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ABSTRACT

This paper chronicles the Teaching Mathematics Using Interactive Videodisk (TMMUIV) pilot project. The project emerged in response to the need to train pre-service teachers in, among other things, the use of mathematics manipulatives. The project now can offer a video database and pilot instructional program that combines full-motion video, digitized audio, text, and graphics. Two instructional modes, classroom presentation and stand alone tutorial, help the teacher develop a repertoire of techniques. The report catalogs all the system's components and provides a brief history of the genesis of the project and subsequent improvements. Formative evaluation was conducted at approrpiate times throughout the course of the project and included informal review by project staff, review by outside experts and the advisory board, and field trails conducted over a 2-year period in mathematics methods classes. Summative research was conducted when the system was close to completion. Four elementary mathematics methods classes were used to test the utility of the TMMUIV classroom presentation system. Two classes received only conventional instruction and two received the same instruction enhanced by TMMUIV. Overall, the group receiving the pilot TMMUIV enhancement reported being better prepared to teach and more highly motivated to teach. Also, they reported gaining more knowledge for teaching than the group receiving conventional instruction alone. The TMMUIV group also scored higher on each of three objective performance measures. These findings suggest the potential impact on teacher training for pre-service and in-service teacher utilization of interactive multimedia. (BEW)

TOWARD GUIDELINES FOR THE RESEARCH & DEVELOPMENT OF INTERACTIVE MULTIMEDIA: THE ARIZONA STATE UNIVERSITY TMMUIV PROJECT

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According to the standards of the National Council of Teachers of Mathematics (NCTM), elementary mathematics instruction can be dramatically improved by the use of concrete manipulative devices and new teaching methods. To help meet the need for improved teacher preparation, the Teaching Mathematics Using Interactive Videodisk (TMMUIV) project investigated the utility of interactive, multimedia instruction for helping pre-service elementary teachers integrate the use of manipulatives, teaching methods, and the NCTM standards into their future instruction. The project developed: (a) a video database, (b) a standalone tutorial system, and (c) a classroom presentation system, and tested the utility of the last for augmenting conventional instruction.

Four elementary mathematics methods classes were used to test the utility of the TMMUIV classroom presentation system. Two classes received only conventional instruction, the remaining two received the same instruction enhanced by TMMUIV. Each of the four classes tested was less than two hours in length, and the TMMUIV-enhanced instructional segment was less than an hour, yet significant differences were found between the two groups. Overall, the group receiving the pilot TMMUIV enhancement reported being better prepared to teach, more highly motivated to teach, and having gained more knowledge for teaching than the group receiving conventional instruction alone. The TMMUIV group also scored higher on each of three objective performance measures. These findings suggest the potential impact on teacher training for pre-service and in-service teacher utilization of interactive multimedia.

Project Overview

Teaching Mathematics Methods Using Interactive Videodisk (TMMUIV) was a pilot project responding to the need to train pre-service teachers in the use of mathematics manipulatives and teaching methods advocated by the National Council of Teachers of Mathematics (NCTM). The project developed a video database and pilot instructional system that combines full-motion video, digitized audio, text, and graphics to give pre-service teachers a large variety of authentic views of expert classroom instruction using the teaching methods with manipulative materials proposed in the NCTM Standards. The two instructional modes, classroom presentation and standalone tutorial, allow mediated instruction and learner exploration of the video database to be integrated to help pre-service teachers develop a repertoire of techniques and professional standards. The third mode, the video database, provides an opportunity for exploration of NCTM Standards.

The pilot system is capable of Level I, II, and III interaction, and consists of hardware, software, and two videodisks. The Level I and II capabilities are designed primarily for classroom presentation by the instructor. The Level III capabilities are designed for both classroom presentation and as a standalone tutorial. The system is based on an IBM PS/2 microcomputer with M/Motion Video Adapter and M/Audio Adapter, and an attached videodisk player.

System software runs in the Microsoft Windows with multimedia extensions 1.0 environment, which operates under the DOS 5.0 operating system. Furthermore, TMMUIV software includes direct linkage to an SQL server in the Microsoft Windows environment. The embedded video database allows access to video clips based on preprogrammed or instructor-developed selection criteria related to instructional characteristics of the video clips.

Two 30-minute videodisks have been developed that display video clips of elementary mathematics instruction with manipulatives. One videodisk has 279 clips of instruction with geoboards; the other has 84 clips of instruction with base 10 (numeration) blocks. The clips on each disc range in length from 1-second stills to 2 minutes. Most clips were taped in elementary classrooms; a few were taped in a university mathematics methods classroom.

In the methods classroom, the instructor typically employs a teleprompter system which presents video segments on a large monitor controlled by a computer (the computer's smaller monitor provides a menu of video options). For larger classes, an overhead projection system is used. The instructor furnishes the immediate instruction, often in the form of a narrative, to complement the video and provide the necessary "context" for understanding the segments. In the laboratory, the system's standalone capabilities allow learners to work on a one-monitor system on which instruction, video, and control menus alternately appear.

Project Development Activities

Year One

During the first year, the TMMUIV pilot project began instructional design, and pilot videotaping of exemplary instructional segments. The videotapes were edited and a "scratch disc" was pressed from the "richest" segments. This disc was used in the initial programming design for Level I. After analysis of the pilot videotaping, procedures were revised (such as clipping a microphone to each student who was being videotaped) and final videotaping was done in first-, third-, and fifth-grade classes. Later, videotaping was done in the methods classroom of Dr. Hatfield so that pre-service teachers could observe her techniques.

The videotapes were then analyzed for specific objectives and edited into two 30-minute videodisks, one presenting geoboard instruction, the other presenting base 10 blocks instruction. Each video clip was analyzed for 22 specific types of information (called "fields"). These fields include the clip number, beginning and end videodisk counter numbers (necessary for accessing clips), grade level, teacher, languages used for instruction (English and Spanish), ethnicity and sex of the elementary students, and descriptions of student and teacher activities.

A programmer evaluated and tested the capabilities of various hardware and software configurations for the TMMUIV system. The DOS operating system and the IBM Linkways authoring platform were selected as the most appropriate available. The programmer also wrote access programs for the database and programmed the control center, the system's main menu.

Year Two

During the second year of the pilot project, several changes were made in the hardware and software configurations of the system to take advantage of technological advances. The Microsoft Windows with multimedia extension operating environment replaced the linkways platform. Major advantages include Windows graphical interface, its ability to incorporate video and audio directly into the software program, and an online SQL server. By utilizing Windows "ease of use" graphical interface, users could "point and click" their choices instead of manually typing them in. With the incorporation of video and audio directly into the program, the users can manipulate digitized audio and full-motion video in the Microsoft Window environment. Furthermore, the linkage between Windows and the online SQL server allowed project developers to find video segments appropriate to particular lesson objectives. The database also allows classroom instructors and independent learners to play video segments related to their own instructional goals. Because the database allows standard query language commands, the data are available to many kinds of users, and video-based instruction can be more easily customized.

The TMMUIV system initially required a TV monitor for full-motion video display and a computer monitor for text and graphics display. The system now runs equally well on a single monitor, due to the IBM full-motion video adapter, an ideal arrangement for the standalone tutorial mode. This improvement allows computer-generated text and graphics to be overlaid on full-motion or freeze-frame video, allows video to be played in an expandable window, eliminates the cost of the second monitor, and allows learners to concentrate on a single instructional display.

With the hiring of instructional design specialists and a graphic artist, considerable advances were made in the instructional design and development aspect of the project during the second year. Full-length lessons on instructing with geoboards and base 10 blocks were developed for the classroom presentation and standalone modes. The instructor's User Manual was completed and the NCTM teaching standards were incorporated into the database so system users can access clips that represent the application of particular standards.

Project Research Activities

Formative Evaluation Research

Formative evaluation was conducted at appropriate times throughout the course of the project. This included informal review by project staff, review by outside experts and the Advisory Board, and field trials in mathematics methods classes. Invaluable information was derived from all these sources, and was used to guide the project's further development.

Field trials were conducted over a two year period. Data collection was by in-depth interviews with the pre-service teachers and short questionnaires. The most common student response to the system was appreciation of the opportunity to see real, elementary classroom instruction in which experienced teachers demonstrated the teaching methods and manipulatives advocated by NCTM standards. Seeing the instruction, and elementary student responses, enabled the pre-service teachers to acquire experience of a sort that would have been impossible without the TMMUIV system.

The critical comments of the methods instructors and their students were useful for improving the system. For example, learners reported that using the initial two-monitor system in the laboratory was distracting. When the IBM full-motion video adapter became available, this problem was corrected.

Summative Evaluation Research

When the system was close to completion, evaluation research with a more summative emphasis was possible. The primary purpose of this exploratory study was to investigate what effects the TMMUIV system had on methods students, over and above conventional instruction. To increase the likelihood that pre-service teachers will instruct effectively with a given manipulative, such as a geoboard, they must learn how to do so, feel prepared to do so, and be motivated to do so.

Therefore, gains in knowledge and competence in teaching with geoboards, perceptions of preparedness to teach with geoboards, and motivation to teach with geoboards upon graduation were the central variables investigated in this study. Subsidiary purposes were to investigate the nature of new variables and to test newly developed measures of these variables.

The most interesting of these new variables is <u>observational power</u>. TMMUIV provides mathematics methods students with opportunities to partake of more guided field experiences than would be feasible if attempted any other way. This exposure to the dynamics of teaching with manipulatives and methods was expected to increase the students' power to observe analytically in the elementary classroom.

Method

<u>Design</u>. To determine the effect of TMMUIV on conventional instruction, four mathematics methods classes were assigned to two groups. One group received the TMMUIV-enhanced instruction, and one group received only conventional instruction on the same material. There were

no significant preexisting differences among the classes according to available pre-study data and the classes were assigned to groups according to the dates that the instructors desired to have geoboards taught.

To assure similarity in instruction of mathematics methods, an outside instructor taught the geoboards segment of mathematics methods to each of the four classes using the same material each time. Instructional time for each class was just under two hours. During the first half of each class period, pre-service teachers used geoboards under the instructor's direction. The second half of the class period was a lecture on using geoboards in the elementary classroom. The TMMUIV-group's lecture was supplemented with about 12 minutes of full-motion video from TMMUIV; the conventional group's lecture was not supplemented.

Reliability and validity. Data were collected in each class with a pencil-and-paper instrument, immediately after the lecture. The instrument measured the variables of (a) motivation to teach with geoboards, (b) attitudes toward teaching with geoboards and toward classroom instruction, (c) background variables such as previous exposure to geoboards, and (d) knowledge gain. Two attitude scales, Guilford and semantic differential, were used. Knowledge gain was also measured in two ways. Three analytic performance posttests provided an objective measure of observational power for both TMMUIV and non-TMMUIV groups. Retrospective pretest-posttest, self-report items provided measures of other areas of knowledge gain. (These self-report items were suggested by Campbell & Stanley, 1966; they were validated by Curry & Purkis, 1986).

Most scales were seven-point bipolar probability or evaluative items. The three analytic performance tests were conducted by presenting three different video clips of elementary instruction with geoboards subjects in both groups. (Neither group had seen the clips before.) Subjects were asked to identify, on an open-ended item, the positive instructional strategy the teacher had used in each instance. The first strategy dealt with teaching estimation, the second with teaching the concept of area, the third with making young children comfortable in the classroom.

The instrument's reliability was examined by test-retest and alpha reliability analyses. A measure of attitude toward the classroom instruction on geoboards was repeated in the instrument and correlation analysis demonstrated test-retest reliability ($r = .67$, $p < .01$). Single-item and multi-item measures of two attitudes were also taken. Measures of attitude toward mathematics correlated rather well ($r = .60$, $p < .01$) as did measures of attitude toward the classroom instruction ($r = .56$, $p < .01$). Quite acceptable alpha reliabilities were obtained on the multi-item scales of attitude toward mathematics (.90) and attitude toward instruction (.91).

The convergent and discriminant validity of the instrument was examined by use of the multitrait-multimethod matrix suggested by Campbell and Fiske (1959). This procedure uses a correlation matrix of at least two traits, measured by at least two methods. The traits were attitude toward mathematics and attitude toward the classroom instruction. Each trait was measured by a single-item Guilford self-rating scale and a four-item semantic differential scale. Convergent validity is demonstrated by high correlations of different measures of the same trait. Discriminant validity is demonstrated by lower correlations of the same measure on different traits. Table 1 reports the results of this analysis. Cell entries that were non-significant demonstrate discriminant validity. Cell entries that are significant demonstrate reliability (one cell) or convergent validity.

Table 1

Multitrait-Multimethod Matrix Analysis of Convergent and Discriminant Validity: Attitudes Toward Classroom Instruction and Mathematics, Each Measured by Guilford and Semantic Differential Scales

	Guilford (G)		Semantic Differential (SD)	
	Instruction	Math	Instruction	Math
Guilford				
Instruction	.67*			
Math	-.05	NA		
Sem. Diff.				
Instruction	.56*	.17	NA	
Math	.14	.60* Convergent Validity	.29	NA Test-retest Reliability

Note. Cell entries represent correlation coefficients. The cell entries marked "NA" indicate no test-retest reliability check. Alpha reliability coefficients for the semantic differential scales were .90 for attitude toward mathematics; .91 for attitude toward the classroom instruction.

The reliability and convergent validity diagonals are indicated. Remaining cell entries demonstrate discriminant validity. Cell entries are non-significant except as noted (*).

* $p < .01$

Pre-exposure differences. The data analysis revealed two pre-existing differences between subjects in the TMMUIV and non-TMMUIV groups that might suggest superior performance by the latter group after instruction. These differences were in (a) their previous exposure to geoboards and (b) their academic ability. (Data reported below are group means; questions were single-item, 7-point, bipolar scales ranging from a low of 1 to a high of 7, through a midpoint of 4.)

The TMMUIV group had received significantly less previous training with geoboards than had the non-TMMUIV group (means of 1.24 vs. 2.68, $p < .05$) and was less likely to have been taught with geoboards when they were elementary students (means of 1.05 vs. 2.72, $p < .01$). There was no age difference between the groups; means were 28.87 and 28.89 years for TMMUIV and non-TMMUIV respectively.

An estimated measure of academic ability was formed by combining SAT/ACT scores and previous GPA into interquartile categories. According to this measure, the TMMUIV group was less "able" (2.80 vs. 3.17; $p = .13$) than the non-TMMUIV group. A third difference, occurring after exposure to TMMUIV, also might be expected to indicate superior performance by the non-TMMUIV group.

A Post-exposure difference. Although attitudes toward the classroom instruction on geoboards were favorable in both groups, the TMMUIV group had slightly (and non-significantly) less favorable attitudes (mean = 5.04) than did the non-TMMUIV group (mean = 5.28). This could be due to the few remaining "bugs" in the system at that time, and the instructor's lack of experience teaching with the system. This essential equivalence of the groups' attitudes toward the instruction, suggests that any "added instructional value" of TMMUIV found in the results, would be real, not due to novelty or other effects.

Results & Discussion

One of the most powerful contributions TMMUIV can make to the training of pre-service teachers is the enhanced observational power that usually comes only after years of full-time teaching. Yet after less than an hour of instruction with TMMUIV, subjects in that group were clearly better able to discern the meaning of elementary-classroom interactions than were subjects in the non-TMMUIV group.

The TMMUIV group scored higher than the non-TMMUIV group on all three of the objective performance items as illustrated by Figure 1. Analysis by Hotellings' T^2 test showed that the overall difference between TMMUIV and non-TMMUIV-group scores was statistically significant ($p < .001$).

This finding that the TMMUIV group was better able to interpret elementary instructional activities is paralleled by the results on one of the self-report items. This item asked subjects to rate their gain in knowledge of what it is like in the elementary classroom. The TMMUIV group scored a mean gain of 2.00, compared with 0.92 mean gain for the non-TMMUIV group ($p < .05$).

Exploratory analyses by chi-square were performed to investigate how TMMUIV might have brought about these strong effects on pre-service teachers. Analyses of data from the TMMUIV subjects has revealed several possibilities. For example, exposure to TMMUIV appears to equalize differences in preparedness to teach and knowledge about teaching with geoboards between subjects who had seen geoboards used in their practicum schools and those who had not. Among TMMUIV subjects, significantly more of those who had not seen geoboards used in their practicum schools reported themselves to be "well-prepared" to teach with geoboards than reported themselves less prepared ($p < .05$). No such difference was found among non-TMMUIV subjects.

Exposure to TMMUIV also appears to equalize differences among subjects in their knowledge of how to teach with geoboards. Over three-fourths of TMMUIV subjects who had not seen geoboards used in their practicum schools reported themselves as having the least knowledge about teaching with geoboards before the classroom instruction. Less than a third of these subjects who had seen geoboards used reported themselves to have the least knowledge. This difference in knowledge before instruction between those who had, and those who had not, seen geoboards used was significant ($p < .05$). However, after the classroom instruction with TMMUIV, this difference disappeared, suggesting that exposure to TMMUIV helped "make up" for the pre-existing difference in knowledge.

It is generally acknowledged that pre-service elementary teachers are not as well trained in mathematics as they might be, and that their attitudes toward mathematics are correspondingly unfavorable. TMMUIV appears to equalize pre-existing differences in preparedness to teach among pre-service teachers with different attitudes toward mathematics. TMMUIV subjects who reported the least favorable attitudes toward mathematics reported themselves well prepared to teach with geoboards after TMMUIV, compared with only 87.5% of those with more favorable attitudes toward mathematics. This difference was significant ($p < .01$) and suggests that although TMMUIV is effective for all pre-service teachers, it might be even more effective for those who have the least favorable attitudes toward mathematics.

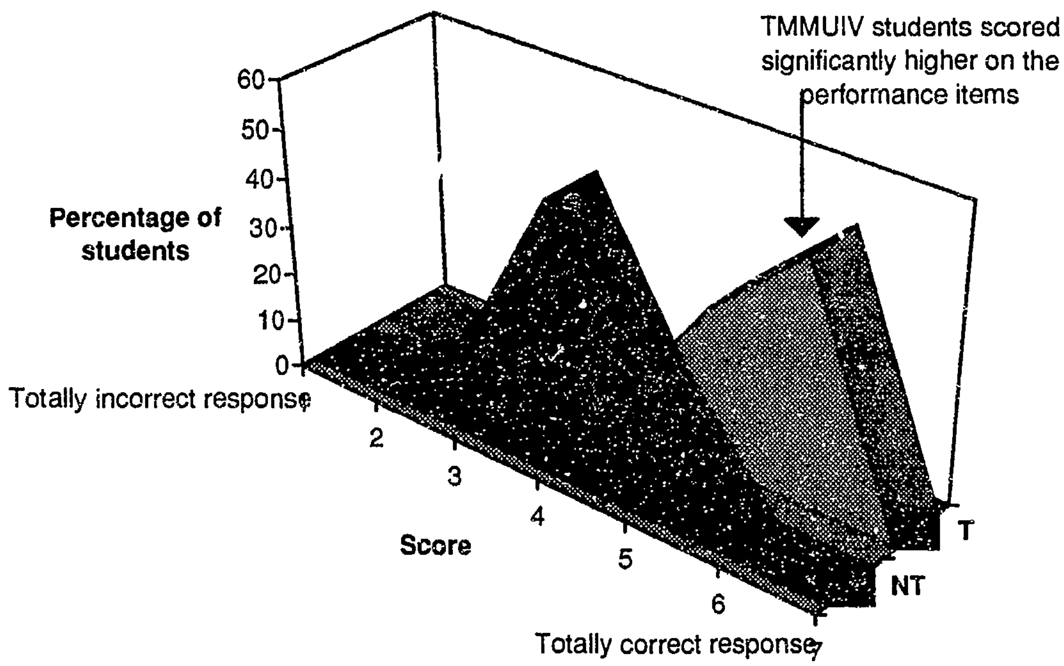

Figure 1. Scores on three performance tests: combined means of TMMUIV and non-TMMUIV groups.

Conclusion

The TMMUIV project has produced classroom-presentation and laboratory-standalone systems that are technologically state-of-the-art. The project's quantitative evaluation has found evidence that pre-service teachers actually learn more from TMMUIV-enhanced classroom instruction than from conventional instruction. The TMMUIV group gained more than the non-TMMUIV group on every single measure of cognitive gain, preparedness to teach with geoboards, and motivation to teach with geoboards. The most striking result is that after less than an hour of instruction with TMMUIV, that group scored significantly higher on three tests of their understanding of the reality of the elementary classroom.

Other findings suggest that TMMUIV equalizes differences in knowledge of how to teach and preparedness to teach between pre-service teachers who have, and who have not, seen geometry instruction with geoboards in their practicum schools. Also, the results suggest that TMMUIV may be even more helpful to pre-service teachers with less favorable attitudes toward mathematics than to those with more favorable attitudes.

The project's qualitative evaluation research has produced other interesting evidence. An interview conducted with one pre-service teacher after she had used the standalone system suggested that it might also be useful for inservice teachers. Thinking about her future teaching, she said:

> I like the idea that, when I want to teach something I haven't taught before, I can just go into the lab and look at examples [of model instruction] on the computer. It would sure be easier than having to go to a class, or sign up for inservice, or something."

The Future: Understanding Teaching

After the project's conclusion, the TMMUIV standalone system was totally re-structured, converted from videodisk to CD-ROM, and re-named Understanding Teaching: Implementing the NCTM Professional Standards for Teaching Mathematics. The utility of Understanding Teaching form instruction of pre-service teachers was investigated in a study by Clark (1995). The use of Understanding Teaching by in-service teachers, in their school, is being investigated in a study currently underway (Charles, 1996).

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