

**A Comparison of Microcomputer Simulations and Hands-on
Laboratory Experimentation for the Remediation of Alternative
Conceptions in Field-Dependent vs Field-Independent
High School Students**

by

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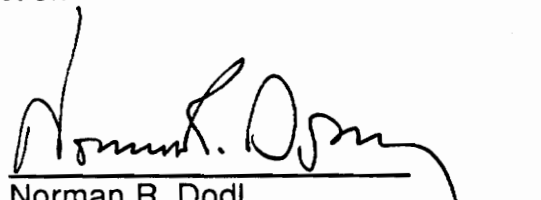
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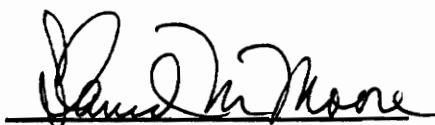
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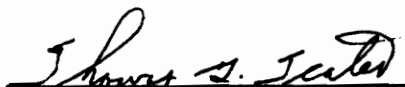
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(ABSTRACT)

Students come to science class with intuitive theories and ideas how the natural world works. These theories may conflict with accepted scientific concepts and can make subsequent learning in science very difficult. Since people differ in cognitive functioning, the nature of the remedial approach to these alternative conceptions is very important.

In this study, high-school students used computer simulations or hands-on experimentation as a remedial approach to their alternative conceptions. It explored the effects of the remediation in the context of the learning style of field-dependence-independence. Also, the use of the instrument (the embedded figures test) for defining field-dependence-independence was explored as a diagnostic tool for determining students who possess alternative conceptions. An Analysis of Covariance was used to determine the main effects and interactions between the treatments (mode of remediation) and field-dependence-independence.

The results of this study indicated that computer simulations and hands-on experimentation were both effective means for the

remediation of the alternative conceptions of force and gravity. Also, the hands-on experimentation was shown to be more effective than the computer simulations. However, the study failed to show any evidence of the differential effects of field-dependence-independence on remediation of the alternative conceptions. There was also no indication of interactions between the independent variables. Although a relationship was shown to exist between the test for alternative conceptions and the instrument for determining field-dependence-independence, due to the low correlation and the expense of administration, the Group Embedded Figures Test was not recommended for the diagnosis of alternative conceptions in high-school students.

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CHAPTER 1

Introduction

Modern science has given us an extensive, deep, and comprehensive understanding of the world around us, which has enabled humankind to accomplish amazing things. Similarly, the goal of learning is understanding and to "understand some new piece of information is to relate it to a mentally represented schema, to integrate with already existing knowledge" (Carey, 1986, p. 1123). However, in the field of science, many facets of existing knowledge and newly acquired knowledge often run counter to the intuitive reasoning of the individual. Therefore, the individual brings to the science class many conceptions of the world which conflict with scientifically accepted concepts and until these alternative conceptions are actively dealt with, expanding on the existing knowledge base is difficult at best (Hashweh, 1988).

In order for positive instruction and understanding in science teaching to proceed, the teacher must have a way of determining the alternative conceptions which exist in the student's knowledge base (diagnosis), a means by which these alternative conceptions can be confronted and changed to conform to acceptable scientific theory (remediation), and a way of determining characteristics of those learners who are most likely to possess alternative conceptions. This study is designed to investigate these three areas.

A microcomputer-based system is used to diagnose the following alternative concepts (Weller, 1990):

1) Quickness of fall depends on mass conception.

With no air resistance, the downward movement of a more massive object is faster than that of a less massive object.

2) Unbalanced force conception.

If an object is moving and no unbalanced force is acting on it, the object will come to rest.

3) Direction of vertical movement depends on type of material conception.

a) Light objects rise because they are made of material which naturally tends to move upward;

b) Heavy objects fall because they are made of material which naturally tends to move downward (pp. 1-2).

In this study, a microcomputer-displayed, graphics-based system developed by Weller (1990) will be compared with a hands-on laboratory apparatus for the remediation of these selected alternative conceptions held by students. The simulation and hands-on laboratory activities are designed for remediation of the quickness of fall and unbalanced force conceptions.

Several general characteristics of field dependent students overlap with descriptions of students who have been found to possess alternative conceptions. One purpose of this study is to explore the

interaction of field-dependence-independence with remedial tasks utilizing computer simulations and hands-on experimentation.

Another purpose of this study is to explore the efficacy of utilizing a tool for determining field dependency (Embedded Figures Test) to identify those students with a tendency to possess alternative conceptions.

Background

Most learning theorists today would agree that cognitive science was officially recognized around 1956, the year the Symposium on Information Theory was held at Massachusetts Institute of Technology (Gardner, 1987). With the stimulus-response (S-R) approach of the behaviorists, such as in the works of Hull, Spence, and Skinner, the focus was on how the presentation of material influenced behavior. In contrast to this, the cognitive approach seeks to understand how information that is being received is processed and stored (Weinstein & Mayer, 1986).

Years before the cognitive revolution, Piaget postulated structures by which we interpret, organize, and adapt our environmental experiences, just as the body has structures such as the organs and nervous system (Wadsworth, 1971). These organized units of long term memory are referred to as schema (Bransford, 1979; Champagne, Gunstone, & Klopfer, 1982; Resnick, 1983; Rumelhart, 1980; Yager, 1991), frames (Minsky, 1975), scripts (Schank, & Abelson, 1977), and knowledge modules (Rumelhart &

Norman, 1978). These structures adapt and change with mental development (Wadsworth, 1971).

Piaget further postulated that a person interacts with the environment utilizing two unchanging processes he termed assimilation and accommodation. Assimilation is the process by which a person interacts with a stimulus in a way that is consistent with existing schema (Ormrod, 1990). It is important to note that assimilation does not change the existing schemata, but adds to them. If the new event does not fit into any existing schemata, then through the process of accommodation either a new schemata must be developed or an existing schemata must be changed.

In accordance with the accommodative reconstruction theory, Spiro (1980) found that errors in recall were more frequent for information that had conflicted with the existing schema because reconciling the conflicting information with the existing schema changed the form of the information during encoding prior to the recall task.

Performance is strongly influenced by one's prior knowledge (Bransford & Johnson, 1972; Chiesi, Spilich, & Voss, 1979). Ausubel has said that "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (Ausubel, Novak, & Hanesian, 1978, p. 163).

"Students bring to the classroom a knowledge base that has been shaped by both formal and informal learning experiences. These experiences can be either positive or negative in its (sic) impact on

future learning. The presence of a performance does not make it possible to conclude that learning has occurred. It is necessary to show that there has been a change in performance. The incapability for exhibiting the performance before learning must be taken into account as well as the capability that exists after the learning. It is, in fact, the existence of prior capabilities that is slighted or even ignored by most of the traditional learning prototypes. And it is these prior capabilities that are of crucial importance ... in determining the conditions required for subsequent learning" (Gagne, 1965, pp. 20-21).

The encoding process can be analyzed into four main components (Weinstein & Mayer, 1986).

Selection - The learner actively pays attention to some of the information that is impinging on the sense receptors, and transfers this information into working memory (active consciousness).

Acquisition - the learner actively transfers the information from working memory into long-term memory for permanent storage.

Construction - The learner actively builds connections between ideas in the information that have reached active memory. The building of internal connections involves the development of a coherent outline organization or schema that holds the information together.

Integration - The learner actively searches for prior knowledge in long-term memory and transfers this knowledge to working memory. The learner may then build external connections between the incoming information and prior knowledge (p. 317).

Instead of viewing learners as passively recording the stimulus that the teacher presents, learning is viewed as an active process that occurs within the learner and which can be influenced by the learner (Weinstein & Mayer, 1986).

A review of literature (Shuell, 1990) found there is reasonable agreement that a learner passes through a series of phases. Meaningful learning is an active, constructive, and cumulative process that occurs gradually over a period of time in which a learner passes through these phases as the knowledge about a subject grows (Shuell, 1990). For example, Rumelhart & Norman (1978) postulated three distinct learning phases. First is the accretion stage where new information is encoded in terms of existing schemata. In the second phase, restructuring, new schemata are created and in the fine tuning phase, there is a slow modification and refinement of the schemata as the acquired knowledge is used in different situations. These are sequential phases, but learning activity could be taking place in all three phases simultaneously. Other phase theories which developed include skill learning with the cognitive, associative and

autonomous phases (Fitts, 1964), the novice-expert continuum (Champagne, 1982) and the novice, advanced beginner, competent, proficient, and expert phases (Dreyfus & Dreyfus, 1986). Procedural learning phases were labeled declarative, knowledge compilation, and procedural knowledge (Anderson & Smith, 1987).

From a social constructivist standpoint, three phases were used in the Science Curriculum Improvement Study (SCIS) labeled exploration, invention, and discovery (Lawson & Renner, 1975). A later study by Glasson & Lalik (in press) labeled the second phase as clarification and the third phase as elaboration.

Constructivism

Cognitive research in science education in the last decade has revealed that most persons have alternative conceptions about nature and that typical schooling is ineffective in altering these conceptions (Yager, 1991). According to Yager, learning outcomes are less dependent on what the teacher presents than a result of what information is encountered and how the student processes it based on perceived notions and existing personal knowledge. Therefore, the learner is active and not just a passive recipient of information. Knowledge cannot simply be transferred by means of words without first an agreement about meaning and some experiential base (Yager, 1991). Learning is a product of self-organization and reorganization.

"As cognitive psychology has elaborated a theory of the human being as an active constructor of knowledge, a

new view of learning has begun to emerge, one that describes changes in knowledge as the result of learner's self-modification of their own thought processes and knowledge structures. This in turn means that instruction must be designed not to put knowledge into learners' heads, but to put learners into positions that allow them to construct well-structured knowledge" (Resnick, 1985, p. 2579).

Human perception is not simply a process of sensing everything in the environment. Instead, it is a constructive event. The person's experience, knowledge, and expectations influence the products of perception particularly the perception of ambiguous events (Marx, & Winne, 1987).

According to Kelly (1969), any phenomenon is open to as many reconstructions as the imagination allows. Whether it exists as reality is not the question, but what can be done with it. Every person has their own unique construction of the world. Alternative conceptions would represent sensible expressions of this personal model (Kelly, 1969). With learning, in order for communication to proceed, these personal constructs need to be investigated by the teacher and used as part of the teaching-learning process.

Situated Cognition and Anchored Instruction

"Knowledge is situated, being in part a product of the activity, context, and culture in which it is developed and used" (Brown, Collins, & Duguid, 1989, p. 32). Unfortunately, one of the tasks of schools in the past was to transfer a body of knowledge to the learner which was often comprised of abstract, out-of-context

concepts. As noted in phases of learning, a concept continually evolves each time it is used because...

"new situations, negotiations, and activities recast it in a new, more densely textured form. A concept is like a tool which can only be understood through use and using them entails both changing the user's view of the world and adopting the belief system of the culture in which they are used (Brown, Collins, & Duguid, 1989, p. 34).

Whitehead (1929) makes a distinction between inert knowledge and useful, robust knowledge. Inert knowledge is knowledge that can be recalled if one is asked to do so, but is not used spontaneously in problem solving even though it is relevant. The major goal of anchored instruction is to overcome this problem of inert knowledge. In anchored instruction, environments are created that permit exploration by the student to help them understand the concepts and explore the kinds of problems that experts in the field encounter (The Cognition and Technology Group at Vanderbilt, 1990).

In past research on a performance-based model for teacher effectiveness, the teacher would exhibit certain behaviors, such as stating objectives, posing higher cognitive questions, praising correct answers, or summarizing. The effectiveness would then be determined by an evaluation of student performance on some instrument. A teacher's teaching behavior (the cause) would be effective if the students performed well on the test (the effect). In the cognitive mediational model, the student is an active learner

using cues from the teacher to select a cognitive operation to achieve the instructional objectives (Marx, & Winne, 1987).

Recognizing the student as an active learner, knowledge to be gained should be applied to as many different contexts as possible throughout the learning process. If it is learned in "real life" contexts, similar to the context in which it will be used, then transfer is much more readily accomplished (The Cognition and Technology Group, 1990).

CHAPTER 2

Review of Literature

Alternative Conceptions

"All students, the weak as well as the strong learners, come to their first science classes with surprising extensive theories about how the natural world works" (Resnick, 1983, p. 477). Much recent research has established the fact that students bring to the science classes an extensive set of personal theories developed to explain how the natural world works in everyday experience (Leboutet-Barrell, 1976; Nussbaum & Novak, 1976).

An extensive literature review (Hashweh, 1988) reveals that not only do alternative conceptions exist, but many of them persist after classroom instruction. Worse, they sometimes hinder the acquisition of new scientific concepts. These theories, existing as part of the student's knowledge base, have been labeled as alternative conceptual systems (Champagne, Klopfer & Gunstone, 1982), alternative frameworks (Driver, 1981), naive theories, (Resnick, 1983), and alternative conceptions (Hewson, 1985).

The occurrence of alternative conceptions has been contributed to two main factors suggested by Hewson. "Firstly, people strive to make sense of their environment. Secondly, people use the knowledge they possess in their attempts to make sense of their experience" (Hewson, 1984, p. 16). The term alternative conceptions is

preferred because "...it is not a matter of 'not understanding' but of 'understanding differently'..." (Nussbaum & Novick, 1982, p. 184).

A study by the constructivist John Baxter (1991) asked students to draw and write about what they think causes seasonal changes. The results suggested that students, just like many scientists, interpret their perceptions so that they support their original conceptions.

In science, there has been much study of the effects that previous everyday experience has had on the ability of students to understand basic science concepts. For example, students often have trouble understanding the function of reflected light because in everyday experience they perceive that light just brightens things allowing us to see things directly. Until they see that this is inadequate for scientific purposes, they will not have the understanding necessary to go further in the study of light (Anderson & Smith, 1987). Teachers who have an understanding of the construct of schema or knowledge structure see alternative concepts as something that can be affected, whereas others who hold to a receptive-accrual view would see this failure to learn science as an innate limitation or insufficient exposure to the correct facts (Anderson, 1989). For example, in a search of recent literature on common sense beliefs about motion, Halloun and Hestenes (1985) found that they are generally incompatible with Newtonian theories and they are very robust, with traditional physics instruction doing little to change them.

Informal or intuitive knowledge is knowledge that is constructed by a student trying to derive meaning from everyday experience. The interpretation is very individualistic (Kelly, 1969) and may contrast with the knowledge that is attained in the classroom (Resnick, 1987). That these alternative conceptions exist and are very difficult to change in students has been verified in many studies in just about every discipline of science (Anderson & Smith, 1987). Novices are said to hold theories that resemble the theories of Aristotle rather than of Newton (White, 1983). These views are relatively unaffected by instruction in Newtonian mechanics (Clement, 1982).

Getting students to change alternative conceptions is not an easy task. Students must first be dissatisfied with them in some way, then they must find the alternative conceptions both intelligible and useful in extending understanding to new situations (Posner, Strike, Hewson, & Gertzog, 1982). Learning then, is not simply adding to the existing knowledge base of the student, but also producing a change in the alternative conceptions of the student. The model of conceptual change proposed by Posner et al. (1982) maintains that, in learning, new concepts are compared with the concepts in the existing knowledge base. If these concepts do not conflict, then learning proceeds without difficulty. However, when the two conflict, they have to be reconciled before learning can proceed. Either the existing conceptual framework must be

altered or the existing alternative conception must be replaced by the new concept.

When new material is contradictory to the existing knowledge base, a learner will either dismiss the new propositions as invalid, try to set the new material apart from the existing material (no integration), or integrate and reconcile the two sets of ideas into a new relationship (Ausubel et al., 1978).

Force

Watts (1983) outlined eight distinctive alternate conceptions of force. The major alternative conception of force is that whenever there is a motion, a force must be present (Clement, 1982). In one study on alternative concepts in force, a diagram showing the path of a coin tossed in the air was shown to students. They were asked to label all the forces acting on the coin during its flight. Ninety percent of the errors that were committed showed a force acting on the coin in an upward direction while the coin was going up (Clement, 1982). Viennot (1979) found that students that had this notion substituted velocity for acceleration in their thinking of Newton's second law. With this thinking, it is hard for students to think of passive agents as exerting a force, such as a table holding up a book, therefore only active agents such as people or machines are exerting forces (Hewson, 1984).

Velocity

In general, a student's alternative conception of speed is caused by the student using a "position" criterion for judging the velocities of two objects in respect to each other. Only when the objects were side by side were they judged to be traveling at the same velocity (Trowbridge & McDermott, 1980). This confusion of speed with position was prevalent throughout all levels of instruction investigated in the study. In the experimental group where the confusion between speed and position was directly confronted by dialog and experimentation, there was a significant improvement in the post-instructional interviews. Another study of eighth-grade students showed that this alternative conception of velocity was held by a significant number of those tested (Hewson, 1985).

Gravity

Watt (1982) isolated eight different alternative frameworks for children's conception of gravity:

- 1) Gravity is a force which requires a medium to act through
- 2) Where there is no air, there is no gravity
- 3) Gravity increases with height
- 4) Gravity is constant - moving objects try, and fail to counteract gravity
- 5) Gravity begins to operate when objects start to fall down and continues until they are at rest on the ground

- 6) gravity is a large force
- 7) gravity is selective
- 8) gravity is not weight (pp. 117-120)

In another study Watts and Zylbersztajn (1981) found a significant portion of the students saw gravity as something that switches on when the object rises to its maximum height. They indicated that there is no force exerted at the peak but soon gravity takes over to cause the object to fall to the earth.

Remediation of Alternative Conceptions

It has been observed that "telling" pupils the right answer does not necessarily result in their discarding their alternative framework in exchange for the taught notion. Frequently, it results in the formation of a hybrid notion, a mix between the pupil's alternative framework and the taught idea (Gilbert, Osbourne, & Fensham, 1982).

The growing body of data on alternative frameworks has given rise to the "constructivist" or alternative conceptions movement (ACM) (Gilbert & Swift, 1985). The main axiom of the ACM is that a child's alternative framework is analogous to a scientific theory, and will only be exchanged when it is challenged and fails to hold good in the light of new evidence. The ACM group has criticized the Piagetian school for using the alternative conceptions of students merely as a diagnostic tool to "identify the stage level of intellectual development" or their "stage (un) readiness" for specific

concept learning (Gilbert & Swift, 1985, p. 693). Gunstone, Champagne, & Klopfer (1982) have shown that the alternative conceptions possessed by students are tenacious and highly resistant to change. They concluded that these conceptions would probably pass into adulthood if left unchallenged.

Gil-Perez & Carrascosa (1990) developed the phrase "methodology of superficiality" which they use to describe the qualitative, common sense way that children and preclassical physics works approach science. They quoted Aristotle (in *De Caelo*): "A given weight covers a certain distance in a given time; a bigger weight covers the same distance in less time, the times being in inverse proportions to the weights. So if one weight is double the other, it will take half the time for a given moment" (Gil-Perez & Carrascosa, 1990, p. 534).

One of the tasks of remediating alternative conceptions is to distinguish this Aristolian thinking from the scientific, Newtonian approach to force and motion phenomenon. Using the logo dynaturtle, as opposed to the more familiar geometric turtle, DiSessa (1982) was able to diagnose Aristotelian tendencies in eighth grade learners. The dynaturtle incorporates Newton's three laws of motion into the logo programming, such that when forces are applied to the turtle, the conservation laws are observed. Without exception, the learners exhibited Aristotelian approaches when instructed to hit a target at a forty five degree heading from the turtle starting position (DeSessa, 1982).

Hewson's (1985) model of conceptual change requires three conditions to be met before a new conception can be added to existing knowledge. Is the concept intelligible (I), plausible (P), and fruitful (F)? Remediation is accomplished through the lowering of the status of the conception. If the introduction of a remedial task causes the status of the alternative concept to drop from IPF to say IP or IP to I, then dissatisfaction with that concept could lead to change. On the other hand, if the remediation task gains in status in the meantime, there is a good likelihood that the new concept would alter or replace the alternative conception in the knowledge base. A study by Champayne, Klopfer and Anderson (1980) supports a two-fold strategy for conceptual change. They conclude that "...the challenge for physics instructors is to enable the students to discover for themselves the limitations and inadequacies of an Aristotelian framework, as well as the far-reaching explanatory powers of the Newtonian paradigm" (p. 1078).

Lampert's approach to remediation of an alternative conception is embedded in his immersion approach in which the teacher provides additional input that helps the student to resolve their own perceptual problem (Lampert, 1989). This approach has been shown to have positive results in science with higher levels of understanding and thoughtfulness on the part of the learner (Roth, Anderson, & Smith, 1987).

Cognitive Styles

Cognitive styles are individual differences which involve distinctly idiosyncratic forms of cognitive functioning in a wide array of content areas including perceptual, intellectual, social-interpersonal and personality defense mechanisms (Goodenough, 1976).

The roots of cognitive style are in the New Look Movement which had its origin in a symposium in 1949 (Witkin & Goodenough, 1981). Research has identified several dimensions of cognitive style. These were summarized by Kogan (1971) in a table taken from Saracho (1989) in which he identifies nine cognitive styles: field dependence-independence, scanning, breadth of categorizing, conceptualizing styles, cognitive complexity-simplicity, reflectiveness-impulsivity, leveling-sharpening, constricted-flexible control, and tolerance for incongruous or unrealistic experiences.

The cognitive style that has generated the most research is field dependence-independence (FDI) (Saracho, 1989). The initial studies of Witkin and Asch (as cited in Witkin & Goodenough, 1981) were focused on determining how well people were able to orient themselves to an upright position. Unexpectedly, they found that people differed in the way they performed on the orienting tasks. Not only were they different, but they were also consistent across tasks as an individual (Witkin & Goodenough, 1981). This led Witkin

into the study of these individual styles which he termed "personal style" (Witkin, Goodenough, & Oltman, 1979).

In perceiving the upright, there are two sets of experiences that are working together to create a person's perception. One is framework, which is the vertical and the horizontal directions in spatial relationships (outside referent), the other is the perceptual orientation produced by gravitational attraction (internal referent). Witkin used three tests to experimentally separate these two means of perception. The three tests were the Body Adjustment Test (BAT), Rod and Frame Test (RFT), and the Rotating Room Test (RRT) (Witkins & Goodenough, 1981).

In the Body Adjustment Test, the person sits in a chair in a room that can be tilted to varying degrees independently of the chair. The task is to adjust the chair to a true upright position. Some people adjust the chair in alignment with the tilted room to varying degrees using the visual context of the room to perceive uprightness. Those that use the body as their primary reference are more likely to bring their chair to the true gravitational upright (Witkin & Goodenough, 1981).

In the Rod-and-Frame Test the room is darkened and the person is instructed to place a rod in the upright position within the frame. When the frame is in a tilted position, those that use the visual field as a referent tended to adjust the rod to align with the tilted frame (Witkin & Goodenough, 1981).

The Rotating-Room Test is used to offset gravitational orientation by producing a "centrifugal" force so that the resultant force on the body is a combination of the "centrifugal" force and the gravitational force. People that use the gravitational orientation are less likely to position themselves in a true upright (Witkin & Goodenough, 1981). The most important outcome is that whether the person uses the external visual field or the body as the primary referents for achieving a perception of upright, they are consistent in their use across all the tasks. Also, success in either orientation is dependent upon which orientational cues are more conducive to accurate performance in a particular task. Therefore, reliance on the body orientation led to more accurate performance on the BAT and the RFT tests and reliance on the external frame led to more accurate performance on the RRT test (Witkins & Goodenough, 1981). Using the external field for a reference for alignment is termed field-dependent and using the body primarily for a reference is termed field-independent (Witkin & Goodenough, 1981).

Reasoning that the real task in these tests was separating an item, such as a rod or body, from an organized field (room or frame), Witkin (1950) developed the Embedded-Figures Test (EFT). In the EFT, a person is shown a simple figure, then asked to find that figure in a complex pattern. Each part of the simple figure is made to be a part of the whole pattern (Witkin & Goodenough, 1981).

Those that have difficulty in separating the simple figure from the whole pattern are also the ones that cannot separate the rod or

body from the frame and room in the upright tasks. This suggests a more general view of field-dependence-independence as "a perceptual-analytical ability that manifests itself pervasively throughout an individual's perceptual functioning" (Witkins & Goodenough, 1981, p. 15).

A field-dependent person deals with a field in more of a passive way, whereas a field-independent person deals with a field in an active way. Not only is a field-independent person able to analyze a field and break it apart into its constituent parts, they are able to impose structure on a field that has little structure to it. "Subjects identified as field-dependent in perception of the upright were found to have greater difficulty in solving that particular class of problems in which the solution depends on taking an element critical for solution out of the context in which it is presented and restructuring the problem material so that the element is now used in a different context" (Witkin & Goodenough, 1981, p. 17).

This ability to analyze and restructure is a broadening dimension of cognitive style, defined by the "mode of field" approach. At one extreme is the articulated mode and at the other extreme the global mode (Witkin, Dyk, Faterson, Goodenough, & Karp, 1962 as cited in Goodenough, 1976). Field-independence has been defined as the ability to overcome embedding contexts in perceptual functioning and is considered to be the analytical component of an articulated mode of field approach as experienced in perception (Goodenough, 1976).

In people with a relatively global cognitive style, experiences are governed by the organization of the field. By contrast, in people with a relatively articulated cognitive style, experiences can be analyzed and structured in new ways, depending on the task at hand (Goodenough, 1976).

Subsequent correlations between field dependence-independence (FDI) and the various constructs of personality theory have broadened field dependence-independence again into the differentiation hypothesis (Witkin & Goodenough, 1981; Witkin, Goodenough, & Oltman, 1979). Underneath the higher-order construct of differentiation theory, Witkin et al. (1979) identified four lower-order constructs:

- 1) articulated cognitive functioning
- 2) articulated body concept
- 3) sense of separate identity
- 4) structured control and specialized defenses

(p. 1128).

This hypothesis has been used to generate predictions concerning linkages to behaviors in other domains such as cognitive restructuring, interpersonal competencies, and cerebral lateralization (Witkin, Goodenough, & Oltman, 1979). The greater the degree of differentiation, the greater the self-nonsel segregation (Witkin, Goodenough, & Oltman, 1979).

Saracho (1989) has compared the observable behaviors of field-dependent & field-independent people:

Field-dependent:

- rely on the surrounding perceptual field
- experience their environment in a relatively global fashion by conforming to the effects of the prevailing field or context
- dependent on authority
- search for facial cues in those around them as a source of information
- are strongly interested in people
- get closer to the person with whom they are interacting
- have a sensitivity to others which helps them to acquire social skills
- prefer occupations which require involvement with others

Field-independent:

- perceive objects as separate from the field
- can abstract an item from the surrounding field and solve problems that are presented and reorganized in different contexts
- experience an independence from authority which leads them to depend on their own standards and values
- oriented toward active striving
- appear to be cold and distant
- socially detached but have analytic skills
- prefer occupations that allow them to work by themselves (p. 77)

One area of FDI research that has received attention in recent years is in the relationship of cognitive processing to FDI. Kent-

Davis & Cochran (1989), reviewed the literature for research in field dependence relating to information processing and developed three basic generalizations. First, field-independent learners are more effective than field-dependent learners in executing some attention, encoding, and long-term memory processes. Second, field-independent learners reach a stage of automatic information processing sooner than field-dependent people. Third, field-independent learners acquire or adopt more successful strategies for overcoming problems associated with limited attentional resources in working memory. They also concluded that field-dependent learners can benefit by focused attention on critical features of information to be processed and allowed ample time and practice to develop automaticity on basics.

In a study of attention, Alexander, Avolio, Barrett & Stearns (1981) presented both visual and auditory tasks to students. The tasks required them to pay attention to relevant stimuli when there was other nonrelevant and competing stimuli present. They found that the field-dependent students made many more errors in identifying relevant stimuli than did the field-independent.

Shinor, McDowell, Rackoff and Rockwell (1978) examined eye movements under simulated driving conditions. In the simulation, when the scenes changed, the field-dependents needed more time to process information. They found that the FD's fixated on smaller and smaller regions of the changing display and therefore took longer to process all of the new information.

In the study done by Fitzgibbons and Goldberger (1971), they found that field-dependents and independents differed in digit-span tasks, especially under more difficult interference conditions. They inferred from this that FDI people differ on the short term memory processes. The key difference was on the type of task, whether it was a low or high interference task. In visual images and in computer assisted instruction, if there is a task that requires recall at a later time, the constraints of field dependency would require that the relevant stimulus be as free from interference from other irrelevant or competing stimuli as possible.

Using longitudinal and cross-sectional data, Witkin, Goodenough, and Karp (1967) demonstrated that developmental curves show a progressive decrease in field-dependence up to the age of 17 at which time they reach a plateau in young adulthood. Also, training has been shown to enhance specific restructuring skills such as disembedding (Witkin & Goodenough, 1981), verbal disambiguating tasks, and verbal perspectivism (Rush, 1990).
Field Dependence-Independence and Alternative Conceptions

According to Witkin (Witkin & Goodenough, 1981), field-dependent and field-independent people differ in the ability to restructure information in both perception and cognition. They indicate that this ability involves three components:

- (1) breaking a stimulus down into its component parts
- (2) providing structures when the situation is

ambiguous

- (3) providing a structure that is different from that which is inherent in the original stimulus

Therefore, whether a person relies on external sources or is self-reliant may influence the development of cognitive-restructuring skills and "a more autonomously functioning person may go beyond the information given when that is required by situational demands or inner needs" (Witkin, Goodenough, & Oltman, 1979, p. 1138). Although a field-dependent person's tendency to rely on external referents stimulates their interpersonal competencies, it could also be responsible for their lesser cognitive restructuring skills (Witkin, Goodenough, & Oltman, 1979).

Several of these traits of field dependency can be seen in students' alternative conceptions of physical science concepts. In the general observations of students' alternative conceptions of gravity, Gunstone & White (1981), concluded that there was "a serious deficiency in the ability to explain predictions" and also a "failure to resolve discrepancies between predictions and observations" (Gunstone & White, 1981, p. 299).

Goodenough (1976) found that field-dependent learners were dominated by the most noticeable or most prominent (salient) features of a piece of information when they are presented with a task. They tended to overlook the other features or details of the stimulus. In the study of student understanding of velocity, (Trowbridge & McDermott, 1980), failure to judge speed properly

was due to improper use of a position criterion to determine the relative velocity. "They fell back on the perceptually obvious phenomenon of passing... and frequently did not relate their intuition of how fast an object is going to the ratio of the distance traveled to the elapsed time or to the idea of velocity at an instant." (Trowbridge & McDermott, 1980, p. 1027)

McClelland (1984) maintains that one of the reasons for alternative conceptions in students is a strategic inattention on the student's part when asked to answer questions on physical events which are not salient enough for them. A field-dependent person who has difficulty separating the objects or events from the dominant field would have difficulty in attending to the proper cues.

Microcomputer Based Simulation and Experimentation

As early as the 70's, computers have been establishing themselves in classrooms in increasing numbers and in a diversity of application in high-school curriculum. Science curriculum, in particular, has been greatly effected by this changing technology, especially in the area of laboratory exploration and experimentation. The term micro-based laboratory, (MBL), used by Bross (1986), and Thornton (1987) refers to the use of microcomputers for laboratory simulations and also for data collection, manipulation, and computation.

Due to the recent use of the microcomputer for experimentation utilizing transducers, MacKenzie (1988), further divides MBL into micro-simulation experimentation (MSE) and micro-based experimentation (MBE). With traditional laboratory experimentation on one extreme (without the use of computers), and MSE on the other extreme (uses only the computer), MBE is somewhere in between. MBE uses traditional laboratory procedures, but also uses the computer for measurement, computation, and interpretation of the data.

Microcomputer Simulation Experimentation

In an extensive literature review summarizing research in science education, Gallagher (1987) concluded that the use of simulations, particularly in science, were increasing steadily. As is prevalent throughout the literature dealing with microcomputers and their use within the science laboratory, most of the literature deals with application of simulation software and very little with research involving computer simulations. There are two types of microcomputer simulation experiments. Firstly, there are those designed as prelab simulations. For example, Wieggers and Smith (1980) used Plato lessons (prelab simulations of organic chemistry experiments) prior to completion of the laboratory experiment. Only completion time was considered as a factor and not the understanding of the concepts presented. In another study, learning was found to be enhanced for students using computer-assisted

videodisc laboratory tutorial simulations in an undergraduate chemistry course by Smith (1986).

Wilson (1980) combined an interactive prelab simulation with actual data collection in the laboratory. The interactive design of the simulation allowed for student input towards experimental development rather than just a "cook book" experimental approach. Results showed a markedly improved attitude and understanding of the laboratory experiments in the students.

In the application of computers in education, two capabilities stand out. Firstly, real world experiences that are difficult to replicate, too complex, or happen too rapidly can easily be observed in a simulation. Secondly, the computer can constantly diagnose student progress and branch to instruction which deals specifically with areas where the student has an insufficient knowledge base or competing alternative conceptions (Zietsman & Hewson, 1986).

In designing simulations for remediation of alternative conceptions, two important design aspects are of primary importance. First of all, the designer needs to find out where the students exhibit erroneous thinking so simulations can be created that focus on the alternative conception and secondly, the simulation needs to provide good, immediate feedback to the student (White, 1984). It was found that students were capable of attending to their own remediation when feedback focused their attention on areas where their knowledge needed revision (White, 1984; Yeany &

Miller, 1983). There was no difference between those that received diagnosis and remediation and those receiving diagnosis only.

The other type of simulation is used in place of the corresponding laboratory experimentation, not just as a pre-lab introductory exercise. Learning has been found to be significantly higher using computer simulations and film loops than students viewing just film loops or the control group interacting only with the teacher (Lunetta, 1972). In another study, Hughes (1973) found that there was no difference between students using computers and those not using computers in the ability to investigate relationships between variables, reach conclusions, and design experiments. A study by Cavin (1978) concluded that there was better performance on the part of students using computer-simulated chemistry experiments.

Research in attitudes toward computer assisted instruction was done when CSE was first introduced (Brown & Gilman, 1969; Schwartz & Long, 1967;). Favorable attitudes toward computer instruction was found, but caution was recommended until computer simulation and instruction had been used a few years (Hall, 1971). A later review of literature (Jamison, Suppes, & Wells, 1974) supported previous findings. Knight and Dunkleberger (1977) found increased positive attitudes on the part of students in computer-managed, self-paced (CMSP) instruction than in the traditional teacher-managed, group-paced (TMGP) format in the laboratory experimental setting. The study did not identify which part of the

CMSP instruction contributed most to the increased positive attitude.

Microcomputer Based Experiments

One of the first MBE was developed in response to a study and follow-up study (Wiser, Kipman, & Halkiadakis, 1988) which showed that most high-school students could not differentiate between heat and temperature. A computer based lab was developed to allow students to use the computer to record heat and temperature data and to display the data in various charts and graphs. No experimental design was used to determine the effectiveness. Only teacher observation of improved comprehension of this particular concept and grades were noted.

A computer interfaced model utilizing an Apple II computer was used by Wiser, Kipman, & Halkiadakis (1988) to successfully change the alternative conception of heat and temperature of ninth-grade, physical-science students. They used heat-pulse generators to heat up substances and temperature probes to record temperature change.

Interfacing of microcomputers for use in experimentation has many sources for "how to". Some examples are the calculation of the density of glass (Harris, 1986), using a potentiometer to measure volume in a chemical reaction experiment (Horst & Dowden, 1986), a moving coil galvanometer(McNeill, 1985), field effect transistor characteristics and circuits (Kidd & Ardini, 1979), and lab exercises

designed to introduce physics students to graphing (Beichner, 1986). There are also numerous lab manuals and books loaded with computer-based experimentation ideas and lesson plans.

Simulation vs Microcomputer based Experimentation

In comparing computer simulation with hands-on laboratory experimentation, a look at the literature suggests that each has benefits depending on the situation. Hands-on experiences may be more effective for learning specific science concepts than simulations (Hofstein & Lunetta, 1982; Olson, 1973). However, laboratory experimentation can be elaborate and complex to set up, sometimes impractical, and errors generated in measurement make it difficult for a student to generalize results (Lunetta, & Hofstein, 1981). Much of the evaluation of simulation and laboratory experiences is by student and teacher feedback without formal studies being conducted. Tinker (1981) concluded by saying there needs to be much more formal research in determining the effectiveness of computer software.

Microcomputer simulated experiences were compared with hands-on laboratory experiences in teaching the concept of volume displacement to junior-high-school students (Choi, & Gennaro, 1987). It was found that computer-simulated experiences were as effective as hands-on laboratory experiences in the teaching, and subsequent retention of, the water displacement concept.

Trowbridge and McDermott (1980) successfully used a hands-on experimental apparatus to remediate the alternative conception of velocity and the "position" criterion. Persons holding this alternative conception judged the velocity of two moving objects to have the same velocity whenever they are in the same position. A follow-up study (Zietsman & Hewson, 1986) used a simulation to diagnose and remediate the velocity alternative conception. The results showed that the simulation did produce a significant change in students holding the alternative conception and also that the simulation itself was a credible representation of "reality".

Summary

New ideas and information are learned and retention is greatest when relevant ideas and concepts are already present in the existing cognitive structure to serve as anchors for the new information. If the new information is in conflict with this knowledge base, the student may completely dismiss the new information as invalid, or may store the new information as isolated "pieces" of information apart from previously developed structures. The student may reconcile the new information through the process of accommodation, possibly developing alternative conceptions contrary to accepted scientific theory which can greatly impair future learning.

Due to individual differences in cognitive functioning, perception of the same event differs from person to person. Field-dependent persons rely on external referents and are global in orientation, as opposed to field-independent persons whose strategies allow them to disassemble complex stimuli and restructure the new information.

Remedial tasks that are designed to change alternative conceptions to scientifically accepted conceptions may present multiple salient stimuli in sometimes complex backgrounds. These designs may hinder a field dependent person from focusing on the strategic stimuli for altered concept formation.

Although both computer simulations and hands-on laboratory experiences have been shown to be effective in learning of science

concepts and the changing of alternative conceptions to more scientifically accepted concepts, cognitive research currently emphasizes hands-on experiences and direct application of new information.

Based upon the review of literature, the following hypotheses have been generated.

1. Students in the hands-on laboratory experimentation group will perform better than the students in the computer simulation group for the remediation of alternative conceptions as measured by the post-test for alternative conceptions.
2. Students in the hands-on laboratory experimentation group and in the computer simulation group will experience greater remediation of alternative conceptions than the control group as measured by the post-test for alternative conceptions.
3. There will be interactions between the control and treatment groups and the levels of field dependence-independence.
 - a. In the hands-on laboratory-experimentation group, field-independent students will experience greater remediation of alternative conceptions than the field-

dependent students as measured by the post-test for alternative conceptions.

b. In the computer-simulation group, field-independent students will experience much greater remediation of alternative conceptions than the field-dependent students as measured by the post-test for alternative conceptions.

4. There will be an inverse relationship between the scores on the Embedded Figures Test and the scores on the Computer Selection Test for alternative conceptions.

CHAPTER 3

Methodology

This study was designed to compare the effectiveness of hands-on laboratory exploration with computer-generated simulations as a means of remediating selected alternative conceptions held by high-school students. The study was also designed to determine the interactive effects (if any) among the computer simulations and laboratory remedial instruction and the cognitive learning styles of field-dependence-independence. In addition, the diagnostic utility of the Group Embedded figures Test (GEFT) was evaluated for use with high-school student populations likely to possess alternative conceptions in the physical sciences.

Research Design

A 3x3 factorial design was used with the main effects being the type of remediation (control, computer simulation, and laboratory apparatus) and cognitive style (field-dependent, field neutral, and field-independent). The pretest, The Computer Selection Test (Weller, 1990), was used to determine those participants who possessed alternative conceptions. These participants were then randomly assigned to the treatment groups and control group. The control group was given the post test without any remedial instruction.

Using the scores from the Group Embedded Figures Test and the scores from the Computer Selection Test, a Pearson Product Moment Correlation Coefficient was calculated to determine if a relationship existed between alternative conceptions and field-dependence-independence. The level of statistical significance was set at $p \leq .05$ for all procedures used in the study.

Participants

The participants in this study were selected from students enrolled in a suburban, private, college-preparatory school, mostly from the middle socioeconomic level. Approximately 90% of the students in the school go on to college after graduation. The students were 8th, 9th, and 10th graders, ages 13 to 16, that had been through the motion portion of the physical-science sequence. The students were from intact, heterogeneously grouped classes. Participation in the study was voluntary. Students were assured that confidentiality would be maintained and only group data would be used in the determination of the results. The students and parents were notified of the location and time requirements of the experiment.

The Group Embedded Figures Test (Witkin, Oltman, Raskin, & Karp, 1971) was given to all participants to establish predominance towards field-dependence or field-independence. Since no cut off scores were given in the manual for the test, a procedure used in other studies (e.g. Reardon, 1987; Rush, 1990) was used. The bottom

40% of the observed scores were designated as field-dependent and the upper 40% were designated as field-independent. The middle 20% of the scores was designated as field neutral and used as a “buffer” between the field-independent and field-dependent group.

Instrumentation

GEFT (Group Embedded Figures Test)

The Group Embedded Figures Test is an adaptation of the Embedded Figures Test for use with groups (Witkin, Oltman, Raskin, & Karp, 1971). With large numbers to be tested, it is more practical to use a group test to screen participants for field dependence. The GEFT tests for disembedding ability by requiring students to find and trace simple geometric designs that are embedded in a more complex figure.

In the GEFT, there are 25 items, 7 of which are used for practice. Of the 18 items on the GEFT which are scored, 17 of them were taken from the Embedded Figures Test. The 18 items on the GEFT are divided into two equal sections. In the actual test, 2 minutes are given for the practice items and 5 minutes are given for each of the 9 item sections. The scores on the test can range from 0 to 18. In order for an item to be correct, each item must be completely traced and oriented correctly with no added lines or incorrect lines. Items that were omitted are scored incorrect. Each test must be scored individually using the scoring key provided with

the simple form traced over the complex figure (Witkin, et al., 1971).

Norms for the GEFT are reported in the manual for college-age and adults. Although norms for high-school students have not been determined, James (1989) cited several studies which successfully used the GEFT with children. The authors of the manual for the GEFT suggest that even time modifications can be used to help determine individual differences (Witkin, et al., 1971). James (1989) retained the 5 minute limit for 10th graders, but increased the time limit per section to 10 minutes for 4th graders, and 7.5 minutes for 7th graders. The 5 minute per section time limit was maintained for this study.

Computer Selection Test

The Computer Selection Test is a diagnostic test for the IBM platform used to diagnose three alternative conceptions using graphics and questions (Weller, 1990). The alternative conceptions addressed are:

- 1) Quickness of fall depends on mass.

With no air resistance, the downward movement of a more massive object is faster than that of a less massive object.

2) Unbalanced force.

If an object is moving and no unbalanced force is acting on it, the object will come to rest.

3) Direction of vertical movement depends on type of material.

a) Light objects rise because they are made of material which naturally tends to move upward;

b) Heavy objects fall because they are made of material which naturally tends to move downward (pp. 1-2).

The content validity of the Computer Selection Test was established through structured interviews of 8th-grade physical-science students (Weller, 1990). The Computer Selection Test consists of a series of 8 multiple choice questions with an accompanying graphic to help students visualize the question situation.

The Selection Test was followed by two remedial simulations used to change the student's alternative conception of falling objects, rising objects, and the inertia of moving objects. Change was determined by administering the Computer Selection Test again as a post-test.

Rationale for Hands-on Laboratory Apparatus

Galileo often employed thought experiments in order to examine physical phenomenon. In one such thought experiment, he imagined two equal masses falling at the same rate. He then imagined a chain between, gradually being shortened, until it was in essence, an object of twice the initial mass, but still falling at the same rate as the two separate masses.

He used this process in actual experimentation. He noticed that greater masses did seem to fall faster than lesser masses. However, through a series of experimental observations, he noticed "that the inequality of speeds is always greater in the more resistant mediums, as compared with those more yielding" (Galilei, 1974, p. 72). "From these observations, Galileo extrapolates beyond all possible experience, arriving at an ideal limiting-case" (Garrison, 1986, p. 333). Therefore, the ideal limiting-case is "freefall with no resistance" (Garrison, 1986, p. 333). Using a water clock and the relationship of distance proportional to time squared, Galileo showed that this relationship held for all angles of an incline plane. He then extrapolated this to an incline plane of 90 degrees, thus concluding that this relationship is also the same for free-falling bodies (Marion, 1971). Using the same equipment, Settle (1961) was able to duplicate one of Galileo's experiments utilizing inclined planes.

The hands-on laboratory apparatus was designed to provide remedial training by presenting a situation to the student that is in

direct conflict with the alternative conception of the student. The intention was to cause the student to experience dissatisfaction with their present conception and, as a result, adopt the more scientifically acceptable concept.

With the falling-objects simulation, the student was able to experiment with different masses in a controlled air resistance situation, from normal atmospheric pressure to as close as possible to an ideal, no-air resistance, environment as the apparatus allows (a vacuum). As the objects fall, "the simultaneous impact with the ground presents cues which a person customarily employs when making judgments about falling objects" (Weller, 1990, p. 34).

By comparing the air resistance and no air resistance environments, the third stated alternative conception (the direction of vertical movement depends on type of material conception) was challenged. Light objects falling rapidly in the low air resistance environment would be incompatible with this belief.

The second alternative conception (the unbalanced force conception) was much harder to deal with in a physical environment. Friction is always present at varying degrees. Utilizing Galileo's process of successive approximations of the ideal, the apparatus consisted of a series of interchangeable surfaces, from high-to low-frictional coefficients. Using a standard force applied to a puck, the acceleration of the puck was calculated as the puck slid through a series of three photogates. As the frictional force decreased, the

negative acceleration approached zero. In an ideal situation (without friction) the acceleration would be zero.

Pilot study

A pilot study was conducted with the hands-on apparatus in order to ascertain:

- a) the workability of the freefall and the friction table apparatus with age appropriate students to be used in the subsequent study.
- b) the quality of the apparatus in terms of durability and ease of use in a reasonable time frame for the number of trials to be used in the study.

With the freefall apparatus, five age-appropriate students from the neighborhood (who did not go to the school in which the study was conducted), were asked to watch a demonstration of the apparatus. After the demonstration, each student was instructed to choose five pairings of items to be dropped in an air resistance and a non-air resistance environment. The students used the apparatus on their own, including operation of the vacuum pump. See Table 1 for average times for completion of trials and evacuations of the freefall apparatus.

Table 1

Freefall Apparatus Test Times

Student	Completion Time (Min.)	Avg Evacuation Time (sec)
1	12.2	54
2	12.8	52
3	16.1	54
4	14.3	55
5	13.6	59

Five additional students were asked to operate the force table apparatus. Three negative accelerations were measured for each of the five surfaces used in the experiments. Overall average accelerations and time to complete the force remedial instruction are in Table 2.

Several changes were made to the freefall apparatus as a result of the initial equipment testing. Plastic tabs were mounted on the trap doors of the freefall mechanism to allow for easier operation of the doors. Holes were cut in the center of the rubber seal mats to prevent the rubber from being sucked into the vacuum chamber. A step stool was procured to allow shorter students to be able to easily reach the top of the freefall apparatus. Originally, the trap doors were to be triggered using the computer. However, this was too distracting and drew the attention of the students away from the apparatus at the time of the demonstration. A mechanical switch was mounted beside the apparatus to trigger the trap doors to avoid this distraction.

Table 2

Unbalanced Force Table Average Accelerations for Each Surface Type

Surface Type	Avg Deceleration (m/s ²)	Completion Time (Min)
Sandpaper	-7.8546	2.8
Cardboard	-5.4599	2.8
Plywood	-4.6580	2.9
Formica	-2.9787	2.7
Air	-1.9322	2.6

Procedure

Participants in the study were given the Group Embedded Figures Test to determine whether they were field-dependent or field-independent. All participants were individually given the Computer Selection Test to determine which of the alternative conceptions the student possessed, if any. This test was self paced with no time restrictions given to the individual. Those that exhibited alternative conceptions were then randomly assigned to one of the two treatment groups or to the control group.

Students assigned to the simulations treatment group worked through the Objects Dropping simulation and the Cube Moving simulation. The Objects Dropping simulation was run 5 times and the Cube Moving simulation was run 5 times. Both simulations were then repeated in order to supply more information to the student (Weller, 1990). Students were permitted to use as much time as needed to complete the number of trials specified. They were then instructed to take the post test in order to assess any changes to their alternative conceptions due to the remedial instruction.

The students assigned to the hands-on laboratory instruction were given as much time as they needed to use the apparatus to experiment with the vacuum chamber and the force table the required number of times. They were given an assortment of objects which they could compare in an air resistance and a non-air resistance environment. These objects were laid out on the table in

no particular arrangement. Each student was instructed to choose five pairings of objects to test, one pair at a time. They first dropped the objects in an air resistance environment and then evacuated the chamber and tested the same pair in a low air resistance environment. After completion of the five trials, they were given the post test to determine the effects of the remedial instruction.

Materials

Materials included:

GEFT Test Booklet for each student

Pretest and Posttest score sheet for each student

Freefall Apparatus

Objects for Testing:

Heavy Objects

Golfball

500 g Weight

Rock

Rubber Stopper

Lead Weight

Light Objects

Feather

Dried Leaf

Tissue Paper

Styrofoam Block

Pith Ball

Analysis

A two-way Analysis of Covariance was used to analyze the post-test data with the variance related to the pretest removed. Adjusted means were provided reflecting the absence of the variance due to the pretest. Main effects and interactions were considered for cognitive style (field-dependence, field neutral, field-independence) and remediation (control, computer simulation, hands-on laboratory experience). A Pearson Product Moment correlation was used to determine any relationship between the GEFT and the existence of alternative conceptions as measured by the Computer Selection Test. This relationship was established prior to the experimental treatment phase.

For the secondary analysis, Scheffe's test for all possible comparisons was performed to determine which levels of the independent variables affected the difference in mean scores on the dependent measures. This was used following the rejection of the overall null hypothesis for the treatment independent variable. The Scheffe Test has "the important property that the probability of a Type I error for any comparison does not exceed the level of significance specified for the overall hypothesis" (Roscoe, 1975, p. 313). In actuality, the probability of a Type I error for any of the comparisons "may be considerably smaller than the level of significance set by the investigator" (Roscoe, 1975, p. 313).

The dependent measure was the difference score between the two administrations of the Computer Selection Test. The eight

questions on the Computer Selection Test pertain to the three alternative conceptions that were addressed by the remedial treatments.

Chapter 4

RESULTS

To determine the level of field dependence, 43 participants in grade 8, 38 in grade 9, and 37 in grade 10 were administered the Group Embedded Figures Test. The distribution of these scores within the three grade levels are listed in Appendix A. Witkin, Goodenough and Karp (1976) determined that the degree of field dependence is both developmental and stable. This means that as students get older they tend to become more field independent. However, they tend to keep their same ranking when compared to others of grade level. Therefore, determination of field dependency was done separately for each grade level. The results are in Table 3.

Table 3

Group Embedded Figures Test Results by Grade Level and Field Dependence Classification

Group	FD	Neutral	FI
Grade 8 n = 39	0 - 6 n = 15	7 - 9 n = 11	10 - 18 n = 13
Grade 9 n = 32	0 - 7 n = 15	8 - 10 n = 5	11 - 18 n = 12
Grade 10 n = 31	0 - 8 n = 8	9 - 11 n = 9	12 - 18 n = 14

A two-way Analysis of Covariance was used to perform a statistical analysis of the comparison of the three levels of treatment (control, computer simulation, and hands-on experimentation) and the independent variable of field dependence. The alpha level for all analyses was set at $p \leq .05$. The results of the ANOCOVA are presented in Table 4.

Table 4

Summary ANOCOVA Table for Treatment and Cognitive Style

SOURCE	DF	SS	MS	F	p
Within Cells	92	87.02	.95		
Treatment	2	63.10	31.55	33.36	.0001*
Cognitive Style	2	2.86	1.43	1.51	.226
Treatment x Style	4	.88	.22	.23	.919

* $p < .05$

Hypothesis #1

Students in the hands-on laboratory experimentation group will perform better than the students in the computer simulation group for the remediation of alternative conceptions as measured by the post-test for alternative conceptions.

As can be seen from the ANOCOVA table, there was a statistically significant difference found to exist for overall treatment, $F(1,92) = 33.36, p < .05$. Group means for treatment were: Hands-on experimentation, 1.860; Control, -.126; and Simulation, .851. See Table 5 for a listing of all the means. The Scheffe Multiple Comparisons Test indicated that there was a statistical difference between hands-on experimentation and simulations for the remediation of the alternative conceptions, $F = 9.37, p < .05$.

Hypothesis #2

Students in the hands-on laboratory experimentation group and in the computer simulation group will experience greater remediation of alternative conceptions than the control group as measured by the post-test for alternative conceptions.

Table 5

Summary Table of Means and Standard Deviations by Main Effects

Group	Treatment (Type of Remediation)		
	Hands-on	Control	Simulation
Field-dependent			
n	13	12	13
Mean	1.692	.000	.846
Adjusted Mean	1.638	-.271	.836
SD	1.109	1.128	1.068
Field-neutral			
n	9	7	9
Mean	1.889	-.143	.444
Adjusted Mean	1.825	-.175	.508
SD	1.364	1.215	.726
Field-independent			
n	14	13	12
Mean	2.286	-.154	.750
Adjusted Mean	2.090	.035	1.124
SD	1.267	.555	.866

The Scheffe Multiple Comparisons Test indicated that there was a statistical difference between the hands-on experimentation ($\bar{X} = 1.860$) and the control groups ($\bar{X} = -.126$), $F=35.08$, $p<.05$, and computer simulations ($\bar{X} = .851$) and the control groups, $F=8.28$, $p<.05$, for the remediation of the alternative conceptions.

Hypothesis #3

There will be interactions between the control and treatment groups and the levels of field dependence-independence.

- a. In the hands-on laboratory-experimentation group, field-independent students will experience greater remediation of alternative conceptions than the field-dependent students as measured by the post-test for alternative conceptions.

From the ANOCOVA table (see Table 4), it can be seen that there was no indication of any interaction between the field-independent and the field-dependent students in the hands-on experimentation group. In the hands-on experimentation group, the group means for cognitive style were: field dependent, 1.638; field neutral, 1.825; and field independent, 2.090.

- b. In the computer-simulation group, field-independent students will experience much greater remediation of alternative conceptions than the field-dependent

students as measured by the post-test for alternative conceptions.

As the case was for hands-on experimentation and cognitive style, so was it for simulation and cognitive style. Group means in the simulation group were: field dependent, .836; field neutral, .508; and field independent, 1.124 (See Table 5).

Hypothesis #4

4. There will be an inverse relationship between the scores on the Embedded Figures Test and the scores on the Computer Selection Test for alternative conceptions.

A Pearson Product Moment Correlation was calculated comparing the scores on the Group Embedded Figures Test and the scores on the Computer Selection test. A correlation coefficient of $-.25$, ($p < .05$), was obtained, accounting for approximately 6% of the variance between the two scores.

Chapter 5

DISCUSSION

Effects of Treatment

This study demonstrated that hands-on experimentation and simulations could be used effectively for the remediation of the alternative conceptions studied. These findings were consistent with other studies dealing with the hands-on approach and simulations (Tinker, 1981; Trowbridge & McDermott, 1980; Zietsman & Hewson, 1986). However, although both were effective, the hands-on method was superior to computer simulations in the study. This differs from the results obtained in the water displacement study of Choi & Gennaro (1987). That particular study, however, dealt with retention in the learning of a concept as opposed to the remediation of an alternative conception. Very little formal research has been done in changing alternative conceptions utilizing hands-on and computer simulation methodologies (Tinker, 1981; Weller, 1990).

Knowledge that is learned in “real life” contexts, which are as similar as possible to the context in which the phenomenon will be encountered, is much more easily understood and retained (The Cognition Technology Group, 1990). Most alternative conceptions are learned intuitively as people strive to make sense of their environment (Hewson, 1984). These alternative conceptions are

strong and very resistant to change (Champagne, Klopfer & Gunstone, 1982; Driver, 1981; Hewson, 1985). Producing a change in the knowledge base of a student involves developing a conflict between existing knowledge and new information (Posner et al., 1982), therefore, the new information must not only produce this conflict but also be situated in the activity or context that most closely resembles the situation in which it will be used (Brown, Collins, & Duguid, 1989). The simulation used to remediate quickness of fall allowed the student to vary the masses that would be compared in the freefall simulation, but the object that actually fell was always the same size and shape. With the hands-on freefall vacuum apparatus, students manipulated actual items such as feathers, tissue paper, golfballs, leaves, and lead. These items are often encountered in everyday situations and may be the actual things that led to the intuitively gained alternative conception in the first place. With the force apparatus, the students could actually feel the frictional surfaces that were employed in the experimentation.

Effects of Cognitive Style

A field-dependent person deals with fields they encounter in a passive way, whereas a field-independent person actively deals with fields, having the ability to analyze a field and break it apart into its constituent parts, thereby imposing a structure on the field (Witkin & Goodenough, 1981). Because of this ability, it was

expected that a field independent person would have fewer alternative conceptions and benefit from remedial instruction with both hands-on experimentation and computer simulation to a greater degree than a field dependent person. However, there was no evidence whatsoever of differential effects of the remediation for field dependence-independence.

The developmental aspect of field-dependency was evident in this study, with each successive grade scoring more toward the field independent side of the scale. This helps to confirm the view that students tend to move toward the field independent portion of the scale as they grow older while at the same time maintaining their ranking among their peers (James, 1989; Witkin & Goodenough, 1981).

With the addition of a neutral group, it was possible to prevent students classified as field dependent from overlapping with students classified as field independent. Scores in each grade were spread out over the entire FDI scale, therefore reinforcing the decision to stay with the five minute timing for each section of the Group Embedded Figures Test.

Effects of Interaction Between Cognitive Style and Type of Remedial Instruction

The present study failed to show any interaction between the type of remedial instruction for changing alternative conceptions and field dependence-independence. A field independent person is an active learner and characterized by the ability to restructure

information in both perception and cognition (Witkin & Goodenough, 1981), whereas, a field dependent person is dominated by the most salient features and tend to overlook other features of a stimulus (Goodenough, 1976). Alternative conceptions are intuitive knowledge gained by individuals deriving meaning from their environment and prior knowledge to make sense of a phenomenon (Kelly, 1969). It was thought that this deficiency in the ability of a field dependent person to explain predictions and to resolve discrepancies between predictions and observations (Gunstone & Whitehead, 1981) would result in an increased number of alternative conceptions and a stronger resistance to remedial instructions to change these conceptions. Although a significant negative correlation was found between FDI and the occurrence of alternative conceptions, it only accounted for 6% of the variance. Since other computer simulations and programs such as Weller's Computer Selection Test and DiSessa's Dynaturtle have been shown to detect alternative conceptions, given the expense and time of administering the GEFT, its usefulness as a tool for the diagnosis of alternative conceptions in students is not practical.

That field independents generally perform at a higher level on visual tasks than field dependents has been consistently established (James, 1989; Witkins, et al., 1981). The lack of interaction of cognitive style with the remedial treatments is interesting given the visual aspects of the remedial tasks.

Recommendations

The effectiveness of computer simulations as a tool for the remediation of alternative conceptions is consistent with previous research (Weller, 1990; Zietsman & Hewson, 1986). Also, hands-on experimentation as a means of remediation has been shown to be effective (Trowbridge & McDermott, 1980). Some studies comparing computer simulation with hands-on experimentation have had mixed results (Choi & Gennaro, 1987; Hofstein & Lunetta, 1982; Olsen, 1973). This study clearly shows an advantage to using hands-on experimental apparatus over simulations as a means of remediating alternative conceptions. Based on these results, further research should be done in order to see if an advantage is maintained by hands-on experimentation as the simulations approach "real life". The simulation in this study used numbers to indicate changing conditions and not an altered visual image.

Due to the lack of differences in the remedial effects upon FDI students, continued research using this cognitive style as an independent variable is not recommended. Also the practicality of using the Group Embedded Figures Test as a diagnostic tool for the students with alternative conceptions is highly questionable. Although a relationship exists, given the significance of the correlation between them, the fact of the low correlational coefficient and the expense of the administration of the GEFT, it is not recommended as a means of determining student susceptibility to alternative conceptions.

With the third alternative conception, direction of vertical movement depends on the material the object is composed of, 64% of the students possessing this alternative conception were remediated using the computer simulations compared to 43% of students receiving the hands-on remedial instruction. However, with alternative conceptions dealing with quickness of fall and unbalanced forces, 64% of the students changed to the scientifically acceptable concepts using the hands-on experimentation compared to only 27% of the students using the computer simulations. Further study into effects of hands-on experimentation and computer simulations on specific alternative conceptions is recommended.

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Appendix A

Distribution of Group Embedded Figures Test (GEFT) by Grade

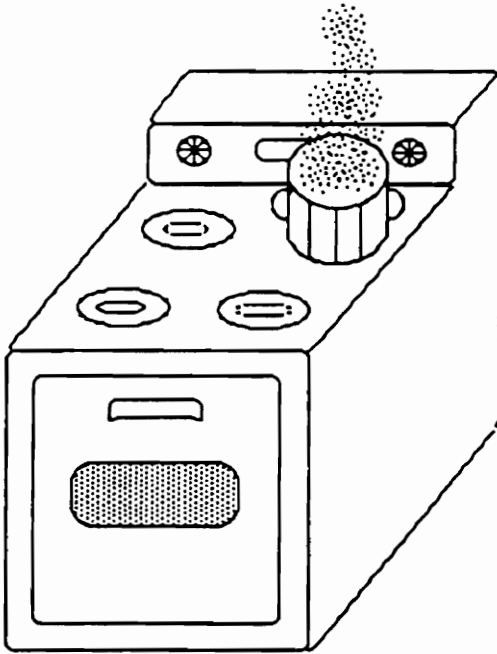
Group Embedded Figures Test Frequencies

Score	Eighth	Ninth	Tenth
0	2	0	0
1	2	1	1
2	1	1	1
3	3	3	3
4	3	3	0
5	1	1	0
6	3	2	2
7	2	4	0
8	2	2	1
9	7	1	0
10	1	2	3
11	2	0	6
12	2	1	3
13	3	3	2
14	1	2	2
15	0	3	3
16	0	1	0
17	2	1	3
18	0	1	1

Appendix B

The Computer Selection Test

Why do the steam droplets move upward instead of downward?



A. The droplets are composed of material which rises naturally.

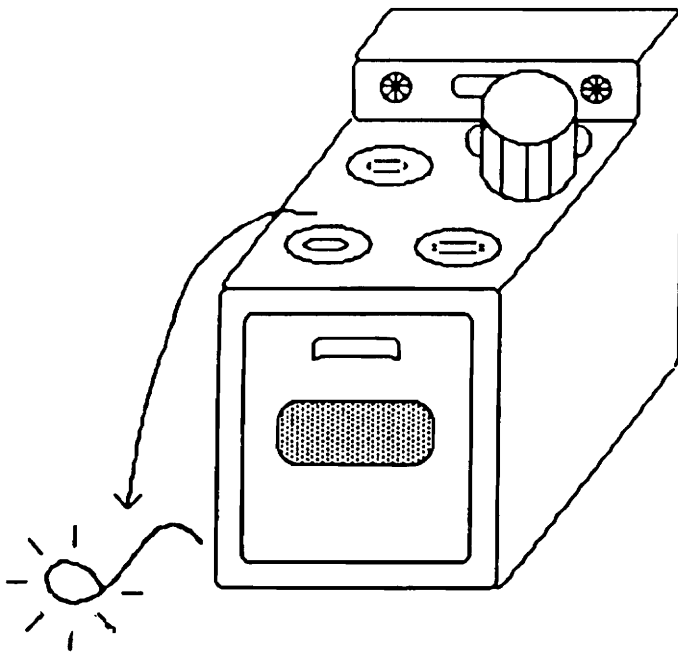
B. There is a stronger upward force on each droplet than the downward force.

(A,B) . . . -

(Press the letter of the best answer)

Figure 1. The Vapor Rising question on the final version of the computer Selection Test.

Why does the steel spoon fall
instead of rise?



A. Steel is a
material which
moves downward
naturally.

B. Gravity pulls
the spoon
downward.

(A,B) . . . _

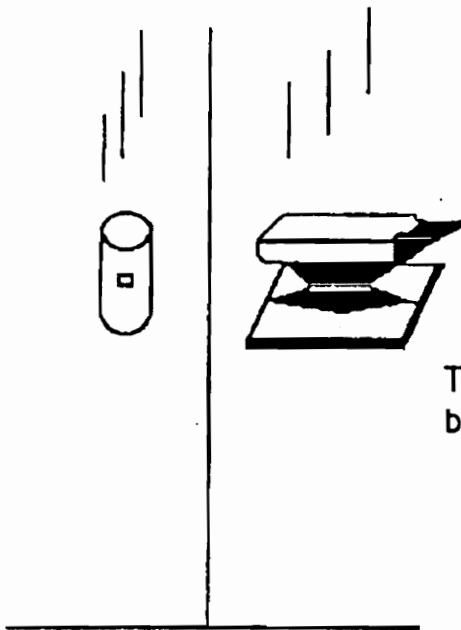
(Press the letter of the best answer)

Figure 2. The Spoon Falling question on the final version of the computer Selection Test.

An iron anvil and an aluminum can are held the same height above the floor, and dropped at the same time.

With no air resistance, which object will gain speed faster?

- A. Anvil
 - B. Aluminum can
 - C. They gain speed equally
- (A,B,C) . . . -



The anvil falls, rather than rises, because

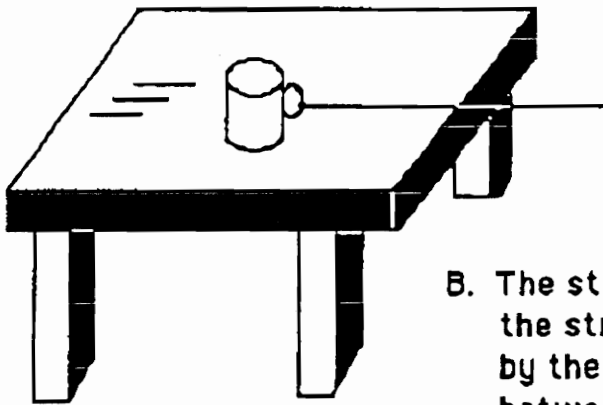
- A. Iron is a material which moves downward naturally.
 - B. Its weight pulls it downward.
- (A,B) . . . -

(Press the letter of the best answer)

Figure 3. The Anvil-Can Falling and Why Anvil Falls questions on the final version of the computer Selection Test.

A cup is being pulled across a tabletop with a string. If the cup keeps moving at the same speed, it is because

A. The steady pull with the string is not balanced by another force.



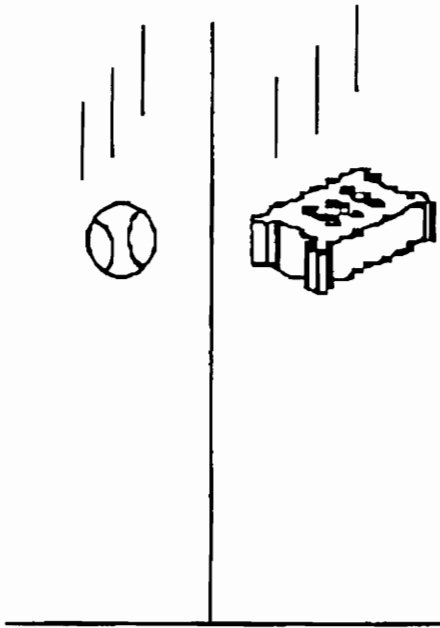
B. The steady pull with the string is balanced by the force of friction between the cup and the tabletop.

(A,B) . . . _

(Press the letter of the best answer)

Figure 4. The Cup Sliding question on the final version of the computer Selection Test.

A softball and a cinder block are held the same height above the ground, and dropped at the same time.



With no air resistance, which object will strike the ground first?

- A. Softball
- B. Cinderblock
- C. They hit at same time

(A,B,C) . . . -

With no air resistance, which object will be moving faster when it strikes the ground?

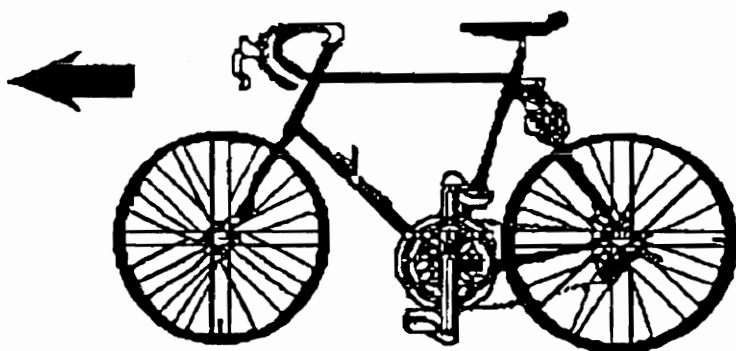
- A. Softball
- B. Cinderblock
- C. They hit at same speed

(A,B,C) . . . -

(Press the letter of the best answer)

Figure 5. The Softball-Cinderblock Falling question on the final version of the computer Selection Test.

The rider has stopped pedalling the bicycle.
The moving bicycle is slowing down.
Why is the bicycle stopping?



A. There is a friction force acting on the bicycle.

B. No force acts on the bicycle, and all objects will stop when no force acts on them.

(A,B) . . . —

(Press the letter of the best answer)

Figure 6. The Bicycle Slowing question on the final version of the computer Selection Test.

Appendix C

Hands-on Apparatus

Vacuum Freefall Apparatus:

The freefall apparatus was constructed utilizing 3/8 inch plexiglass sheeting bonded together with a solvent creating an air tight chamber with a vertical height of 36 inches (See Figure 7). Plexiglass was also used to make the plates to cover the chamber access ports on the top and bottom of the apparatus. Single-ply rubber sheeting was used to cover the access plates and create an air tight seal. The force of the external normal atmospheric pressure was sufficient to maintain the tight seal with near vacuum conditions existing inside the chamber.

In order to allow for the manipulation of objects, a pair of trap doors were made that would swing downward and drop the objects simultaneously. Two electromagnets were wired in parallel and connected to a 12 volt power supply to hold the trapdoors in a horizontal position until released. An external switch was used to control the state of the electromagnets. Tabs on the doors allowed for resetting the doors easily. Two valves were installed, one for connection to the vacuum pump and one for allowing air back into the chamber to equilibrate internal and external pressures after the demonstration.

By using the chamber, the students were able to compare various light and heavy objects in both an air resistance and a non-air resistant environment. Using a 1/3 Hp Vacuum pump, the chamber was successfully evacuated in less than one minute.

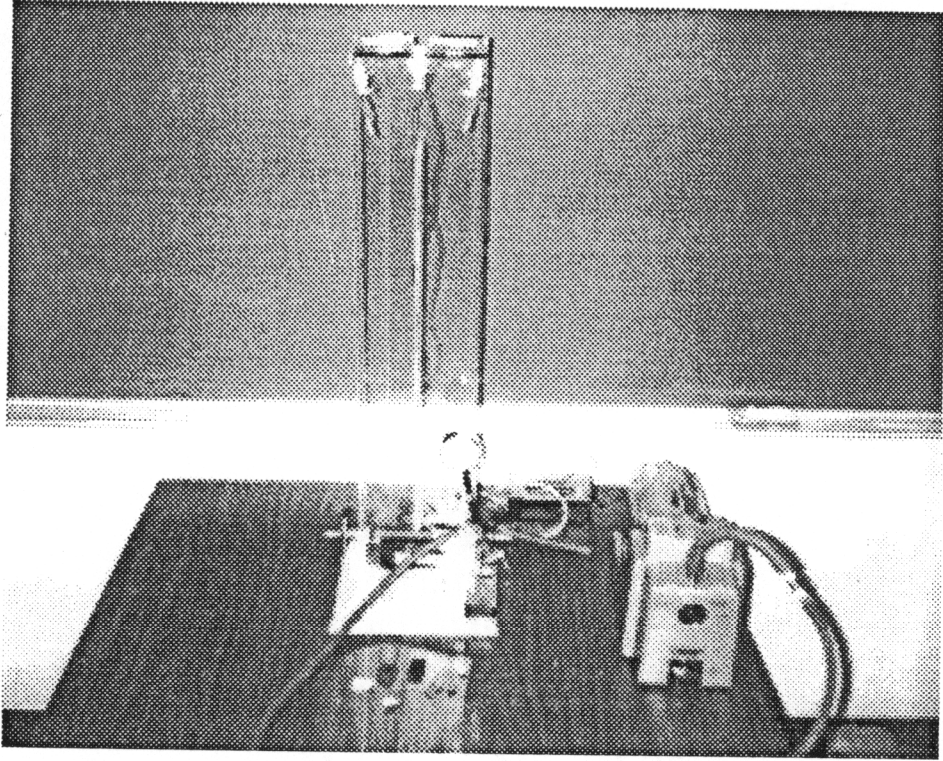


Figure 7. Freefall Apparatus

Force Table:

A 48 x 6 inch force table was constructed out of oak and particle board with a sheet of black formica forming the smooth top surface (See Figure 8). Holes $\frac{1}{64}$ th inch were drilled every $\frac{1}{2}$ inch to provide an air surface when the apparatus was turned on. Other removable surfaces of plywood, sandpaper, cardboard, and plexiglass were constructed for comparison to the air surface.

Acceleration was measured utilizing 3 Vernier photogates placed 18 inches apart along the air track. The photogates were connected to an Apple IIe computer which measured the time it took for the puck to travel the distance between each photogate. With the time and the distance measures an acceleration was calculated. The acceleration was displayed on the screen so the student could observe the change in the negative acceleration using the various surfaces.

A constant force was applied to the puck, a standard sized petri dish, using a pin ball plunger obtained from a vending machine company. A hair dryer was used to provide the cushion of air to provide the least frictional surface for observation of the negative acceleration.

By observing the reduction in negative acceleration with a reduced coefficient of friction, students were able to see the role friction plays in an object slowing down in the absence of an force applied to the object.

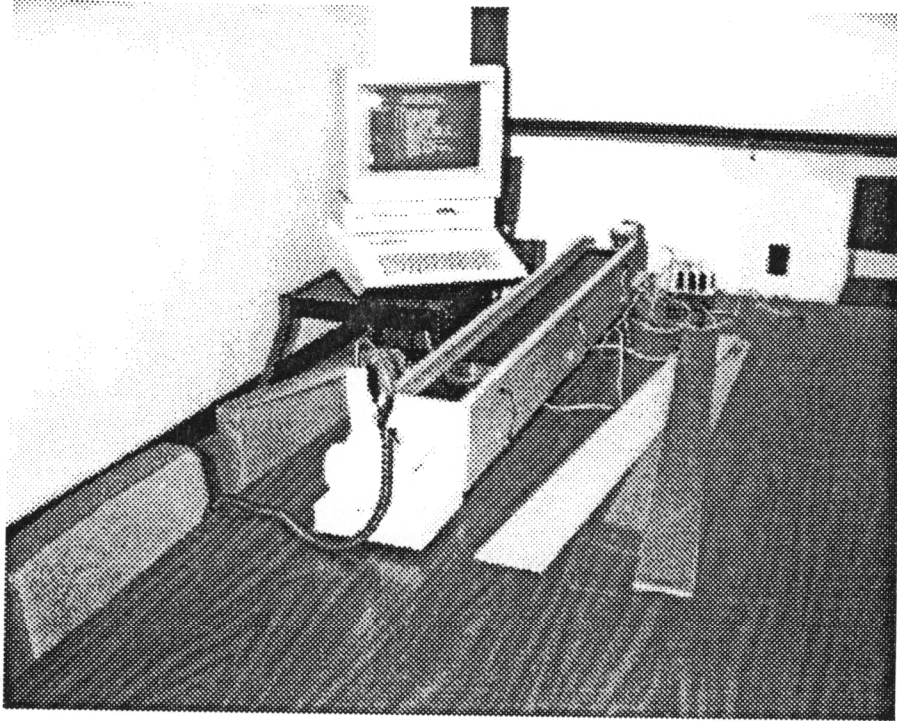


Figure 8. Force Table Apparatus

VITA

Dennis E. Buckwalter was born on February 15, 1953 in Lancaster, Pennsylvania. He attended Rochester Institute of Technology and Geneva College, receiving a Bachelor of Science Degree in Psychology with a minor in mathematics. He then worked as the coordinator of production and rehabilitation at a sheltered workshop for handicapped adults while attending graduate school at West Chester University in Pennsylvania.

In 1980, Dennis moved to Roanoke, Virginia to teach in a private high school. For nine years he taught science, math, and computer, coordinated the standardized testing program, developed the elementary computer program and coached junior varsity soccer. In the summer of 1986, he began graduate work at Virginia Tech in the Excellence in Teaching Physics and Physical Science program and completed his masters work in the summer of 1988. After teaching one more year Dennis began advanced graduate studies leading toward a Doctor of Philosophy degree in Curriculum and Instruction. He supervised student teachers in science, worked as a graduate assistant in the education technology lab, and taught courses in Instructional Technology and Educational Psychology. His main interest is in the application of technology to classroom teaching.

Dennis is married to Diane Cardwell Buckwalter and they have two daughters, Melinda and Susan, and a son, Daniel. In the fall of 1992 he will join the faculty at the University of Charleston in

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