1992

Multimedia and its effects on different cognitive styles in the mathematics classroom

Richard G. Strike
University of Northern Iowa

Multimedia and its effects on different cognitive styles in the mathematics classroom

Abstract

Technology has provided the education world with 3 many tools to present information. Multimedia is the latest tool. Multimedia in itself is not a new concept. In the past, teachers and students have used multiple forms of media to create projects such as filmstrips, tape recordings and videos. "Today, the computer has become the conductor of the multimedia orchestra" (Epstein, 1990, p. 40).

MULTIMEDIA AND ITS EFFECTS ON DIFFERENT COGNITIVE STYLES IN THE MATHEMATICS CLASSROOM

A Graduate Project

Submitted to the

Department of Curriculum and Instruction

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts in Education

UNIVERSITY OF NORTHERN IOWA

by

Richard G. Strike

July 1992

This Research Paper by: Richard G. Strike

Entitled: MULTIMEDIA AND ITS EFFECTS ON DIFFERENT COGNITIVE STYLES IN THE MATHEMATICS CLASSROOM

has been approved as meeting the research paper requirement for the Degree of Master of Arts in Education.

August 1, 1992
Date Approved

Sharon E. Smaldino
Director of Research Paper

August 1, 1992
Date Approved

Sharon E. Smaldino
Graduate Faculty Advisor

August 3, 1992
Date Approved

Charles V. L. Dedrick
Graduate Faculty Reader

August 3, 1992
Date Approved

Peggy Ishler
Head, Department of Curriculum and Instruction

TABLE OF CONTENTS

CHAPTER I

Introduction

> On the threshold of the 21st Century, educators in all settings are challenged to develop new tools and strategies for information management. In the next few years, more data will be generated and disseminated than is currently contained in all of world history (Raker, 1989, p. 18).

Technology has provided the education world with many tools to present information. Multimedia is the latest tool. Multimedia in itself is not a new concept. In the past, teachers and students have used multiple forms of media to create projects such as filmstrips, tape recordings and videos. "Today, the computer has become the conductor of the multimedia orchestra" (Epstein, 1990, p. 40).

This new type of multimedia, which includes the integration of the computer, has obvious potential because of its ability to bring together a good expository medium with a good interactive medium (Laurillard, 1984). As described by Epstein (1990), through interactive multimedia, students and teachers can use computers to link and present information by associations rather than by the linear format of textbooks or plain videotapes. With this medium, students are not just idly sitting in front of a computer, they are actively engaged. An example of this would be having the student using a multimedia package involving the computer with a CD Rom display. The student can read a story while having the CD Rom present the same story utilizing animation. The student would control the pace and be able to associate the written story with the animation presented.

An increasing amount of research is being conducted examining the learner and his/her cognitive learning style in the classroom within a preferred independent or dependent field area. Interactive multimedia has been singled out as a possible connecting link for these different styles. Laurillard (1984) noted that learning behaviors and styles differ significantly among students and if learning is to take place, these differences need to be addressed. If the teaching profession is to survive, teachers need to learn more than stand up delivery skills (Green, 1989).

It is commonly assumed that individual differences in abilities and aptitude are better accommodated if the learner has more control over the pace, the amount of practice, and the style of instruction that he/she receives (Gay, 1986). As presented by Hannafin and Colomaio (1987), interactive video allows for a continuum of learner control which leads to greater individuality, personal responsibility for learning, and the potential to optimize learning efficiency.

One area where differences in cognitive learning styles and the use of different instructional methods can be used to optimize learning is in the mathematics field. A correlation has been shown between cognitive learning styles and mathematics achievement (Hadfield and Maddux, 1988). There are many classroom settings where, because the material to be learned is not organized or is presented in a singular style, students with certain cognitive learning styles may be at a disadvantage (Witkin, Moore, Goodenough & Cox, 1977).

As noted by Saracho (1989), teachers need to understand possible differences that exist among cognitive learning styles and become proficient at teaching techniques which are individually focused toward the varying styles. This, in turn, would allow the teacher to establish a multicognitive classroom environment. The use of interactive multimedia can be used in the mathematics classroom to help expand on the teaching techniques of individual instructors. This incorporation of multimedia into a classroom would help to broaden the range of teaching styles presented to students and their corresponding cognitive learning styles.

To date, there has been a great deal of work in the area of creating multimedia packages for the classroom. There appears, however, to be a lack of empirical research concerning the integration of this technology with the specific cognitive styles of the learner.

Statement of the Problem

The purpose of this paper is to provide an integrative review of the literature relative to the role of multimedia and its effects on field independent/dependent style learners in the mathematics classroom. Specifically, the study will investigate the following questions:

1. To what extent does the implementation of a computer-based instructional format actually affect learning in respect to achievement scores, time on task and retention?
2. To what extent does the incorporation of multimedia into the classroom benefit field

independent or dependent style learners?

3. Does the incorporation of multimedia into the mathematics classroom actually contribute to improvement in achievement scores?

Significance of the Study

There is a significant amount of research being conducted in multimedia and its uses in education. Technology is allowing teachers to present material in a greater variety of ways. There appears, however, to be a lack of research in the integration of this multimedia technology with the specific cognitive styles of the learner. More specifically, how can both the field independent and field dependent style students learn in the same mathematics classroom that involves only one instructional style? This study will identify the findings of several authors with respect to the use of multimedia and the different cognitive learning styles in the mathematics classroom with a focus on field independent/dependent style learners.

Definition of Terms

For the purpose of this paper, the following terms are defined.

Multimedia: the integration of a computer with media components such as sound, music, animation, video, film, and telecommunications (Raker, 1989). Synonymous terms are: interactive video, interactive multimedia, and hypermedia.

Field Independent: An analytic perceiver of stimulus information, able to perceive relevant items as discrete from their background, is able to restructure information in memory into well organized, stable, and clear clusters to facilitate later recall of available memory information and when experiencing a chaotic visual stimuli is able to impose a structure on the visual perceptual information (Conelos & Taylor, 1981).

Field Dependent: A global thinker, confuses figure ground relationships, has difficulty abstracting relevant from irrelevant data in a visual percept, tends to store conceptual data in general or overlapping categories rather than in discrete conceptual categories and tends to have difficulty during encoding structuring information in a well organized way in memory (Canelos & Taylor, 1981).

CHAPTER II

Review of Literature

Multimedia in the classroom

> Throughout this century we have seen a parade of technological innovations, each of which has been touted to be the salvation of education. With the advent of the computer and optical disc, a new technological tool is available, which could have a profound impact on the way we approach learning. That tool is the interactive videodisc (IVD), which evolved during the mid-1970s and into the 1980s (Beardslee & Davis, 1989, p. 7).

This new technology, as stated by Beardslee & Davis, can provide the means to facilitate both traditional and non-traditional methods of educating and training. As reported by Beardslee & Davis (1989), the most widely used method of instruction stills remains the lecture. Today, however, this traditional method is supported by a variety of resources, such as books, workbooks, manuals, slides, filmstrips, films, videotapes, television, and computers. All of these have inherent weaknesses: the reliance on the instructor's experience and expertise for lecturing, print materials requiring high literacy skills, and the limited interaction with various visual media putting the learner in a passive role. There even exists a problem in the traditional computer-based instruction in that it is one-dimensional and must depend on a certain degree of computer literacy.

As reported by Beardslee & Davis (1989), interactive video can overcome the inherent weaknesses of these traditional instructional modes by combining all of the media into one comprehensive package. "It provides the vehicle for effectively presenting most instructional components, while at the same time simulating traditional learning environments" (Beardslee & Davis, 1989, p. 9).

In most academic subjects, teachers can expect students to come to a lesson with different levels of knowledge and skills. One of the most important aspects of interactive video is that it has the ability to deal with these differences by means of a prerequisite test followed by appropriately channeling students into a track designed for their level (Beardslee & Davis, 1989). This in turn would allow students the ability to control the pace, be presented with a variety of stimuli, and be provided with a mulitiple of levels of information.

According to Levenson, Morrow & Signer (1986), interactive video offers numerous features which promise to enhance an individual's knowledge, attitudes and practices. These include the capabilities to:

1. create an instructional program with a variety of options that meet the diversified needs and learning patterns of individual participants and provide immediate feedback in a manner tailored to particular individuals
2. react to a wide variety of possible learner responses, evaluating complex performances, and coaching the learner through judgmental and even psychomotor progressions
3. provide actual performance opportunities through realistic, life-like simulations, observations, and development of decision making progressions
4. manage lessons and track learner progress through computer documentation of

responses (Levenson, Morrow & Signer, 1986, p. 194).

Koran, Snow & McDonald (1971) designed an experiment to investigate individual differences in acquiring a teaching skill from written and video-mediated modeling. The experiment utilized 121 intern teachers from the Stanford Teacher Education Program. The subjects were selected by subject matter speciality and then randomly assigned to one of three treatment groups: video modeling, written modeling, and no modeling. All subjects received the same initial instructions and pretest followed by two cycles of their specific model treatment. Three written measurements were utilized to complete the treatments.

In their findings, video modeling led to significantly higher frequency, variety, and quality of analytical questioning than did written modeling and no modeling. They also found that, while audiovisual presentations placed demands on perceptual coding abilities, such presentations could also conceivably compensate for deficiencies in a learner's perceptual processing of analytical skills.

With the increase of student control over the pace of the presented information offered by multimedia, a question arose as to whether this increase in control would correspond to an increase in learner abilities. In a study performed by Gay (1978), 156 volunteer subjects from an introductory biology class were given a twenty-three item pretest on a given biological concept. Eighty subjects were randomly selected, forty from the low-conceptual-understanding group and forty from the high-conceptual-understanding group. Scholastic Aptitude Test scores revealed that there were no significant differences in aptitude between groups.

The two groups were then randomly assigned to either a learner-controlled treatment or a program-controlled treatment. Under the learner-controlled treatment the subjects were allowed to control the pace, sequencing, and depth of study. Under the program-controlled treatment, the material was sequenced logically and no choice of order was given to the subjects.

The post-test results demonstrated that the ways in which learners accessed information and made decisions about which information to retrieve affected their ability to assimilate, retain, and use it later on. This setting allowed for the learner to control the pace, the amount of practice, and the style of instruction he/she wished to receive. Gay summarized that, with this control, individual differences in abilities and aptitudes are better accommodated for, thus providing a more positive learning environment.

A study was performed by Hannafin & Colamalo (1987) to investigate the effects of learner control. In the study, three control versions of a lesson were developed: linear control, designer control, and learner control, with the intent of determining which produced the greatest increase between a pre and post test on the lesson. The authors' findings supported their hypothesis that, with an increase in learner control, there was a greater individual, personal responsibility for learning and greater potential to optimize learning efficiency.

The question arises then, does a form of computer-based instruction enhance students' achievement? A study performed by Kulik, Bangert & Williams (1983), addressed the questions: How effective is computer based teaching? Is it especially effective for certain types of outcomes or certain types of students? And under which conditions does it appear to be most effective? In the study, they utilized a quantitative technique to integrate the findings from 51 independent evaluations of computer-based teaching in grades 6 through 12.

The study revealed that computer-based teaching raised final examination scores by approximately .32 standard deviations showing a dramatic increase in achievement. The computer also substantially reduced the amount of time that students needed for learning. It was also noted that students who were taught on the computer developed very positive attitudes towards the computer and also gave favorable ratings to the computer-based courses they were taking. Computer-based style teaching also raised scores on follow-up examinations given several months after the completion of instruction, but these retention effects were not as significant as the immediate effects of computer-based teaching.

With the concept of video presentations enhancing learning, the question arises - why incur the expense of interactive video as opposed to merely utilizing a television lesson? Cennamo, Savenye & Smith (1991) conducted a study that investigated learner preconceptions of the difficulty of interactive video, instructional television, and television. The study also examined the effects of actively or covertly responding to practice questions on perceived mental effort, recall, and inferences. In the mental effort category, learners felt it was significantly easier to learn from interactive video than from the other mediums, with television being the most difficult. On the post-test results, labeled the recall scores, it was found the mean score for interactive video was 20.47, the mean score for instructional television was 18.08, and the mean score for television was 15.52. This indicated a greater recall of information from the interactive video than from the other two mediums.

In a collection of data on actual lesson times, the interactive video and instructional television groups took significantly longer to complete the lesson than the television group. There was, however, no significant correlation between reported lesson times and learners' recall scores, negating the concept of the longer the lesson takes, the greater the achievement. In respect to inferences, the results indicated that it was significantly easier to learn from interactive video than from the other two mediums.

Learning Styles

An important consideration in the designing of instructional methods is the analysis of the actual learner. An individual learner's cognitive learning style appears to affect how pupils learn, how teachers instruct, and how students and teachers interact in a classroom context (Saracho, 1989). A dimension of cognitive style that has been investigated widely is field independence/dependence. Saracho (1989) cited that most educational programs are designed with little or no attention to cognitive style, yet this area plays a major role in the students' educational program. "Although field independent and field dependent individuals may have the same intellectual capacity, they differ in regard to their ability to use different kinds of information" (Saracho, 1989, p. 149).

Some important concepts involved in these forms of cognitive styles are: field independent individuals rely more on internal frames of reference while field dependent individuals rely more on external frames of reference; field independent individuals respond faster and more correctly in high information load conditions; field dependent individuals require more time to process information when utilizing a visual display; field independent and field dependent individuals' achievements are relatively the same when a small amount of information was presented; and field dependents make the greatest gains when given an advanced organizer (Kent-Davis & Cochran, 1989).

In many classroom situations, students do not have the opportunity to learn to function in the style required by the instruction. They may encounter conflict and frustration as they attempt to deal with the demands of the cognitive styles which are utilized in the classroom. Most classrooms are orientated toward field independent learning conditions producing the possibility of frustration and difficulty for the field dependent learner (Saracho, 1989). There exist biases in the classroom which could limit certain cognitive learning styles from maximizing their learning potential. These biases include the presentation of material in only one manner (i.e. chalkboard, lecture), and the control of the pace of instruction (i.e. teacher controlled versus student controlled).

> Teachers need to understand all the possible biases and to become proficient in teaching techniques which are effective for both cognitive styles. Classroom activities should be responsible to both cognitive styles. A "bicognitive environment" should be part of the classroom ... (Saracho, 1989, p. 156).

In research conducted by Canelos & Taylor (1981), it was found that field dependent learners were at a significant learning disadvantage when learning from complex visuals. When presented with two types of tests, a list learning test and a spatial learning test, the field independent learner scored significantly better than the field dependent learner. When the field dependent learners were supplied with a networking strategy, however, their test scores significantly improved. This led to the conclusion that by providing field dependent learners with a learning strategy which facilitates their basic processing of information, their learning performances can be improved.

Learning styles in mathematics

There is currently a widespread concern about mathematics achievement test scores among public school students in America (Hadfield & Maddux, 1988). A wide variety of possible explanations for scores has been offered; however, researchers have begun to focus their attention on the possible effects of varying cognitive learning styles as a factor contributing to declining mathematics achievement scores.

In a study performed by Hadfield & Maddux (1988), a correlation between mathematics anxiety and cognitive style as defined by field independence/dependence was observed. The study consisted of a sample of 481 students enrolled in mathematics classes in a large high school in a suburban community. Two instruments were used to generate data: the Mathematics Anxiety Rating Scale for Adolescents to test mathematics anxiety and the Witkin Group Embedded Figures Test to measure cognitive style.

The results of the tests indicated that there was a greater mathematics anxiety on the part of students with field dependent, rather than field independent, cognitive styles. "Reasonable adjustments in instructional methods might be effective in reducing the mathematics anxiety of those students who are markedly field dependent" (Hadfield & Maddux, 1988, p. 82).

In a survey conducted by Vaidya & Chansky (1980) on the correlation between mathematics achievement and cognitive styles, field independent learners consistently scored higher on tests than field dependent learners at all grade levels. They summarized this significant relationship between a field-independent cognitive style and mathematics achievement by emphasizing the importance of gearing instruction to the cognitive style of the individual learner.

Multimedia in the mathematics classroom

The incorporation of multimedia into the classroom has been demonstrated to be an effective tool. Research indicates that it is a specifically useful as a tool in the mathematics classroom. In a study conducted by Henderson, Landesman, and Kachuck (1985), forty-five students from a general math and intermediate algebra class were randomly assigned to two groups. One group received a remedial lesson with a computer-video based instructional format while the other group received the same lesson through a standard lecture format. The results showed that the group that received the computer-video based instruction attained a higher achievement score than the control group by approximately one standard deviation.

It was important to note that the students initially selected for the study were all students who had not attained much initial success in mathematics. "The results of the field trials show quite clearly that the computer-video instructional modules were effective in teaching or reteaching mathematical skills and concepts to secondary school students who had not made normal progress in mathematical learning" (Henderson, Landesman, & Kachuck, 1985, p. 219-220).

Kelly, Cainine, Gersten, & Grossen (1986), provided another study into the effects of interactive video versus regular text instruction for lower level high school mathematics students. Three tests were administered - a pretest, a posttest, and a maintenance test. The pretest was used to determine a sample group that was composed of students who were comparable in pre-mastery skill levels. The sample group was then randomly assigned to either the interactive video lesson group or the regular text lesson group. After the lessons were presented, the posttest and maintenance test were administered.

A review of the test scores revealed that the two different instructional methods produced two different mastery levels. The students who received the interactive video instruction scored significantly higher, both on the post test and on the maintenance test. It was also shown that the interactive video group scores dropped less over time than the traditional text group.

Henderson and Landesman (1989), reported on a project they designed utilizing interactive video in the pre-calculus setting. The project was designed so that the learner could individualize his or her learning activities appropriately. In turn, this accommodated the learning needs of the individual student who possessed a relatively wide range of knowledge and skill in mathematics. Upon completion of the preliminary field trial results, the authors concluded: "The interactive videodisc medium, while certainly not a cure-all, may provide some students who otherwise would not be able to learn mathematics with the individualized instruction and motivation required to succeed in their study of pre-calculus" (Henderson & Landesman, 1989, p. 99).

In a more recent study, a program was introduced in a community college for the use of interactive video in teaching remedial mathematics to incoming students (Hardiman & Williams, 1990). The program was developed using Bloom's concept of mastery learning. Hardiman and Williams felt that if given enough time, the students would achieve a mastery level in the mathematic skills desired. The program needed to address a wide range of background skills due to the variance in incoming students. It was found that the medium forced the students into an active participation role which, in turn, allowed for a motivational value through the control of the learning environment. In a report of final grades it was found that in the interactive video group, 71% of the group achieved a passing mark as compared to 52% for a group that received normal text instruction.

It is apparent from available research that students have different learning styles. Data also indicates that those gaps are further exhibited in the area of mathematics. If, as studies have shown, multimedia presentations enhance and help facilitate learning, research should begin on integrating mathematics and the multimedia presentation.

CHAPTER III

Conclusions

The purpose of this paper was to provide an integrative review of the literature relative to the role of multimedia and its effects on field independent/dependent style learners in the mathematics classroom. This purpose was further broken down into three specific areas: the implementation of a computer-based instructional format and its effect on learning in respect to achievement scores, time on task and retention, the incorporation of multimedia into the classroom and its benefit for field independent/dependent style learners, and the incorporation of multimedia into the mathematics classroom with respect to improvement in achievement scores. Several important conclusions can be drawn from this review of literature in regard to the given questions.

Does the implementation of a computer-based instructional format actually enhance learning? The findings of Koran, Snow, & McDonald (1971) revealed that video modeling produced significantly higher performances than traditional written modeling when presented to an intern teacher's group. Gay (1986) also reported that students presented with a video enhanced lesson attained higher test scores than students presented with a traditional text lesson. The primary reason given for this difference was, "...individual differences in abilities and aptitudes are accommodated if learners have more control over pace, amount of practice, or style of instruction they receive" (Gay, 1986, p. 225). This belief was again mentioned by Hannafin & Colamaio (1987) in their research findings showing an increase in learning efficiency for students who were given greater learner control by the use of interactive video. A recent study concluded that through the use of interactive video, students were able to achieve higher test scores and also perceived it easier to learn as compared to other traditional teaching methods (Cennamo, Savenye & Smith, 1991).

It is quite apparent, given the literature, that the use of multimedia as an instructional tool provided many opportunities not afforded the learner in traditional instructional settings. With the increasing demands being placed on education and the increasing diversity of the student population, interactive video can provide a consistency of instruction, subject mastery, and self-paced learning to increase student achievement.

Is the incorporation of multimedia into the classroom a benefit for field independent/dependent style learners? The studies mentioned earlier indicate yes. One specific type of learning style that could receive the greatest benefit from this medium is the field dependent style learner. It has been shown that field dependent style learners are at a distinct disadvantage when simply presented information without structure. When provided with an external structure frame, however, their scores significantly improved (Canelos & Taylor, 1981). With most classrooms orientated toward the field independent style learner (Saracho, 1989), instructors need to provide another source of instruction (medium) to help facilitate the field dependent style learner. The needs of the field dependent learner are one of external references and slower paced instruction when dealing with visuals and high load information conditions (Kent-Davis & Cochran, 1989). Multimedia can provide a solution to these needs by continuing to incorporate the visuals and the information needed for the lesson while offering the learner the luxury of self-paced learning.

In specifically addressing the needs of the mathematic student, again, the field independent/dependent learner's limitations need to be focused on. Researchers agree that the field independent style learner achieves a greater success rate in mathematics than does the field dependent style learner (Vaidya & Chansky, 1980, Reberge & Flexer, 1983, and Hadfield & Maddux, 1988). As mentioned earlier, most classrooms are geared toward the field independent style learner. In this situation, the field dependent style learner begins at a disadvantage in the mathematics classroom. Another limiting factor associated with the field dependent style learner is the high rate of math anxiety experienced (Hadfield & Maddux, 1988). These factors in combination with the overall learning style of the field dependent student demonstrate a need for an alternative form of information presentation.

> The video-modeling treatment...through explicit, concrete presentation of the stimulus elements...may provide a behavioral representation for the learner that he could not generate for himself if given the

> written-modeling treatment. (Koran, Snow, & McDonald, 1971, p.226)

This video-modeling treatment can be in the form of a multimedia design.

Is the incorporation of multimedia into the mathematics classroom actually showing improvement in achievement scores? In a simplistic form of multimedia utilizing computer-based instruction, Kulik, Bangert & Williams (1983) found that this type of instruction improved mathematics scores by approximately .4 standard deviation units at the elementary level and approximately .3 standard deviation units at the high school level. More recent research into this field has shown that, in all cases the multimedia incorporation improved achievement test scores (Henderson, Landesman & Kachuck, 1985, Kelly, Cainine, Gersten, & Grossen, 1986, Henderson & Landesman, 1989, Hardiman & Williams, 1990, and Lowry & Thorkildson, 1991). It becomes very evident that the use of this new technology is providing an impact on mathematics achievement scores.

Technology, no matter how powerful, cannot be considered a cure-all for education. In retrospect, teachers must learn how to utilize this medium to enhance their own personal instruction. The individual cognitive styles existing in the mathematics classroom need to be addressed by the teacher in their presentation of material. With the limitations evident in the field dependent style learner, multimedia can be used as a tool to compensate for these limitations.

A great deal of research has been done in the field of a student's cognitive learning style and an increasing amount of research is being conducted in the field of multimedia. There appears to be, however, a lack of research in the combination of these two fields and their incorporation into the mathematics classroom. More research needs to be conducted correlating these three fields if the true benefits of multimedia in the mathematics classroom are to be attained.

References

Beardslee, E. C. & Davis, G. L. (1989). Interactive videodisc and the teaching - process. Bloomington, Ind.: Phi Delta Kappa Educational Foundation.

Canelos, J. & Taylor, W. (1981). A networking information processing strategy and the learning of field dependents receiving visual instructional information. Journal of Experimental Education, 50(1), 42-46.

Cennamo, K., Savenye, W. & Smith, P. (1991). Mental effort and video-based learning: The relationship of preconceptions and the effects of interactive and convert practice. Educational Technology Research and Development, 39(1), 5-16.

Epstein, A. (1990). Multimedia tools for education. Media & Methods. 27, 40+.

Gay, G. (1986). Interaction of learner-control and prior understanding in computer-assisted video. Journal of Educational Psychology, 78(3), 225-227.

Green, E. (1989). Making the process of instructing more visible. T.H.E. Journal, 17, 81-85.

Hadfield, O. & Maddux, C. (1988). Cognitive style and mathematics anxiety among high school students. Psychology in the Schools, 25, 75-83.

Hannafin, M. & Colamaio, M. (1987). The effects of variations in lesson control and practice on learning from interactive video. Educational Communication and Technology Journal, 35(4), 203-212.

Hardiman, B. & Williams, R. (1990). Teaching developmental mathematics: The interactive videodisc approach. T.H.E. Journal, 17, 63-65.

Henderson, R. & Landesman, E. (1989). Interactive videodisc instruction in pre-calculus. Journal of Educational Technology Systems, 17(2), 91-101.

Henderson, R. , Landesman, E. & Kachuck, I. (1985). Computer - video instruction in mathematics: Field test of an interactive approach. Journal for Research in Mathematics Education, 16(3), 207-224.

Kelly, B., Cainine, D., Gersten, R. & Grossen, B. (1986). The effectiveness of videodisc instruction in teaching fractions to learning-disabled and remedial high school students. Journal of Special Education Technology, 8(2), 5-17.

Kent-Davis, J. & Cochran, K. (1989). An information processing view of field dependence - independence. Early Child Development and Care, 51, 31-47.

Koran, M., Snow, R. & McDonald, F. (1971). Teacher aptitude and observational learning of a teaching skill. _Jounal of Educational Psychology_, _62_(3), 219-228.

Kulik, J., Bangert, R. & Williams, G. (1983). Effects of computer-based teaching on secondary school students. _Journal of Educational Psychology_, _75_(1), 19-26.

Laurillard, D.M. (1984). Interactive video and the control of learning. _Educational Technology_, _24_(6), 7 15.

Levenson, P., Morrow, J. & Signer, B. (1986). A comparison of noninteractive and interactive video instruction about smokeless tobacco. _Journal of Educational Technology_, _14_(3), 193-202.

Lowry, W. & Thorkildson, R. (1991). Implementation levels of a videodisc-based mathematics program and achievement. _1991 Annual Convention of the Association for Educational Communications and Technology, 13th Annual Proceedings of Selected Research Presentations_.

Raker, E. (1989). Hypermedia: New technology tool for educators. _The Computing Teacher_, _17_(1), 18-19

Roberge, J. & Flexer, B. (1983). Cognitive style, operativity, and mathematics achievement. Journal for Research in Mathematics Education, 14(4), 344-353.

Saracho, O. (1989). Cognitive styles and classroom factors. Early Child Development and Care, 47, 149-157.

Witkin, H., Moore, C., Goodenough, D. & Cox, P. (1977). Field-independent and field-dependent cognitive styles and their educational implications. Review of Educational Research, 47, 1-64.

Vaidya, S. & Chansky, N. (1980). Cognitive development and cognitive style as factors in mathematics achievement. Journal of Educational Psychology, 72(3), 326-330.