ARTICLE
Effective Use of Computer Simulations in an Introductory Neuroscience Laboratory

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Introductory Neuroscience courses are being offered more regularly at diverse institutions. On the other hand, the creation of an independent laboratory curriculum for introductory neuroscience courses puts a strain on financial and human resources of a small college. A solution to this situation might be presented through the use of relevant simulation software in order to eliminate the binding of resources; but nevertheless, provide sufficient, effective, and engaging education to students. This paper suggests the use of a combination of different software during Introductory Neuroscience laboratory sessions, which are finely tuned with the material presented during lecture. Two student cohorts were evaluated and compared using three types of measures: exam grades, course evaluations, and software evaluations. The results show that the use of software simulations had a positive effect on the performance of students on exams, and on the favorability of course ratings. The findings suggest the use of software simulations for Introductory Neuroscience courses to be beneficial for the learning experience of the students.

Key words: computer software simulations; pedagogy; laboratory activities; Introductory Neuroscience

Undergraduate Neuroscience programs have seen a dramatic increase in recent years, particularly within small, liberal arts colleges. To meet the growing popularity of a Neuroscience major, small colleges have responded with the creation of stand-alone approaches, often as interdisciplinary programs between Biology and Psychology departments. Neuroscience education in small, liberal arts colleges bears the advantage of small class sizes, fostered by a selective, often ambitious student body and close relationships to professors. However, neuroscience programs in this kind of college are faced with multiple limitations, including space, financial means, and equipment exclusively dedicated to the teaching of neuroscience laboratories.

Increasingly popular courses in Introductory Neuroscience cover a wide range of material, from cellular physiology to cognition. Consequently the requirements for an appropriate laboratory experience are extensive. Areas that are desired to be taught in the laboratory of an Introductory Neuroscience course involve dissection, single cell recording, animal laboratory for learning and memory experiments, and cognitive neuroscience. This breadth of material is not only difficult to achieve in terms of time or space, it can also put a significant financial and organizational strain on a small college. Additionally, these tasks are desired to not only teach the specific skills, but also enhance interest in the material and teach critical thinking skills.

Nevertheless, research and laboratory experience are a crucial part of the undergraduate neuroscience education. The curriculum should not demonstrate to the students what they will perform in graduate school, but rather equip them with the necessary skills and understanding to perform well in an advanced training environment (Wiertelak, 2003).

Given the above mentioned obstacles, alternatives to traditional laboratory approaches are necessary to fully serve the students at these institutions. Approaches involving the use of more passive learning through video and multimedia demonstrations and non-interactive observation of laboratory techniques are typical, but are limited in the interactive experience of the student. While the non-interactive approaches may initiate active learning if designed properly (Grabe & Grabe, 1998), the lack of interactivity may limit a responsive environment in which students receive feedback from their actions (McKeachie, 1999). Realistic computer simulations may provide an efficient and practical alternative to these more traditional approaches to laboratory experiences in neuroscience, as it has been in other disciplines (Kozma, 1982). Some of the benefits of computer simulations may include the reduced need for specialized equipment, classroom space, etc. Laboratories can take place in a regular class room where only computer resources and software are needed, as opposed to the many types of different equipment previously mentioned. However, it is still yet to be determined whether computer simulations are effective from a pedagogical perspective. The purpose of this paper is to examine the efficacy of a selected sample of computer simulations as a potential alternative to more traditional or non-interactive viewing laboratory techniques.

METHODS

Participants
Participants were included in this study based on their enrollment in an Introductory Neuroscience course at Ursinus College in either the fall of 2005 or the fall of 2006. Within both of these cohorts, there were 16 undergraduate students. Within the 2005 cohort there were six science majors, six social science majors, and four humanities majors. Of the 16, there were four freshman, nine

sophomores, one junior, and two seniors. The 2006 cohort consisted of the same distribution of majors, with five freshman, eight sophomores, two juniors, and one senior. In order to further demonstrate the general equivalence of the two cohorts, mean overall GPA of the two cohorts were 3.04 and 3.09, respectively.

Procedure

The Introductory Neuroscience course at Ursinus College combines three lecture hours per week and three laboratory hours per week. As such, the course meets the science laboratory requirement for the College's core. Within the lecture section of the course, four exams are given, each covering three chapters in the textbook, and the related lecture material. The textbook used in both sections of the course was Brain, Mind, and Behavior (Bloom et al., 2001). Laboratory assignments were given throughout the semester to complement the material for each section of the course.

In the fall of 2005, the lab section of the course consisted of a series of non-interactive learning exercises, including multimedia presentations and research demonstrations by faculty, in which the students were asked to attend to a presentation and complete writing assignments based on the information. Each presentation was congruent and complementary with the material covered in the lecture. Multimedia presentations included videos and video clips of topics including electrochemical communication in neurons, development of the nervous system, sleep and the nervous system, and the actions of drugs on the nervous system. Faculty presentations included a cellular neurobiology demonstration using weakly electric fish, a molecular neurobiology demonstration related to synaptic vesicle release, an eye movement demonstration using an eye tracker, and a demonstration of various neuroimaging techniques. In the fall of 2006, the lab section was overhauled to include mostly computer based simulation exercises also relevant to the material in the lecture portion of the class. The interactive software included a series of online websites used for gaining knowledge in gross brain anatomy, a simulation of single cell recording, a series of cognitive computer-based tasks to demonstrate various concepts including visual processing and memory formation, and a simulated rat in a skinner box useful for demonstrating the principles of operant and classical conditioning. It was assumed that the only measurable difference between the two presentations of the course was the interactivity of the exercises within the lab.

Computer Simulations

The computer simulations used in the 2006 cohort of the lab included online and offline software designed as either an educational tool or as a currently used research-based tool. Under the context of the material covered in lecture exam 1 (e.g. gross brain anatomy, neurophysiology), the programs included: The Whole Brain Atlas, 2003 Edition (http://www.med.harvard.edu/AANLIB/cases/caseNA/pb9.htm) used to familiarize the student with identification of critical brain regions, MRICro (http://www.sph.sc.edu/comd/rorden/mricro.html, ver. 1.40) for anatomical identification as well as measurement of regions of interest, the Talairach Daemon (http://ric.uthscsa.edu/TDapplet/) for anatomical identification. These programs were utilized to familiarize the student with the terms used in describing the gross anatomy of the human brain and the locations and shape of particular structures. For example, students were asked to identify the substantia nigra based on Talairach coordinates, and measure the volume of the thalamus. In the following evaluations these three are treated as one (MRICro/ Brain Atlas/ Talairach Daemon). In addition to the gross anatomy and brain area identification, exam 1 included much material describing cellular neurophysiology. NerveWorks 2.0 was used in the lab to demonstrate the principles of single cell recording and the concepts of concentration gradients and resting potentials. In our lab, we used pre-made labs provided by the publisher. In the "Recording 101" lab, students are introduced to the equipment needed to perform intracellular recording and how the wiring of this equipment affects the voltage on the oscilloscope. Additionally, students completed the "Basic Resting Potential" lab which allows students to examine the effects of membrane permeability, concentration gradients, and use of the Nernst equation. For each of these labs, a series of thought-provoking questions were required while completing the steps.

The lab component of exam 2 consisted of a series of cognitive tests examining visual perception and hemispheric asymmetry. The software used for this series of tasks was Coglab (version 2.0, Wadsworth) and consisted of students completing a series of individual tasks followed by data collection and analysis as a group. The visual perception tasks included a test of the location and size of the blind spot and a simulation in which students were required to determine the location of the receptive fields of neuron in the visual cortex. The brain asymmetry task consisted of a reaction time task in which visual or verbal stimuli were presented to either the left or right hemisphere. The lab component of exam 3 consisted of more computer-based cognitive tests from Coglab used to demonstrate various aspects of learning and memory. The tasks included a false memory task, an implicit learning task, and a serial position effect task. For all of the cognitive tasks, students completed the tasks individually, the data was then summarized for entire class, and the students had to write a lab report detailing the methods and findings. Finally the lab component for exam 4 consisted of the use of a virtual learning environment (i.e. Skinner box), using a simulated rat, Sniffy Pro (version 5.2f3, Wadsworth). The Sniffy program was used to explore the principles of classical and operant conditioning. During the initial session, students trained a naïve rat to press the lever using the principles of operant conditioning. Following this, students explored the effects of schedules of reinforcement and finally used the trained rat to explore classical conditioning through fear (i.e. shock). During each of the "Sniffy" labs, students were required to respond to a series of discussion questions and generate formal lab reports.

Efficacy Measurements

In order to evaluate the efficacy of the passive versus the active learning labs, we used three general classes of outcomes and compared them between the 2005 cohort (i.e. passive) and the 2006 cohort (i.e. active). First, we compared the exam scores for each of the four lecture based exams between the two cohorts. Each exam covered material for three textbook chapters and was composed of multiple types of questions, including multiple choice, diagrams, short answer, and long essay. While the content of the exams was consistent between cohorts, the actual test items were alternated with care taken to maintain the level of difficulty across cohorts.

The second set of measures was taken from the voluntary, semester end course evaluations. Specifically, three questions relating to the content of the course, including the lab, were evaluated. The three questions pertained to the level at which the course inspired the student to think critically, the level at which the course increased the skills of the student, and the degree to which the student thought the course was challenging. Each was rated on a 1 to 5 scale with larger numbers indicating greater level of critical thinking, skill increase, and challenge, respectively.

The final set of measures was an evaluation of the simulations software itself, and was only conducted on the 2006 cohort. The evaluation asked student to rate each set of software simulations on measures of ease of use, interest, and relevance to the course material. Each rating was based on a Likert Scale from 1 to 6 with the lower numbers indicating less user friendliness, less interesting, and less relevance to the course. Of the 16 students in this cohort, 15 completed this section of the evaluation.

RESULTS

To evaluate whether the usage of active learning based computer simulations made a difference to the knowledge gained in the student, the four exam grades were compared between the 2005 (passive learning) cohort, and the 2006 (active learning) cohort. Independent samples t-test for each exam score was used and we discovered that the active learning cohort scored significantly better on exam 4, $t(30)=-2.091$, $p=.045$. The lab component for exam 4 was primarily the use of the virtual learning environment to grasp the concepts of classical and operant conditioning. Although the between-group differences on exams 1, 2, and 3 were not significant, there was a trend toward better performances in the active cohort on exams 1 and 2. The fact that the trend towards significance was in the opposite direction for exam 3 scores suggest that the significant difference observed during exam 4 was not due to a sampling confound in which the active learning cohort may have been better prior to the start of the class. If that was the case, the trend should have continued on all four exams, which was not observed (Fig. 1).

The second set of analyses used independent samples t-tests to investigate the effects of cohort on the course evaluations. First, the students' perception of their increase in skills differed significantly between cohorts, $t(22)=2.086$, $p=.049$, with the active learning cohort (2006) perceiving a larger increase in skill levels. Secondly, the students perception of the level of challenge within the course significantly differed between cohorts, $t(22)=2.213$, $p=.038$, with the active learning cohort (2006) perceiving the course as more challenging than the passive learning cohort (2005). Finally, the difference between the cohorts on the level of critical thinking required in the course was non-significant, although the ratings are in the direction of the active learning cohort (2006) perceiving more critical thought (Fig. 2).

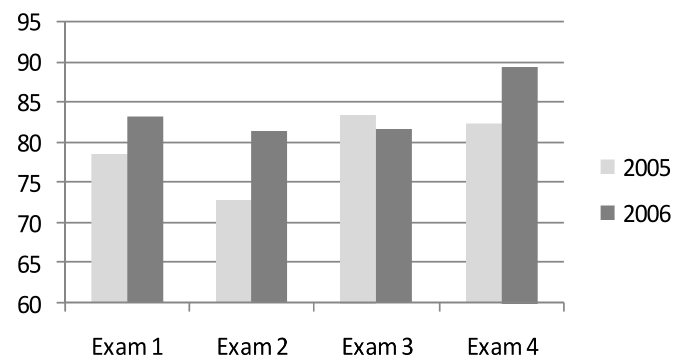

Figure 1. Exam results out of 100 possible points. Light gray represents cohort 2005 (passive), dark gray represents cohort 2006 (active).

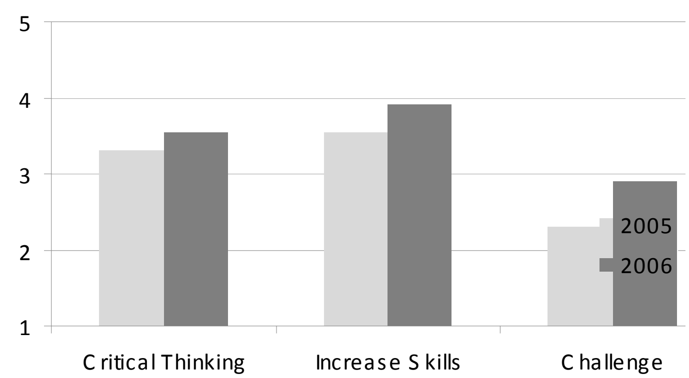

Figure 2. Student evaluation of Introductory Neuroscience course in general. Light gray represents cohort 2005 (passive), dark gray represents cohort 2006 (active). Scale ranges from 1-5 with 5 being a most favorable rating and 1 being the least favorable rating.

The final set of analyses regarding specific evaluation of the software was computed on the interactive learning cohort alone, as the non-interactive learning cohort did not use the software. First, the summary ratings for ease of use, user interest, and relevance to the course are presented graphically (Fig. 3).

It should be noted that a mean rating of 3.5 would indicate a neutral evaluation of the software. Students rated the Cognitive tests and the Sniffy Pro software as easy, interesting and relevant, while the anatomical and NerveWorks software was rated difficult and uninteresting, although relevant. Spearman correlations were then computed between the various ratings to determine the relatedness. Significant positive correlations ($p<.05$) were present between Ease of Use and User interest for the anatomical software, NerveWorks, and for the Sniffy Pro software. In other words, there was a significant relationship between user friendliness and student interest.

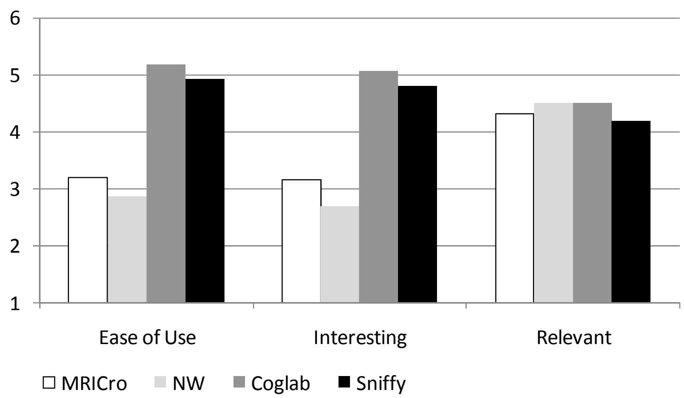

Figure 3. Student evaluation of software. White with black border represents MRICro, lightest gray represents NerveWorks, second lightest gray represents the cognitive test series, and black represents Sniffy. Scale ranges from 1-6 with 1 being least favorable and 6 being most favorable.

DISCUSSION

The purpose of this paper was to examine the usage of computer software simulations in Introductory Neuroscience laboratories. Because of the interdisciplinary nature of Introductory Neuroscience courses, complex and expensive equipment and lab facilities are required to fully equip the student with the necessary educational resources. Unfortunately, many institutions interested in offering Neuroscience courses do not have direct access to this type of lab space and equipment. The software simulations evaluated here may provide a practical and useful alternative for those institutions and still involve the student in an active learning environment. This is not to say that other inexpensive alternatives do not currently exist, see Land et al. (2004) for a good example.

The use of software simulations in this type of lab, appear to have directly impacted the level of understanding obtained by the student as evidenced by increase in exam scores across three of the four exams. Additionally, students participating in the active simulation cohort rated the overall course as more challenging and helped to increase their skills more relative to the passive viewing cohort. Interestingly, the active learning cohort did not necessarily view each of the software simulations favorably (i.e. ease of use, and interesting), but each of the software packages was deemed relevant to gaining knowledge within the overall course.

The results of this examination would suggest the adoption of interactive learning simulations in the Introductory Neuroscience course to be beneficial to the learning environment. While the authors will continue to evaluate the specific software chosen for efficacy, and search for viable alternatives, the fact that multiple alternatives exist is promising. However, the findings should be evaluated critically as experimental validity was reduced due to the classroom environment, potential selection biases, and the inability to randomly assign students to a particular cohort. Additionally, use of exam grades as a dependent measure of knowledge gained is not particularly precise and a study is currently being designed to implement other measures of learning. With the growing interest of Neuroscience worldwide, issues of pedagogy within the Neurosciences are becoming critical, suggesting the need for further investigations of this type. The efficacy of these types of pedagogical tools may allow institutions, who would otherwise be unable to offer a course such as this, to enhance their curriculum with an interdisciplinary Introductory Neuroscience course.

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