Lab Safety and Bioterrorism Readiness Curricula Using Active Learning and Hands-on Strategies as Continuing Education for Medical Technologists

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Frequent reports of laboratory- (and hospital-) acquired infection suggest a deficiency in safety training or lack of compliance. To assess the need for continuing education (CE) addressing this problem, an original education needs assessment survey was designed and administered to medical technologists (med-techs) in Northeast Ohio. Survey results were used to design a learner-centered training curriculum (for example, Lab Safety and Bioterrorism Readiness trainings) that engaged med-techs in active learning, integrative peer-to-peer teaching, and hands-on exercises in order to improve microbiology safety knowledge and associated laboratory techniques. The Lab Safety training was delivered six times and the Bioterrorism Readiness training was delivered five times. Pre/posttesting revealed significant gains in knowledge and techniques specific to laboratory safety, security, risk assessment, and bioterrorism readiness amongst the majority of med-techs completing the CE trainings. The majority of participants felt that the hands-on exercises met their needs and that their personal laboratory practices would change as a result of the training course, as measured by attitudinal surveys. We conclude that active learning techniques and peer education significantly enhance microbiology learning amongst participating med-techs.

INTRODUCTION

The clinical laboratory scientist, or medical technologist (med-tech), is an example of a science-trained professional requiring continuing education that incorporates new information and skills. Continuing education (CE) is essential to remain competent and proficient in the workplace, and may be required by employers or for license/certification renewal. For med-techs, CE may include education and training relevant to job-specific duties, employer-mandated topics (e.g., sexual harassment), and those required by regulatory and accrediting agencies (2). Although no uniform CE requirements are prescribed by the various accrediting agencies, typical continuing education requirements include courses in safety, blood banking, chemistry, hematology, microbiology and extra courses within the area of specialization; up to 15 continuing education hours may be required every year. In other words, med-techs must continue to learn throughout their career since “up-to-date” knowledge is essential for providing a high standard of care as a member of a health care team.

Unlike the incentives of typical undergraduate science majors, the motivation of adult learners is more intrinsically derived. Adult learners seek justification for the time and financial costs incurred by (continuing) education (11). The cost-benefit analysis seems to intrinsically weigh the pedagogical style of continuing education in addition to other factors. Thus, a successful continuing professional education curriculum must address learning outcomes with high impact for career success, and emphasize the value of the adult student’s time and role in a shared teaching and learning environment (20). We therefore suggest that effective curricula that supports the continuing education goals of the medical technologist will not only be content driven, but will be transformative by engaging med-techs in on-the-job analytical thinking situations that require the integration of new scientific content. In other words, by sharing personal experiences, the adult student serves as a peer-to-peer learner and teacher with other med-techs. In this way, students foster the integration of new knowledge and best practices into their theoretical and conceptual frameworks as they learn together.

The need for sound safety curricula that are pedagogically-designed for the med-tech learner is evidenced in the frequently-reported, laboratory-acquired (13) and research-acquired (15, 17) infections, suggesting that laboratory workers fail to practice the safest laboratory methods. In fact, reports of hospital-acquired H1N1 influenza infections in healthcare workers (14) suggest that hospital employees, in general, are ill-prepared in the practice of standard microbiological techniques (i.e., universal precautions). Furthermore, evidence suggesting the need for biopreparedness training comes from after-action reports resulting from the anthrax attacks of 2001, where med-techs who assisted in the testing of thousands of “white powders” and patient specimens were deemed to be “unprepared to respond appropriately” (22).

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Society for Microbiology (ASM), the Centers for Disease Control and Prevention (CDC), and the Association of Public Health Laboratories (APHL) recommended substantial bioterrorism readiness training and enhanced laboratory safety practices to be provided as continuing education to med-techs. To this end, the Bioterrorism Training and Curriculum Development program was established as part of the Public Health Security and Bioterrorism Response Act of 2002 (7). However, we have found no curricular materials, thus far, that have been both pedagogically-designed for the med-tech learner and specifically assessed for their effectiveness. We, therefore, developed curricula for med-tech professionals, based on perceived need; using the content recommended by the CDC, ASM and APHL, but, pedagogically-designed for the adult, med-tech learner. The evaluation and assessment of these curricula are presented in this study.

To develop a successful adult curriculum, active learning strategies (e.g., problem-based learning, inquiry-based laboratories, hands-on investigations, interrupted case studies (25), and concept inventories (18)) are used in place of the traditional Socratic method or “the lecture” so as to engage learners in scientific discourse and sharing of successful on-the-job strategies. Ultimately, the curriculum can be developed to include even more transformative learning strategies (19). The proposed pedagogical methodologies span the cognitive learning outcomes predicted by Bloom (4), Paul and Elder (21), and Domin (9), as similarly shown to extend undergraduate student learning successes. Our pedagogies were integrated into “Lab Safety” and “Bioterrorism Readiness” curricula designed for adult learners and specifically integrating adult learners as peer-educators. Peer-educators offered practical experience, providing case studies and best practices, for example. The “Lab Safety” workshop was taught on six separate occasions and the “Bioterrorism Readiness” workshop was taught five times. This report presents the assessment of these curricula through pre/post testing and attitudinal surveys.

MATERIAL & METHODS

Needs assessment survey

In order to appropriately design CE curricula, we first assessed the educational needs of employees from 29 hospitals in the 13-county Northeast Central Ohio (NECO) region, using an original survey instrument. Survey questions were designed to evaluate opinions of hospital personnel regarding (1) employee education needs, (2) necessity of continuing education credit, (3) preferences for education and training delivery, (4) barriers to training, (5) existing educational resources, and (6) other information to define educational preferences and specific hospital demographics. Survey question formats included Likert scale-coded responses, binary (yes/no) options, and open-ended responses. The Likert scale was set with six possible responses: Very Strong Need (value = 5), Strong Need (value = 4), Moderate Need (value = 3), Little Need (value = 2), No Need (value = 1), and Not Applicable (as a checkbox). The survey was delivered electronically using the internet-based Survey Monkey™ (Portland, OR) service provider over a two-week time period.

Curricular design, development and facilitation

Curricular materials were designed and developed in response to needs determined from the assessment survey. Learning objectives reflected specific content as recommended by the National Institutes of Health (NIH), the Centers for Disease Control and Prevention (CDC), the American Society for Microbiology (ASM), and the Association of Public Health Laboratories (APHL). Laboratory safety, security, risk assessment, and emergency response planning curricula were guided by the NIH advisory document, Biosafety in Microbiology and Biomedical Laboratories, 5th edition (6). The following curriculum modules were designed and developed in accordance with guidance documents provided online by the CDC (http://www.bt.cdc.gov) and the ASM (http://www.asmusa.org/pcsrc/biodetection.htm): (1) handling of hazardous microorganisms including select agents, and (2) methods for the recognition, ruling out and referral of select agents. Additional content was provided according to Klietmann and Ruoff, with modifications (16). Curricular components were designed to engage laboratory personnel in higher-order thinking exercises (18, 19) via small group didactic interactions guided by (1) content materials presented by PowerPoint® (Redmond, WA) software, (2) active learning exercises, and (3) hands-on laboratory exercises. PowerPoint slides and ancillary materials were presented and provided to students, however, these were used as reference material to drive conversations relating work practice and new guidelines for laboratory safety and microbiology methods, rather than for a more traditional undergraduate lecture-based didactic (1, 8). Examples of learner-centered training activities included: a guided risk assessment exercise where learners made drawings (an expressive representation) of their own lab space identifying hazards. Subsequent peer-to-peer discussions resulted in the rank ordering of risks based on health hazard. Instructor-directed, think-group-share activities then led to mitigation strategy design with virtual implementation. These activities specifically addressed learning objectives to (1) understand and practice laboratory risk assessment, and (2) apply evidence-based hazard mitigation strategies, respectively. Problem- and case-based exercises were used as integrative active learning strategies to direct emergency response planning. These exercises specifically addressed learning objectives to (1) predict lab emergencies, and (2) design effective emergency responses. One example of this process was to present a case to the learners where a med-tech working with multidrug-resistant Mycobacterium tuberculosis has a heart attack. Learner discussion rightly balanced the health of the med-tech with decontamination issues. Skills-based curricula were designed and developed to teach BSL-2 practices and procedures (e.g., correct use
of personal protective equipment and biosafety cabinets, decontamination strategies, and molecular microbiology (rt-PCR and Biolog<sup>®</sup>) techniques with modifications (3)). The skills practiced met learning objectives by addressing correct use of personal protective equipment and decontamination protocols. By example, spills of highly contagious lab specimens were simulated so as to provide opportunities for med-tech learners to collaborate on best practices.

**Assessment and evaluation**

Two original 20-question assessment instruments were designed to test the efficacy of each of the following curricular components: (1) Lab Safety, Security, and Risk Assessment; and (2) Bioterrorism Readiness. Each assessment was administered to laboratory personnel — once prior to participation in the training program (preassessment) and once following completion of the training program (postassessment). Assessment questions were presented to laboratory personnel in a multiple-choice format. Six of the twenty questions were used as content measures; these questions had unequivocal answers that were addressed throughout the duration of curriculum facilitation. A sample question from the Lab Safety, Security, and Risk Assessment curriculum assessment was: “The typical contact time for most lab surface decontamination is? a. 2 min, b. 5 min, c. 10 min, d. 15 min, e. 30 min.” A sample question from the Bioterrorism Readiness curriculum assessment was: “Which of the following is NOT considered to be a select agent? a. Ebola virus, b. Yersinia pestis, c. methicillin-resistant Staphylococcus aureus, d. tetrodotoxin, e. smallpox virus.” The frequency of correct responses to each preassessment was compared to the frequency of correct responses to the corresponding postassessment for each curriculum section: Lab Safety, Security, and Risk Assessment, and Bioterrorism Readiness. Pre- and postassessment responses to the six content questions were evaluated independently to measure understanding of specific content. Statistical analyses were performed using GraphPad InStat (San Diego, CA). Statistical significance was set a priori at \( p \leq 0.05 \).

Attitudes towards the curriculum and facilitation process were assessed amongst laboratory personnel. Learners completed a post-course evaluation which measured attitudes related to personal laboratory practices as well as various logistical aspects of the course. Two specific questions asked if the learner would change work practices as a result of their training and if the hands-on training met the participant’s training needs. Evaluation questions were formatted into Likert-scale responses: Strongly Agree (value = 5), Agree (value = 4), Neutral (value = 3), Disagree (value = 2), Strongly Disagree (value = 1). Data are reported as the geometric mean ± the standard deviation about the mean. Statistical analyses were performed and graphical representations of the data were generated using GraphPad InStat (San Diego, CA) and GraphPad Prism (San Diego, CA), respectively. Statistical significance was set a priori at \( p \leq 0.05 \).

**RESULTS**

**Needs assessment survey**

Data from the Needs Assessment Survey directed our learner-centered curricular design and face-to-face, hands-on delivery. In our survey of hospital laboratory personnel, over half desired continuing education and training as observed from the data collected through the on-line Survey Monkey™ service provider from June 27 to July 11, 2007 (Table 1). A total of 77 hospital participants completed the survey, not always answering all questions. Seventy-three hospital participants responded to the laboratory-specific questions of the survey. While all respondents indicated that they had access to the internet (90% at home or work and 10% at work only) and were able to participate in on-line activities, the top three preferred education and training methods were (1) traditional classroom instruction, (2) group or team trainings, and (3) desktop videoconferencing. The least preferred methods were asynchronous, internet-based and CD-ROM/ DVD-based techniques. Absence from work and curriculum cost were the two most frequently reported impediments to education and training opportunities (100% indicating Strongly Agree or Agree). Travel, with associated costs, was also a reported barrier (50% indicating Strongly Agree or Agree). Approximately 59% of the respondents reported dissatisfaction with education and training resources at their hospital; thirty-six percent of the students responded Strongly Agree or Agree, indicating that the needed education and training were not available.

**Lab safety, security and risk assessment curriculum efficacy**

Significant improvement in knowledge was observed in lab personnel following completion of lab safety, security and risk assessment curriculum (Table 2). The data demonstrate statistically significant improvement in the knowledge base of the learners \( (p < 0.001) \) in each of the content measures. Tracking the responses of six specific questions indicates that learning outcomes were being met, even though 100% of students did not retain the content to correctly respond on the test instrument. Posttest scores exceeded pretest scores in all content measure areas. All increases were statistically significant.

**Bioterrorism readiness curriculum efficacy**

Significant improvement in knowledge was also observed in lab personnel following completion of the bioterrorism readiness curriculum (Table 3). Total test score means for pre- and posttraining suggest that the curriculum was successful \( (p < 0.001) \). Posttest scores exceeded pretest scores in all content measure areas. Significant increases in content knowledge were observed in all content measures except aspects of biosecurity.
### TABLE 1.
Results of hospital needs and gaps survey (laboratory responses)

<table>
<thead>
<tr>
<th>Educational/Training Need</th>
<th>% Positive Response(^\text{a})</th>
<th>Most Frequent Response (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSL-2 Practices and Procedures</td>
<td>72.6</td>
<td>strong need (34.2)</td>
</tr>
<tr>
<td>Biosecurity</td>
<td>75.3</td>
<td>moderate need (34.2)</td>
</tr>
<tr>
<td>Clinical Lab Safety and Risk Assessment</td>
<td>63.0</td>
<td>moderate need (32.9)</td>
</tr>
<tr>
<td>Decontamination Strategies</td>
<td>74.0</td>
<td>moderate need (32.9)</td>
</tr>
<tr>
<td>Emergency Response Planning</td>
<td>76.7</td>
<td>moderate need (32.9)</td>
</tr>
<tr>
<td>Handling High Hazard Agents</td>
<td>82.2</td>
<td>moderate need (45.2)</td>
</tr>
<tr>
<td>Lab Readiness for Bioterrorism</td>
<td>74.0</td>
<td>strong need (34.2)</td>
</tr>
<tr>
<td>Procedures for Rule-out of Select Agents</td>
<td>67.1</td>
<td>strong need (28.8)</td>
</tr>
<tr>
<td>Standard and Select Agent Microbiology Techniques</td>
<td>69.9</td>
<td>moderate need (35.6)</td>
</tr>
</tbody>
</table>

\(^{a}\) the sum of moderate, strong, and very strong need responses

### TABLE 2.
Results of six questions used to measure learning during the laboratory safety, security, and risk assessment course

<table>
<thead>
<tr>
<th>Content Measure</th>
<th>% Students Meeting</th>
<th>(p) value(^{b})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
</tr>
<tr>
<td>Most common cause of laboratory acquired infection:</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>Example of secondary containment:</td>
<td>75</td>
<td>80</td>
</tr>
<tr>
<td>Contact time for most lab surface decontamination:</td>
<td>55</td>
<td>75</td>
</tr>
<tr>
<td>Secondary barriers to protect workers and environment:</td>
<td>75</td>
<td>90</td>
</tr>
<tr>
<td>Aerosol induced laboratory acquired infection:</td>
<td>60</td>
<td>85</td>
</tr>
<tr>
<td>Biosafety cabinet cleaning:</td>
<td>70</td>
<td>85</td>
</tr>
<tr>
<td>Total Test Score Mean</td>
<td>65±11.0</td>
<td>82±7.9</td>
</tr>
</tbody>
</table>

\(^{a}\) percentage of students providing correct responses to the content measure

\(^{b}\) statistical differences between group means as determined by Chi-square test (one-tailed), \(n=25\)

\(^{c}\) statistical differences between group means as determined by paired t test (one-tailed), \(n=25\)

### TABLE 3.
Results of six questions used to measure learning during the laboratory safety, security, and risk assessment course

<table>
<thead>
<tr>
<th>Content Measure</th>
<th>% Students Meeting</th>
<th>(p) value(^{a})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
</tr>
<tr>
<td>Most common cause of laboratory acquired infection:</td>
<td>51</td>
<td>89</td>
</tr>
<tr>
<td>Identification of select agents:</td>
<td>70</td>
<td>97</td>
</tr>
<tr>
<td>Use of biosafety cabinet:</td>
<td>89</td>
<td>100</td>
</tr>
<tr>
<td>Aspects of biosecurity:</td>
<td>73</td>
<td>84</td>
</tr>
<tr>
<td>Goals of emergency response planning:</td>
<td>54</td>
<td>81</td>
</tr>
<tr>
<td>Role of the laboratory response network:</td>
<td>38</td>
<td>78</td>
</tr>
<tr>
<td>Laboratory-acquired infection:</td>
<td>57</td>
<td>70</td>
</tr>
<tr>
<td>Total Test Score Mean</td>
<td>57±11.9</td>
<td>67±10.2</td>
</tr>
</tbody>
</table>

\(^{a}\) percentage of students providing correct responses to the content measure

\(^{b}\) statistical differences between group means as determined by Chi-square test (one-tailed), \(n=37\)

\(^{c}\) statistical differences between group means as determined by paired t test (one-tailed), \(n=37\)
Learner attitudes

The evaluation instrument administered to each student at the completion of each workshop was analyzed to assess learner satisfaction and training efficacy. The Likert scale for each response ranged from Strongly Agree (value = 5) to Strongly Disagree (value = 1). The numbers of responses to the two attitude questions reflecting workshop impact are presented in Figs. 1 and 2, respectively. To the question, "The hands-on exercises were appropriate and met my training needs," a mean response of 4.63 ± 0.50 was observed following completion of the lab safety workshop, and a mean of 4.27 ± 0.78 was observed following completion of the bioterrorism readiness workshop. To the second question, "I will change my lab practices and procedures based on what I learned during the workshop," a mean response of 4.84 ± 0.37 was observed after the lab safety workshop, and a mean response of 4.42 ± 0.76 was observed after the bioterrorism readiness workshop.

DISCUSSION

Hospital laboratory personnel demonstrate a strong desire for additional education and training, especially trainings with curricula directed toward select agent identification and bioterrorism readiness as evidenced by the survey data (Table 1). These data suggest that the potential contact with select agents (whether due to regular working conditions or a bioterrorism-related event) remains a powerful motivator for medical technologists to seek the continuing education necessary to remain prepared and proficient in a changing workplace. Additionally, survey data reveal a strong need for regular reviews of BSL-2 practices and procedures among hospital personnel. It may be that recent reports of laboratory-acquired infections (LAIs) (13), especially H1N1 (14), and of research-acquired infections (15, 17), may spur motivation for an update of BSL-2 practices and procedures. In addition to the continuing education safety training requirement, acquisition of LAIs may generate interest in laboratory safety trainings in the same way as the potential of bioterrorist attacks generally spurs demand for bioterrorism readiness trainings.

Trainings for laboratory personnel must meet their personal needs as adult learners. Based on the results from this study, current laboratory personnel prefer traditional learning methods in combination with active learning methods. Group interaction is also preferred. By engaging laboratory personnel in this pedagogical method, they feel valued as they share their personal experiences with others, serving as “peer-to-peer” learners and teachers. Learners work collaboratively, as they do in the laboratory, to solve rigorous problems relevant to their profession. They practice critical thinking skills that can be applied in the workplace. In this manner of instruction, course instructors aid students in the synthesis (or construction) of old and new concepts. This “constructivist” approach to science learning has been implemented successfully in K-12 settings for several decades (24). Learning preferences are individual and generational and may change as the composition of the workforce changes. Age and technological proficiency may influence preferences for web-based learning (i.e., webinars, web videos, on-line learning games, e-courses, on-line self-assessments). It is imperative that laboratory trainers and curriculum developers follow trends in pedagogy and workforce development on a regular basis. Yearly needs assessment surveys are recommended to remain aware of learning preferences of laboratory personnel. In this way, training programs can best meet the needs of the desired audience.

Interestingly, a relationship was observed between perceived need for training and performance on assessments. The higher the perceived need for training, the greater was the gain in knowledge on the assessment from pre- to posttest (Tables 2 and 3). This was observed with the following content measures specifically: decontamination, emergency response planning, and identification of select agents. Additionally, there was a significant increase in overall test scores for both the
lab safety, security and risk assessment and bioterrorism readiness trainings (Tables 2 and 3) reflecting course efficacy. This parallels other reports that active learning and hands-on activities increase success in learning over traditional "lecture-based" teaching styles (10, 23).

The majority of med-techs reported benefits from the hands-on training. The majority of learners (88.9%) felt that the hands-on training was appropriate and met their needs (responded Strongly Agree or Agree). This was observed in both the lab safety and bioterrorism readiness workshops (Fig. 1). Not only does test performance improve when hands-on trainings are included, but the participants report that this method of teaching was effective for them as adult learners. Most participants also noted that they would change their laboratory practices as a result of their training (Fig. 2). This suggests that the adult learner-centered trainings, based on content recommendations by the CDC, ASM and APHL, and delivered as active learning, peer-to-peer guidance and hands-on laboratory exercises, were effective curricula for med-techs. Indeed, other reports support our findings and strongly recommend use of current information when bioterrorism preparedness is the course topic (5, 12).

Based on the results of this study, we recommend continual training for laboratory personnel in order to maintain the highest level of scientific knowledge and laboratory techniques. Trainings should integrate active learning experiences and hands-on laboratory exercises, as well as traditional learning methods, in order to meet the needs of adult learners. Importantly, curricula should be routinely assessed for efficacy and regular needs assessment surveys of laboratory personnel are suggested to meet the needs of the changing workforce.

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REFERENCES


