

# Emerging Technologies in Education and Training: Applications for the Laboratory Animal Science Community

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## Abstract

This article examines several new and exciting communication technologies. Many of the technologies were developed by the entertainment industry; however, other industries are adopting and modifying them for their own needs. These new technologies allow people to collaborate across distance and time and to learn in simulated work contexts. The article explores the potential utility of these technologies for advancing laboratory animal care and use through better education and training. Descriptions include emerging technologies such as augmented reality and multi-user virtual environments, which offer new approaches with different capabilities. Augmented reality interfaces, characterized by the use of handheld computers to infuse the virtual world into the real one, result in deeply immersive simulations. In these simulations, users can access virtual resources and communicate with real and virtual participants. Multi-user virtual environments enable multiple participants to simultaneously access computer-based three-dimensional virtual spaces, called “worlds,” and to interact with digital tools. They allow for authentic experiences that promote collaboration, mentoring, and communication. Because individuals may learn or train differently, it is advantageous to combine the capabilities of these technologies and applications with more traditional methods to increase the number of students who are served by using current methods alone. The use of these technologies in animal care and use programs can create detailed training and education environments that allow students to learn the procedures more effectively, teachers to assess their progress more objectively, and researchers to gain insights into animal care.

**Key Words:** augmented reality; avatar; emerging technology; multi-user virtual environment (MUVE); pedagogy; radiofrequency identification (RFID); simulation; ubiquitous computing

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## Introduction

New and exciting communication technologies abound in many sectors including, most notably, the entertainment industry. However, many additional industries are currently discovering the capabilities these technologies afford and are implementing them according to their own needs. New technologies can link people who are separated in distance and time, can foster collaboration, and can allow for situated modeling and experiences (i.e., learning within the context in which the knowledge will be used). Such characteristics of these technologies encourage exploration for their utility in advancing laboratory animal care and use through better education and training. In this article, we present some ideas as to how new technologies can be used to support and improve laboratory animal care and use. We first identify some unmet needs in animal care and use and then discuss how emerging technologies might offer new approaches to serve those needs.

To avoid misinterpretation, it is important to first clarify our definitions. Laboratory animal care comprises husbandry, veterinary support, and regulatory oversight of vertebrate species maintained in confinement (vs. field studies of wild animals), whereas laboratory animal use pertains to research, testing, and educational situations that involve live vertebrates maintained in confinement for those purposes. Similarly, a subtle distinction applies to training versus education. Training involves developing a set of skills necessary for specific tasks or responsibilities and, therefore, is for immediate application and often of limited scope. By contrast, the purpose of education is to impart knowledge and understanding that will form the foundation for lifelong learning. As a result, education does not necessarily involve a defined timeline or purpose in order to determine its value. We also distinguish between current methods of training and education, which include face-to-face experiences (classrooms, conference presentations, and occasional lectures), text-based methods (newsletters, journals, and textbooks), and mediated experiences (videoconferences, television, and the Internet), versus methods using emerging technologies (augmented reality and multi-user virtual environments).

## Drivers for New Technologies and Barriers to Their Adoption

Drivers for change in how workers are educated and trained in a given field can be diverse. In this article we concentrate

on two: the rate of change of information within a given field and the demographics of the community. The faster a field of knowledge and opinion is evolving, the more it needs media and methods for education and training that can disseminate continuous and complex change quickly. Face-to-face presentations and the Internet are often relied upon to “get the word out” quickly, while text-based methods (e.g., journals) are utilized so that others can more thoroughly digest and assess the specifics. This type of field would be unlikely to use methods such as textbooks for education due to the time lag in publication. Conversely, in fields characterized by slow rates of change of content, additional approaches involving multiple versions of the same lessons are appropriate for education and training of a wider audience with diverse learning styles. Not all persons retain information to the same degree when taught or trained by the same method, so the use of multiple strategies for teaching and training a large audience increases the odds that new information and skills will be understood and used by all, especially when the relevant body of knowledge does not change quickly.

Likewise, the characteristics of a given community of workers and students can drive how education and training are best conducted. A community that is small and contained can rely on traditional methods of face-to-face education such as site-based classes and lectures. However, the prevalence of small and contained communities of workers and students is decreasing. Currently, many students are already full-time employees who wish to change career paths or upgrade their skills. Others cannot easily access training centers due to geographical or family responsibility reasons (Dede et al. 2003). For these workers and students, there is a strong need for other methods of education and training.

How do these drivers play out in the field of animal care and use today? The field of animal care has a slow rate of change in content, but the personnel make up a large, diverse, and disparate community. In contrast, advances that affect how laboratory animals may be used occur literally daily due to the pace and scale of biomedical research, and those researchers comprise multiple small communities. In support of this distinct difference, animal care training and education have typically used multiple conventional methods such as personal or group instruction, published material in print or on the web, and presentations at regional or national meetings, whereas animal use workers have typically relied on describing advances at scientific meetings, in peer-reviewed journals, and via personal or group instruction in the traditional apprenticeship mode.

But are these conventional approaches the best methods for educating and training laboratory animal workers? We believe that the training and education of animal use workers (i.e., scientists) currently relies on a well-proven approach that fits the rate of change of information and the size of the community. However, the same may not be true for training and educating animal care workers. To answer

the question above and to explore other avenues that involve the use of emerging technologies, it is first necessary to identify barriers to adopting or even creating new technologies for education and training in animal care.

One barrier is general resistance to change. Such resistance is sometimes justifiable in this field due to the necessity for comparing experimental data and reports across institutions and across time without confounding differences in animal husbandry or veterinary support. However, such resistance is illogical if it ignores potentially better ways to teach and train.

Another barrier is the relative insularity of the field. This characteristic results in part from individuals’ preference for avoiding public scrutiny and the institution’s failure to recruit managerial talent from other industries where different management tools may have been used. Consequently, there are few, if any, comparative studies to assess the costs and effectiveness of new education and training methods that differ from more conventional media in laboratory animal care. The absence of such studies makes animal care providers further unaware of possible alternatives. The good news is that many new technologies have already proven to be cost effective and useful in other industries and circumstances, and their applicability to laboratory animal care is potentially promising. The features and potential applications of some of these new technologies are contrasted to current methods and discussed in detail below.

## **The Evolving Relationship Between Education and Technology**

Traditionally, education and training have relied on face-to-face strategies, supplemented with print materials. These strategies have various obvious advantages that include quick feedback between teacher and students and learning conducted within a social framework. These characteristics have kept face-to-face methods as the gold standard in education; however, these methods are not without disadvantages. As discussed above, students must live near a school or training center and must be available during scheduled class times. In addition, students must have the personal initiative and desire to contribute in classes that are expected to be participatory. Students who do not fulfill one or more of these criteria are prevented from benefiting fully, if at all, from the experience.

Although the framework of education has relied on a relatively static structure, the methods of teaching (i.e., the pedagogy) have not been stagnant. Theories about how people learn (Bransford et al. 2002) are constantly evolving, with the historically “indispensable” lecture being supplemented with or even in some disciplines replaced by other methods such as problem-, inquiry-, and case-based methods, to name only a few. Some pedagogical strategies are associated strongly with one discipline or another (e.g., the case method for law and business), but most disciplines utilize a diverse set of strategies to best fit the learning goals.

Evolving pedagogies have also taken advantage of newly designed technologies. As one illustration, distance education has a long history of incorporating technology as it evolves in an effort to address problems in instruction and delivery (Dede et al. 2003). For example, in the early 1900s, distance education was characterized by a high attrition rate. Then in the 1920s, the “new” technology of the time—radio—was utilized as a vehicle to deliver information with a voice to those far away from traditional schools, with the hope of making the experience more engaging than simply delivering education via paper materials. Since then, although many education and training experiences have similarly adopted various technologies into their pedagogies, there are still those for whom technology equates to chalk and a blackboard!

## Emerging Technologies to Consider

Technology in education has evolved significantly from the use of radio to deliver distance education lectures. According to Dede (2002), technology interfaces that are or could be easily adapted for education may be classified into three main categories, with the latter two illustrating emerging technologies:

- *The familiar “world to the desktop” interface*, which provides access to distant experts and archives and enables collaborations, mentoring relationships, and virtual communities-of-practice;
- *Interfaces for “ubiquitous computing,”* in which portable wireless devices infuse virtual resources as people move through the real world; and
- *“Alice-in-Wonderland” multi-user virtual environments and interfaces*, in which participants’ avatars (defined as one’s representation in a virtual world) interact with each other, with computer-based agents, and with digital artifacts in virtual contexts.

We focus our discussion on the two latter examples provided above. Ubiquitous computing has already started to infuse our lives. Radiofrequency identification (RFID)<sup>1</sup> technology represents the most familiar and the most simple conceptual approach to ubiquitous computing because it has been adopted by many industries for inventory tracking and quality control needs, as well as automatically debiting drivers’ bank accounts as they drive through toll booths. In its most basic form, each RFID tag with its unique assigned code merely signals “this is me” to a transmitter/receiver, simply for identification purposes. Other immediate applications of so-called first-generation RFID tags include pharmaceutical inventory control to ensure quality as well as prevent theft and counterfeits (Ahlund 2005). More sophisticated, second-generation RFID tags can also relay real-

time information about their immediate environment and position, generating continuous data on temperature, lighting, location, motion, and many other parameters (Culler and Mulder 2004; Want 2004). These tags have begun to invade the public consciousness with commercials such as those from international shipping companies, which show how RFID labels can track the location of a package at any moment.

Somewhat related to RFID is “smart” clothing, which provides enhanced inputs and outputs on the wearer through multiple and complementary channels (Anon 2004; Service 2003). Sensor-laden garments are being developed to monitor vital signs and the locations of soldiers in combat or elderly people afflicted with dementia. The garments transmit the information wirelessly to receivers that are monitored by physicians or commanders. Others are creating powered clothing for personal entertainment and artistic expression purposes such as heat-activated light-emitting diodes on sleeves or hems.

Ubiquitous computing is being used for education and training to provide “augmented reality” interfaces, which are characterized by the use of handheld computers to infuse the virtual world onto the real one, resulting in deeply immersive simulations. In these simulations, users can access virtual resources and communicate with real and virtual participants. For example, researchers at the Massachusetts Institute of Technology have created a simulation that allows students to track an environmental contamination on the campus. Using location-aware handheld computers, students can explore the campus and at various locations access data, drill virtual wells, and interview virtual players to determine the cause and extent of the contamination (Klopfer and Squire 2003). Their research with precollege teachers and students indicates that this and other similar projects help foster in-depth conceptual understanding (Klopfer and Yoon 2005).

Similarly, multi-user virtual environments (MUVes<sup>1</sup>) enable multiple participants to simultaneously access computer-based three-dimensional virtual spaces, called “worlds,” and to interact with digital artifacts. In contrast to ubiquitous computing interfaces, participants engage in this interaction while they are fully immersed in the virtual world (Dede and Palombo 2004; Nelson et al. 2005). MUVes are best known as the platform for many online computer games. These virtual worlds are becoming pervasive beyond straightforward gaming to include design and role play. It is estimated that nearly 30 million people participate around the world, and 10 million of them are regularly paying customers of various gaming sites (Hof 2006).

MUVes are also useful for education because they allow for authentic, immersive simulations that promote collaboration, mentoring, and communication (Kirriemuir and McFarlane 2004). They are used in the armed services, in the medical field, and in education to simulate experiences for education and training purposes. For example, *VirtualU* (<http://www.virtual-u.org/>) allows users to manage all aspects of a university and to learn more about the intricacies

<sup>1</sup>Abbreviations used in this article: MUVE, multi-user virtual environment; RFID, radiofrequency identification; SOP, standard operating procedure.

of the role of a university president. Periodic evaluations from the *VirtualU*'s Board of Trustees help participants understand their job.

We mentioned above that face-to-face pedagogies offer advantages in the immediacy of interaction and the social network within which the learning occurs. However, face-to-face interactions have the drawback of requiring a specific time and place for learning to take place in addition to restricting students to a specific learning approach. By contrast, both the RFID and MUEVE emerging technology interfaces offer unique solutions to these problems.

First, as described above, learners today are often unable to attend classes in a specific location and/or time due to geography, family, or job constraints. By using virtual environments, learners and experts can meet simultaneously in virtual schools for the purposes of education and training without the need for travel to a central location. Learners can conduct virtual experiments, receive mentoring in authentic contexts, and participate in learning activities with their colleagues. This capability allows them to create a sense of community that is similar to face-to-face interactions. In addition, it is possible to store learning materials and activities in the virtual environment for those who want to return later for deeper explorations on their own or with a subset of learners. Although this asynchronous use of the technology does not facilitate community formation well, it does allow time for reflection, which synchronous interactions, including face-to-face, do not.

Second, these various technologies also enable different learning capabilities that allow diverse learners to experience success. For example, ubiquitous computing allows those with kinesthetic learning styles (i.e., learning through physical interaction) to physically connect what they are learning with the actual environment in which it is to be used. MUEVEs also offer participants the ability to connect their learning to an authentic environment; however, in this case learners are not physically located in the environment but can be located wherever there is a computer. Additionally, MUEVEs allow users to assume different identities during the learning process and to gain insights into various roles. Virtual environments also offer educators and trainers the ability to create an almost infinite array of settings and situations into which they can place students to learn.

Some experts suggest that the use of a mixed methodology wherein face-to-face pedagogies are paired with technology-based pedagogies would allow multiple entry points for students with different lifestyles and learning styles (Dede et al. 2003). Research indicates that when students are given a distributed learning experience in which some classes are taught face-to-face and others are conducted at a distance using various media, as described above, more than half of the students choose a method other than face-to-face as their preferred learning method (Ketelhut et al. 2005). The use of these different formats offers different opportunities for expression. It is not uncommon for the "quiet" student in the face-to-face class to become very outspoken in a mediated communication.

## Potential Applications in Laboratory Animal Care and Use

The unique capabilities of these emerging technologies are already in use in some aspects of animal care and use, and we expect that additional benefits will become apparent in the future. Preliminary assessment of RFID applications in the vivarium has already hinted at the potential of this technology for routine animal care (Beck et al. 2004). First, the optimal location for affixing RFID labels to microisolator mouse cages was determined. Then, tagged cages were simply "read" by an RFID receiver over the doorway, thereby replacing labor-intensive bar-code scanning to capture census data. Tagged cages were also automatically monitored if they were or were not in the room, providing an effortless means to monitor and document the movement of cages that may be otherwise restricted (e.g., BL-2, quarantine). It is therefore easy to envision how RFID and other ubiquitous computing technologies may be used in education and training for laboratory animal care and use.

For example, consider a common task in laboratory mouse husbandry such as handling microisolator cages. Proper technique and appropriate equipment must be used to move mice to a new cage or replenish supplies in the cage to ensure that the environment of the mouse remains free from contaminants such as rodent viruses that may be present in the room. In addition, if those mice are used for a biosafety-level-2 or higher protocol, it is equally as important to ensure that whatever biohazard exists in the cage remains confined to that cage. To that end, a training approach for handling these mice by using ubiquitous computing might include sensors and transmitters attached to the room, the cage rack, the changing station, a dummy cage, and dummy "mice." The trainees may also wear sensors on their gloves, sleeves, and other locations.

Following a programmed sequence, airflow sensors could determine whether the blower within the changing station was switched on. Moisture sensors in the hood could detect the application of disinfectant to the work surface and could measure the time between application and drying while, at the same time, location sensors on the disinfectant container could confirm that the correct bottle was used and that it did not leave the confines of the hood. Then motion and location sensors on the cage lid and within the changing station could determine whether the cage had remained closed until it was within the designated work area and whether the lid was properly removed only after it was disinfected. Subsequent steps in the procedure could be tracked similarly, and any mistake could be immediately identified by a light or sound alarm. After numerous attempts, the trainee could learn the proper sequence and could then be timed during future training sessions to measure productivity against a predetermined target length of time as well as to confirm adequate proficiency. To make the sessions more fun, error alarms could be accompanied by encouraging verbal messages, and rewards could be provided after success is achieved. Repeated failure by a trainee

to learn the proper sequence using this technology could provide a more objective (and less contentious) management tool to identify personnel who should not be assigned to handling microisolator cages until they demonstrate mastery of the steps required.

To digress briefly, it is even possible to envision departmental games in which teams of animal caretakers compete for the best score using this technology, all the while reinforcing proper technique to the entire staff. One of us (S.M.N.) recently launched an “SOP Olympics” in which teams of animal care personnel from various vivaria within his institution competed in the use of standard operating procedures (SOPs<sup>1</sup>). The first event, which involved handling microisolator cages, was selected in an effort to highlight the need for uniformity among different animal facilities. Mid-level managers served as judges to evaluate competitors not by how quickly a task (e.g., sexing and transferring weanling mice to new cages) was performed but instead, by how closely each “athlete” followed the pertinent SOPs. Gold, silver, and bronze medals were awarded to the top three teams as well as to the respective facility manager. Subsequent competitions will focus on other common husbandry tasks that will benefit from a similar focus on standardization.

Thus, the use of ubiquitous computing as described above is appealing because it would eliminate the human factor in judging and would encourage more potential competitors to practice at more convenient times. In addition, such a technology platform could serve as an educational tool to explore alternative sequences or methods in microisolator cage technique, in combination with bacteriological monitoring, to establish an even more reliable or more efficient approach.

Turning to larger species used in research, ubiquitous computing technology could be similarly established to ensure that the proper sequence is followed in the preoperative preparation of the surgical subject. Sensors attached to the animal (initially a dummy), as well as to other components (e.g., various medications, restraint tie-downs, hair clippers, gauze packages, disinfectant containers, endotracheal tubes, electrocardiogram and oxygenation leads) could track how closely an SOP is followed. Sensors could also monitor the motion of the real animal to highlight unnecessary struggling or indicate whether and at what time the desired anesthetic plane was achieved. A prolonged sequence of preparation and induction using a live animal could identify which stages of the process were especially vexing for the trainee and focus attention on those particular steps. A similar ubiquitous computing environment was constructed for training human surgery teams and has been employed successfully for several years. This “Operating Room of the Future” uses RFID tags and sensors to help minimize, among other purposes, errors involving a patient being wheeled into the wrong operating room or a patient being implanted with the wrong medical device. In Figure 1, a computer display is shown from one such operating room of

the future, set up at the Massachusetts General Hospital (Figure 2).

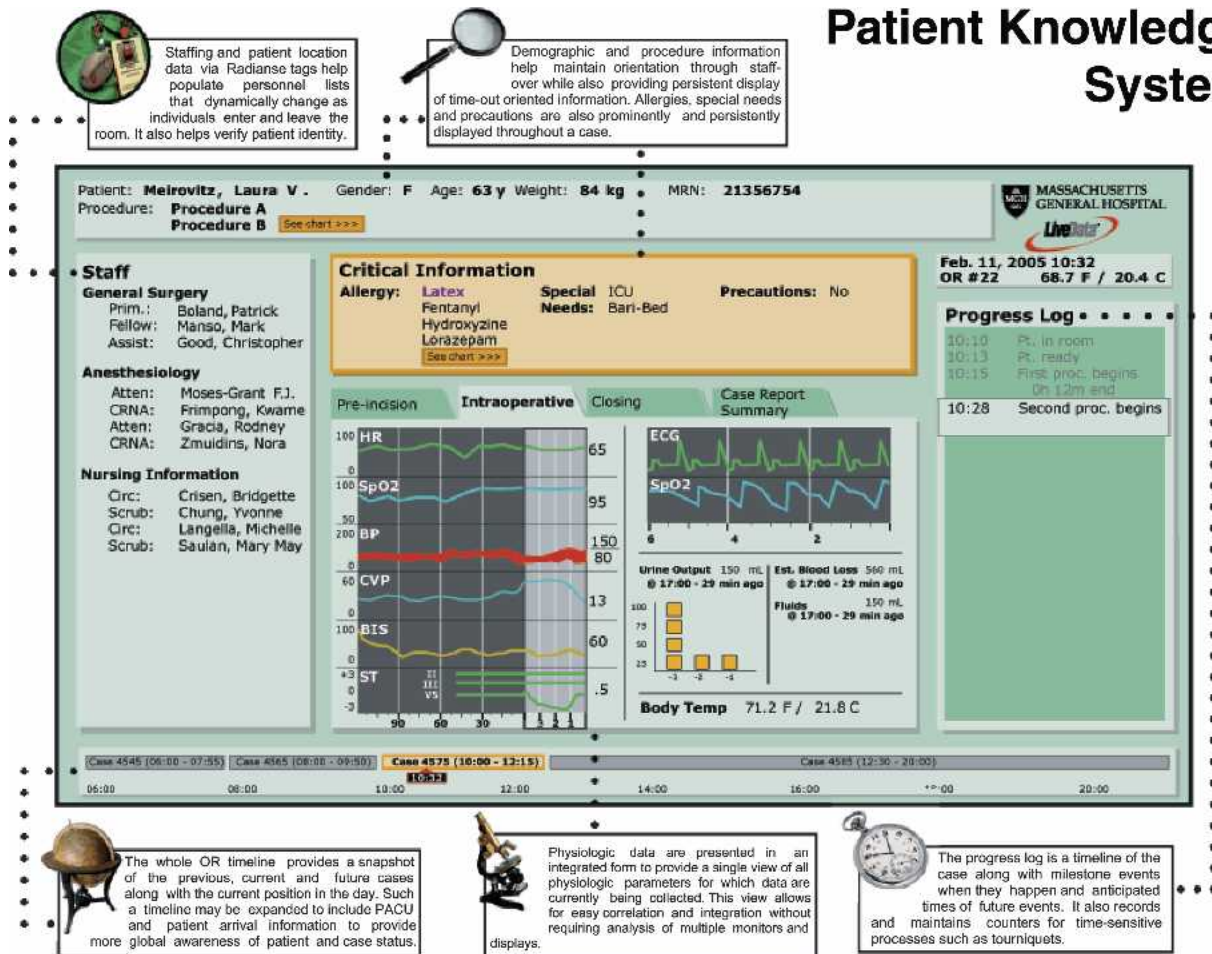
More complex scenarios that involve education and training via ubiquitous computing will quickly surpass these simple examples as this technology becomes more commonplace. In addition, further miniaturization of the pertinent hardware, combined with more parameters to measure at higher levels of precision, will lead to learning opportunities not currently conceivable. However, all of these applications still require a physicality, which may inhibit their adoption. The use of these tools depends on staff availability at a specified location, may consume expensive supplies, and will occupy expensive space if training is performed within the vivarium.

Because of these limitations of RFIDs, MUVes may be even more attractive for education and training because the only physical object needed is a computer; everything else is performed in a virtual world. One can envision the creation of a perceived three-dimensional landscape on the computer that replicates any animal facility, down to the detail of doorway heights, electrical outlet locations, and moveable cage racks. The trainee would be able to “walk” through this virtual workspace, “touch” various virtual surfaces, and listen to the sounds of the workspace to get acquainted with the facility layout and specific sites relevant to the workday (e.g., locker room, feed and bedding storage, cage wash). The training session could also be more complex than simply an orientation tour. For example, a trainee could watch computer-generated workers perform tasks in the correct manner and could then manipulate his or her avatar to try those same tasks. One obvious lesson could be how to operate potentially hazardous equipment like autoclaves and irradiation chambers in this virtual space before the trainee is allowed to operate actual machines. Alternatively, the training exercise described above on handling microisolator cages could occur first in a virtual barrier mouse room before any real cages would be handled. Positive and negative alerts could be easily programmed in any session to guide the trainee to the correct outcome.

The realm of animal use (vs. animal care) is also very compatible with MUVe-based training. One could design virtual animals of any species and have the student “handle” them to learn correct methods of physical restraint, administering drugs, collecting blood, and performing euthanasia, to name a few. In addition, like the human mannequins developed for ubiquitous computing applications such as the operating room of the future mentioned above, virtual laboratory animals could be programmed to present with various complications with the objective of alerting students to situations they may encounter with real animals.

A key feature of MUVes that distinguishes them from ubiquitous computing is that they allow a person to experience more than one role and to see the experience from different perspectives. It would be possible to design MUVes that would allow those who care for the animals to follow the needs and experiences of those who use animals for research, and vice versa. We believe that this insight into

# Patient Knowledge System



**Figure 1** A computer display in an Operating Room of the Future integrating all pertinent information from various sources throughout the hospital, including RFID information on which patient and personnel are currently in the room. Reprinted from Olsen S. 2005. Tomorrow's operating room to harness Net, RFID. Cnet.com, October 19, 2005. Available online ([http://news.com.com/Tomorrows+operating+room+to+harness+Net%2C+RFID/2100-1008\\_3-5900990.html?tag=ne.gall.related#](http://news.com.com/Tomorrows+operating+room+to+harness+Net%2C+RFID/2100-1008_3-5900990.html?tag=ne.gall.related#)), accessed July 4, 2006. Used with permission from CNET Networks, Inc., Copyright 2005. All rights reserved.

other roles and motivations would help foster better communication and understanding between the various groups involved in animal care and use. Another advantage of MUVes over ubiquitous computing is that it is much easier for more than one person to participate in the same session. This characteristic provides an opportunity for team-based training for collaborative tasks such as preparing clean cages or servicing an animal room. When trainees then enter their actual work environment, they are likely to be more familiar with the variety of tasks involved and to more easily appreciate the value of working compatibly with others.

## Conclusion

We have endeavored to introduce readers to new education and training technology platforms and to describe how they may be applied in the closely linked fields of laboratory

animal care and use. We initially posed a question as to whether the currently used methods of education and training for animal care and use workers are believed to be optimal. We then illustrated that although the status quo is adequate in many cases, it would benefit from the infusion of new methods that utilize emerging technologies. Because personnel learn and train differently, it may be necessary to combine technologies and applications to ensure that intended instructional goals are achieved.

The use of ubiquitous computing, MUVes, and future technologies should not be considered as isolated platforms. All of these technologies are likely to be more effective and more quickly adopted when they are combined with each other and with current methods. Several approaches may be even more efficacious when used in sequence rather than in parallel. For example, the virtual environment permits initial training before any live animals are involved.

It is also important to remember that technology alone is not a panacea. Its use, per se, does not guarantee a positive



**Figure 2** Operating Room of the Future set up at the Massachusetts General Hospital, Boston, MA. Adapted from Olsen S. 2005. Tomorrow's operating room to harness Net, RFID. Cnet.com, October 19, 2005. Available online ([http://news.com.com/2300-11393\\_3-5902109-1.html](http://news.com.com/2300-11393_3-5902109-1.html)), accessed July 4, 2006. Used with permission from CNET Networks, Inc., Copyright 2005. All rights reserved.

outcome but instead, offers an alternative or a boost to current approaches with possibly better results in less time and at lower cost. However, we believe that continued research is needed in this area to track effectiveness and to answer other questions that arise. As these technologies become more commonplace in the laboratory animal sector, it will be essential to learn whether their adoption substantially accelerates the learning curve, thereby reducing the time spent to prepare staff for new tasks and improving the quality of their performance and, in turn, the welfare of the animal subjects. We also believe that it is important to consider whether such tools will enable more employees, including those whose native language is not English, to participate at higher levels of responsibility than currently expected. It is incumbent upon institutional administrators and officials to understand these and similar cost-effective metrics as new technologies are adopted.

As our knowledge of biomedical science and of effective learning and training methodologies increases, there will likely be needs and solutions in the future that are not even envisioned today. We believe that the interface between these two knowledge domains will continue to provide fertile ground for further advancements.

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