USING AN AUTHORING SYSTEM TO FACILITATE STUDENT-CENTERED DISCOVERY ORIENTED LEARNING

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Abstract—Introductory students "brainstormed" experiments on subliminal messages and behavior, then evaluated them in terms of ethics, practicality, measurement, and control. The instructor used Authorware Professional and a Macintosh IIx to implement five student-generated experiments in which students served as subjects. The pedagogical rationale for the exercise was to give students a sense of investment and ownership in the process of scientific inquiry, to "create a demand" for knowledge of statistics and experimental methods, and to make a convincing case for empiricism as a way of knowing. The exercise generated enthusiasm, produced meaningful discussions, and increased students' understanding of experimentation, measurement, control, and statistics. It was concluded that providing students with this experience would not have been possible without a sophisticated authoring system, and that this student-centered discovery oriented approach may be used effectively in a number of natural science and social science courses where on-line experimentation is appropriate.

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Two important developments in science education are the use of hands-on, discovery oriented experiences for students and the development of student-centered pedagogy. This paper demonstrates that computers equipped with sophisticated authoring systems can be powerful tools for facilitating student-centered, discovery oriented learning.

The goal of student-centered education is to provide an environment where students can develop their own ideas about the natural and social world. Student-centered approaches have been used in teaching scientific writing[1], developing analogies for understanding biological processes[2], and creating metaphors for comprehending geologic time[3]. Discovery oriented learning makes students active participants in the learning process by promoting hands-on investigations. Recently, teachers in several disciplines have combined these approaches to form a student-centered discovery oriented approach to science education. In essence, this approach emphasizes providing students with the theoretical and methodological tools to develop and test their own hypotheses.

Recently, discovery oriented approaches to science education have been used in fields as diverse as astronomy[4], biology[5], ecology[6], geophysics[7], and statistical sampling[8].

Although the discovery oriented approach has generally been reserved for upper-level students, it can also be successfully used with less experienced students. The exercise reported here encouraged students in their first social science course to generate ideas for experiments. The experiments were designed to answer a question of interest to them and of relevance to the course: can subliminal messages affect human behavior? The goal was to provide students with an opportunity to apply scientific methods to their own hypotheses in their first encounter with empirical behavioral science. Until recently, such an approach posed a large number of logistical problems. However, with microcomputers, and powerful programming tools for on-line experimentation such as the Micro Experimental Lab MEL[9,10] Authorware Professional[11], and a variety of "hyper systems"[12] such as HyperCard and LinkWay, implementing students' ideas is now feasible, even in relatively large classes.

The setting for this exercise was "Is Freedom Possible?," the first of a series of four team-taught interdisciplinary social science courses. The course examined perspectives in the social sciences, behavioral sciences and philosophy on issues such autonomy, rationality, free will and determinism. The issue of subliminal messages was chosen because it is intrinsically interesting to most students,
and because of its relevance to the course. The topic lends itself particularly well to introducing experimental methods. By definition, the effects of subliminal messages are not accessible through introspection, and students readily agree that experimentation is the best way to determine whether subliminal messages affect behavior. This exercise provided students with their first experience with empirical methods in the behavioral sciences.

The pedagogical rationale for introducing students to experimental methods through student-generated experiments was three-fold. First, to give students a sense of investment and ownership in the process of scientific inquiry early in their education, second, to create a demand for knowledge of statistics and experimental methods that can be fulfilled in upper level courses, and third, to make a convincing case for empiricism as a way of knowing and to promote data collection in response to empirical questions. This student-centered approach puts the instructor in the position of research consultant and facilitator rather than content area expert.

**PROCEDURE**

Students formed five discussion groups of 15-20 students in the eighth week of a 16-week semester. They were told that the Macintosh Illcx and software would give them the ability to flash words and pictures on the screen, distort words and images, hide messages in a visual display, present speech forwards and backwards, and distort speech.

To encourage students to think empirically, the class started with a "brainstorming session" in which students freely expressed ideas and withheld criticism until the group as a whole had evaluated each idea with respect to the following questions on the blackboard: Is the experiment ethical? Is it practical to actually do the experiment this semester? Is the message truly subliminal? Will the message affect a specific decision, preference or behavior? How will we know if the experiment works: what are we measuring? How will you know that the message caused the response: what are the controls?

After the brainstorming session, the discussion group as a whole evaluated each idea, and arrived at an idea for an experiment. Many ideas were discarded for ethical reasons. Five experiments were developed to see if subliminal messages could affect aesthetic judgments, preferences between pictures, numeric estimates, and a decision to continue or quit a task. The subliminal messages were either flashed on the screen, embedded in pictures, or presented in sounds played backwards.

Over the next 2 weeks, the instructor further developed the student's ideas into well controlled experiments and implemented them in Authorware Professional, an icon-based object oriented authoring system. Below is an illustration of authoring with Authorware Professional using Experiment 1, and a brief description of each of the five experiments. For a more detailed discussion of Authorware Professional see Wolfe[11].

Discussion group one's hypothesis was that a message flashed on the screen for a brief duration would affect the rating of a picture. A picture of a crane was presented to subjects, and the number 1 or 7 (nothing in the case of the control group) was flashed in the bird's reflection for approx. 80 ms (Fig. 1). Subjects rated the picture on a Likert scale by entering numbers on the keyboard. Responses outside the acceptable range of 1-7 were rejected, and the subject was cued to respond again. When an acceptable number was entered, the subject was presented with another item.

Discussion group two hypothesized that a message hidden in a picture could affect people's preferences. In Experiment 2, subjects selected the preferred one of two pictures presented side-by-side. The words "Pick Me" were hidden in a stylized picture of a face for some subjects, or a picture of trees for other subjects (neither for the control group). The "Pick Me" message was distorted to make it less obvious.

Experiment 3 was based on discussion group three's hypothesis that verbal commands played backwards could affect peoples' preferences. Digitized recordings of the author saying "Pick One", "Pick Two", or "Picnic" (for the control group) were made with the Authorware Professional digitizer and played backwards before subjects listened to a recording of a babbling brook or a train and expressed their preferences by entering 1 or 2 with the keyboard.
The fourth group was curious about whether subliminal messages could affect performance on a test. This idea was implemented by flashing "15%" or "75%" in the middle of an estimation task where subjects had to estimate the number of Harvard students graduating with honors. This experiment and Experiment 5 employed the same technique for flashing messages as Experiment 1.

Finally, group five wanted to test the idea that subliminal messages affect decision making. In Experiment 5, subjects were asked whether they wanted to see the answers to the questions they were asked previously. The words "quit" or "see" were flashed on the screen as they made this decision (except for the control group).

Students were required to sign-in at the Miami University School of Interdisciplinary Studies Center for Computer Assisted Learning (SISCCAL) during the 10th–13th weeks of the semester (they were not required to actually participate). The instructor then analyzed the data and presented it to the students in a lecture in his discussion sessions during the 14th week of the semester. These occasions were used to explain the basic theory behind inferential statistics and the conceptual basis of the ANOVA and $\chi^2$. In seminar discussions, the students discussed the procedure, results, analysis, and interpretation of our findings as well as the importance of replication.

RESULTS

Eighty-one first year social systems students in the School of Interdisciplinary Studies at Miami University participated in the experiments. Data concerning the effectiveness of this exercise were collected from 45 of the 81 students during the final lecture of the semester in the 16th week of the course. Unfortunately, turnout at the last lecture was very poor because many students had a final examination in another course that day (attendance was not required). However, there is no reason to suspect that those students present differed from the others with respect to ability or involvement with the experiments. All responses were anonymous, and the author did not examine the data until after the end of the semester. Students were asked a number of questions about the exercise, and the responses were classified by the author. The first question was "If you participated, did you enjoy it?" Thirty-five of 44 students (80%) answered in the affirmative. The second question was about the experience of being a subject in the experiment, "did you feel like you were being manipulated by subliminal messages?" Forty-three of 45 students (96%) said they did not feel manipulated.
The third question was “did you understand why people were randomly assigned to groups?” Answers to this question were classified as “good” if they included the notion of controlling for irrelevant factors and eliminating systematic biases. For example, the responses “to evenly distribute any kinds of inaccurate data”, and “so that there was randomness even if a group of friends decided to ‘play with’ the experiment” were classified as “good”. Twenty-nine of 42 students (69%) produced good answers to the question concerning why subjects were randomly assigned to groups.

The fourth question was “did you understand why a control group was included?” Answers to this question were classified as “good” if they said the control group forms the basis of comparisons, and estimates the base rate for task performance in the absence of experimental manipulations. For example, the response “to give a reference point to compare the other data to—what people naturally tend to prefer” was classified “good.” Thirty-eight of 43 students (88%) produced good responses to the question on why a control group was included.

The fifth question was “did you understand why statistics were used?” Answers to this question were classified as “good” if they stated that statistics were used to determine whether the results were due to the experimental manipulations, or chance. For example, the response “to see if variances were just chance or because of the messages” was classified “good.” Twenty-four of 43 students (56%) produced good answers to the question concerning why statistics were used.

The sixth question was “did the experiment increase your understanding of experimental methods in the social sciences?” Thirty of 41 students (73%) answered in the affirmative. For example, one student responded “Yes, I would not have known how to set up a control group or how to know whether results meant anything or not.” Another noted, “I never thought about the random sampling.” A third student said, “The experiment demonstrated all the intricacies of designing something like this. I was impressed by all the variables one must take into consideration”, and a fourth student said “its much more difficult and concerned with detail then I had ever imagined.”

As expected, four of the five experiments failed to find significant effects ($F$’s < 1 and small $\chi^2$’s), but surprisingly, Experiment 3, in which verbal commands were digitized and played backwards, yielded significant results, $\chi^2=6.54$, $P<0.05$. However, this result was not replicated through subsequent experimentation, $\chi^2=2.089$, $P=0.35$.

**DISCUSSION**

By using Authorware Professional on an Apple Macintosh IICx computer, it was possible to turn student’s ideas into five on-line experiments, collect data from 81 students, and analyze the results over a period of less than 6 weeks. Without a computer and a sophisticated authoring system, it would not have been feasible to employ this student centered discovery oriented approach. Using Authorware Professional, the task was labor intensive, but also feasible and interesting. Given adequate software development tools such as MEL and Authorware Professional, this student-centered discovery oriented approach may be used effectively in a number of natural science and social science courses where on-line experimentation is appropriate.

It is obvious that it would have been very difficult to perform these experiments without a computer. The time, energy, and expense of setting up T-scopes and reel-to-reel tape recorders and doing the statistical analyses by hand would have made this exercise a logistical nightmare. Less apparent, but equally important is the advisability of using an authoring system such as Authorware Professional or MEL rather than a traditional programming language. Having programmed experiments in Authorware Professional and Pascal, it is useful to consider some of the differences between these two approaches to software development.

Perhaps the most important difference between developing experiments (presenting stimuli and collecting data) in Pascal and Authorware Professional is the amount of time and level of proficiency required for the task. Presenting moving pictures and sound are, of course, possible in Pascal and other programming languages. However, because authoring systems were specifically created to present stimuli, it is considerably easier to set up experiments in Authorware Professional. For example, a useful feature of Authorware Professional is “direct editability”, the ability to make changes in a program segment and observe their consequences immediately. Direct
editability is especially well suited to piloting and refining experiments. For many software developers, these characteristics of authoring systems will be the difference between whether or not a project is feasible. Promising students that you will turn their ideas into actual experiments requires a faith that you can not only do the task, but do it quickly. This exercise would not have been attempted without an authoring system.

Another way of thinking about the difference between developing on-line experiments in traditional programming languages and authoring systems is as a tradeoff between elegance and programming efficiency. Although the empirical test has not been done, it seems reasonable to assume that on-line experiments created with authoring systems use more disk space and are slightly slower than traditional programs. However, the Authorware Professional software will be easier to create and modify and every bit as accurate and reliable as the best programs created in a language such as Pascal.

If this exercise had a hidden agenda, it was exposing first year students to many of the capacities of the Macintosh IleX and other hardware and software in our School of Interdisciplinary Studies Center for Computer Assisted Learning (SISCCAL). All too often, undergraduate liberal arts students come to see the microcomputer as little more than a fancy word processor. Through this exercise, these students learned that the computer is a complex symbol manipulation machine with the ability to process words, pictures, sounds and statistical data.

Overall students were enthusiastic about the project. When asked to provide feedback, 80% of the students said they enjoyed participating in the experiments, and a majority produced good answers to questions on why people were randomly assigned to groups, why a control group was included, and why statistics were used. Students also reported an improved understanding of experimental methods. Thus, the exercise served to promote course goals for quantitative reasoning[13].

As anticipated, most hypotheses were not supported by the data. Although this may have disappointed some students, null results teach many valuable lessons. Perhaps because natural and social science courses stress major findings, rarely failures, students generally underestimate the difficulty of finding reliable significant results[14]. Finding null results in their first social science experiments may give students a greater appreciation of the classic studies they will study later. More importantly, confronting null results leads students to question their initial beliefs, and focus on the process of discovery.

The exercise also prompted students to question two common and incompatible beliefs: (a) that people (or at least they) are free and autonomous decision makers who are generally immune from outside influences, and (b) that people are bombarded daily by effective subliminal advertisements such as images flashed on television, suicide messages hidden in rock lyrics, and the word "sex" embedded in ice cubes in magazine ads. Even as they were warned against accepting the null hypothesis, students gained a greater skepticism about claims of widespread "brainwashing" and "mind control" through subliminal messages. It appears that students also gained a greater understanding of scientific methods in the social sciences.

REFERENCES