Distance Learning and Simulation Technologies to Support Bioterrorism Preparedness Education

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Abstract - The primary objective of the Idaho Bioterrorism Awareness and Preparedness Program (IBAPP) is to administer and deliver continuing-education classes relevant to bioterrorism preparedness to healthcare professionals in rural Idaho. This program will address the gaps and deficiencies in current curricula identified through our in-depth needs assessment data. In Idaho, the current training methodologies in bioterrorism preparedness are limited mostly to face-to-face traditional classroom format. The IBAPP program will expand this traditional delivery mode so as to reach as many healthcare workers and emergency response professionals as possible. To achieve this we are designing a mixed mode of training delivery that will complement, enhance, and in some cases replace face-to-face classes. Our broader spectrum of delivery mechanisms will include virtual tabletop exercises, online and off-line simulations, and webcasting of various types namely interactive, non-interactive, on-demand, and live. This paper provides a snapshot of the different underlying learning technologies of the IBAPP program. We also outline our evaluation plan to determine the effectiveness of our delivery mechanisms and teaching methodologies.

Index Terms – distance-learning, multiplayer environments, medical simulations, bioterrorism preparedness.

I. INTRODUCTION

The Institute of Rural Health at Idaho State University (IRH-ISU) has received a grant, wholly funded by the U.S. Health Resources and Services Administration (HRSA) to provide bioterrorism and emergency preparedness training to healthcare providers statewide. The program's objective is to enhance the knowledge and skills of healthcare professionals to meet the public health preparedness and emergency response demands resulting from acts of bioterrorism and other incidents. Training will assist and facilitate an increasing understanding of healthcare needs and response measures as they relate to the following:

- recognizing indicators of terrorist events;
- meeting the acute healthcare needs of patients and victims, including pediatric or other vulnerable populations, and those with mental health needs;
- participating in coordinated, multidisciplinary responses to terror events or other health emergencies; and
- alerting, rapidly and effectively, the public health system of such an event at the community, state, or federal levels.

To determine and identify gaps and vulnerabilities in emergency preparedness and response measures, we conducted a needs assessment of bioterrorism training initiatives for healthcare and emergency response professionals in Idaho. Using this data, we are building mechanisms for delivering appropriate continuing-education training programs to a broad spectrum of stakeholders. These initiatives will provide the necessary knowledge and skills to address deficiencies in both the identification of the events as well as the delivery of bioterrorism-related public health response training.

Another issue that had to be considered was the delivery of healthcare in rural areas. Rural communities face severe shortages in critical healthcare worker categories, challenging our ability to meet surge capacity requirements for emergency events. Idaho has a shortage of mental health providers and all of the state's counties have been federally designated as mental health professional shortage areas. More than 75% of the state faces a shortage of primary care and dental health professionals and we have one of the lowest number of physicians per capita (145 per 100,000) in the country [4]. In addition, the elderly, children, and minorities are severely underserved.

Currently, first responders are the focus of bioterror-related training. However, we need to ensure that all healthcare workers are trained to recognize and respond to all types of events. A survey [6] indicates that 84% of the workforce need additional incident command training, 80% need HazMat and 78% need DeCon training. Training opportunities in bioterrorism preparedness are largely limited to face-to-face courses.

In terms of connectivity, Idaho is dominantly a rural state with poor transportation facilities. Carrying out a GIS exercise, one finds that more than 50% of the non-metropolitan population of Idaho lives at least 66 miles (straight-line distance) from the nearest tertiary healthcare facilities—25% live at least 95 miles away and 10% live 106 miles away from these facilities [1].

The telecommunication capabilities in rural communities are constrained by only modest bandwidth availability. Very few have videoconferencing capabilities. Given these kinds of limitations we need to expand the delivery mode options to reach out to as many healthcare workers as possible. This leaves us with the option of having to adapt to a low infrastructure environment. Table 1 presents our estimate of the yearly number of courses per delivery type that our program will now be able to sustain.

Table 1 Course delivery mechanisms and yearly frequency

	Delivery mechanisms (a single course can be delivered by more than one mechanism)	Courses using mechanism/Year
1	Face-to-Face	20
2	Face-to-Face with integrated medical simulators	5
3	Courses with integrated online threaded discussion list support	40
4	Online courses streamlined for low bandwidth (56 kbps) access	10
5	Online courses with interactive simulations of medical devices and medical emergency procedures	20
6	Courses integrated with webconferencing support	5
7	Courses integrated with live and archived webcasting support	10
8	Courses involving Incident Command Training simulator	5
9	Courses involving massive multiplayer virtual training environment	5
10	Virtual Grand Rounds	3

II. Methodology

Our intent is to focus on improving the process of delivering the material through distance-learning methodologies coupled with computer simulations whenever appropriate. This two-pronged approach is likely to result in more effective learning and give rise to better opportunities for performance evaluations.

While distance-learning constitutes the main thrust of our efforts, we are aware of the importance of using this approach for appropriate contexts. Published literature indicates both positive and negative aspects of the application of technology to distance learning. Among the positive aspects are that online courses and distance education provide greater flexibility and student convenience, improved access/interaction with the instructor, better grades, and a more positive overall learning experience [12]. In addition, many online collaborative learning environments seem to better engage students in the learning process. Distance learning has been especially successful for the nursing students at Idaho State University given the rural nature of the state. Fifty per cent of all undergraduate and 100% of all the graduate nursing students are taught via distance-learning through web-based or televised courses. We also kept in mind the documented negative aspects of distance learning [12] described in terms of reduction in face-to-face interaction, concerns over technology and logistics, increased student workload, and increased costs to the student. We thus adopted a blended approach as far as course content delivery mechanisms are concerned. It is thus clear early on that our aim is not to replace face-to-face learning in classroom situations but to complement this delivery mechanism using computing technologies. Computer based learning also provide opportunities not only to broaden access to course content but also to present this content in ways that fit various learning styles.

Computer-assisted simulation training is understood to be valuable in many mission-critical industries and the military, where it has been shown that large, multi-user distributed simulations can help people train to work together effectively [9]. However, in the civilian emergency response domain, there is little documented evidence of its proven efficacy. One of the intended outcomes of the IBAPP program is to provide such evidence. In other domains, evidence has been documented regarding how computer simulations evoke emotions and tensions similar to real life [5]. This suggests that simulations can be engaging. More importantly, there is a sustained decrease in resistance to acknowledge the positive impact of such environments on learning especially as their quality to cost ratio goes up. Since recent technologies have facilitated the creation of simulations that are able be integrated easily with web content, we see a tremendous opportunity here to improve the pedagogic quality of our online courses.

Adding interactive content that addresses identified needs on the scale that is planned for IBAPP requires a close partnership with established industry solution providers involved in distance learning and the development of computer based simulations. In this spirit, we partnered with industry specialists such as SimMedical™, Laerdal™, Equipment Simulations LLC™, Elluminate Live™, and Linden Lab™ either to incorporate their relevant courses that use simulators or to use their technology to support our own relevant courses. Following is a summary of the main objectives for our methodology and a description of our strategy for developing the underlying information technology infrastructure.

A. Main objectives for our methodology

1. To use secure, commercial, off-the-shelf, web-based information dissemination services and learning management system services to maximize infrastructure robustness, minimize development time, and increase curriculum sustainability.
2. To accelerate the integration of off-the-shelf, state-of-the-art web-based collaborative applications and

simulation technologies to augment the pedagogical value of our proposed courses and tabletop exercises.

3. To develop a distance-learning curriculum that supports self-directed, self-paced, exploratory learning through interactive simulations and support social learning through technologies ranging from threaded discussion to webconferencing.
4. To augment face-to-face courses with interactive learning content.
5. To monitor student progress through the capture of data from quizzes and student interactions with simulated devices and in simulated environments.
6. To avoid duplication of course content creation and to reuse and readapt as far as possible courses produced by previous HRSA and CDC grantees.

B. Strategy for underlying information technology (IT) infrastructure

Our overriding strategy to implement the technical aspects of this program is to utilize industry-proven services rather than develop our own [10]. This is practical for a number of reasons. First, (1) it is more likely that the infrastructure for this project will be robust and maintained regularly. All of our service and software providers are firmly established in their own niche markets. Based on our past experiences, such an approach minimizes cost in the long run without sacrificing quality and sustainability. Second, (2) this approach allows project personnel to focus on pedagogical aspects of the curriculum, its delivery and evaluation, thereby providing better opportunities for enhancing course quality. Third, (3) in our experience, outsourcing services to industry specialists also reduces stress on academic staff during service downtimes partly because the service specialists are typically in a better position than academics to troubleshoot and bring their systems back up again at short notice. Fourth, (4) in many cases, outsourcing IT infrastructural services also comes with the benefit of having access to the latest versions of the services without having to invest in expensive in-house upgrade processes. Fifth, (5) most outsourced IT infrastructures have a well-established, multi-level support and user training system that cannot be replicated in-house without significant additional investments in personnel and equipment.

On the flip side, the selection of service providers is not an easy process and needs to be led by experienced in-house staff who are able to see through industry marketing strategies, are in sync with existing and emerging technologies, and have the skill to do hands-on evaluations of the outsourced services. A few of the important selection parameters that need not be missed are, for example, the frequency of service downtime, the sophistication of the security and privacy infrastructure, and data backup guarantees. The bottom line is that we are currently in the midst of an evolution towards what has been dubbed as “Web 2.0.” where increasingly the tendency will be to outsource complex applications which will run on the secure servers of niche service providers in their own locations. It is important to keep in mind that this approach can backfire if an extensive evaluation of the services by in-house specialists is not carried out.

III DISTANCE-LEARNING TECHNOLOGIES

We have studied the effectiveness of commercial communication services to support both synchronous and asynchronous forms of interaction within the context of delivered course content. We are working in partnership with the Institute of Emergency Management ISU Boise to leverage their existing Learning Management System—the Idaho Preparedness Learning Management System (IPLMS)—which is hosted and managed by Meridian Knowledge Solutions, Inc. At the level of text-based communication, the IPLMS can easily be configured to support searchable threaded-discussion lists for all the courses we provide. Discussion lists have proven very effective as a social-learning medium where instructors can interact with students and students can support each other in their own time.

The IRH routinely uses high-end Tandberg-based teleconferencing systems for weekly interactions between partners across Idaho and less frequently for Virtual Grand Rounds. However, this mode of teleconferencing requires significant investments in equipment and bandwidth access. In order to provide teleconferencing opportunities for students from whatever bandwidth they have access to (minimum 28 kbps) and using minimum grade PC-based equipment with a low-cost noise cancellation microphone (~$20) and up-web camera (~$19), we have expanded our spectrum of teleconferencing technologies to include web-based conferencing tools.

A number of IBAPP courses will involve live lectures and webconferencing facilities to sustain two-way interactions. All the sessions will be recorded and warehoused forming an archive accessible at the convenience of the student. We evaluated a number of web-conferencing solutions, including Macromedia Breeze™, WebEx™, Microsoft NetMeeting™, and Elluminate Live™. The selection criteria included their ability to adapt gracefully to a range of bandwidths starting from 28 kbps and up, their pricing schemes, their user interfaces, their ease of integration with Learning Management Systems, their ability to hold under heavy loads up to 500 concurrent users, and the complexity of the required workflow for recording and archiving webconferencing sessions. Most webconferencing applications also provide desktop- and application-sharing functionalities, integrated polling, and quiz management applications. In addition to providing courses where instructors will interact with students directly, the courses that also contain PC-based simulations that run on the more powerful machines of the instructors can now also be accessed by students with typically lower-end hardware from their homes. Our evaluation led us to select Elluminate Live™ (Figure 1) as the most suitable platform that fits our needs.

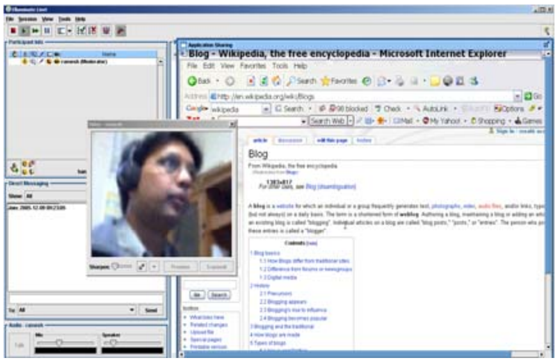

Figure 1 Elluminate Live™ webconferencing application with integrated desktop and application sharing functionality.

IV. Simulation Technologies

Our attraction to simulations using virtual environments e.g. online simulations of medical devices and interactive real world props—e.g., interactive manikins or body parts —as a learning platform is that they provide opportunities for problem-based learning [3] and experiential learning [7]. We provide a few snapshots to sketch a picture of our vision in this regard. As the project progresses, the details will surely change to adapt to the current status of our knowledge.

A. Online device simulations for training and competency assessment

Our blended approach includes distance learning with web-based applications that simulate medical devices used in medical emergencies. An example of the later is described in Figure 2. It illustrates an interactive Macromedia Flash-based online simulation of the Nihon-Kohden bedside monitor simulator designed by HealthStream, Inc. and built by Equipment Simulations LLC. This simulator can be instrumented to capture student interaction data for instructor-tailored scenarios thereby providing better opportunities not only for providing point-of-need training for relevant healthcare staff but also for evaluating their competency in using the devices.

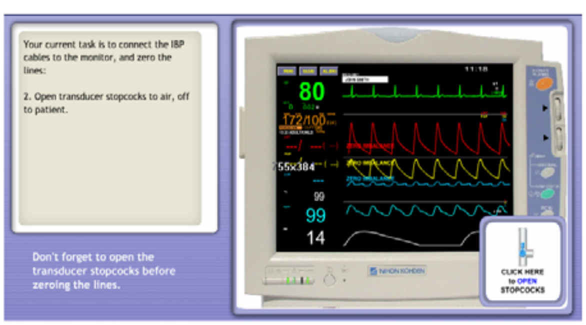

Figure 2 Interactive online simulation of medical device

B. Face–to-face training with interactive manikins

Many face-to-face IBAPP courses will benefit from the integration of medical simulators such as interactive manikins or body parts. The ability to identify the effects of abnormal or normal skin reactions to biological agent exposure is a critical competency in bioterrorism awareness. An interactive course can include simulations to help students acquire this skill. For example, select face-to-face courses will integrate interactive manikins and body-part simulations that replicate the effects of toxic agents/gases on the skin and on the central nervous system by producing realistic frothy, bodily fluids from tear ducts, nose, and mouth. Such an environment is likely to be more engaging and provide better opportunities for learning and working within teams.

We have selected the SimMan® manikin from Laerdal® to support our training efforts partly because it is already being used in a number of departments at ISU. SimMan® is a portable and advanced patient simulator for team training. It has realistic anatomy and clinical functionality and provides simulation-based education to challenge and test students' clinical and decision-making skills during realistic patient care scenarios. This advanced interactive manikin allows learners to practice the emergency treatment of patients (Figure 3).

Figure 3 An ISU nursing instructor demonstrating a medical procedure using the SimMan®

ISU has recently purchased the SimBaby® (Figure 4), a portable advanced interactive infant patient simulator for team training. Like the SimMan®, it has realistic anatomy and clinical functionality that enables simulation training.

Figure 4 SimBaby®

To address the increasingly important goal for clinicians, first responders, and educators to be able to recognize, diagnose, and treat the symptoms of bioterrorism attacks, we are procuring additional modules to augment the fidelity of the manikins so at to increase their effectiveness in bioterrorism preparedness training. For example, the Laerdal Simulated Smallpox Module Set® (Figure 5) provides opportunities for students to identify the effects of abnormal and normal skin reactions. The set also includes a blank deltoid pad for practice inoculation that can be adapted with many Laerdal manikins that use deltoid injection pads like the SimMan®. Another example is the Laerdal Simulated nuclear, biological and chemical training module that can replicate the effects of toxic gasses on the central nervous system by producing realistic, frothy, bodily fluids that emanate from tear ducts, mouth, and nose (Figure 6).

Figure 5 Smallpox module set®

Figure 6 Nuclear, biological, chemical training module

The ISU Nursing Department also uses the Virtual I.V.™ for training intravenous catheterization (Figure 7). In this simulator, 3D graphics provide visual realism, while a state-of-the-art force feedback device accurately simulates the sense of touch and on-screen virtual patients respond with bleeding, bruising, swelling, as well as other patho-physiological reactions. The instructors at ISU using this simulator claim that it is definitely one of the most effective tools in their teaching arsenal. One of the goals of IBAPP is to experimentally verify such claims.

Figure 7 Virtual I.V.™ at ISU Nursing Department

C. Virtualizing table-top exercises

A review of emergency responders' effectiveness indicates communication barriers and the lack of standard emergency management practices. For example, the U.S. Department of Homeland Security has recently encouraged the use of plain text instead of coded communications. This is because codes are agency specific and reduce the ability to communicate across agencies in an emergency. One of the solutions proposed to deal with such issues is to make it mandatory for emergency services to adopt a standardized approach to managing emergency situations, crises, and disasters. The Institute of Emergency Management at ISU Boise, an IBAPP partner, is already providing face-to-face National Incident Management System (NIMS), Incident Command System (ICS) and Hospital Emergency Incident Command System (HEICS) training to local agencies (Figure 8). One of the goals of IBAPP is not only to increase the reach of this training through distance-learning methodologies but also to increase their effectiveness through simulation technologies. We therefore plan to include applications that simulate emergencies and procedures to help develop decision-making skills.

Figure 8 IBAPP staff attending a face-to-face National Incident Management System training class

We are considering the use of the state-of-the-art Incident-Command Training simulator from Equipment Simulations LLC to virtualize relevant existing table-top exercises. This platform is ideal in cases where a detailed simulation of emergency equipment is required (Figure 9, Figure 10). This Incident-Command Training simulator is already being used by the Orange County (Orlando, FL) Fire Department.

Figure 9 Snapshot shows what a user sees when using the simulator

Figure 10 Firefighters using the simulation to practice ICS

We will be using a customizable massive online multiplayer environment, SecondLife™, to host virtual table-top exercises for the NIMS, ICS, and HEICS courses. This is because of its relatively low access cost and its ability to handle dynamic content seamlessly. This environment is ideal for a large number of participants to role play disaster scenarios that are designed rapidly by non-programmers using menu-driven tools (Figure 11, Figure 12). The SecondLife™ environment is poised to revolutionize the way virtual environments are created and used for training purposes.

The fidelity of a training environment often influences its effectiveness as a training tool. The SecondLife™ platform provides the necessary tools for content specialists to create realistic-looking indoor and outdoor environments. It also provides tools for the creation of realistic-looking avatars with realistic animation to represent the various professions involved in the training. All the stakeholders involved in a given scenario, including victims and bystanders, can therefore be easily integrated.

Figure 11 Realistic looking and interactive content

Figure 12 Collaborative building of props to be used in virtual exercises

Since the virtual environment allows object level scripting of behavior, it is possible not only to represent the look of devices in the virtual environment, but also to simulate how they work. For example foldable beds, interactive Patient Controlled Analgesia (PCA) pumps, ventilating machines, flyable helicopters (Figure 13), and virtual operating rooms, can be developed and used by the various professions involved in the training scenarios. The ability to program the behavior of virtual objects also facilitates the simulations of human-made (accidental/intentional) or natural disasters. For example, the platform allows the building of virtual bombs (Figure 14) that can be set to explode and lead to an unforeseen mass casualty event that will have to be dealt with by the personnel under training.

Figure 13 Hazmat and emergency response equipment

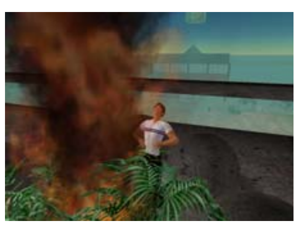

Figure 14 Potential for creating realistic engaging scenarios

It is well known that environmental conditions can play an important role in the success of rescue efforts. In that respect, SecondLife™ allows for the simulation of realistic climatic conditions ranging from heavy rain, snow, high wind conditions, to unstable terrain caused by earthquakes.

Two of the major underlying infrastructures that are required to enhance the degree of a virtual environment's realism are the physics engine and the particle engine. SecondLife™ is adequate on both counts. This environment also provides opportunities for streaming audio and video into and out of the virtual world. Figure 15 depicts a situation where members of the IRH team are testing the streaming of a talk by the Surgeon General rendered on a screen inside the virtual world.

The environment supports avatar behavior customizations as well. This is important if the avatars need to have access to a palette of gestures necessary for increasing the believability of interactions or scenarios (Figure 16).

Figure 15 Streaming of video into virtual environments

Figure 16 Effective role playing through controllable avatar gestures

The object level scripting environment of this platform enables data to be sent from local virtual world events to external applications. The communication facilities between events within the virtual environment and external applications can facilitate the integration of courses delivered inworld to an external learning-content management system. For example, data captured inside the virtual world can be sent automatically to an external database allowing such functionalities as automated student progress tracking.

V. Evaluation

The project evaluation will seek to answer several questions, including the program's impact and the extent to which the program has helped Idaho meet its preparedness goals. The measure of impact is determined by developing parameter profiles like numbers trained by discipline, contact hours, geographical regions, populations served, and special population needs addressed. All evaluation targets are tied to the objectives and activities of the program. The evaluation criteria for competencies will be related to the field in which the learner is employed. For each case, we will collect both qualitative and quantitative data on each objective and activity. We anticipate grouping variables by gender (male, female), location (rural, urban, or by the seven health districts), and profession (medicine, nursing, allied health, mental health, first responders, etc.). Our evaluation team will develop a comprehensive data analysis scheme for both qualitative and quantitative data.

Evaluation will be a structural part of each activity. For example, web usage will be generated by automated means. The indicators for the proposed activities reported in the previous sections will be aggregated into a master data collection plan. The entire team will collaborate on strategies for automatically obtaining as much data as possible.

Outcomes will be measured directly if there is a specific criterion (for example, a target value or %) or by comparison using multivariate generalized least square method (e.g., pre-post measures, comparing participants in this project with participants in other projects on course satisfaction). Other data analyses may be conducted based on years in field or anticipated years remaining in the field in an effort to understand the effect of bioterrorism preparedness training on retention. Additional data will be collected online as part of student registration. These data will include discipline and demographic data and professional quality of life data. Protocols can be viewed at telida.isu.edu [11].

The Advisory Board and other partners will receive evaluation data that will inform their advice and guidance. At the end of each project year, a summative evaluation report will be produced, compiling the lessons learned.

We will apply validated user interface evaluation methodologies to identify usability issues that may impact negatively the effectiveness of the proposed training solutions. The impact of training using instrumented interactive manikins and body parts, and massive multiplayer environments on teamwork and performance will be assessed by applying existing evaluation tools. These tools include the Behaviorally Anchored Rating Scales (BARS) [8], previously validated in aviation, and the NASA task load index [2] that can be used to measure workload experienced by a given participant during a given task in a wide range of situations ranging from interactions with real world devices to interactions within virtual environments.

VI. Conclusion

The IBAPP program is under way to enhance the healthcare workforces' ability to address the consequences of a bioterrorism attack, a large-scale natural disaster, or outbreak of infectious disease. There is a compelling need to have hospitals, emergency response personnel, and local healthcare officials trained to recognize a terrorist activity and to swiftly respond in a coordinated manner.

We are setting up an infrastructure that expands the delivery mode options and social learning to reach as many healthcare workers as possible. We have designed a mixed mode of training delivery that will enhance, complement, and in some cases replace face-to-face classes. Our broader spectrum of delivery mechanisms will include virtual tabletop exercises, online and off-line simulations, and webcasting.

With the blended approach described in this paper, we expect not only to increase the reach of bioterrorism and emergency training, but also to increase its effectiveness through simulation technologies.

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