AC 2011-162: A COMPARISON OF LEARNING BETWEEN EXPERIMENTS USING VIRTUAL REALITY AND HANDS ON EXPERIMENTS WHAT IS REAL ENOUGH?

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A Comparison of Learning Outcomes Between Experiments Using Virtual Reality and Actual Hands On Experiments – What is Real Enough?

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Abstract

The purpose of this study was determining if engineering students performing a simulation of an experiment using virtual reality would learn concepts as well as a group of students who performed the actual hands-on experiment. The results have obvious implications for the delivery of engineering education, especially considering the method of delivery: Java ™ applets using open GL, delivered over the Internet using standard web browsers available on most computers.

Students were divided into two groups: a control group performed the actual hands-on experiment and a test group performed a simulation using a Java applet that simulated the hands on experiment. Students in both groups were given the same laboratory instruction and performed the experiment either virtually or in reality. At the conclusion of the lab, they were given a brief multiple choice test about the experiment and the results of this test were compared. No difference was observed in the results of the tests. This appears to indicate that student learning immediately after the experiment was similar in both groups.

Introduction and Background

The purpose of this study was to determine if engineering students performing a simulation of an experiment using Virtual Reality demonstrated similar learning when compared to a control group of students who performed the actual experiment. In the early 2000's, Klahr[1,2] published a series of studies involving K-12 students that indicated that student experiential learning using simulations was comparable to learning using actual hands-on experiments. At about the same time, several including one of the authors[3,4,5] wrote describing the use of Internet-based simulations in undergraduate engineering laboratories.

On line simulations are relevant to chemical engineering community and are used, in our curriculum, to train students in process control and top prepare students for complex laboratory experiments in distillation. These experiments, however, used early versions of Java™ abd were much simpler to implement than the more recent versions (JOGL and Java 3D) yhat require considerable development time.

Hands-on experiences have been a significant component of engineering education. Simulations offer several potential advantages over hands-on experiments: safety, 24/7 availability, and the ability to be performed regardless of weather (a consideration for experiments performed outdoors). Additionally, the number of groups that can simultaneously perform an actual experiment is limited by the availability of computers or online connections whereas the number of groups that can simultaneously perform a computer simulation is essentially unlimited.

Finding a suitable course for a test: Introduction to engineering

To conduct a study with hands on control and a virtual reality experiment requires a class that is large enough for a statistical comparison of the control and the test subjects. The challenge at a small school is being able to find a suitable class of engineering students for such a comparison presents a challenge. At our school most engineering classes are under 20 students (often fewer than 10 students) and are therefore not suitable for a comparison of student learning because the class size is too small. There is only one class large enough to provide a pool of students for a statistical analysis of student learning for such an experiment, the freshman introductory course “Engineering Techniques”.

“Engineering Techniques” is a freshman engineering course offered each fall semester and taken by all engineering students. This course is an introductory course designed to acquaint freshmen with the fundamental concepts of various disciplines of engineering. Engineering Techniques is a 2 credit hour course consisting of 1 one hour lecture per week and one 2 hour laboratory period. The laboratory experiments are drawn from the various engineering disciplines. As an introductory course, it is essential that the level of difficulty of the experiment and the analysis of the results be appropriate for the academic level of the students. That is, some students enrolled in the course are taking pre calculus.

The experiments in Engineering Techniques normally require a written report, however, for our study, we chose to supplement that assigned written report with a multiple choice test to provide a more objective measure of student learning. This multiple choice test was given immediately at the end of the period to minimize impact of the study on the rest of the course’s schedule. We choose to select the chemical engineering experiment as the experiment for our study.

The number of students enrolled in this course (~130+ students) is large enough for a statistically meaningful comparison. We limited the participants to entering freshmen over 18 who are enrolled in the fall 2010 semester. Of the entering class, 127 students choose to participate.

The Prototype Experiment: How Strong is my Coffee?

The experiment used for our test was entitled “How strong is my coffee?” and used a spectrophotometer to measure the strength of coffee. The experiment’s objective was to determine the strength of coffee to reference coffees from the measurement of the transmittance of coffee. The learning objectives for the experiment were:

1. Understand the concepts of zero and span associated with experimental analysis by correctly setting up the spectrophotometer.
2. Demonstrate the use of various transformations that generate linear relationships by using a semi log plot and understand how to interpret experimental data.

At the start of the laboratory period, students were given a handout explaining the theory and procedure for the experiment. The procedure for the experiment required that students establish the zero and the range for the spectrophotometer, prepare samples of coffee diluted with water to several dilution ratios. Students then measured the transmittance of the diluted coffee using a Spectrumlab 21a spectrophotometer. Measurements were made at the specified wavelength of 410 nm, which corresponds to an absorption band for coffee. The strength of the coffee was determined from a semilog plot of transmittance vs. dilution ratio, according to the well known equation

$$\ln(T) = Ac + b$$

where T = transmittance
c = the fraction of the sample that is coffee
A and b are constants of the least squares fit.

Students were asked to identify their sample as “strong”, :”normal” or “weak” by comparing their experimentally determined slope to reference values for “strong”, “normal” or “weak” coffee previously measured and included in the handout.

A blind procedure, in which the lecturer did not know whether students were performing the experiment virtually or “hands on” was not possible in this experiment because the instructors knew in advance which type of procedure (actual or virtual) each section was doing. Laboratory limitations prevented having dual setups for both experiments.

Another consideration is student interest in the use of simulations in experiential learning. Would students prefer one delivery method (hands on) over another (virtual)? The determination of student interest was not a direct goal of this study however the nature of the experiment indicated that, for this study, students had little preference for one method over the other. When students signed the consent forms to participate in this study, they were given the option of participating in either the experimental laboratory selected for their section or the other type. Only one student chose to change his assigned experimental method (choosing the virtual experiment over the “hands on”) experiment.

Both the control and the virtual experiments were followed by a ten question multiple choice test at the conclusion of the experiment which provided the researchers with a measure of learning. The questions used are shown in Appendix A. No follow up was used in this study to minimize upsetting the course schedule. Post testing after a period of time would be highly desirable and would be part of further work.

Virtual Reality Experiment

The test group used the same handout as the control groups which showed instructions for the real prototype, although help screens showing the use of the user interface were available online. The simulation used randomly generated values of the constants for the strength of the “coffee”.

The experiment proceeded in the same manner as the real experiment; including the establishment of the zero and range for the virtual spectrophotometer. The similarity of the virtual experiment to the actual equipment is illustrated by the photograph and screen shots shown in Figure 1.

The virtual reality experiment used a Java ™ applet using Java openGL for the graphics. The applet existed in a “virtual laboratory” containing a simulation of the spectrophotometer, showing the key controls. A comparison of the actual spectrophotometer and the virtual are shown in Figure 1.

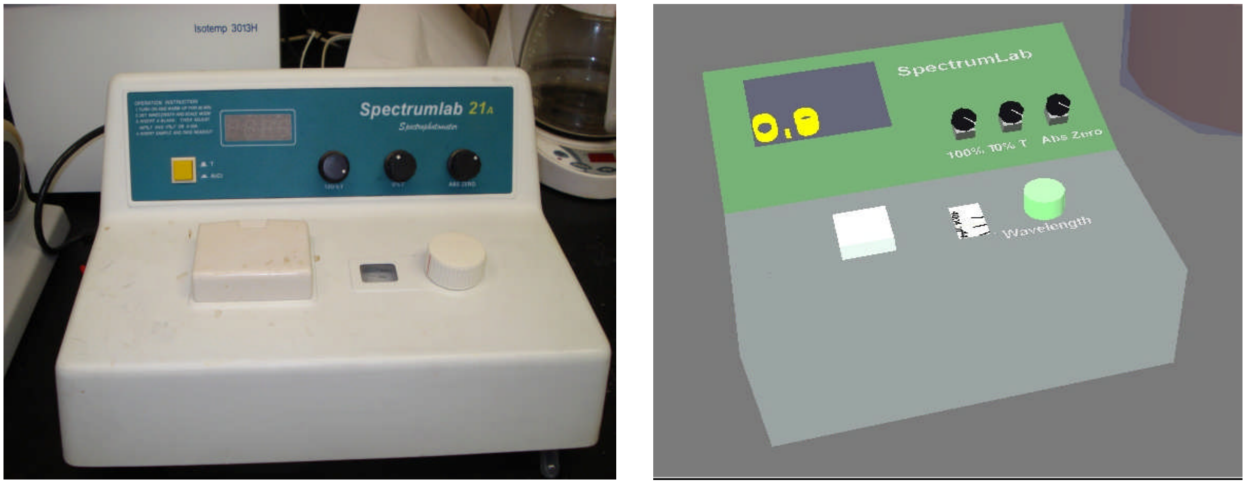

Figure 1. Spectrum Lab 21 Spectrophotometer and Virtual Lab Version

Multiple Choice Test and Results

The primary measurement tool in this study was a multiple choice test that was given immediately at the conclusion of the laboratory period. The content of the test is based on a handout distributed. Engineering Techniques is designed as an introductory course with minimal background by the freshmen students. Therefore, it was felt that a pretest would not yield useful information. Additionally, pretests would seriously inconvenience the course's schedule.

The principle result was that no difference was observed in student learning for the test given immediately after the experiment. The control group consisted of 67 students and the virtual lab consisted of 62 students. The average score for the test group was 65.0 and the hands on group was 66.9. The t-test for the average score is 0.72 indicating that the hypothesis that there was no difference in average score was supported at the 99 % confidence level. It is clear that the statistical result was confirmed as found by in this study.

Given the anticipated size of the sample (~127) breaking the sample into subgroups (e.g. by sex, SAT score, etc) was not be attempted because of the loss of statistical significance in attempting to analyze such small subgroups. Additionally, only 4 females (all in the control group) were included in the test. Breakout by sex was not attempted.

Future work

1. Repeat with post testing after a longer period of time (say 2 weeks) to determine if longer term retention is influenced.
2. Future setups could provide a method of randomizing the individual groups. This setup would require modification of schedule and space not permitted in these studies.

References

[1]Lara M. Triona and David Klahr, "Point and Click or Grab and Heft: Comparing the Influence of Physical and Virtual Instruction Materials on Elementary School Students' Ability to Design Experiments", Cognition and Instruction, 21(2) 149-173.

[2]David Klahr, Lara M. Triona, Cameron Williams, “Hands on What? The Relative Effectiveness of Physical Versus Virtual Materials in an Engineering Design Project by Middle School Children”, Journal of Research in Science Teaching, 44:1, 183-203 (2007)

[3]Nippert, C.R, "*On line Experiments - The Results of The Online Widener Laboratories"*, 2002 FIE Conference, Boston (Nov. 11, 2002)

[4]Nippert, C.R., *"Use of JAVA Applets to Provide Simulations for Process Control* ", 2001 Annual A. I. Ch. E. Annual Meeting, Reno , Nev..

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Appendix A: Multiple Choice Test Questions

1. "Transmittance" is defined as
   (a) the fraction of incident light at a specified power that passes through a sample
   (b) the fraction of light at a specified wavelength that passes through a sample.
   (c) the amount of light that is absorbed by a sample at a specified power.
   (d) the amount of light that passes through a sample.

2. A wavelength of 410 nm was chosen for this experiment because
   (a) It represents a typical value of transmittance for coffee and gives typical results.
   (b) It has a low transmittance and therefore is more likely to give accurate results.
   (c) It has a high transmittance and therefore is more likely to give accurate results.
   (d) There was no reason given. The wavelength was selected at random.

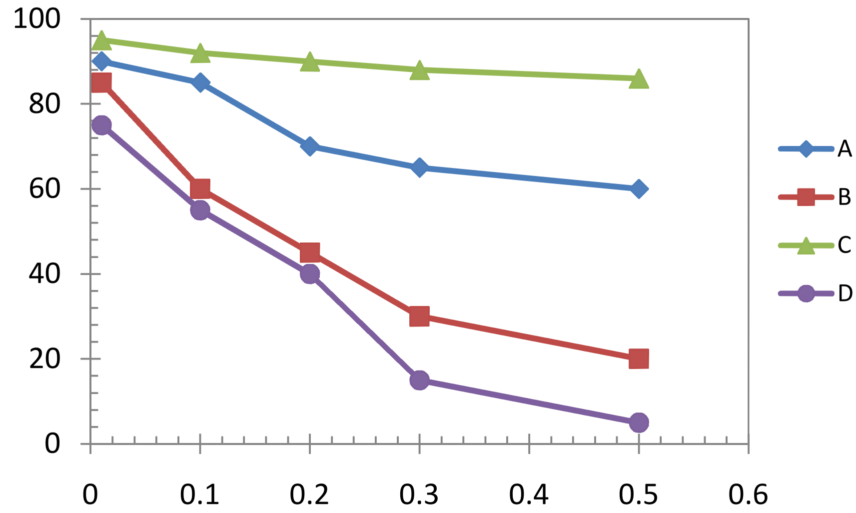
3. When calibrating a measurement the zero of an instrument is values that are often specified are called
   (a) the value of the display when no signal is received by the detector.
   (b) the display value when the instrument is turned off.
   (c) a signal that the instrument is broken.
   (d) a signal on the display when the detector gets the maximum amount of light

4. When calibrating an instrument, the span is set after the zero because
   (a) the zero value is an offset that is added to every value and must be set first.
   (b) there was no reason given.
   (c) The statement is false. The span must be set before the zero.
   (d) The statement is false. The zero and span can be set in any order.

5. Setting the span is similar to
   (a) adjusting the volume on a radio.
   (b) changing the channel on a television.
   (c) changing the album on an MP3 player.
   (d) none of the above.

6. A plot of transmittance(T) vs. concentration (c) is described by the formula
   (a) $T = mc + b$ where m and b are constants.
   (b) $\log(T) = mc + B$ where m and b are constants.
   (c) $T = Kc^{a}$ where K and a are constants.
   (d) $T = mC + \frac{b}{C^2}$ where m and b are constants.

7. Below are shown several plots of experiments conducted for this experiment. Which line shows the strongest plot of the coffee?



(a) A
(b) B
(c) C
(d) D

8. Which of the samples shown above contains the *smallest* amount of dissolved material
   (a) A
   (b) B
   (c) C
   (d) D

9. What is the general meaning of the statistic r^2
   (a) A statistical measure that represents the percentage of a variables movements that can be explained by movements in the independent variable.
   (b) a statistical measure of a variable that is not explained by the independent variables measure.
   (c) This was not part of the experiment.
   (d) A statistical measure of the number of significant figures in the constants to a linear function of a fit of the dependent variable to the independent variable.

10. The cover over the sample holder does which of the following
   (a) Turns on the photodetector.
   (b) Turns on the light source.
   (c) Prevents stray light from interfering with the measurement.
   (d) None of the above.