Using Logic Puzzles for Critical Thinking

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Introduction

Industry is looking for the graduate that can organize and assimilate information to solve problems. There is continued call for universities to increase the number of citizens capable of effective personal and professional problem solving and leadership (Ellerbroch et al., 1987). But many high school graduates who enter college may lack the ability to solve complex problems (Fulkrod, 1986). This may be due, in part, to the emphasis in education on memorization. Overemphasizing memorization has a tendency to keep students at the lowest level of learning (Posler, 1987).

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Piagetan theory states that intellectual development exists in four levels and that completion of the fourth level, formal operational, occurs around 15 years of age (Piaget and Inhelder, 1969). McKinnon (1971) disagrees with this, stating that as many as 50% of college freshmen still operate at level 3, concrete operational. Herron (1975, 1978) supports the concept that students may not be at the formal operational level; however, much of science is taught assuming that students can handle formal thinking.

Fulkrod (1986) would strongly support the idea that many of our college students are not equipped to think on the fourth level, probably due to lack of training and experience. Herron (1978) found that students exhibiting formal operational development scored considerably higher on exams than students with concrete operational abilities. Instructors need to develop methods which encourage students to use the formal operational thought process in science courses, especially those students with weak science backgrounds. But, using concrete scientific examples that are not understood by these students may further hamper their development to think at the formal level. This article presents a teaching

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to express their thoughts and motivations (strategy) orally or in writing. By requiring a writing assignment or series of assignments with each simulation, students will learn how to express what they did, why they did it, what they accomplished, and what they are going to do next. Depending upon the format of the questions, students can be asked for information requires they to remember, process, create, or evaluate what they have learned from the simulation.

Finally, organizing students into teams and having them interact and arrive at one set of decisions promotes social interaction, develops interpersonal communication skills, and prepares them for working in an organization after graduation. Too often, students are able to sit through a course and never say more than, "Here," or learn the names of any of their classmates. By providing some of these social benefits, team simulations are a very valuable addition to any class.

Summary

Given that the art of management is something that is best learned through practice, students need to be provided with sufficient opportunities to develop their decision making skills when the cost of failure is relatively inexpensive and painless. Computer simulations provide the opportunity for reinforcing management concepts discussed in lecture by presenting realistic outcomes that result from various management decisions within a hypothetical firm. By incorporating a series of computer simulations into a horticultural management class through a common computer interface such as HortManager, students will also experience minimum program learning time and a sense of continuity across classroom computer assignments. However, failure to develop simulation assignments and test questions that focus on the higher levels of cognition, creating and evaluating, will result in students only becoming familiar with another computer program and not fully comprehending the intricacies of managing a business.

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method utilizing logic puzzles that may help students learn to think at the formal operational level. The puzzles also may sharpen reading skills and improve vocabulary by repetition.

Methods

Five logic puzzles in Animal Science 1053, Introduction to Animal Science at the University of Minnesota, Waseca (UMW), were developed as homework to discover whether or not an improvement in organization and critical thinking would occur. The puzzles were designed to parallel course units such that vocabulary would be reinforced. Students were given a preliminary puzzle and instructed on the mechanics of solving the puzzle. Every attempt was made to allow each student to successfully solve it. Subsequent puzzles became progressively more complex and were required work for the course. An example of the third puzzle given to the students is illustrated in Figure 1.

The purpose of the logic puzzles was to help develop thinking skills. Problems were given in lecture using some of the same thought processes dealing with a practical topic on that unit. The same problems were never used in the short answer exams. It was the intent to have the students use the thought processes that they had learned and to prevent any sort of rote memorization of the problems, thus getting them to use high-level problem solving.

To assess the puzzles' effect on problem solving ability, four different groups were compared: 1)Students who were administered multiple choice exams but did not have logic puzzle instruction and training, 2) Same as group 1, except logic puzzles were required in class, 3) Students who were given short answer exams, but were not instructed and trained in logic puzzles, 4) Same as group 3, except logic puzzles were required in class.

The puzzles were allotted using randomization tables to Fall, Winter, and Spring quarters for a two year period beginning Spring, 1984. The same multiple choice tests were used each quarter. The difference of the mean total scores for the first and third exams was used for comparison of treatment groups 1 and 2. Likewise, puzzles were allotted randomly for six quarters beginning Fall of 1987, and responses to short-answer essay tests were compared. Comparison of groups 3 and 4 followed the same procedure as for groups 1 and 2. Means were tested by T-test (Snedecor and Cochran, 1976). In addition, students that were exposed to the logic puzzles were given a questionnaire at the end of the quarter to assess their opinion.

Results

The mean scores of the study to test the effects of the logic puzzles are shown in Figure 2. Comparing the differences in scores of the first and third exams, there were no significant differences between classes of students taking the multiple choice exams whether or not they had used the logic puzzles. However, for the short answer exams, there was a highly significant difference in scores between the first and third exams ($P<.001$); that is, students who were introduced to logic puzzles scored significantly higher than those who were not.

Of the 402 students surveyed about the logic puzzles, 71% liked completing them; 22% enjoyed them at first, but not after the puzzles became more difficult; and 7% didn't like them at all. Most (80%) of the students surveyed felt that the logic homework improved their vocabulary.

Discussion

The fact that no significant differences occurred between groups tested by multiple choice exams is not surprising, because many times multiple choice questions do not measure critical thinking ability. Hart (1989) stated that tests require basically three types of responses: 1) recognition and recall, 2) comprehension and single application, and 3) critical thinking and problem solving. It is difficult to present enough information in any multiple choice question to achieve much more than the first two types of responses. Therefore, the multiple choice exam may not be a good tool for testing how well students are able to critically think.

One of the most effective questioning formats is the open ended question where there are many equally appropriate answers or responses (Hart, 1989). The significant increase in mean test scores on short answer exams for the students who did logic puzzles may be due to some or all of the following reasons:

1. The students may have become more critical readers, learning to analyze what they read, and becoming more aware of what the sentence said as well as what it did not say.
2. The students may have attained better organizational skills, since they were required to organize a given set of facts and then arrive at a solution. Perhaps these organizational skills, which are very important in written and verbal communications, helped them organize their thoughts for the short answer exam.
3. The puzzles may have served as building blocks for critical thinking and allowed students to construct higher skill levels.

Conclusion

The logic puzzles were successful in helping to teach critical thinking in introductory animal science. Keeton (1983) stated, "The best learning results in an interplay between theory and experience, idea and application, reflection and encounter." Problem solving and other critical thinking activities create those situations. When we stimulate good thinking, we help develop a lasting interest in education (Kuhns, 1977).

Herron (1978) states that several high school teachers have designed their courses to operate at the concrete operational level since less than 50% of the students could do formal operational. This however, may not be the right approach. Rather than shying away from formal operational, educators must understand the problem exists and try to help the students attain the ability to reason at the formal level. We need more research to provide strategies to accomplish this. The use of logic puzzles as reported in this study is one way to help students think on that formal level. We must begin to design more courses to involve the higher levels of

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TEACHING SOIL CONSERVATION AND NON-POINT SOURCE POLLUTION

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Abstract

Several non-point source pollution models have are used in the undergraduate and graduate teaching programs at the University of Guelph to simulate watershed behavior in southern Ontario. In particular, the simulation of soil conservation measures (e.g., conservation tillage, crop rotation, grassed waterways), and of various strategies for implementing such measures (e.g., random implementation over an area, targeted remediation) has greatly enhanced the learning environment. Examples of simulation exercises are presented and discussed from a teaching perspective.

Introduction

In recent years numerous soil conservation and agricultural non-point source (NPS) pollution simulation models have been developed, e.g. AGNPS (Young et al., 1985), ANSWERS (Beasley et al., 1980) and WEPP (Foster, 1987). As these models have become more convenient to use (i.e., user-friendly software has been developed for microcomputer applications, and the microcomputers themselves have acquired more storage and are faster), many are seen to be state-of-the-art tools for planning soil and water management systems, e.g. CREAMS (Knisel, 1980) and GAMES (Dickinson et al., 1987). Further, there has been considerable effort devoted to the review and evaluation of agricultural NPS models in an attempt to clarify their application strengths and weaknesses (Leavesley et al., 1988; Rose et al., 1988).

The development and application of NPS models have coincided with the more broadly based advocacy for using computer software for teaching purposes. As a result, many of these simulation models are now presented in textbooks (Novotny and Chesters, 1981; Haan et al., 1982; Lal, 1988) and incorporated into classroom projects (Rudra et al., 1987a and 1987b; Dickinson et al., 1988).

Although the use of computer simulation models in the educational environment is a recent phenomenon, the classroom use of other types of simulation models is not new. Iconic models involving pipe networks, water flumes, soil erosion flumes and rainfall simulators have been used for demonstration and experimentation purposes for some time. Also physical and electrical analogs, e.g., the Hele-Shaw apparatus (Todd, 1954; Todd, 1955; and Marino, 1967) and resistance paper models (Luthin, 1952; Karplus, 1958; and Bouwer, 1962) have proven to be popular teaching aids. With the increased familiarity, popularity, and availability of digital microcomputers _ and with economic pressures on campuses leading to less physical laboratory space, time and equipment _ there has been a noticeable shift away from the more physically based simulation teaching devices to computer based models. The move to using NPS models in the classroom, therefore, can be viewed not so much as a change in philosophy of approach as a change in the means of taking

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thinking so students may attack the ill-structured problems they will face in real life, personally and professionally. Improving thinking skills may be a more important educational function than disseminating knowledge in the classroom.

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