

STUDENT TEST SCORES ARE IMPROVED IN A VIRTUAL LEARNING ENVIRONMENT

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This study evaluates the effectiveness of delivering the core curriculum of an introductory neuroscience course using a software application referred to as a virtual learning interface (VLI). The performance of students in a virtual learning environment (VLE)¹ is compared with that of students in a conventional lecture hall in which the *same lecturer presented the same material*. This study was not designed to determine whether grades are improved by augmenting a lecture with other information. The VLI takes advantage of audio, video, animation, and text in a multimedia computer environment. Our results indicate that raw average scores on weekly examinations were 14 percentage points higher for students in the VLE compared with those for students in a conventional lecture hall setting. Moreover, normalized test scores were over 5 points higher for students in the VLE. This analysis suggests that a core curriculum can be effectively presented to students using the VLE, thereby making it possible for faculty to spend less class time relaying facts and more time engaging students in discussion of scientific theory.

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INTRODUCTION

Neuroscience is one of the most rapidly growing fields in biology today. Recently, several academic institutions have created an undergraduate major in Neuroscience; The Johns Hopkins University is one of these. This major, which was initiated just two years ago at Johns Hopkins, is now the third largest in the school of Arts and Sciences and continues to expand. Offering a degree in such a rapidly emerging field has stressed the importance of resolving several issues that are common to most fields of science education. These include:

- How can the essential information be provided to students when the quantity of information is increasing so rapidly?

- How can professors more effectively address the educational needs of their students given limited contact hours?
- How can introductory level students be given the opportunity to discuss current research with both their colleagues and professors without making prohibitive demands on faculty time?

It is clear that educational reforms are an important and intense focus of the academic community (4, 8, 9, 12). Many investigators have developed techniques for enhancing the classroom experience (14, 16, 18), and these enhancements have tended to serve as augmentations to the curriculum (6, 10, 11, 22, 23).

¹ The VLE is defined as the VLI plus content.

Several studies have investigated the use of technology to deliver core content, but these results were either analyzed subjectively (15, 17) or indicated that there was no significant difference in student performance (21).

The purpose of this study was to compare the effectiveness of the conventional lecture hall with that of a virtual learning environment (VLE) for the presentation and dissemination of the core curriculum. In this study, the *same* lecturer presented the *same* material in both the VLE and the conventional lecture hall. The results show that the VLE was more effective than the conventional lecture hall as a platform for delivering core content. Furthermore, these findings indicate that the VLE could be used to *redefine* the role of the professor from one responsible for the dissemination of facts to a leader of seminar style discussions. Redefining the role of the professor does not imply a reduction in student-faculty contact hours. The advantage of the VLE is to relieve faculty from the potential obligation of making large lecture hall, didactic presentations and to provide faculty with the opportunity for instructing students in a more informal setting.

METHODS

Five lectures of an introductory course, Topics in Neuroscience, were used as the basis for this study and covered the second half of a semester-long, two-credit course. The lectures were presented weekly and included the following topics: 1) Neural Development (A. Ghosh), 2) Learning and Memory (J. Baraban), 3) Synaptic Transmission (J. Pevsner), 4) The Visual System (M. Steinmetz), and 5) The Motor System (R. Shadmehr).

The primary benefit of the VLE was to provide students with different instructional pathways (1, 7) to the content. The VLE is a hybrid compact disc (CD) system: content requiring high bandwidth such as digital video and animation is stored on CD-ROM, whereas text-based information can be transmitted across the Internet. The virtual learning interface (VLI) used in this study divides the computer screen into several components. A digital video recording of the lecturer occupies one of these areas. In another, a full lecture-length, detailed animation is delivered in parallel with the lecture video and provides students with a different perspective of the content. For example,

photo-transduction in the retina is presented as an animation that includes the conformational changes of rhodopsin on exposure to light, the subsequent activation of a G protein, amplification of this signal through phosphodiesterase, and the eventual inactivation of a photoreceptor as cGMP is cleaved. This is a difficult concept to describe using words and static images. However, using animation, students of the VLE achieved a strong understanding of this difficult concept, as demonstrated by their test scores.

Another component of the VLI can be best described as an electronic notebook. Students use this area to type notes, collect images or animated sequences, and to bookmark any portion of the lecture video. This notebook can be saved to the user's hard drive or to removable media such as a diskette and can be printed as a learning aid.

The transcript module is another major component of the VLI. This window contains the paginated lecture transcript. The text-based learner (3, 13) may use this region of the screen as the primary focus.

The Internet component consists of a web site designed and hosted exclusively for the neuroscience course. On this web site students can post questions or comments to a common message board. Students may also enter an electronic chat room to converse with their colleagues, teaching assistants, or the faculty member of the course. This site can also be used to retrieve class assignments, reference papers, or other postings. The Internet component was disabled for this controlled study because it would permit students to access material not available to students of the conventional lecture hall.

The 40 students enrolled in this study were divided randomly into two groups of equal size. For the first half of the study, one group of students was instructed using the VLE, and the other group was instructed using a conventional lecture format; these groups were switched at the midpoint of the study (see Table 1 for class schedules). The same lecturer presented the same material in class and in the VLE. Experimental design called for use of the first lecture as a practice session. The group of students initially instructed in the conventional lecture hall received a 15-minute

TABLE 1
Schedule of classes for VLE students and conventional classroom students

Group Name	Synaptic Transmission	Neural Development	Visual System	Motor System
A	VLE	VLE	Conventional	Conventional
B	Conventional	Conventional	VLE	VLE

VLE, virtual learning environment. An examination followed each lecture.

tutorial on the use of the interface before they were crossed over to the VLE for the last two lectures.

Students enrolled in the VLE could utilize it at any time during the week. To prevent students of the conventional lecture hall from viewing the virtual lecture, students were required to use the VLE in the University's computer facilities. A sign-in sheet for VLE students indicated that on only three occasions did a student listen to a lecture on more than one occasion. The computer facility contained six Apple G3 Macintosh and ten PC 233-MHz computers with headphones.

The same examination was given to both groups at the end of each week (see Table 2 for a sampling of questions). Examinations were short essay, proctored examinations each composed of approximately five questions. Students had one hour to complete each examination. To minimize the influence of previous grades on preparation for subsequent examinations (for example, to reduce a student's tendency to not fully prepare for the final examination following four strong performances), students were informed of their grades only at the end of the course. The examinations were graded by teaching assistants who did not know the students personally or to which group they belonged. Students were asked to fill out a

TABLE 2
Sample Test Questions

- 1) What role does phosphorylation of membrane-bound proteins play in vesicular transport?
- 2) Describe how a photon of light causes a photoreceptor to become hyperpolarized.
- 3) Given that cells of the temporal cortex of a monkey respond to only a generic monkey face, how might the animal recognize individual monkeys?
- 4) Compare the behavior of NMDA channel opening to AMPA channel opening.
- 5) What determines whether an axon of a developing neuron located in the cortex moves to deep layers of the brain (e.g., the thalamus) or to superficial layers of the brain?

questionnaire at the end of this study and to write a short paper describing their view of the VLE experience. Questionnaire questions included a request for students to rank the effectiveness of the VLE in terms of content delivery; to rank their preference of the VLE relative to the conventional lecture hall format; to comment on the application of the VLE to other large, introductory classes; and to describe the benefits and weaknesses of the VLE.

Statistical analysis. As specified in the experimental protocol, students were encouraged to familiarize themselves with the VLE during the initial lecture. Consequently, data from the first week of testing were not included in the analysis. Participants were also excluded from the analysis if they did not complete at least three of the four testing sessions. These exclusions resulted in 18 participants using the VLE for the first two lectures and 20 participants using the VLE for the second set of lectures. Student test scores were standardized to a mean score of 80 and a standard deviation of 10. Following this normalization, mean test scores across the four weeks were calculated for each individual participant, and this mean score was subtracted from each of the individual's test scores to obtain a deviation score on each test for each individual. This was done to eliminate effects of individual differences among participants that may have influenced the outcome. With the use of the four deviation scores for each participant, a two-way ANOVA was used to compare the conventional lecture hall versus the VLE testing condition with week of test and form of content delivery as the two factors. Statistical significance was assessed using an $\alpha = 0.05$.

RESULTS

Learning outcomes. Figure 1 displays the mean, median, 1st/4th quartile, range, and 10th/90th percentile of the student's raw test scores. The first box of each examination pair represents the range of scores received by students in the conventional lecture hall,

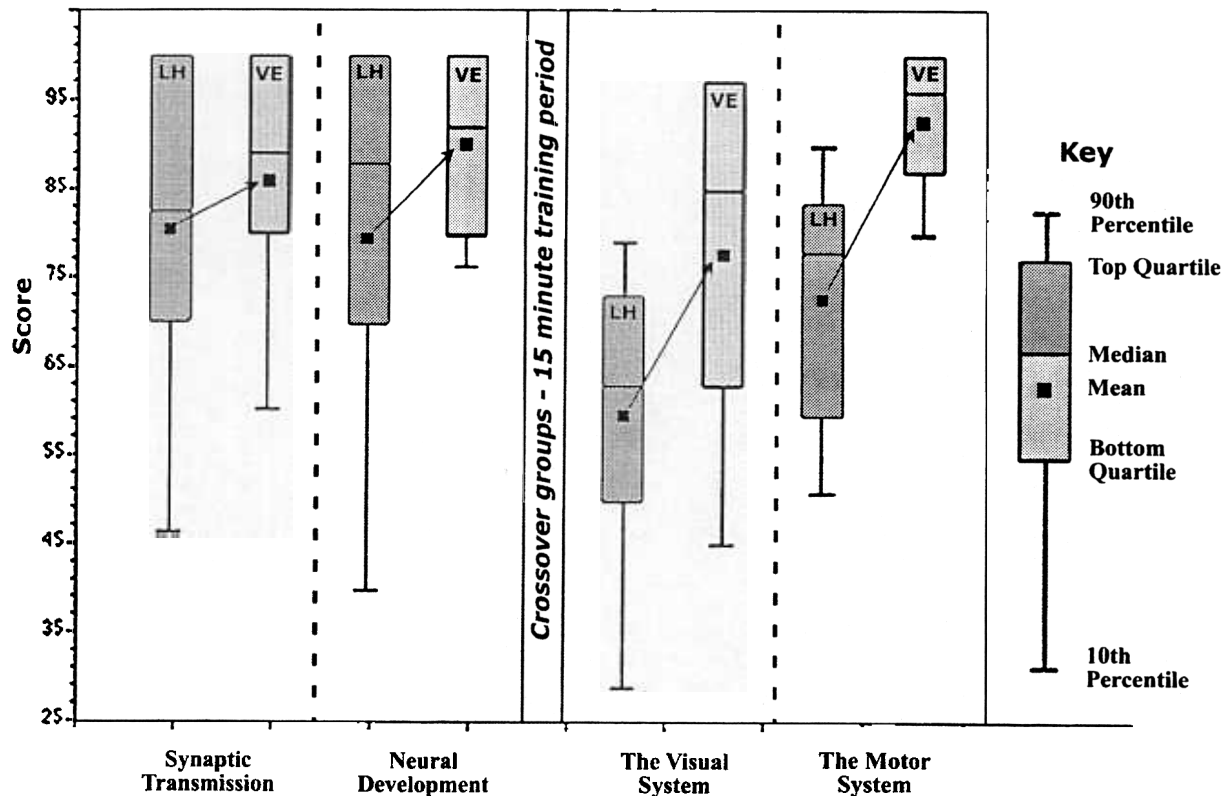


FIG. 1.

Box plot representing raw test scores for conventional lecture hall students and virtual learning environment (VLE) students. Each box represents a range of raw test scores received by lecture hall (LH) students or VLE (VE) students. Each pair of boxes represents scores for an examination for a specific lecture. The horizontal line spanning each box represents the median score for each student group, and the solid square in each box represents the mean score for each student group. The arrow connecting each pair of boxes represents the difference in mean score between groups.

and the second box of each pair represents the range of scores received by students in the VLE. The solid square within a range represents the mean score for that examination. The mean for each section of the VLE is higher than the mean for each section of the conventional lecture hall. The top quintile scores were >95 percentage points for all VLE sections and fluctuated for the population of students in the conventional lecture hall.

Mean deviation scores for the VLE and conventional lecture hall examination after standardization are given for four weeks of testing in Fig. 2. The mean normalized VLE score was consistently higher than the mean normalized conventional lecture hall score for all lectures. This difference was significantly significant with $P < 0.01$.

The results of the two-way ANOVA revealed a main effect for the type of lecture format received [$F(1, 144) = 6.696, P < 0.01$]. Individual standard deviation scores were higher when students used the VLE format (mean = 1.698, SD = 8.381) compared with those using the conventional lecture hall format, (mean = -1.698, SD = 7.183). There was no main effect for a particular week of testing [$F(3, 144) = 0.023, P > 0.05$] and no interaction between the testing week and the lecture format [$F(3, 144) = 0.671, P > 0.05$]. These results indicate that test scores were consistently higher for students of the VLE than scores of the conventional lecture hall. The lack of a main effect for week of testing indicates that high VLE test scores are not a consequence of the passage of time or the progression of the course. The lack of an interaction between type of test and testing week further indicates that this effect cannot

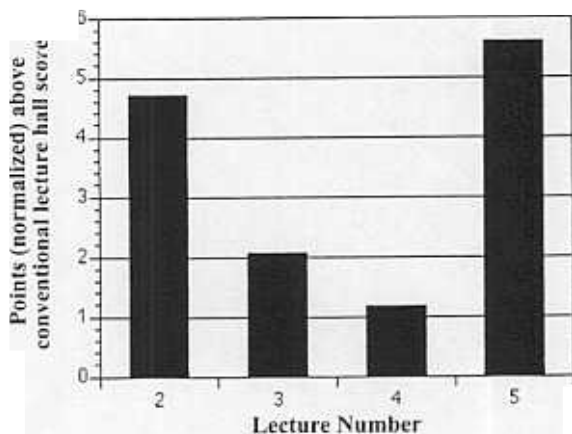


FIG. 2.

Differences in normalized scores. Each data point represents an average number of points that VLE students scored for a particular week of testing that were above average scores received by conventional lecture hall students. A score of 0 indicates no difference in average scores for the two types of testing. Scores >0 indicate that participants scored higher on VLE tests versus conventional lecture tests.

simply be attributable to students becoming more familiar with the VLE format as time progresses. In fact, students consistently demonstrated higher test scores in the VLE as opposed to the conventional lecture hall, regardless of the time in the semester at which the tests were given.

Survey outcomes. Student responses to a questionnaire taken after the fifth lecture are summarized in Figs. 3 and 4. The majority of students ranked the VLE as being more effective than the conventional lecture hall in delivering information. The majority of students also ranked the VLE as being more desirable than the conventional lecture hall as a content delivery format.

DISCUSSION

The current study compared the progress of students in a VLE with the progress of those in a conventional lecture hall environment when the same material was presented by the same lecturer. The performance of students on examinations indicates that the VLE effectively delivered the material of the Topics in Neuroscience course. Student evaluations on the use of the VLE were positive. Over 70% of the students 1) believed that the VLE was more *effective* than the

conventional lecture hall in delivering content and 2) would *prefer* to enroll in a class that used the VLE for presenting the core curriculum.

During informal conversations that took place after this study, several students described the VLE lecture as being significantly longer than the classroom lecture. This was not the case. In fact, the running time of the virtual lecture was shorter than that of the conventional lecture. It is the *density* of content that is significantly higher in the VLE. When a lecturer illustrates a concept using the blackboard in the conventional lecture hall, the delivery of the presentation is delayed. In the VLE, all images and animations are pre-prepared and displayed simultaneously with the lecture; at no time does the lecturer stop speaking in this environment. Additionally, in the VLE, students have greater control over the delivery of the lecture. They can rewind, fast-forward, and play the presentation in double speed. They can also return to different segments of the lecture and are able to suspend the lecture to request that the virtual lecturer respond to questions selected from a comprehensive list of potential questions. The student can also respond to questions presented by the virtual lecturer. This flexibility increases the time that the user spends using the VLE.

Another concern described by students was their inability to interact with the lecturer throughout the presentation. This is a valid point and one that cannot be ignored. It could be argued that this response was based on the idealized view of the conventional lecture hall. It is commonly observed that in a large lecture hall setting, students rarely query the lecturer even though they are often encouraged to do so. This limitation of the VLE may have been reduced if seminar sessions had been scheduled to follow the virtual lecture or if the chat room, database, and bulletin board functions of the VLE had been activated. However, any fully implemented electronic delivery system should not be expected to replace completely interactions between students and instructors.

The underlying hybrid CD technology of the VLE contrasts with remote learning systems that rely on the Internet and on the transmission of information by satellite or closed circuit television. Satellite systems and television have been used primarily to deliver

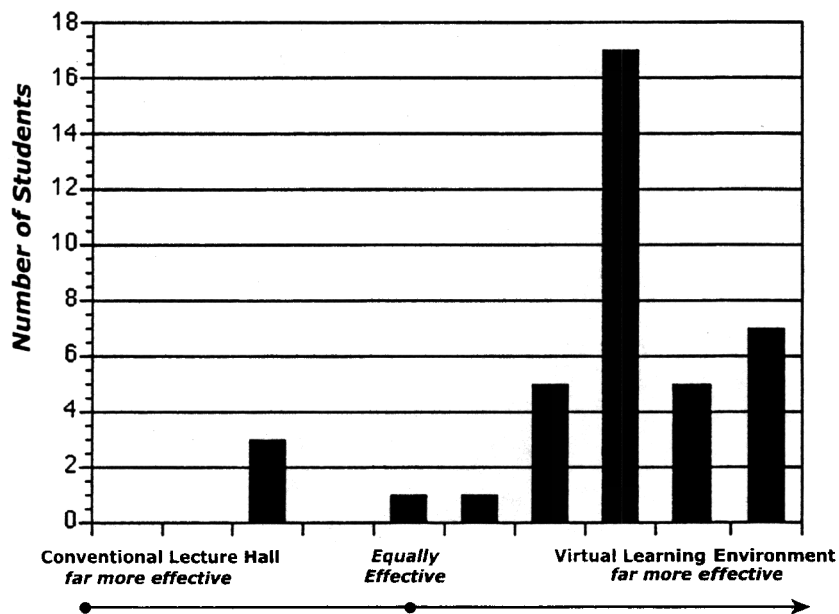


FIG. 3.

Results of student questionnaire on the *effectiveness* of the VLE for content delivery in the Topics in Neuroscience course. Each bar represents the number of students ranking the effectiveness of the VLE as specified by the x-axis.

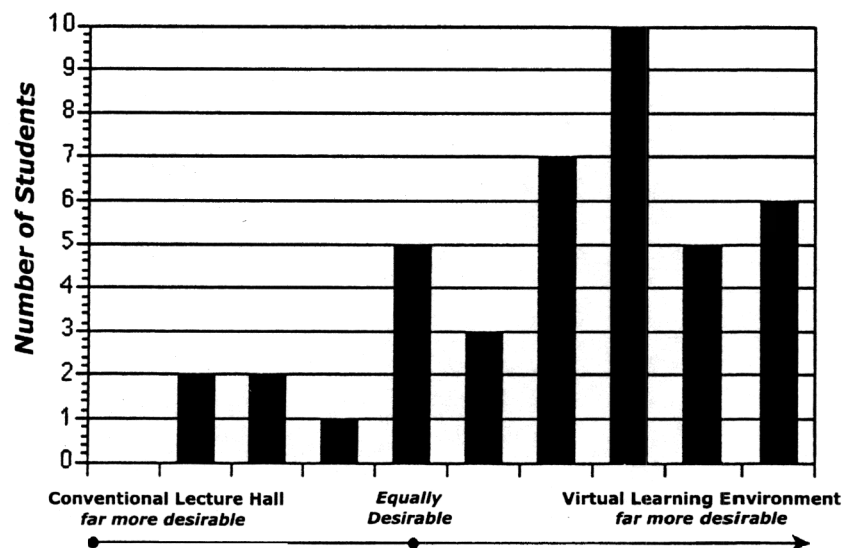


FIG. 4.

Results of student questionnaire on the *preference* for the VLE over the conventional lecture hall. Each bar represents the number of students ranking the desirability of the VLE as specified by the x-axis.

information to groups of students. Under certain circumstances, these technologies have effectively presented information (2, 5, 20). Two of the major drawbacks of satellite and closed circuit television delivery systems are the high recurring fees associated with their use (especially true of satellite systems) and the requirement that students attend the lecture at a specific time and place.

Content delivery software based on the Internet is becoming ubiquitous. At the extreme, these solutions have been used to provide students with a four-year college education in which students meet their faculty for the first time on the day of graduation (19). Bandwidth limitations of the Internet require that these systems have a primary reliance on text. Although streaming audio and video technologies are firmly in place, the output quality of these delivery formats is limited. Audio delivered by the Internet is often sampled at 7-11 kHz compared with 44-kHz CD-quality sampling. Video tracks are generally of low resolution and size. When the speed of Internet access increases, one would expect to see a richer multimedia environment delivered using this format.

A VLE represents one way in which undergraduate education can be improved. VLE lectures can be presented by individuals with a recognized depth of knowledge. The student of the VLE may learn at his or her own pace, at any time, as many times, and in any location through a variety of modalities. The student may "bookmark" the lecture to provide random access through the presentation. The student may access an online dictionary of terms, request a series of on-line review questions to be presented (to mimic the professor asking questions in class), and request answers to "typical" student questions. For atypical questions, the student has access to an Internet-accessible bulletin board and chat room. It is indicated that the effective application of this technology can benefit the education of students in programs ranging from high schools to community colleges to universities. This technology relieves the professor from being primarily responsible for delivering core content and enables the professor to use the physical classroom for engaging students in higher level seminar-style discussions.

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