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ABSTRACT

Contemporary researchers often refer to the information processing paradigm to exlain the relative ineffectiveness of contemporary instructional techniques for modifying incorrect scientific concepts that students often bring to a learning situation. As a result of this research, instructional procedures have been developed that maximize the chances that conceptual change will occur. It is within the context of this conceptual change framework that this study takes place. Commonly accepted conceptual change strategies identify specific basic conditions that need to be met before students' existing mental constructs are changed. The document contends that the attention to imagery inducing procedures would make these strategies significantly more effective. The major hypothesis of this study is that, particularly for abstract concepts, the imposition of a mental image by the presentation of a dynamic model would result in higher achievement than the presentation of a verbal or static model representing the concept. The laser videodisc was used to generate the appropriate images in this study. The technology affords the ease of presentation that makes the results of this study potentially more generalizable. (CW)

The Effectiveness of Laser Disc Generated Models on Conceptual Shifts in College Students

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INTRODUCTION AND PURPOSE

Research conducted over recent years has demonstrated that students' misconceptions about scientific theories are quite resistant to change and, more times than not, are not modified by conventional methods of science instruction (Driver & Easley, 1978; Selman et. al. 1982; Champagne & Klopfer, 1984). The present study's contribution to science teaching is twofold. First, since students' existing knowledge with respect to the implicit premises underlying various theories is often at odds with scientific explanations of the phenomena understood in terms of those theories, an effective teaching method needs to be constructed that will move students away from their preconceived (alternative) beliefs to an understanding that is consistent with a model prescribed by a particular theoretical paradigm. This is particularly important in light of the fact that students' preconceptions about one topic are likely to interfere with an understanding of other interrelated areas of study (Hashweh, 1988). Secondly, if generalized alternative teaching strategies can empirically demonstrate success in changing students' misconceptions, then those strategies may be considered "generic" and applicable to a wide array of other scientific topics across

different curricula offered at a college. Consequently, there are many interdisciplinary implications resulting from the development of such an approach.

The purpose of this study is to build upon the current knowledge base of conceptual change strategies in the literature (refer to the Review of the Literature) by incorporating the use of "dynamic" images contained on laser disc to induce conceptual change in students' understanding of scientific models. It was hypothesized that videodisc-enhanced images of theoretical models (in this particular case, the Kinetic Theory of Gases) would be superior to the "static" images students seemingly receive under conventional (classroom) verbal instruction, in terms of inducing conceptual change of students' naive concepts.

RATIONALE AND REVIEW OF THE LITERATURE

Efforts have been made to identify effective teaching practices in science education. The definition that Anderson and Smith (1985) propose provides the rationale for the present line of research:

> Our definition of effective science teaching focuses on (the problem of conceptual change). At a minimum science teaching must help students overcome naive conceptions or habits of thought and replace them with scientific concepts and principles. If teachers fail to achieve this

minimal goal, then misunderstanding or rote memorization is inevitable. (pp. 14-15)

Research in science education has demonstrated that students (and teachers) enter science classes carrying with them their own naive conceptual frameworks for interpreting scientific theories and phenomena before they receive formal instruction (Driver & Easley, 1978; Selman et. al., 1982; Hewson & Hewson, 1983). Students' naive conceptual frameworks are also referred to as "alternative conceptions" and "misconceptions." In any case, this construct has been found to be very resistant to change, unaffected by conventional instructional methods and persist into later years (Champagne & Klopfer, 1984; Novick & Nussbaum, 1981). The result is that students' ability to apply interrelated theoretical concepts and interpret scientific phenomena in a manner that is consistent with the assumptions underlying a particular paradigm is compromised at best, or nonexistent at worst.

To date, research has concentrated on descriptive studies which describe the kinds of misconceptions students have (Hashweh, 1988) and explanatory studies aimed at predicting what factors may affect conceptual change (Hashweh, 1986). However, studies that seek to test explanatory studies to induce conceptual change through various effective teaching models "are limited in number...most of the studies do not carefully describe and defend the theory of conceptual change on which these strategies are based" (Hashweh, 1988, p. 122). Furthermore,

these studies tend to focus on elementary through high school grade levels (Smith & Anderson, 1986). The present authors can only locate one study from one institution that is aimed at the post-secondary level (Anderson, 1986). This lack of research on conceptual change at the post-secondary level is curious in light of the fact that conceptual "shifts" are associated with formal reasoning; hence, students who have the propensity to utilize higher thinking skills should be better able to change their naive conceptions (Rogan, 1988).

It is appropriate to develop a "model" that can be utilized by teachers who want to foster conceptual changes in students through instructional techniques. If the model is to have much interdisciplinary utility in science education, then it would entail effective teaching strategies that are "generic" in the sense that they could readily be applied to many science topics. Enough information has been generated by descriptive studies (Posner & Gertzog, 1982) to begin to formulate such a model. Posner, et. al. (1982) reviewed conceptual change studies and determined that certain conditions in the instructional approach must be met to increase the likelihood of inducing change. Those conditions are as follows: "1) There must be dissatisfaction with existing conceptions, 2) A new conception must be intelligible, 3) A new conception must appear initially plausible, 4) A new concept should suggest the possibility of a fruitful research program" (p. 214). These criteria, based upon classroom transcripts, are

further operationalized in Posner's review. Knowledge that instructors also need to consider when teaching for conceptual change has been advanced by Anderson and Smith (1985). This includes diagnosis of students' present understanding, knowledge of specific questioning techniques to challenge students' thinking and understanding of science content with respect to the potential problems and difficulties students typically face because of their naive conceptual frameworks. It is, however, the contention of the authors of the present study that the incorporation of videodisc models in conjunction with present conceptual change strategies can be an effective technique in inducing conceptual shifts in students that require dynamic understanding of models. The premise of this contention is based upon the realization that today's students have become consumers of imagery, and the laser disc technology available to teachers provides us with the means by which we may compete, complement, and enhance the dynamic imagery students are already exposed to in their daily lives (Phillipo, 1988).

DESIGN AND METHODOLOGY

Subjects

Subjects consisted of intact classes of college students enrolled in an introductory General Science or Physical Science course. The sample for which complete data was collected totaled 36 students, who were then randomly assigned to either a control or treatment group.

Instrumentation

The dependent variable (conceptual shift) was measured by an instrument developed by Novick and Nussbaum (1978) and modified by Fazio (1988), called the Test About Particles (TAP). The purpose of the TAP was to assess students' understanding of the kinetic theory of gases. Fazio has determined the split half reliability of the TAP to be .90, and it has been reviewed by science educators and teachers to establish content validity. Additionally, four separate naive conception model tasks, referred to as "revealing events" (2 for the pretest and 2 for the posttest), modified from Fazio (1988) were used to assess visual differences in students' thinking.

Students were also pretested using compiled visualization tests from the kit of Factor-Referenced Cognitive Tests (Harmon, 1976). Harmon strongly recommends the use of more than one test when attempting to study underlying constructs; hence, two visualization tests were selected on the basis of their appropriateness for the present study.

Firstly, since students must be able to retain an image before they can manipulate it, the Shape Memory Test was used to examine the ability to recall the configuration, location and orientation of figural models. Construct validity has been established by Petrov (1970), Bradley et. al. (1969), and Ekstrom et. al. (1975). Harmon (1976) reports reliability at .68.

Secondly, since students must also be able to recognize models from different perspectives, the Cube Comparison Test was selected to examine the ability to manipulate and rotate

images while performing serial operations. Construct validity has been established by Ekstrom (1967), Ekstrom et. al. (1975) and Werdelin and Stjernberg (1971). Harmon (1976) reports reliability coefficients ranging from .77 to .84. For the purpose of the present study, these two compiled instruments will be referred to as the Visualization Test.

Method of Instruction and Testing

Inasmuch as all classes were to receive the conceptual change strategy identified by Posner et. al. (1982) and the diagnosis of students' present understanding to be used as challenging questions for students in the instructional phase as suggested by Anderson and Smith (1985) (refer to literature review), all classes were pretested using the TAP and two revealing events. The order of the tests were varied. Two days later, all students responded to the Visualization Test. Prior to instruction, the revealing event pretests were reviewed by the instructors and coded into several categories that revealed prevalent student misconceptions. In this manner, questions could be formed that would challenge the students' beliefs concerning the behavior of gases with respect to the Kinetic Theory of Matter.

The unit of study was the Kinetic Theory of Matter. The main concepts to be conveyed within the unit included the following principles of gases: 1) gas particles are uniformly distributed in a closed system; 2) gas particles are in constant motion; 3) heating and cooling causes changes in particle motion; 4) there is empty space between

the particles in a gas.

On the day of instruction, the students' responses to the revealing events were returned. The students were told that they must provide an explanation based upon their "model" (their responses to the revealing event) to account for the behavior of several demonstrations. The demonstrations were selected on the basis of illustrating the aforementioned principles of gases and the instructor "challenged" students' models by revealing inconsistencies between their explanations and the observed behavior of the demonstrations, thereby inducing dissatisfaction with existing conceptions.

The main content (Kinetic Theory of Matter), states of matter) of the unit was now presented to the treatment and control groups. However, the treatment group viewed approximately four minutes of dynamic models of the kinetic theory on a laser disc player and color monitor. The instructor explained the observed behavior of the previous demonstrations with respect to the images the students were viewing. This aspect of the treatment was designed to impose images representing molecules behaving in a fashion consistent with kinetic molecular theory. It was hypothesized that the laser-disc images would facilitate concept learning. Related studies lend credence to this notion. Rigney and Lutz (1976) in a study with college undergraduates, found that a computer generated graphic presentation of complex chemical concepts was superior to a verbal presentation in terms of overall learning and attitude towards the subject. Students in the graphics

group also reported experiencing greater mental imagery. In a study focusing on rule learning, Gropper (1966) used an imagery induced lesson to teach Archimedes' principle. His findings supported the assumption that rule transfer can be enhanced by linking images to concepts.

In place of the laser disc intervention, the control group reviewed the main points of the kinetic theory with respect to the demonstrations. With the above exception, every effort was made to make instruction similar for both treatment and control groups by following the same protocol for the lesson. Both groups received posttests for the TAP and two different revealing events two days after the treatment. The duration of time between pretests and posttests was one week.

RESULTS AND DISCUSSION

It should be emphasized that this study implemented teaching strategies that were consistent with the conditions necessary for inducing conceptual change as suggested by Posner et. al. (1982) and Anderson and Smith (1985) (refer to review of the literature). Each group (treatment and control) received those strategies. Paired samples t-tests revealed significant pretest to posttest differences within each group. Table 1 illustrates values of $t(17) = 6.85$, $p < .0001$, $\alpha = .05$ for Group 1 and $t(17) = 4.81$, $p < .0001$ for Group 2. These findings support the conceptual change strategies reviewed in the literature.

(Insert Table I here)

However, it was also the contention of the present authors that using ynamic models via laser disc images would prove to be an effective means of inducing conceptual shifts when used in conjunction with present conceptual change strategies. It was hypothesized that students, as consumers of imagery, would be apt to internalize and comprehend models that simulated three-dimensional motion and apply it better to their present understanding than simply being exposed to the conceptual change strategies alone. Gain scores between the experimental group and the control group reveal a significant difference favoring the experiment group ($t(32) = 2.41$, $p < .02$, $\alpha = .05$). Table II shows complete results of the t-test for independent means.

(Insert Table II here)

An Analysis of Variance was performed to determine the effects of imagery alone and the aptitude treatment interaction of imagery with group assignment. Table III illustrates the 2 x 2 design that was used (group assignment vs. high and low imagery). The high and low imagery groups were formed on the basis of students' performance on the Visualization Test using a median split. The scores for the high imagery group ranged from 60 to 36, while the scores for the low imagery group ranged from 35 to 12. Although the ability to remember and manipulate images seemed to have no significant effect on criterion scores, Table IV reveals that the interaction of imagery and placement in treatment groups did have a significant impact on learning ($F(1,32) = 4.14$, $p = .05$, $\alpha = .05$). The group means for the interaction variables (Table III) reveal that the largest mean

difference exists between the low-imagery control group and the remaining groups. It would seem that students who demonstrated low-imagery aptitude found the imagery imposition that was a part of the experimental treatment to be quite advantageous when learning about kinetic theory. This same low-imagery group performed poorly without this treatment. The high-imagery group seemed to be unaffected by the treatment. This result is similar to previous research data (McIntosh, 1986); that imagery encouragement during instruction leads to significant rule transfer gains for low-imagery students. Perhaps members of this group created their own images if not provided with one. The images related to molecular behavior and the kinetic theory are unique in that they represent an attempt to provide an image of a phenomenon that is inaccessible to common experience. Since molecules cannot be seen, it may be that high-imagery students create their own representations and, while they are not similar to the imposed representations, they are useful when learning new material. This possible explanation warrants further study.

(Insert Tables III and IV here)

Finally, the revealing events were examined to help provide qualitative insight as to the nature of students' image representations and possible misconceptions of a "kinetic model." Four different pictures which depicted "before" and "after" events of gas behavior were used. Students were asked to predict and draw what changes might occur in a particular event given certain specified changes in the picture. In two of the events, gas molecules were

already drawn for the students in the "before" picture.

Scheduling difficulties pre-empted all the subjects from completing both the pretests and the posttests for the revealing events; hence, the following conclusions warrant tentativeness. However, a non-parametric binomial test was performed on pretest to posttest changes for all those completing both sets of revealing events (n=23). A significant difference ($p < .002, \alpha = .05$) between students' conceptions of models relating to the Kinetic Theory prior to the conceptual change strategy, and those models that students proposed which were consistent with the Kinetic Theory after the strategy implementation, was found. There was evidence of certain recurring patterns which were evident when the pretest revealing events were examined. For example, some students failed to accurately represent a three-dimensional model of gas behavior and depicted a "flat", two-dimensional model with the molecules in a non-random fashion (see Figure 1). Other students' prevalent naive conceptions included molecules that were "clumped" in clusters with changes in size or number as illustrated in Figure 2. The presentation of dynamic images represented as three-dimensional constructs coupled with effective conceptual change strategies would appear to be a plausible approach to dispel such naive thought. Such revealing events can also provide teachers with valuable insight into how students view various models, theories or scientific concepts, and may be used to challenge their naive convictions when presented with contrary evidence.

(Insert Figures 1 and 2)

The advent of technology, such as the laser disc, makes the generation of images representing science concepts easier to use. The appropriate questions that must be raised are those relating to the instructional effectiveness of this capability. Results from this study indicate that images imposed during conceptual change instruction can be effective albeit more so for that group of students demonstrating low-imagery aptitude.

TABLE I

Paired Samples t-test for Within Group Differences on the Test About Particles

Group	TAP	Mean	SD	n	t	df	2 - Tail Probability
Group I	Pretest	12.50	3.94	18			
					6.85	17	.0001
(Experimental)	Post-test	17.33	4.03	18			
Group II	Pretest	14.72	4.60	18			
					4.81	17	.0001
(Control)	Post-test	17.39	3.90	18			

TABLE II

Independent Samples t-test for Between Group Differences on the Test About Particles

Group	Mean Gain Score	SD	n	t	df	2 - Tail Probability
Group I (Experimental)	4.83	2.99	18			
				2.41	32	.022
Group II (Control)	2.67	2.35	18			

TABLE III

Matrix of ANOVA for Conceptual Change Gain Scores on TAP

	Experimental Group	Control Group
Low Imagery Group	X = 5.71 SD = 3.50	X = 1.82 SD = 1.78
High Imagery Group	X = 4.27 SD = 2.65	X = 4.00 SD = 2.65

TABLE IV

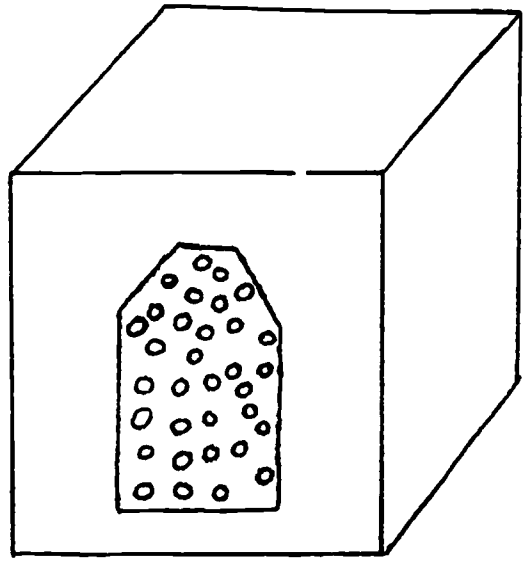
Aptitude Treatment Interaction
Effect for Conceptual Change

Source of Variation	Sum of Squares	df	F	Probability of F
Imagery	1.17	1	0.17	.681
Group	37.17	1	5.48	.026
Imagery X Group	28.08	1	4.14	.050
Explained	71.50	3	3.51	.026
Residual	217.25	32		
Total	288.75	35		

FIGURE 1

Figure (A) contains a gas in a sealed container which was then placed in a sealed square glass box. Figure (B) shows the same container which has now ruptured and the gas has escaped into the outer glass box. Using "dots" to represent the gas, show the location of the gas in Figure (B) after a great deal of time has passed.

(A)



(B)

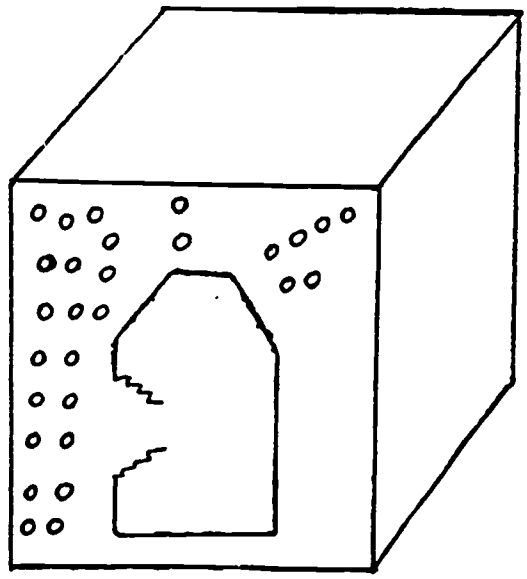
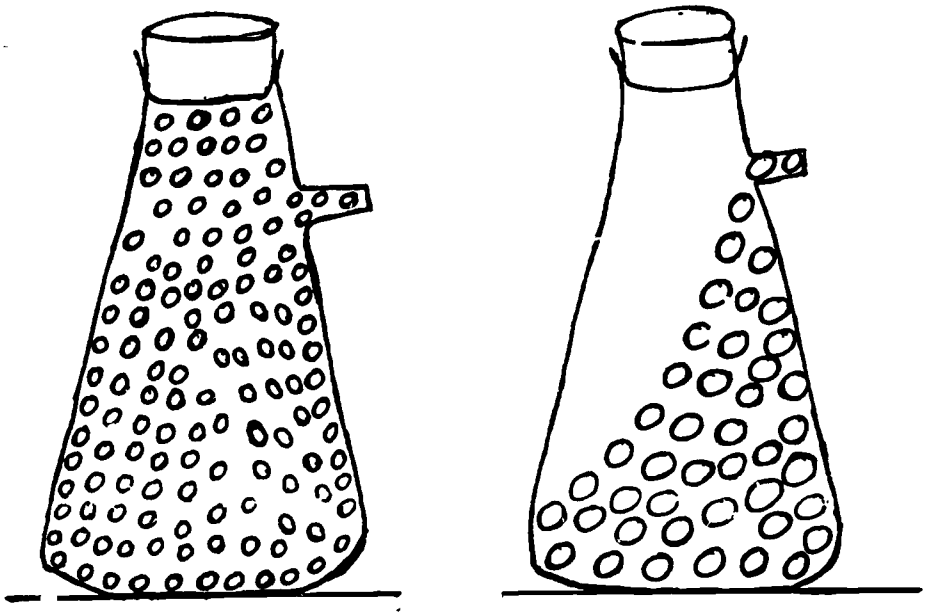


FIGURE 2

BEFORE REMOVING GAS

AFTER REMOVING ONE-HALF GAS



(A)

(B)

Figure (A) shows a sealed flask of gas. Using "dots" (circles) to represent the gas, draw how the gas may appear in the flask.

Figure (B) shows the same flask after one half of the gas has been removed. Illustrate how the gas now appears in the flask.

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