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Development and Implementation of Multimedia Content for an Electronic Learning Course on Rodent Surgery

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The development of new rodent models of human disease and advances in surgical equipment and technologies have increased the demand for expertise in rodent surgery. Because of the limited availability of rodent surgical training courses, electronic (e-) learning is presented as an alternative to in-person education and as a means to hone the expertise of current surgeons in biomedical research, similar to e-learning applications for human surgery training. Translating this model to the biomedical research field provides participants with an opportunity to train themselves on rodent surgical techniques prior to operating on live models. An e-learning rodent surgery course was incorporated into a training class of undergraduate (*n* = 39) and graduate (*n* = 12) laboratory animal students, and a portion of the course was presented to laboratory animal professionals (*n* = 15). The effectiveness of the method was evaluated using written examination and postcourse surveys. The exam data demonstrated that the e-learning course transferred knowledge comparable to a lecture course on surgery that was presented in-person. Students responded favorably to videos, step-by-step photographs of surgical procedures, and the ready accessibility of the course. Critiques included the need to improve video resolution and quality of the voice-overs. These results support the continued development and implementation of electronic rodent surgical technique courses for use in laboratory animal and biomedical research communities.

Abbreviation: e-, electronic.

Electronic (e-) learning has increasingly been relied on as an efficient and effective teaching tool in numerous fields of education, including medical school surgical programs, often as an adjunct to more traditional hands-on methods.[4,8,12,14,19,27] Overall, the quality of presentation and content can be heterogeneous, both within institutions as well as between institutions.[1] E-learning applications for online surgical courses include the ability to incorporate videos, audio files, images, and animations[30] that can accommodate auditory, visual, and kinesthetic learning styles. On-demand e-learning can provide a flexible[11] and rapidly accessible route to training.[33]

Additional general advantages to e-learning include the promotion of social learning through synchronous contemporary communication formats (for example, instant messaging, chat-rooms, video conferencing) as well as asynchronous communication (for example, email and discussion boards).[6,23] The e-learning environment potentially can minimize hierarchies (that is, between supervisor and participant) and diminish professional boundaries, thereby enabling participants to work as a cohesive unit.[5] The flexibility of delivery also allows providers to access specific content and track an individual participant's progress with data collection. E-learning training allows participants to view materials and concepts repetitively without time constraints, while providing the chance for self-assessments and instructor feedback for overall skill improvement.[16]

Surgical skills traditionally are acquired through 3 consecutive stages—the cognitive, associative, and autonomous stages.[32] During the cognitive phase, the student learns surgical theory and concepts. During the associative stage, the student practices surgical skills, and by the autonomous phase, surgical skills are performed without conscious thought.[28] The surgical cognitive stage and a portion of the associative stage can be delivered through the use of e-learning. However, associative-stage objectives are achieved by conventional rodent surgery training methods including readings, lectures, use of videos, and hands-on training, often with inanimate models[26] and live animals. Hands-on surgical workshop training provides participants with opportunities to practice and hone skills, supporting the autonomous phase of learning. Importantly, surgical training cannot be composed of only initial basic training; instead, continued learning must be incorporated to stay abreast of emerging and refined technologies, procedures, analgesics, and anesthetics. E-learning has particular advantages in the realm of surgical training; it allows for customization and rapid updating[25,31] of the courses and can provide a continuous reference tool accessed at the students' convenience.[9] Introduction of study materials prior to hands-on courses provides participants with background information, allowing them to participate more fully in the hands-on workshops. This feature may lead to more active interaction with the training faculty, which results in more efficient learning and better retention of material.[15]

Despite the exponential increase in applied e-learning technologies through the development of online courses across multiple disciplines, few published reports exist that provide guidance for the basic design of an e-learning course. Only a few reports assess objective testing, student feedback, and course results,[10,18] particularly within surgical education.[4,8,12,19] Ideally,

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each e-learning course should be validated through comparison with conventional lecture presentations of the material to determine its effectiveness. However, this comparison cannot be made before development and implementation of the electronic course, which requires considerable investments of effort, expense, and time. Another challenge in the field of laboratory animal science may be acceptance of the applied e-learning by the surgical community at large and promotion of its inherent benefits.[29,30]

The goal of our study was to develop, implement, and validate an e-learning rodent surgical course, which would provide a basic understanding of principles of rodent surgery to members of the laboratory animal science and biomedical communities. Our subsequent aims were to explore participants' attitudes toward this teaching methodology, evaluate the modules to assess potential benefits, and determine whether this course could serve as a useful model for future surgical e-learning courses.

Materials and Methods

A course titled *Basic Principles of Rodent Surgery* and comprising 15 topics (Figure 1) was developed in 2 formats: classroom lectures and e-learning modules. For the classroom format, six 1-h lectures were designed, constructed, and presented by using PowerPoint (Microsoft, Seattle, WA). Live, onsite teacher interactions occurred throughout the classroom lecture presentations to students.

For the e-learning format, the identical classroom lectures were translated into 15 HTML modules and presented with an e-learning education management software, Electronic-portal (Veterinary Bioscience Institute, Harleysville, PA), specifically developed for this project. Modules were self-paced and designed for completion within a 2-wk period. Electronic-portal (e-portal) software allowed participants to readily access the e-learning course modules by using an individual-user identification name and password. E-portal permitted the tracking of participants' access through login files, provided live (real-time) e-learning discussion forums and email, and included lecture material and exams online. Each lecture and module included prelecture–premodule and postlecture–postmodule questions.

The video content used in this course was collected in high-definition files and then translated into flash video by Adobe software (Adobe Systems, New York, NY) for optimal streaming for online presentation. Video compilation included a rodent surgical process reviewed from beginning to end, starting with the surgeon's preparation for surgery through the actual surgical procedure with animal recovery from anesthesia. Video clips were individual, isolated pieces of the compilation video and addressed such items as methods of animal skin preparation and making the initial incision.

Exams comprised multiple-choice questions for study I (n = 50) and study II (n = 40), which included images and videos to augment the text. Questions were designed to accompany course outcomes and required students to demonstrate in-depth understanding and application of the material. Case-based questions were used whenever possible, to engage students in an advanced level of critical thinking. Multiple-choice questions were developed by following the stem, lead-in, and options format[21] and were designed without technical item flaws, as described previously.[2] Questions were balanced by matching the material presented and by covering the main concepts in proportion to the emphasis they received during the course.[2] Questions for the exams were provided by a team of veterinarians (n = 2), high-school faculty (n = 1), and undergraduate students (n = 2) to assess clarity and relevance. Multiple-choice exams were graded (corrected) automatically by the e-portal computer software.

Topic 1	Laws, regulations, and guidelines
Topic 2	Surgical facility design and preparation
Topic 3	Surgical equipment
Topic 4	Stereomicroscope basics
Topic 5	Principles of surgery and aseptic technique
Topic 6	Tissue healing basics
Topic 7	Appropriate tissue handling and dissection
Topic 8	Surgical patient preparation
Topic 9	Surgical patient monitoring
Topic 10	Surgical personnel preparation
Topic 11	Appropriate macro- and microsurgical instrument selection
Topic 12	Appropriate macro- and microsurgical instrument handling
Topic 13	Principles of instrument sterilization
Topic 14	Needle and suture material basics
Topic 15	Basic suture patterns and knots

Figure 1. Topics included within the classroom and in the e-learning course *Basic Principles of Rodent Surgery*.

Study I: Undergraduate participants. During this study, a course in both formats (lecture and online) was presented to undergraduate students (n = 39) with backgrounds ranging from no surgical experience to surgical veterinary assistant experience. Students were divided into subgroups A and B. Subgroup A participated in classroom lectures (lectures 1, 2, and 3) and corresponding online modules (9 through 15). Subgroup B participated in the classroom lectures (lectures 4, 5, and 6) and corresponding online modules (1 through 8).

The course was evaluated by using postcourse survey data addressing accessibility, usability, relevance, and content. Acquisition and transfer of knowledge was assessed by multiple choice exams. A survey was designed in which students responded by short answers, yes-or-no answers, and scaled assessments (Likert scale) of 1 (low) to 5 (high).

Study II: Graduate participants. During this study, the e-learning format of the course (modules 1 through 15) was presented to graduate students (n = 12) enrolled in an advanced laboratory animal science program. Participants within this program had backgrounds ranging from no surgical experience to surgical veterinary assistant experience. The course was evaluated by using postcourse survey data and exams were similar to those described for study I.

Study III: Postgraduate participants. During this study, 2 modules (2 and 11) of the e-learning course were presented to postgraduates (n = 15), including laboratory animal veterinarians and veterinary residents, regulatory compliance personnel, veterinary technicians, and veterinary students. The course was evaluated by using postcourse survey data as described in study I.

Table 1. Responses (mean ± SEM) to the Likert-scale questions (from 1 [low] to 5 [high])

	Undergraduates (study I)	Graduates (study II)	P^a	Graduates (studies II and III)	P^b
The e-learning course website was easy to access	4.641 ± 0.1005; *n* = 39	4.083 ± 0.2876; *n* = 12	**0.0243**	4.172 ± 0.1651; *n* = 29	**0.0131**
The e-learning course website was easy to navigate	4.513 ± 0.1094; *n* = 39	4.083 ± 0.2289; *n* = 12	0.0727	4.034 ± 0.1445; *n* = 29	**0.0090**
Initial impression of the course presentation (colors, outlay)	4.256 ± 0.1502; *n* = 39	4.083 ± 0.2876; *n* = 12	0.5841	4.103 ± 0.1744; *n* = 29	0.5085
Functionality of the system	4.179 ± 0.1417; *n* = 39	4.333 ± 0.2562; *n* = 12	0.6010	4.034 ± 0.1682; *n* = 29	0.5104
Reliability of the system	4.053 ± 0.1598; *n* = 38	4.333 ± 0.3333; *n* = 12	0.4129	4.077 ± 0.1994; *n* = 26	0.9241
Web site guidelines and instructions were clear	4.231 ± 0.1535; *n* = 39	4.750 ± 0.1306; *n* = 12	0.0771	4.385 ± 0.1367; *n* = 26	0.4847
Course guidelines and instructions were clear	4.462 ± 0.1093; *n* = 39	4.583 ± 0.1930; *n* = 12	0.5895	4.231 ± 0.1692; *n* = 26	0.2344
The resources in the course (photos, videos and voice-overs, Diagrammatic layouts and animations) were straightforward and easy to use and understand	4.026 ± 0.1580; *n* = 39	4.167 ± 0.2410; *n* = 12	0.6564	4.042 ± 0.2039; *n* = 24	0.9505
Photos were helpful and appropriate	4.395 ± 0.1102; *n* = 38	4.545 ± 0.2473; *n* = 11	0.5392	4.304 ± 0.1714; *n* = 23	0.6437
Videos were helpful and appropriate	4.395 ± 0.1487; *n* = 38	4.545 ± 0.2073; *n* = 11	0.6164	4.190 ± 0.1905; *n* = 21	0.4081
Voiceovers were helpful and appropriate	3.816 ± 0.1763; *n* = 38	4.444 ± 0.1757; *n* = 9	0.1002	4.231 ± 0.2308; *n* = 13	0.2160
The structure of the content was easy to follow	4.231 ± 0.1490; *n* = 39	4.417 ± 0.1930; *n* = 12	0.5246	4.440 ± 0.1166; *n* = 25	0.3196
The e-learning course was interesting and enjoyable	3.923 ± 0.1814; *n* = 39	4.545 ± 0.2817; *n* = 11	0.1023	4.208 ± 0.1700; *n* = 24	0.2900
The content was clear and easy to understand	4.641 ± 0.08605; *n* = 39	4.545 ± 0.1575; *n* = 11	0.6027	4.458 ± 0.1039; *n* = 24	0.1863
The content gave me sufficient information	4.282 ± 0.1556; *n* = 39	4.417 ± 0.2289; *n* = 12	0.6646	4.280 ± 0.1474; *n* = 25	0.9928
The course materials were easy to read	3.897 ± 0.1715; *n* = 39	4.167 ± 0.3445; *n* = 12	0.4618	4.200 ± 0.1915; *n* = 25	0.2553
The course was a valuable learning experience	4.333 ± 0.1290; *n* = 39	4.500 ± 0.2303; *n* = 12	0.5329	4.400 ± 0.1291; *n* = 25	0.7290
The material flowed in logical order	4.436 ± 0.1089; *n* = 39	4.333 ± 0.2562; *n* = 12	0.6731	4.320 ± 0.1381; *n* = 25	0.5110
The material was well-prepared and -organized	4.462 ± 0.1029; *n* = 39	4.333 ± 0.2843; *n* = 12	0.5988	4.269 ± 0.1525; *n* = 26	0.2815
The material was explained in a clear and understandable manner	4.359 ± 0.1190; *n* = 39	4.500 ± 0.1508; *n* = 12	0.5442	4.308 ± 0.1077; *n* = 26	0.7643

Table 1. Continued

	Undergraduates (study I)	Graduates (study II)	P^a	Graduates (studies II and III)	P^b
The course was flexible (moving back and forth between lessons and chapters)	4.385 ± 0.1452; *n* = 39	4.333 ± 0.2247; *n* = 12	0.8605	4.308 ± 0.1546; *n* = 26	0.7255
The postchapter review questions were appropriate and reasonable	4.359 ± 0.1349; *n* = 39	4.333 ± 0.1880; *n* = 12	0.9234	4.240 ± 0.1194; *n* = 25	0.5419
Overall impression of the e-course web site	4.231 ± 0.1535; *n* = 39	4.500 ± 0.2303; *n* = 12	0.3822	4.400 ± 0.1291; *n* = 25	0.4407
I would recommend this course to others	4.395 ± 0.1224; *n* = 38	4.417 ± 0.2289; *n* = 12	0.9313	4.417 ± 0.1335; *n* = 24	0.9071

[a]Values from studies I and II were compared. Significant *P* values are bolded.
[b]Values from studies II and III were compared. Significant *P* values are bolded.

Statistical analysis. Data were analyzed blindly to avoid bias in interpretation and by using ANOVA and Tukey posthoc analysis. Statistical analyses were performed by using Prism software (Graphpad Software, La Jolla, CA), and results were considered throughout all experiments to be statistically significant when the *P* value was less than 0.05.

Results

Mean exam grades from the e-learning (92.82% ± 0.7625%; *n* = 39) and lecture (90.90% ± 0.9450%; *n* = 39) courses were not significantly different (*P* = 0.1174) when the 2 methods of teaching were compared within group 1. Furthermore, mean exam grades for the undergraduate and graduate groups (92.82% ± 0.7625%, *n* = 39; 91.42% ± 1.485%, *n* = 12, respectively) were not significantly different for the e-learning course (*P* = 0.3849). The results from the group surveys are summarized in Table 1. Responses from undergraduate and graduate level participants were not significantly different, with the exception of 2 questions. Regarding *Ease of accessing the e-learning course website*, the undergraduate group in study I stated that the course was more easily accessible than did the graduate group in Study II and graduates combined (studies II and III). Regarding *Ease of navigating the e-learning course website*, responses from the undergraduate participants from study I and the graduate participants from study II were not significantly different. However, when the undergraduate group (study I) was compared with both graduate groups (studies II and III) combined, the undergraduate group stated that the course was easier to navigate than was indicated by the graduate groups' responses.

All participants responded favorably, with an average of 4.2 (maximum, 5) on the Likert scale, to videos, step-by-step photographs of procedures, and the 24-h availability of the course. Videos with voice-overs were preferred over silent videos by 65% of the students (*n* = 80), and short video clips embedded in the text were preferred over compilation videos by 87% of the students (*n* = 80).

Discussion

As the proponents advocating for the application of e-learning have increased, the acceptance of e-learning education methodologies has grown rapidly in various educational fields.[7,13] The outcome of our study shows that it is possible to develop and implement an interactive, electronic rodent surgical course that successfully delivers information (as verified by examination) to a range of participants from undergraduate to graduate levels. Knowledge transfer and retention was comparable between the 2 undergraduate cohorts taking the online course versus the lecture course, as reflected in similar scores on the final exam. These results were comparable to similar published studies. For example, the results of a web-based surgery course for undergraduate medical students showed that students significantly improved their surgical knowledge and accepted the ability of an e-learning course implemented into a medical setting.[4] Another study demonstrated that an e-learning surgical module in an undergraduate course could convey information and understanding successfully to students.[8] The current study provided a basis for additional studies, which should include item-analysis evaluation of multiple-choice exams and compare different age groups, different geographic areas, asynchronous and synchronous learning, and the effect of previous surgical experience to nonexperienced personnel.

In the e-learning evaluation described herein, the noted difference in survey responses between the undergraduate and graduate groups regarding ease of course access and navigation could have been due to an increased comfort level with computers and e-learning programs among students that have had an exposure to computer technology for a longer period of time, frequently starting at a young age. Overall, this e-learning course received good reviews for ease of accessibility, use, and content relevance, suggesting a broad acceptance of the online format.

The advantages of e-learning are becoming increasingly apparent in the laboratory animal science and biomedical communities.[10,17,22] Online training can provide increased flexibility in delivering both appropriate content and a quality educational experience.[24] E-learning options are increasingly in demand within the laboratory animal and biomedical communities, both in the United States and internationally at locations where access to laboratory animal education is limited. We feel that e-learning technology can increase the effectiveness of existing surgical training programs and can benefit a larger number of participants.[29,30] One of the important concerns with e-learning is preventing participant isolation, defined as a lack of immediate contact with other students or faculty during the teaching process.[20] We believe that participant isolation can be overcome through asynchronous and synchronous communication,[23] and by using either supplemental or hybrid models systems. Specifically, using the supplemental model, an instructor could videorecord material that was presented during a hands-on session and make the content available on a website for subsequent review by students. In a hybrid model, students would be introduced to material and techniques online before beginning hands-on training, to diminish the time needed for review during the training session. Students have been reported to particularly benefit from a hybrid model, because they have time to acclimate to the background material prior to the training session. Overall, the delivery of material in the e-learning course should be designed carefully to develop the skills necessary for successful completion of each stage of the surgical learning process, and the electronic course should play a complementary role with hands-on training.

Our study is the first to provide objective evidence to suggest that the incorporation of e-learning interactive material into the design of rodent surgical training leads to reliable surgical knowledge transfer. Participants agreed that the e-learning course should be incorporated into a rodent surgical training curriculum, as an adjunct to hands-on training sessions, and that it provided a valuable online source of reference material. Applications of e-learning, for those with computer access, will facilitate surgical training of globally dispersed members of the laboratory animal and biomedical communities and provide accompaniment to traditional rodent surgical training paradigms.

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