases in mean changes from precourse test scores to the 6-month scores for the live mode ($P = .004$, avian influenza; $P < .001$, both smallpox and toxins), but we noted no significant differences for the Web mode (all $P > .01$). The anthrax course...
was presented in live mode only, so no comparisons of delivery formats can be made for this topic.

**Avian Influenza.** The mean test scores over time for live and Web formats were similar for the avian influenza topic (Figure 2A). Participants appeared to have similar levels of initial knowledge, learning, and retention (Figure 2A). There were few differences among participants in the live meetings and those in the Web presentations relative to the amount of knowledge retained or lost over time. However, the knowledge loss between the postcourse

![Figure 2A](image_url)

**Figure 2.** Retention of knowledge of bioterrorism agents by delivery mode (live versus Web-based courses). Pre Test indicates precourse test; Post Test, postcourse test; 3 Months, 3-month follow-up test; 6 Months, 6-month follow-up test.
test and 3-month follow-up was less pronounced among learners in the live meeting formats (mean loss, –5.1%) than for those participating in the Web formats (–11.6%; \( P = .06 \)).

**Smallpox.** Test scores for the live and Web-based formats were more similar for the smallpox topic than for avian influenza (Figure 2B). The difference in changes in participants’ test scores over time among the delivery modes was not statistically significant.

**Toxins.** Participants in the live activities had a lower level of initial knowledge but learned more than those who participated in the Web activities (Figure 2C). There was a significant difference between delivery modes with respect to the amount learned during the course, with participants in the live activities showing a 30% increase in mean test scores, compared with an 11% increase for those who took part in the Web activities (\( P < .001 \)). Although participants in the live activities appear to have lost more knowledge over time than the Web participants (–10% drop-off versus +0.9% gain, respectively), the change was not statistically significant. There were also no statistically significant differences between modes of delivery in the changes seen between the postcourse test and the 3-month follow-up, or between the 3-month and 6-month follow-ups (\( P > .01 \)).

**Comparisons of Interactive and Didactic Formats**

The overall level of interaction between instructors and participants did not produce meaningful statistically significant differences in scores for the interactive format versus the didactic format for 3 of 4 topics (anthrax being the exception).

**Avian Influenza.** The mean test scores in the postcourse test and the 3- and 6-month follow-ups were slightly higher for those participants in the interactive courses than for those in the didactic courses, but there were no statistically significant differences in avian influenza test scores or changes over time between the interactive and didactic groups (Figure 3A).

**Smallpox.** There was a greater increase in knowledge for participants who took a didactic course than for those in an interactive course, but there was also a greater drop-off in knowledge between the postcourse test and the 3-month follow-up (–17% for the didactic course versus –10% for the interactive course; \( P = .11 \)) (Figure 3B). Conversely, between the 3- and 6-month follow-ups, participants in the didactic courses retained the knowledge better than those in the interactive courses (trend toward statistical significance: \( P = .014 \)).

**Toxins.** Although the precourse test scores for participants randomly assigned to the interactive or didactic group for the toxins activities were not equal, there was no statistically significant difference between the 2 groups in the amount learned (Figure 3C). There was also no significant difference in the drop-off in knowledge over time; however, we did observe an increase in knowledge from the 3-month score to the 6-month score for the didactic group.

**Anthrax.** Participants in the interactive modules came to the precourse test with less knowledge than those in the didactic modules (Figure 3D). There was no statistically significant difference in the changes between pre- and postcourse test scores; thus, a similar amount of learning appears to have occurred. Although there was a more precipitous drop-off in knowledge between the postcourse test and the 3-month follow-up for participants in didactic modules than for those in interactive modules (–21% versus –2%; \( P = .002 \)), learners in the didactic modules who remained at the 6-month follow-up had a level of knowledge similar to those in the interactive modules.

**DISCUSSION**

This large exploratory study showed that educational interventions regarding bioterrorism resulted in learning by healthcare professionals, regardless of the educational-delivery mode or the level of instructor–participant interaction. It is reasonable to expect that physicians and other healthcare professionals will lose some of their newly learned knowledge over time if they are not reminded of the educational messages, if they do not apply the learning to their clinical practice, or if there is no reinforcement of the knowledge on an intermittent basis [11]. Because the content of these activities did not relate to a current practice question, the learning was not reinforced by practice after the activities. Studies have demonstrated that CME activities without practice-enabling tools (ie, protocols, algorithms, or practice guidelines) and reinforcement have limited impact [12-14]. In fact, participants in this study did tend to lose some of their newfound knowledge in the 3 months after completing the activity, but further erosion of knowledge between the 3- and 6-month follow-ups appeared to be limited. However, these results may have been affected by the time interval between tests, the high attrition of participants, and the limited number of questions. Previous studies of CME activities in other therapeutic fields have demonstrated knowledge-retention rates higher than those found in the current study [5,15].

**Live versus Web Comparisons**

In 2 of 3 topics (avian influenza and smallpox), there was no difference in learning between participants in the live and Web-based activities. Previous studies have reported similar observations with little or no difference in learning between these 2 educational-delivery modes [6,16]. Electronic enduring materials are more common than live events because of the ease and convenience of Internet access and because of their cost-effectiveness [6,17]. In addition, Web-based courses are becoming more interactive and more effective [5,6,18,19]. In the recent 16th Annual
Physician Preferences in CME Survey, 50% of 175 physician respondents said that they plan to attend fewer meetings requiring overnight travel in the year 2009 [20]. Thirty-eight percent of respondents said that they plan to attend more local CME meetings in 2009, and 50% said they plan to earn more of their CME credits with approaches that do not require travel (eg, online formats) [20].

Figure 3. Retention of knowledge of bioterrorism agents by learning environment (interactive versus didactic courses). Pre Test indicates precourse test; Post Test, postcourse test; 3 Months, 3-month follow-up test; 6 Months, 6-month follow-up test.
Literature reviews report that Web-based courses compare favorably with live classroom instruction with respect to knowledge acquisition and participant satisfaction [6,16]. A randomized controlled trial observed that online CME courses can cause objectively measured changes in physician behavior and sustained increases in knowledge that are equivalent or superior to those from effective live instruction [5]. Additionally, an analysis of a multicenter online educational intervention showed that the ability of physicians to recognize, diagnose, and manage patients presenting after a bioterrorism attack can be improved with an online didactic module [1].

For toxins, the bioterrorism topic about which participants knew the least at baseline, there was a difference in scores that was based on the educational-delivery mode. Participants in the live activities started with less knowledge than those in the Web activities, yet they learned and retained more and finished with a level of knowledge equal to that of the participants in the Web activities. This study suggests that Web-based activities are at least as effective as live activities in presenting material on some bioterrorism topics to healthcare professionals.

The exploratory design used in the current study is supported by the results of a retrospective survey of physicians who completed an online medical-education activity on bioterrorism [21]. The results showed that an online course can help prepare physicians to better diagnose conditions associated with bioterrorism agents and to report bioterrorism events to the proper public health authority [21].

**Interactive versus Didactic Comparisons**

Many studies have demonstrated that an interactive learning environment is more effective than a didactic one [8-10,22-24]. Davis et al conducted a meta-analysis of randomized controlled trials that evaluated formal didactic and/or interactive CME interventions. The investigators concluded that interactive activities improved physician performance and—in some instances—heath outcomes, whereas didactic interventions were not effective in improving physician performance [22].

Level of instructor–participant interaction was not associated with a significant difference in scores in the current study. For 3 of 4 topics (anthrax being the exception), there were no meaningful statistical differences between scores for participants in the didactic formats and those in the interactive ones. For the anthrax activity, which was presented only in the live mode, there was a larger drop-off in knowledge between the postcourse test and the 3-month follow-up for participants in the didactic module than for those in the interactive one (−21% versus −2%), but learners in the didactic mode who remained until the 6-month follow-up had a level of knowledge similar to those in the interactive mode. In addition, the didactic mode of presentation appeared to be directionally better than the interactive mode for presenting information about smallpox, although this difference did not reach statistical significance.

**Study Limitations**

There are several limitations to this exploratory study. The study involved a time-series before/after design without control or comparison groups. Delivery mode (live, Web-based) could not be randomized because of the real-world constraints of mandating travel and schedules of busy healthcare professionals. Participants were expected to select their preferred mode of instruction, and if participants selected activities based on their preferred learning styles, the decision was expected to have an impact on learning because evidence suggests that individuals learn better in their preferred styles [25-28]. Individuals may not have selected just on the basis of learning preference, however. Their choice may have been related to cost, location, or timing of the selected activity. Differences in promotional approaches for live versus Web-based modes could also have affected the learners’ activity selection.

It is unknown at this time why clear and consistent differences between interactive and didactic formats were not observed in this study. The high attrition rate and differences in the educational-delivery mode (ie, live versus Web-based) may have affected test scores. It is possible that the interactive modules (particularly in the Web-based delivery mode) were not as interactive as necessary to truly engage the participants. Perhaps the lack of differences between the interactive and didactic formats can be attributed to the quality of information disseminated by the instructor. It is also important to recognize that comparisons between didactic and interactive formats within each mode were not performed because of the high attrition rates. Although the results reported here are interesting and worthy of further investigation, data from this study are too limited to adequately demonstrate a conclusive and consistent effect.

The motivation to participate in 3- and 6-month follow-up exams appeared to be low. Many healthcare professionals initially opted out of the study, and others terminated their participation in the study before completing the 3- and 6-month follow-ups. Thus, there was a large decrease in sample size at these time points (particularly for Web-based activities), which made it difficult to measure how the different modes and formats of delivery may have affected retention of knowledge [29,30].

The limited number of test questions also made it difficult to evaluate the amount of learning and retention that took place. For example, a single additional correct answer on a test that included 7 questions would increase the score by 14%, yet it is unclear whether this represents a meaningful increase in knowledge. The restricted range of the scores makes the practical significance of the statistical analysis problematic. Access to information
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during tests (eg, notes, course, and other materials) likely differed between the live and Web-based modes, and this difference may have affected test scores.

Future Directions
As more specialty boards and state medical boards implement maintenance of certification and maintenance of licensure requirements based on identified clinical competencies, physician participation in educational activities may evolve [31,32]. Likewise, many medical educators are striving for compliance with new accreditation policies [33,34] and are enhancing their instructional design and evaluation/assessment capabilities. Enhancements in the design and assessment of medical education, as well as a renewed emphasis on lifelong learning by clinicians, may enhance participant motivation and improve the acquisition and retention of knowledge and, ultimately, health outcomes.

CONCLUSIONS
This study found that Web-based activities were at least as effective as live activities for physicians and other healthcare professionals who need to stay abreast of updated information regarding diagnosis and management of diseases caused by bioterrorism agents. The overall results support earlier studies that reported no tangible difference in learning between Web-based and live activities [6,16]. Although participants did tend to lose some of their newfound knowledge in the 3 months after completing the educational activities, there was minimal further erosion of knowledge between the 3- and 6-month follow-ups.

This study was an important investigation of a unique topic, given that education about bioterrorism cannot be immediately applied to clinical practice. In the absence of a bioterrorism attack, the participants in the courses have no opportunity to apply their knowledge. Data suggest that knowledge acquisition and retention for interactive versus didactic formats may vary by bioterrorism topic, but this conclusion will require further investigation. As CME evolves, studies should attempt to identify factors that improve motivation for participation in educational activities and subsequent outcomes assessments.

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Study Group Authorship and Acknowledgments
The authors are fully responsible for the methodology, analyses, and interpretation of data, and for the opinions and conclusions expressed in this report, which are independent of and not necessarily reflective of those of the study funder. The authors had full access to all data, reviewed each manuscript draft, and approved the final manuscript. G.F.W. and G.H. served as principal investigators of the study; G.F.W., G.H., and D.R.-S. designed the study and oversaw the implementation; R.H. and S.R.L. chaired the educational activities’ Steering Committee and oversaw content development; P.A.D. was responsible for study oversight and direction; A.M. was responsible for study implementation and data collection; and B.S., S.B., and C.R. analyzed the data and confirmed the accuracy of the data interpretations in the manuscript. We thank Karen Overstreet, Joe Riley, Michael Raffin, and Carol Greco for their editorial support during preparation of this manuscript, and we thank Kia Gray, MPH, for project management. We also acknowledge (1) the medical and nursing staff of Eisenhower Medical Center for their assistance in developing the precourse and postcourse tests and (2) the Annenberg Center staff for contributions regarding the development and administration of the actual educational activities described herein.

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