TECHNOLOGY IN THE TEACHING OF NEUROSCIENCE: ENHANCED STUDENT LEARNING

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The primary motivation for integrating any form of education technology into a particular course or curriculum should always be to enhance student learning. However, it can be difficult to determine which technologies will be the most appropriate and effective teaching tools. Through the alignment of technology-enhanced learning experiences with a clear set of learning objectives, teaching becomes more efficient and effective and learning is truly enhanced. In this article, I describe how I have made extensive use of technology in two neuroscience courses that differ in structure and content. Course websites function as resource centers and provide a forum for student interaction. PowerPoint presentations enhance formal lectures and provide an organized outline of presented material. Some lectures are also supplemented with interactive CD-ROMs, used in the presentation of difficult physiological concepts. In addition, a computer-based physiological recording system is used in laboratory sessions, improving the hands-on experience of group learning while reinforcing the concepts of the research method. Although technology can provide powerful teaching tools, the enhancement of the learning environment is still dependent on the instructor. It is the skill and enthusiasm of the instructor that determines whether technology will be used effectively.

One of the most important aspects of being an educator is developing the skills needed to successfully organize and present a set of difficult concepts to a classroom full of students. This is especially true in an advanced physiology course, where so many areas of science come together. From the intricate molecular reactions that drive a physiological response to the physical properties of a particular system, the integrative nature of physiology can challenge even the best teachers. With such complexity, the use of a blackboard and a piece of chalk no longer seems adequate.

Yet, far too few college-level instructors use new education technologies effectively in their courses (15). The reasons for this are many and vary from institutional limitations such as large class sizes and a need for a complex grading system to a lack of training and resources (2, 10, 15). However, if instructors are to keep up with their tech-savvy students and present course material in the best possible way, they need to develop new skills and make particular forms of education technology part of their teaching method (3, 5, 10).
Before any form of technology can be incorporated into a particular course or curriculum, a basic question must be answered: How do students learn and how will technology enhance the learning process? Effective teaching, for its part, depends on the degree to which students have a clear understanding of the intended course outcomes. What are the learning objectives and what methods will an instructor use to teach and assess whether students meet these objectives? To reach the level of critical thinking, there is a need to move students from a “surface” approach to learning (i.e., memorization of factual content) to a “deep” approach, in which there is a true understanding of central themes, principles, and applications. Technology can play a major role in this process, but it is effective only when it is applied with respect to the learning objectives.

From a conceptual perspective, the traditional approach to teaching that is seen in many classrooms can be considered “misaligned” and ineffective. In these cases, where course objectives are not clearly aligned with what is actually taught in the classroom, Cohen suggests that learning will suffer. If education technologies are to be used effectively, their use must be considered with respect to this process, not just for the sake of using technology. When course objectives are aligned with learning experiences that incorporate new technologies, it can lead to a high degree of effective teaching, with a low degree of instructional effort. In addition, it will result in a higher (or deep) level of learning and becomes even more effective as the complexity of course material increases. Although learning can be enhanced just by the use of new education technologies, aligning their use with course objectives will only increase their effectiveness. This concept is known as constructive alignment.

The first step in the process of constructive alignment is to define the learning objectives. In the case of the two courses that I will present as case studies, these objectives are: 1) development of a clear understanding for the location, connectivity, and function of the anatomic structures in the central nervous system, 2) demonstration of a fundamental understanding for the major concepts in the field of neurobiology, 3) an understanding of the dynamic properties at the basis of neurophysiological responses, and 4) a comprehension of the critical role the central nervous system plays in the control and coordination of all other physiological systems. In addition, I expect that students will be able to engage in thoughtful discussions that convey their understanding of the course material as well as develop the ability to approach a scientific question through the use of the research method.

For the physiologist several different forms of education technology can be used to enhance learning experiences and lead to a greater understanding by the students of the course material. Interactive CD-ROMs and multimedia presentations can enhance the classroom experience and substitute for the use of bulky models and the occasional noninteractive video. In the teaching laboratory, computer-based physiology recording systems can replace outdated equipment such as respiratory spirometers and strip chart recorders, improving the hands-on experience of group learning and reinforcing the concepts of the research method. With the move to a digital age of paperless classrooms, the course website has also become a valuable tool, providing students with easy access to all relevant documents and course information as well as links to on-line resources that promote critical thinking. In addition, the use of a website discussion board can provide an interactive forum for student discussion outside the classroom and function as a useful tool for an instructor in assessing whether or not course concepts are being understood.

Although only certain forms of education technology may be suitable to the personal methodology of an instructor or to a course with a particular emphasis and class structure, most recent studies would suggest that the use of any new form of education technology, especially when aligned with the learning objectives, will lead to enhanced student learning. However, this still depends on selecting the right technology for a particular situation and implementing its use effectively. For two neuroscience courses, presented as case studies in this article, a comprehensive use of technology has created a learning environment that is beneficial to the students and has improved my efficiency and ability to teach. Course websites function as resource centers, providing access to all related documents and links to additional resources, as well as group e-mail lists and an interactive discussion board.
Lecture presentations are regularly used in the classroom and are supplemented with interactive CD-ROMs. In addition, computer-based physiological recordings have become an integral component of teaching laboratory sessions, making them more interactive and valuable learning experiences.

TECHNOLOGY AND IMPLEMENTATION

In determining the best forms of education technology to use, the classroom dynamics as well as the learning objectives become critically important. For the courses I teach, each presents its own limitations for integrating technology. Neurobiology is a survey course that exposes students to the dynamic interdisciplinary nature of neuroscience, with an emphasis on the physiology and anatomy of the nervous system. The use of technology in this course is influenced by a large class size of 80–100 students and a schedule of three hourly lectures each week. Neurophysiology is an advanced course that is focused on the electrical and chemical signaling of the nervous system and its ability to regulate the activity of other physiological systems. It differs in structure from Neurobiology by the addition of weekly laboratory sessions and a much smaller class size of only 20–40 students.

Institutional support. To achieve any measurable success in the implementation of technology to enhance student learning, there needs to be a high level of institutional support. This must include training in the use of available software and classroom hardware as well as access to these resources. At the College of William and Mary, there has developed a very strong Academic Computing Program. In addition to formal training sessions, this program is responsible for the maintenance of the University’s network system and providing access to it from virtually anywhere on campus. This also includes maintaining 11 public access labs that are always open to the students, guaranteeing them the ability to use course websites and network resources in their studies. On the instructional side, there are currently 40 technology-enhanced classrooms across the campus, which are equipped with computer-based presentation systems (i.e., dedicated computer and/or laptop connection to an LCD projection system). During formal lectures, these systems provide for the use of PowerPoint-style presentations, CD-ROM or DVD multimedia, and network access to other resources. Additional mobile computer presentation systems (i.e., laptop computer and portable LCD projectors) are also available and can be quickly set up in almost any classroom on campus. Without such a strong and supportive infrastructure, the use of technology in the classroom would be severely limited, which is the case at many smaller universities and colleges.

Course websites. For both Neurobiology (http://courseinfo.wm.edu/bin/common/course.pl?course_id=3638_1&frame=top) and Neurophysiology (http://courseinfo.wm.edu/bin/common/course.pl?course_id=3113_1&frame=top), comprehensive course websites have been established using the Blackboard 5 Software Platform (http://www.blackboard.com/), which also supports nearly 600 other websites at the University. The standardized layout that is provided by this course management system gives students some consistency from one course to another, yet allows each instructor the flexibility to edit or remove preset pages. Course documents can be quickly loaded onto a dedicated server and accessed through specified links that are found on related pages of the website. Changes can be made to these pages with relative ease and access to certain documents restricted to when they are needed. In addition, access to certain pages of the website can be restricted to those enrolled in a course. This provides for the confidential posting of grades and the development of statistical data concerning how the students use the website and the effectiveness of a particular page or document.

With a well-organized website, students gain a valuable resource that begins on the opening page, where important announcements and links to the other pages can be found. Within the website, students can access information such as how to contact the instructor and find the course syllabus. There may also be sets of organized “Course Documents” such as summary notes, lecture presentations, supplementary readings, and laboratory handouts. In addition, instead of turning to generic search engines to research a topic, students may use a selected list of “External Links” that lead to internet resources that are specific to the course material. All of these functions support the learning objectives by providing students with the
ability to quickly access information that they need in their endeavors to gain new knowledge.

Another major benefit of the course website is that it can provide students with the ability to interact outside the classroom. Through a “Communication” page, they can access an e-mail class roster, making it easy for them to contact one another. With large classes, such as my Neurobiology course, it can be difficult to generate in-class discussions during formal lectures. However, I have found that the use of a website “Discussion Board” can create an interactive forum outside the classroom that can become a significant part of a course. Although this is not a live, “virtual-type discussion, the weekly posting of course-related questions can generate some exciting interaction that may last for several days. In addition, many students who are unwilling to speak during lectures are willing to post their comments, including themselves as an active part of the class discussion. This use of a discussion board is also aligned with the learning objectives, encouraging students to become engaged in discussions concerning course topics, improving their ability to convey their knowledge.

PowerPoint presentations. Another valuable form of education technology that can be used to enhance learning experiences is the PowerPoint-style lecture presentation. Although many instructors commonly use this format when giving formal research seminars, its use in regular course lecture sessions has yet to become standard, and its effectiveness in the classroom has recently been called into question (see DISCUSSION). This may result from a lack of training and limited access to technology-enhanced classrooms or from the perception that an exceedingly large amount of time will be required for the conversion of lecture notes into this style of presentation. With recent improvements in computer software and hardware compatibilities, PowerPoint presentations are now much easier to create, and their use has become more dependable and effective. Although the availability of technology-enhanced classrooms is still an issue of institutional support that must be addressed across a campus, this may be circumvented at a relatively low cost through the use of mobile computer presentation systems.

To be effective as a teaching tool in the classroom and as a student resource, PowerPoint presentations need to have relatively simple formats and should not resemble copies of the instructor’s notes. The text should be concise and consist primarily of topic headings, lecture objectives, and points for discussion. Long definitions or explanations should be avoided, since they can lead instructors to perform a reading of their presentations instead of using them as points of interaction. Solid-color backgrounds and contrasting large font sizes should also be used to ensure that the presentations are readable, even from the back of a large lecture hall and by students with minor visual impairments (i.e., color blindness). Although an important advantage of using this style of presentation is the ability to incorporate animations and high-resolution images, their use should be kept to a minimum. This is because of the inherently large amount of memory they require, making it difficult for students to view these presentations on-line or download them to their computers. However, instructors should take advantage of the recent inclusion of artwork CD-ROMs with the supplementary materials of most current texts. These digital images of the text figures are already compressed and formatted for easy incorporation into PowerPoint presentations. By being kept simple, these presentations can become effective course supplements and provide students with a clear outline of the material covered in each lecture.

Interactive CD-ROMs. As with many areas of science, students find physiological concepts difficult to learn, and instructors find them hard to teach. This is because they may involve such dynamic aspects as motion, changes occurring over time, or the complex integration of multiple events. Although these concepts may be hard to present and visualize using static drawings, the multimedia approach of mixing text and graphics with sound and animation can enhance their presentation and lead to greater understanding. With the integration of computers into the learning experience, interactive CD-ROMs that use multimedia have become valuable teaching tools and student resources.

However, choosing the right interactive CD-ROM for use in a particular course can be quite challenging. Three factors that must be considered when selecting a CD-ROM are 1) how well the material correlates
with course content, 2) the accuracy and presentation of each concept, and 3) student accessibility. As with the integration of other forms of technology, the use of a particular CD-ROM should be aligned with the learning objectives of a course. Some CD-ROMs may be quite broad in their focus around a topic or field of study, whereas others can be tightly correlated with a specific text. Multimedia presentations must also be well organized, have clear goals for learning, generate interaction that can lead to in-class discussions, and provide review sections for independent study. Although students should have the option of purchasing a CD-ROM on their own, bundling with a correlated text can greatly reduce the cost. Other access options may include on-line learning websites that are set up in support of a CD-ROM or a site license that allows an instructor to install the content on dedicated computers that the students can use for review.

A well-designed set of multimedia CD-ROMs that I use in both Neurobiology and Neurophysiology is the ADAM Interactive Physiology Series (http://education.adam.com). This set of seven CD-ROMs covers the physiological concepts that govern the dynamic activity of the major body systems. For Neurobiology, I use two of the CD-ROMs in the series, which present the fundamental physiological responses that lead to neural communication. In the more advanced Neurophysiology course, I use segments from several CD-ROMs to describe the interaction of the nervous system with effector tissues (i.e., activity at the neuromuscular junction) and autonomic control over major body systems (i.e., cardiovascular and respiratory systems). By alignment of the use of these CD-ROMs with the presentation of the more dynamic aspects of neurophysiology, they have become useful enhancements to course lectures.

Although I do not use a text in either course that is directly correlated with the ADAM Interactive Physiology Series, the structure and content of this material are designed so that these CD-ROMs can easily be used as independent resources. Each CD-ROM is organized around a system or physiology topic and is divided into a series of lessons. Each lesson starts with a set of “Learning Goals” that are the focus of several segments of logically presented text, graphics, and animations. Throughout the lessons, interactive questions and breaks at the end of each segment allow for review and the generation of class discussions. After each lesson, there are sets of interactive study questions that can be done as a group or used for independent review outside the classroom. In addition, these questions can be integrated into formal examinations or used as a review lesson. Students are given the option of purchasing the entire series or individual CD-ROMs, viewing the material through an on-line learning website, or reviewing the lessons on a dedicated laboratory computer that is available on a regular weekly schedule.

Because my Neurobiology course is commonly my students’ first opportunity to focus their studies on the nervous system, I spend the initial few weeks covering the basics of neuroanatomy to make future discussions of physiological concepts easier for the students to comprehend. Through the use of the Sylvius 2.0: Fundamental of Human Neural Structure CD-ROM (Sinauer Associates, Sutherland, MA), I have enhanced these classroom lectures and discussions, while providing an additional resource to the students. This CD-ROM presents the structures of the nervous system in high-resolution graphics that are correlated with histological sections and three-dimensional models. Because the text I use in this course is produced by the same publisher, I have been able to bundle this CD-ROM with the text, providing it to the students at a substantial discount.

In the more advanced Neurophysiology course, laboratory sessions allow physiological concepts such as sensory transduction to be presented in greater detail. However, the equipment required to perform advanced laboratory exercises that involve the intracellular recording of single neuron activity can be expensive, and student-led exercises at this level may not always result in analyzable data. In place of these exercises, and now as a supplement to the actual experiments, I use a Virtual Neurophysiology Lab, which is available through the Howard Hughes Medical Institute: Bio Interactive Lab Series (http://www.biointeractive.org). In this virtual laboratory, recordings are made from the sensory neurons of the segmental leech ganglia in response to different sensory stimuli. In addition, neuronal morphology is characterized through the use of fluorescent dyes. A
corresponding lab notebook provides background information and detailed notes on the methodology as well as interactive results and discussion sections. This laboratory can be run through an on-line connection to the Bio Interactive website or from a CD-ROM that can be obtained from the Howard Hughes Medical Institute.

**Computer-based physiology recording systems.**
In many research laboratories and medical clinics, physiological measurements are no longer recorded using mechanical equipment such as respiratory spirometers, strip chart recorders, or mercury column sphygmomanometers. Through the use of computer-based systems, physiological responses can now be measured accurately and stored for later analysis. Basic systems are available for recording individual responses, and more complex systems can simultaneously record multiple physiological measurements. This provides the researcher or clinician with quick and easy access to recorded data as well as to integrated information that can better guide an experiment or the treatment of a patient. In the teaching laboratory, computer-based recording systems can expose students to these methods of data collection and analysis and provide a cost-effective resource that can be used for virtually any physiology laboratory exercise.

Since the inception of my Neurophysiology course, I have made use of the iWorx data acquisition and analysis system (http://www.iworx.com). Each year, I have incorporated it into more of the course laboratories, until it has now become a part of virtually every weekly lab session. The hardware component consists of a computer interface (iWorx 204) that has four input channels and an isolated stimulator output channel. A series of transducers and front-end components is available for recording physiological responses from animal preparations or from the students themselves. The iWorx-designed Labscribe data acquisition software fully supports their computer interface as well as hardware from National Instruments (http://www.ni.com). During the actual recording of a physiological response, this software offers several acquisition and analysis options that include the addition of four channels of integrated output, signal amplification and filtering, and the ability to mark and comment directly into the record.

Once an experimental procedure has ended, there are additional options for analysis and use of an integrated “Journal,” where students can create laboratory reports that incorporate their data and the results of further analysis. Another aspect of the Labscribe software is a library of integrated laboratory exercises that are fully editable and, when opened using the Labscribe software, preset the recording and analysis channels with the parameters for a particular exercise. Through the use of computer-based systems like the iWorx system, students are provided with an interactive framework for meeting one of the learning objectives, developing an ability to use the scientific research method in addressing complex physiological research questions.

One of the main objectives of my Neurophysiology course is that students come to understand the interactivity of physiological systems and the role the nervous system plays in this interaction. Near the end of the course, students use the iWorx system to perform a laboratory exercise that integrates their knowledge into a true learning experience. This exercise focuses on the concept of vagal tone, which refers to the nervous system’s control over heart rate and can be considered a measurement of the overall activation of the parasympathetic division of the autonomic nervous system (PNS). In a resting, nonstressful environment, PNS activation through the vagus nerve is high, and heart rate will remain relatively low (based on the fitness and cognitive state of the individual). In response to the changes in the activity of other body systems, complex neural reflexes can produce small changes in heart rate that can be measured during even the slightest physiological adjustments (i.e., moving from a reclining to a standing position). At rest, these variations in heart rate will be tightly correlated with respiratory rate. When a cognitive stressor is applied, PNS control decreases as sympathetic input increases to heighten physiological responses. Small changes in heart rate will no longer be detectable. This is a result of a decrease in vagal tone that can be measured as a change in pulse or blood pressure or more directly by comparing heart rate and respiratory rate to determine the respiratory sinus arrhythmia (Fig. 1). With the iWorx system, a subject’s electrocardiogram, integrated heart rate, and respiratory rate can be recorded simultaneously during a change in vagal tone. Once recordings are com-
completed, students can use the results of their data analysis to make conclusions about an individual’s overall fitness and response to stress.

Through the use of a computer-based physiological recording system such as the iWorx system, valuable laboratory time can be redistributed to enhance the learning experience. Less time is spent setting up equipment and collecting analyzable data that have a good signal-to-noise ratio. More time can then be used in the discussion and development of an experimental hypothesis, data analysis, and interpretation and in formulating conclusions. The result is the use of technology that is aligned with the learning objectives, leading to a higher level of student understanding from these laboratory learning experiences.

**ASSESSMENT**

The goal of integrating new education technologies into any course or curriculum should always be to enhance the learning experience. Through constructive alignment, the potential for education technologies to be effective tools for learning is maximized. However, this can be difficult to assess in any given course. Authentic assessment is a measure of a student’s conceptual understanding of course material and ability to solve problems on the basis of this understanding (4, 6). This is usually characterized through traditional methods such as formal examinations, presentations, performance on laboratory exercises, and regular student feedback. However, this assessment can be more qualitative than quantitative,
and the perception that a form of technology works well or poorly in the classroom can quickly lead good instructors to make immediate adjustments aimed at improving their courses.

New education technologies, however revolutionary they might be, are simply tools for learning, and it is their application that determines their effectiveness. In 1987, Chickering and Gamson (8) presented seven basic principles that lead to enhanced student learning in undergraduate education (Table 1.) These principles include concepts such as the encouragement of interaction, active learning, and immediate feedback as well as setting high expectations and bringing diverse populations of students to the same level of understanding. With the rapid push to use technology in the classroom, Chickering and Ehrman (7) recently revisited these original principles and suggested ways in which technology can be used to advance them further. Their overall conclusion is that new education technologies can provide students with the ability to become more involved in the learning process. When these principles are combined with those of constructive alignment, the full potential for the use of technology in the classroom can be achieved.

Because students’ involvement in their own education is a key to better learning and technology can enhance the learning process, I have applied the principles presented by Chickering and Gamson and those of constructive alignment in my efforts to integrate technology into my Neurobiology and Neurophysiology courses. I have found that course websites provide students with an important resource that allows learning to go beyond the classroom. Their use sets a high standard for learning through easy access to course materials and additional resources as well as providing a forum for interaction. PowerPoint-style presentations increase the effectiveness of classroom lectures and encourage more group discussions. Multimedia presentations promote an active learning environment that can be used to present difficult concepts and provide valuable feedback to the students on their current level of understanding. Computer-based laboratories also enhance the active learning environment, allowing laboratories to focus effectively on learning objectives and the research method of scientific discovery. In addition, using this technology in the teaching laboratory promotes a high level of student proficiency with complex methods of physiological recording that are now the standard in today’s research labs and clinical environments.

Three forms of qualitative assessment that I have used to determine whether technology has enhanced student learning in both Neurobiology and Neurophysiology are 1) peer assessment, 2) student numerical evaluations, and 3) student comments. As part of a teaching development program, I participated in group sessions with instructors from various disciplines in an effort to provide developmental support during the preparation of new courses. This support culminated in a peer classroom evaluation, which suggests that the use of new technologies has been effectively incorporated into my teaching method (Table 2). Numerical course evaluations for both Neurobiology and Neurophysiology also indicate a student perception that they learned a great deal in these courses and that lecture presentations (primarily using PowerPoint or multimedia) were also well organized (Table 3). With the addition of technology into these courses, students were also asked whether course objectives were clearly stated, whether these objectives were met, and whether examinations reflected the course material that was covered. For all

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<tr>
<th>Table 1</th>
<th>Seven Principles for Good Practice in Undergraduate Education [Chickering and Gamson (8)]</th>
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<td>Good practices...</td>
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<tr>
<td>1. Encourage contact between students and faculty</td>
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<td>2. Develop reciprocity and cooperation among students</td>
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<td>3. Use active learning techniques</td>
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<td>4. Give prompt feedback</td>
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<td>5. Emphasize time on task</td>
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<tr>
<td>6. Communicate high expectations</td>
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<td>7. Respect diverse talents and ways of learning</td>
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<th>Table 2</th>
<th>Peer evaluation comments</th>
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<tr>
<td>“You successfully integrate technology with more traditional techniques.”</td>
<td></td>
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<tr>
<td>“The combination of computer animations and short explanations during the lecture portion of the lab consistently held my interest as well as the interest of the students.”</td>
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Written comments from Dr. Tom Linneman, Department of Sociology, College of William and Mary. Based on a visitation to a Neurophysiology laboratory session.
three questions, which reflect how well learning experiences are aligned with course objectives, students gave very positive responses that had numerical scores of 4.69 ± 0.06, 4.67 ± 0.06, and 4.30 ± 0.09 respectively (n = 59; see Table 2 for scoring details). In addition, the students had a very good overall impression of these courses. Written comments from course evaluations also confirm the student perception that technology enhanced their learning process (Table 4).

DISCUSSION

From a pencil and paper to chalk and a blackboard to a computer and an LCD projector, technological advances have always been applied in the classroom in an effort to enhance learning. Today’s dilemma with how to use technology is not that different from when the overhead projector entered the classroom as a teaching tool in the 1970s, only to now have its use threatened by PowerPoint-style lecturing (16). However, technology itself is neutral to its own effectiveness as a teaching tool. Although it can support creative approaches to learning and positive changes in education, it can also promote undesirable practices and poor teaching (10). The major limitation for the use of technology in the classroom is that it is still up to the instructor to use technology appropriately and to the benefit of the students.

Although recent studies have suggested that the use of PowerPoint presentations in the classroom may not lead to enhanced learning, they would also suggest that this is dependent on the level of quality teaching and not on the technology itself (16, 17, 18). When the use of technology is appropriate and aligned with the learning objectives, the result is a higher degree of effective teaching and student learning (2, 17). Education technologies have the potential to improve a student’s ability to access information and turn that information into understanding through critical analysis. They can also help instructors become more efficient and productive in the classroom, creating better learning environments. Several studies have also shown that complex scientific concepts become easier to present and students gain a greater understanding of them when using such technologies as web-based tutorials and multimedia-style presentations (4, 20). In almost every area of undergraduate

<table>
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<tr>
<th>Question</th>
<th>Neurobiology (n = 48)</th>
<th>Neurophysiology (n = 11)</th>
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<tbody>
<tr>
<td>Did you learn anything in this class?</td>
<td>4.60 ± 0.12</td>
<td>4.91 ± 0.10</td>
</tr>
<tr>
<td>Were presentations organized?</td>
<td>4.40 ± 0.14</td>
<td>4.64 ± 0.15</td>
</tr>
<tr>
<td>Instructor’s overall teaching performance?</td>
<td>4.30 ± 0.13</td>
<td>4.82 ± 0.12</td>
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<tr>
<td>Overall course evaluation?</td>
<td>4.38 ± 0.12</td>
<td>4.73 ± 0.14</td>
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Numerical scoring: 1 = no/poor; 3 = sometimes/average; 5 = yes/excellent. All reported numbers are means ± SE and are above the means for all departmental courses during the same semester.

Table 4

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<th>Student comments</th>
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<tr>
<td>1. The course was really well organized. The PowerPoint slides and website were quite helpful and extremely useful.</td>
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<tr>
<td>2. I really liked that the lectures were on PowerPoint and available to print.</td>
</tr>
<tr>
<td>3. I appreciated the PowerPoint presentations because they made the lectures a lot more organized and easy to follow.</td>
</tr>
<tr>
<td>4. Your lectures had a very good balance of PowerPoint and participation. You allowed the computer to open you up to interactivity with the class.</td>
</tr>
<tr>
<td>5. I found the website with lecture outlines very helpful and I also thought the discussion questions we posted answers to online were a great way to know what other students were thinking in such a large class.</td>
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<tr>
<td>6. Having a discussion board to express ideas about certain topics was a great idea.</td>
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<tr>
<td>7. The Sylvius CD was very helpful for the early part of the course on anatomy.</td>
</tr>
<tr>
<td>8. I thought the interactive physiology CDs were great. I think it added a lot of depth to the topics we studied that would not have been possible just through assigned readings.</td>
</tr>
<tr>
<td>9. Laboratories were fun and a great hands-on way to see things in action.</td>
</tr>
<tr>
<td>10. Laboratories were very effective and definitely added a lot to my understanding of the material.</td>
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Along with a set of survey questions, students were asked to provide comments on their views of the course, particularly on the use of technology in the course. Above are selected comments from the students.
science education as well as in advanced medical physiology teaching, today’s new technologies have proved effective in enhancing student learning (11, 13, 20).

Although technological advances will continue to offer instructors new ways to think about teaching, the effectiveness of technology in the classroom will always depend on its appropriate use as well as an instructor’s skill and attitude (3, 5). The well-planned and enthusiastic application of technology will undoubtedly benefit students and lead to enhanced learning. It has even been suggested that those instructors with a high level of technology in their teaching are better at instilling students with a desire to learn and the development of skills for critical thought. They are also more creative in their teaching methodology and devote more class time to inquiry-based learning. On the other hand, instructors who rely primarily on more traditional teaching methods tend to be more structured in the classroom and to stress content over practice in their courses (19). They are less creative and rely primarily on lecturing and a single text as the only methods by which the students are exposed to course material. In the future, students will demand more from their instructors and expect technology to be part of the classroom experience as it is already part of their everyday lives (12).

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References